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Environmental Protection
Agency

Office of
Water Program Operations
(WH-547)
Washington DC 20460

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EPA

Analysis of Operations & Maintenance Costs for Municipal Wastewater Treatment Systems

	OPERATION						MAINTENANCE				TOTAL
	SALARIES & WAGES	EMPLOYEE BENEFITS	MATERIALS & SUPPLIES	POWER & LIGHT	MISCEL-LANEOUS	SUB TOTAL OPERATION	SALARIES & WAGES	EMPLOYEE BENEFITS	MATE-RIALS & SUPPLIES	SUB TOTAL MAINTE-NANCE	OPERATIO MAINT NANC
eatment*	$1,192,473	$252,135	$1,551,462	$ 780,709	—	$3,776,779	$ 593,304	$125,448	$249,188	$ 967,940	$4,744,7
ain Pumping	200,228	42,335	18.512	209,662	—	470,737	57,238	12,128	46,740	116,106	586,8
boratory	130,446	27,581	17,751	694	—	176,472	4,942	1,036	594	6,572	183,0
ver Survey & Industrial Wastes	73,386	15,514	3,111	580	—	92,591	22	—	2	24	92,6
tercepting Sewer System	—	—	2,972	6,061	—	9,033	263,036	55,612	43,702	362,350	371,3
pper Allegheny System	—	—	43	8,777	—	8,820	24,804	5,241	4,220	34,265	43,0
lling & Collecting	360,076	76,153	32,314	4,888	$207,733	681,164	5,332	1,124	164	6.620	687,7
gineering	179,112	37,873	6,752	1,447	34,503	259,687	69	—	6	75	259,
ministration & General	261,830	55,416	73,375	1,270	125,151	517,042	94,202	19,912	19,237	133,351	650,
tal Operating Expenses—1974	2,397,551	507,007	1,706,292	1,014,088	367,387	5,992,325	1,042,949	220,501	363,853	1,627,303	7,619,
Percent of Total	31.5	6.6	22.4	13.3	4.8	78.6	13.8	2.9	4.7	21.4	100.
tal Operating Expenses—1973	2,065,646	418,282	954,845	457,197	366,445	4,262,415	855,311	179,691	221,827	1,256,829	5,519,
Percent of Total	37.4	7.6	17.3	8.3	6.6	77.2	15.5	3.3	4.0	22.8	100.
tal Operating Expenses—1972	1,706,988	348,972	878,859	323,483	275,835	3,534,137	750,132	153,146	137,525	1,040,803	4,574,
Percent of Total	37.3	7.6	19.2	7.1	6.0	77.2	16.4	3.4	3.0	22.8	100.
tal Operating Expenses—1971	1,586,838	257,278	669,868	286.812	262,706	3,063,502	647,883	104,497	146,224	898,604	3,962,
Percent of Total	40.1	6.5	16.9	7.2	6.6	77.3	16.4	2.6	3.7	22.7	100.
tal Operating Expenses—1970	1,389,711	285,348	522,648	246,387	263,730	2,707,824	549,136	112,739	124,228	786,103	3,493,
Percent of Total	39.8	8.2	15.0	7.0	7.5	77.5	15.7	3.2	3.6	22.5	100.
Year Avg. Operating Expenses	1,829,348	363,377	946,502	465,593	307,221	3,912,041	769,082	154,115	198,731	1,121,928	5,033
Percent of Total	36.3	7.2	18.8	9.3	6.1	77.7	15.3	3.1	3.9	22.3	100.
*Breakdown of Treatment Expenses:											
reening & Grit Removal	185,995	39,344	27,717	2,082	—	255,138	37,637	7,960	8,776	54,373	309
eaeration & Sedimentation	178,912	37,823	9,376	3,585	—	229,696	73,554	15,546	14,143	103,243	332
ndary Treatment	190,350	40,256	181,152	529,243	—	941,001	72,673	15,370	14,771	102,814	1,043
um Filtration	314,296	66,418	607,697	84,769	—	1,073,180	108,368	22,911	43,763	175,042	1,248
eration	322,920	68,294	725,520	161,030	—	1,277,764	301,072	63,661	167,735	532,468	1,810

MCD—39

EPA REVIEW NOTICE

The three technical reports listed below were prepared in conjunction with the 1976 Update of Needs Municipal Facilities, a biennial report to the U.S. Congress. These series of reports provide construction cost relationships for wastewater treatment plants and sewers presently under construction and also related operations and maintenance (O&M) cost relationships for existing facilities. The data base for all three studies is representative of the ten regions.

Document Number	
430/9-77-013 MCD-37	Construction Costs For Municipal Wastewater Treatment Plants: 1973-1977
430/9-77-014 MCD-38	Construction Costs For Municipal Wastewater Conveyance Systems: 1973-1977
430/9-77-015 MCD-39	Analysis of Operations & Maintenance Costs For Municipal Wastewater

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EPA 430/9-77-015 MCD-39

TECHNICAL REPORT

ANALYSIS OF OPERATIONS AND MAINTENANCE COSTS FOR MUNICIPAL WASTEWATER TREATMENT SYSTEMS

BY

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FEBRUARY 1978

PREPARED FOR

ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF WATER PROGRAM OPERATIONS
WASHINGTON, D.C. 20460

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1.0 SUMMARY

1.1 PURPOSE

The purpose of this report is to present the results and analyses of the most comprehensive survey made to date on the operation and maintenance (O&M) costs of the nation's municipal wastewater treatment plants and collection systems. The results have been derived from actual plant operating records across the continental United States. Costs are presented for different levels of wastewater treatment, types of plants and collection systems, and segregated cost categories. A number of analyses are also presented as relative costs for certain treatment variables and characteristics. The cost data utilized in the study range from fourth quarter 1972 to first quarter 1977. All costs have been adjusted to third quarter 1977 dollars. Only treatment plants of 1.0 million gallons per day (mgd) capacity or larger were sampled in this survey. The analyses in this study were performed with the assistance of a computer statistical package.

This report is addressed to a large and diverse user community of Federal, state and municipal decision makers, and interested citizens. It is intended to be of value to funding agencies, to municipal administrators and elected officials, and to the engineering community, when planning the construction of new facilities, as well as in comparing O&M costs of a facility with others in the geographic area or in the nation.

1.2 BACKGROUND

Virtually all wastewater treatment plants and most sewage collection systems will expend more fiscal resources for operation, maintenance, and repair over the lifetime of a given facility than will be invested in initial capital costs (construction costs). With the advent of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500) and the Clean Water Act of 1977 (Public Law 95-217), the number of wastewater treatment facilities being constructed and brought on-line nationwide is constantly increasing. The costs necessary to operate and maintain these facilities will increase at proportional rates, plus inflation, to staggering amounts. The public and the engineering community are very cognizant of the high costs of operating such facilities, and it is their joint responsibility to provide an adequate annual level of funding to perform these functions. While capital costs are funded with massive Federal grants-in-aid of construction, no Federal subsidies are available for operating and maintaining the treatment facilities. The decision, therefore, as to the type of plant, level of treatment, and projected mode of operation must be considered during the planning stages to allow the decision makers to formulate the most cost effective long-term solution to an existing pollution control or collection problem.

In order to satisfy legal and administrative requirements of funding agencies and municipalities, to conserve financial resources, and to protect the nation's waters, it is imperative that operation and maintenance costs be known and integrated into comprehensive wastewater treatment plans. This report is an outgrowth of that need. The Office of Water Program Operations of the U.S. Environmental Protection Agency has recently published reports on the construction costs of both wastewater treatment and collection facilities. The data presented in the three reports noted in the frontispiece of this document are intended to present the most recent cost information for those individuals and organizations with responsibility for planning, designing, financing, and operating wastewater treatment facilities. This report was prepared as a first step in evaluating the costs associated with operating and maintaining these facilities. It is not intended to supersede other reports by the U.S. EPA or reports by other organizations on this subject, but it has been developed to supplement and, in some cases, update these documents.

The costs presented in this study are strictly O&M costs, i.e. those operating costs necessary and essential for the normal functioning of wastewater treatment plants and sewer systems. Costs for debt service or amortization of capital construction were not included in the data presented herein. Also, no attempt was made in this study to assess the replacement of wastewater treatment facilities required in user charge systems under the auspices of Public Law 92-500. Only minor replacement costs and normal, daily repair services were included in this study.

1.3 DATA BASE

The primary data base utilized for this nationwide study consisted of 348 individual wastewater treatment plants and 155 sewer systems. The primary data were collected by the contractor's engineers visiting each facility and obtaining fiscal information from plant records and in consultation with the owner's operating and management personnel. The types of treatment systems included in the survey were primary, secondary (trickling filter, activated sludge, aerated lagoon, oxidation ditch), and advanced wastewater treatment systems. The collection system data base includes cost relationships for gravity sewers, force mains, and lift stations. The data base for treatment plants was limited to facilities designed to receive greater than 1.0 mgd flow. The 1976 Needs Survey (EPA Report MCD-48B, February 10, 1977, Office of Water Program Operations, Washington, D.C. 20460 - 430/9-76-011) reports that at the time there were a total of approximately 13,220 municipal treatment plants nationwide. Of these treatment plants, approximately 1,900 have design capacities greater than 1.0 mgd. Therefore, the sample used in this survey includes about 18 percent of the treatment plants (those greater than 1.0 mgd design capacity) in the continental United States. The plants selected were from representative states in each of the ten EPA regions.

In addition to the primary source of the data collected by the contractor, the Association of Metropolitan Sewerage Agencies (AMSA) performed a survey of its membership in 1974-75. Data from this survey were obtained and analyzed in a cooperative arrangement among U.S. EPA, AMSA, and the contractor. From the AMSA survey 99 municipal questionnaires contained sufficient data for a cost analysis. One-half of the AMSA plants have a design flow capacity greater than 20 mgd while all of the AMSA plants used in this study have a design capacity greater than 1.0 mgd. Thus, approximately 24 percent of all treatment plants of capacities greater than one mgd were used in the combined analyses presented herein. Due to the nature and ease of recording fiscal information for treatment plants by various categories versus that for sewer systems, the results of the data are considered to be more precise for plants than for sewers.

One factor which became very apparent after the data were collected was the operation and maintenance costs of both treatment plants and sewer systems as a function of the number of years (age) that they have been in service. Again, this may prove to be significant in the results, but because of the nature of treatment plant additions and modifications over the years, a statistically valid relationship could not be obtained.

1.4 FINDINGS

This study quantified and confirmed certain economic principles relative to operating costs of process related facilities. As would be expected, wastewater treatment plants that are operating at less than design capacity (less than 90 percent) have substantially higher operating costs per million gallons treated than plants treating flows at design capacity (90-110 percent). Overloaded plants have lower average operating costs per million gallons treated than plants processing flows at hydraulic design capacity. For example, the average costs of all activated sludge treatment plants examined resulted in the following values: $192 per million gallons treated at design; $176 per million gallons treated for overloaded; and for underloaded plants, $198 per million gallons treated at 70-89 percent of design, $315 at 50-69 percent of design, and $436 at less than 50 percent of design.

Operating efficiency analyses indicate that the larger the plant, up to a limit of approximately 85 mgd, the lower the operation and maintenance costs per million gallons treated. Likewise, the more sophisticated the treatment process, the more costly waste is to treat per million gallons. Pollutant removal costs, i.e., the average cost per pound of Biochemical Oxygen Demand (BOD) or Suspended Solids (SS) removed, increase as the level of treatment increases but these average pollutant removal costs decline as the size of the plant increases.

For all types of treatment levels, personnel, power, and chemical expenditures accounted for approximately 80 percent of total operating costs. Advanced wastewater treatment plants had lower relative personnel costs and higher percent chemical and power costs than other processes, because these plants are all relatively new and are highly automated.

Other key findings regarding treatment plant operations are briefly noted. As an ultimate sludge disposal method, incineration is the most costly alternative for all levels of treatment while land spreading is the most economical. Increasing amounts of industrial waste do not necessarily increase O&M costs appreciably. The average flow per capita increases as the size of the plant increases. However, per capita costs in general decline for all levels of treatment as the treatment plant size increases. Per capita treatment costs are generally higher east of the Mississippi River than in the western United States. Average personnel costs per employee are higher at the larger size treatment plants.

The data indicate that the total operating costs per capita are highest for sanitary sewer systems and lowest for a mixed system which has sanitary sewers plus storm sewer systems. The sanitary sewer system also has the highest per mile operating cost, and the mixed sewer system has the lowest maintenance cost per mile. The data are not as precise for sewer systems as for treatment plants due to the difficulties in recording and allocating costs in the former.

2.0 INTRODUCTION

2.1 PURPOSE

As an integral part of the EPA construction grants review process, each proposed wastewater treatment construction project must undergo a cost-effective analysis which ensures that projected Operations and Maintenance (O&M) costs are reasonable and appropriate for the planned level of treatment and process train. In addition, the U.S. General Accounting Office in their December 1976 report entitled "Better Data Collection and Planning Is Needed To Justify Advanced Waste Treatment Construction," urged the EPA to consider information on expected water quality improvements, high initial capital costs, and projected annual operation and maintenance expenditures before approving construction grants.

This study provides municipal cost information that should assist such evaluations by presenting current O&M wastewater treatment facilities data. Further, the study evaluates existing operating costs for various treatment levels and process trains. Another purpose of this study is to examine the effect on O&M costs of more stringent wastewater treatment standards and the current national energy requirements. In particular, personnel, power, and chemicals are important component O&M costs that have been subjected to increasing emphasis due primarily to recent inflationary trends.

This study also serves as a corollary to the construction cost reports for municipal wastewater treatment plants and sewers by providing cost data that supplement the capital construction cost data. These companion documents are "Construction Costs for Municipal Wastewater Treatment Plants: 1973-1977" (EPA 430/9-77-013, MCD-37) and "Construction Costs for Municipal Wastewater Conveyance Systems: 1973-1977" (EPA 430/9-77-014, MCD-38). Municipal wastewater planning officials should find the combined results particularly useful in evaluating a community's long term costs for operating and maintaining wastewater treatment facilities.

2.2 OBJECTIVES

Objectives of the operations and maintenance study are enumerated and grouped according to treatment system objectives and sewer system objectives. The Treatment System Objectives are as follows:

1) To identify and analyze significant operating cost parameters for various treatment levels and processes;
2) To assess the relative economy of various sludge disposal methods for different levels of treatment;
3) To estimate the effect or significance of industrial loadings on O&M costs and;
4) To assess variations in operating cost per capita for comparable levels of treatment by plant size and by region;
5) To estimate O&M costs in dollars per million gallons of wastewater treated for various size plants and levels of treatment;

6) To estimate O&M costs in terms of dollars per pound of biochemical oxygen demand (BOD) removed and dollars per pound of suspended solids (SS) removed;
7) To compare primary and secondary treatment O&M costs and to identify the cost differentials for upgrading a wastewater treatment facility to the next higher level of treatment;
8) To estimate, if possible, at what point larger (or regional) wastewater treatment plants become less economical to operate and maintain than smaller treatment systems; and
9) To estimate the incremental O&M costs of treating wastewater beyond the conventional secondary treatment processes.

The Sewer System Objectives are as follows:

1) To identify significant operating cost parameters for gravity sewers, force mains, and lift (or pump) stations;
2) To estimate total operating costs per capita for various types of collection systems; and
3) To estimate total operating costs per mile of gravity sewer and force main.

2.3 SCOPE

In order to provide meaningful O&M cost relationships, municipal wastewater treatment plants are classified by both type and level of treatment. Level of treatment is mandated by the National Pollutant

Discharge Elimination System (NPDES) permit conditions and type of treatment indicates the major processes used to obtain that required level. The level of treatment and types of plants considered in this study are categorized as:

LEVELS	TYPES
a. Primary Treatment	Primary
b. Secondary Treatment	1) Trickling Filter 2) Activated Sludge 3) Oxidation Ditch 4) Aerated Lagoon
c. Advanced Wastewater Treatment (AWT)	AWT

The major goal of primary treatment is to remove from wastewater those pollutants which will either settle (such as the heavier suspended solids) or float (such as grease). Primary treatment will typically remove about 60 percent of the raw sewage SS and about 35 percent of the BOD. The major goal of secondary treatment is to oxidize the soluble BOD that escapes the primary process and to provide added removal of SS. These removals are typically achieved by using biological processes, providing the same biological reactions that would occur in the receiving stream if it had adequate capacity to assimilate the wastewater discharges. When incorporated with primary processes, secondary treatment processes remove approximately 85 percent of the BOD and SS. In cases where secondary levels of treatment are not adequate, advanced wastewater treatment methods are applied to the secondary effluent to provide further removal of the pollutants. AWT processes may involve chemical treatment and physical treatment, including filtration of the wastewater. Some of these AWT processes can remove as much as 99 percent of the BOD and phosphorus, nearly all SS and bacteria, and 95 percent of the nitrogen. The final effluent is a sparkling clean, colorless, odorless effluent indistinguishable in appearance from a high quality drinking water (Culp, 1977).

Wastewater treatment plants are also grouped by size, and only facilities with permit flows or design flows equal to or greater than one million gallons per day (mgd) are included in this study. Plants with a hydraulic design capacity less than one mgd were not sampled because the U.S. EPA has an ongoing, comprehensive research and development study emphasizing operational efficiencies for the treatment plants with flows less than one mgd. Hence, these smaller plants were excluded from this O&M study to preclude duplication of effort. Each level of treatment is subdivided into the following size categories:

a.	Small	1.0 mgd to 5.0 mgd
b.	Medium	5.1 mgd to 20.0 mgd
c.	Large	Greater than 20.0 mgd

In addition to level of treatment and size, results of this study are also presented for the 10 EPA regions. Where appropriate, findings are reported which consider industrial loadings and operational-design capacities. Many municipal agencies provided detailed expenditures by individual treatment process or groups of processes. In those cases total O&M costs are categorized and presented by object of expenditure classes such as personnel, power, chemicals, materials, outside services, etc.

For sewer systems, operations, maintenance, and minor repair (OM&R) costs are presented for gravity sewers, force mains, and lift (pump) stations. Comparisons are reported for sewer systems that are similar to wastewater treatment systems, but the amount and level of detail are not as extensive nor are the reported costs as thorough. Probable reasons for the apparent weakness in sewer maintenance cost reporting are proffered. Because most components of sewer systems are underground, preventive maintenance is not routinely scheduled or performed. In some cases such preventive maintenance may not even be cost-effective. Most sewer maintenance work is corrective in nature. Corrective maintenance occurs on demand such as a line stoppage or break, which requires immediate action. Another reason for lack of good sewer system data is that sewer systems have existed over considerable periods of time, and unless maintenance personnel are knowledgeable about existing sewer lines, adequate maintenance records and first-hand experience of potential problems are perfunctory.

3.0 METHODOLOGY

3.1 INFORMATION SOURCES

In order to establish a valid and uniform data base for the analysis of O&M costs, the assumption was made that the most accurate and complete information could be obtained directly from the local municipal officials at the treatment facility. For this reason, site visits were attempted for every facility included in this survey. In some instances additional sources of data were used, such as state or regional files, U.S. EPA O&M inspection reports, NPDES permit files, and self-monitoring information.

The EPA form 7500-5, employed in the annual O&M inspection for treatment plants and completed by U.S. EPA or state staff, is generally available in files at the municipal, state, and sometimes regional levels. These reports include plant performance data, which were used in this study only when the inspection period coincided with the municipality's fiscal year, i.e., when comparable periods of time corresponded. In some instances, however, recent inspection reports provided acceptable information on process trains and design loadings.

Also available at U.S. EPA regional and state offices were NPDES permit files containing permit applications, imposed effluent limitations, and usually, quarterly or monthly self-monitoring reports for treatment plants. The format of these latter reports varied somewhat, depending on whether the permit program was state or federally-administered, but they served as the official records of flow and water quality data as monitored according to NPDES requirements. From these self-monitoring reports, average annual flow and water quality parameter data were obtained for the most recent fiscal year of each facility. Permits and permit applications were also used since they often contain effluent limitations, information on design parameters, and service populations.

Remaining operating data and virtually all cost data were obtained at the municipal level, either from facility operators or administrators in the operating authority office. Due to differences in accounting procedures, it was occasionally necessary to contact more than one municipal department in order to collect requisite data for both the treatment and sewer systems. Actual expenditures were recorded whenever available; however, when auditing schedules or other constraints precluded the use of such figures, budget estimates for the year under consideration were accepted. The O&M cost estimates contained in this study do not include any allowance for amortization of capital debt or any provision for debt service retirement.

During the formative stages of this survey the U.S. EPA became aware that the Association of Metropolitan Sewerage Agencies (AMSA) had conducted an extensive O&M study among its membership in 1975 but had yet to complete the data analysis and prepare the survey results. The U.S. EPA project personnel contacted AMSA officials to volunteer data processing and analytical assistance in exchange for use of the AMSA-acquired

O&M data. AMSA officials agreed to this arrangement and the EPA project officer concurred with this agreement.

3.2 APPROACH TO DATA ACQUISITION

3.2.1 Selection of Facilities

To establish significant national cost relationships, a sample of treatment systems greater than one mgd was selected that would be reasonably representative of existing facilities across the nation. The smaller treatment plants (less than one mgd) were excluded from this study. The prime reason for this exclusion was to avoid duplicating an in-depth, continuing U.S. EPA research and development study specifically oriented toward operating efficiencies of the nation's smaller treatment plants. Sizes and locations of the sampled facilities in this O&M study were determined using a percentage of existing facilities as tabulated by design flow, type, and level of treatment in the U.S. EPA 1976 Needs Survey. From these percentages, the number of facilities to be surveyed by EPA region were established.

On the assumption that each EPA region can be accurately represented by one or two states, 17 states were selected to represent the nation. The selected states were California, Colorado, Florida, Georgia, Maine, Massachusetts, Mississippi, Missouri, New York, Ohio, Oregon, Pennsylvania, South Dakota, Texas, Virginia, Washington, and Wisconsin. Sample facilities within each state were selected with respect to such factors as geography, terrain, urbanization, and climate. The selected facilities were, in most cases, reviewed by state or EPA regional authorities for their suitability within the context of the survey. A more detailed description of the sample selection procedure appears in Appendix A.1 (Sample Selection -- Treatment Plants).

3.2.2 *Data Collection Procedure*

Following the initial determination of the sample characteristics and the state or states to be considered in each region, the Operation and Maintenance (O&M) Branch in each EPA region was contacted. From the NPDES permit files and other information available in the O&M offices, specific facilities were selected to satisfy the desired survey requirements. The predesignated state or states and facilities were reviewed by the O&M staff of each regional EPA office.

In some regions more complete information, such as accessibility of permit files, was available in the state offices. Whenever this occurred, the facilities selection took place at that level. In many states flow and water quality data were readily obtained from the self-monitoring reports in the state offices, thereby reducing the volume of data required from local contacts.

Upon approval of the selected sample facilities, appointments were scheduled with personnel at the municipal level. Generally, the facility design and performance data were provided by the superintendent of the facility or the director of public works, and the costs of operation and maintenance from the same source or from the municipal finance department. A visit was made to every facility in order to assess the operational processes and to obtain other required information.

3.2.3 Data Collection Format

In order to facilitate data management, a pre-printed coded worksheet was devised on which to record the desired data. The treatment system data worksheet provided space for recording flow, influent and effluent quality, treatment processes, and pumping data in addition to cost data for each treatment facility for a given fiscal year. A second worksheet was designed for recording design and cost data for sewer systems, whether operated by the treatment system authority or an independent authority. A third worksheet was available for including additional information or comments. Each format was flexible enough to accommodate itemization of varying systems for cost and physical system data as records management and accounting procedures often differ substantially among municipalities.

A detailed description of the categories of data obtained and the worksheet used are included in Appendix A.2 (Data Collection Procedures).

3.3 DATA BASE

The data base of this nationwide operations and maintenance study consists of two sources: the 1977 survey conducted by the U.S. EPA and the 1975 survey performed by the Association of Metropolitan Sewerage Agencies (AMSA).

The U.S. EPA survey includes current O&M cost and operational data for 348 municipal wastewater treatment plants and 155 municipal sewer systems, providing a representative national sample. A detailed description of the sample selection and data collection procedures employed in the EPA survey appear in Appendix A.

The 1975 AMSA survey yielded extensive data on plant operations, design parameters, staffing levels, and operating costs for 99 AMSA member facilities. No contributary sewer system data were included in the AMSA survey. Appendix B describes the AMSA survey and presents a listing of these wastewater treatment plants.

Table 3.1 shows the number of wastewater treatment plants surveyed by plant size group (design flow capacity) in the EPA and AMSA studies. The EPA survey is a representative national sample of existing treatment plants by hydraulic design capacity greater than one mgd: approximately two-thirds of all plants contained in the survey are classed as small (1.0-5.0 million gallons per day); about one-quarter are medium-sized plants (5.1 to 20.0 mgd); and the remaining number or approximately one-tenth are categorized as large wastewater treatment facilities (greater than 20.0 mgd). The AMSA survey, however, represents a bias toward the larger capacity treatment plants with one-half of all surveyed plants greater than 20 mgd. The balance of the AMSA data is equally divided between small and medium-sized facilities, 25 percent each.

TABLE 3.1

NUMBER OF WASTEWATER TREATMENT PLANTS SURVEYED BY SIZE GROUP

Size Group: Design Capacity (Million Gallons Per Day)	EPA Survey		AMSA Survey	
	Number	Percent	Number	Percent
1.0-5.0	227	65	25	25
5.1-20.0	89	26	25	25
>20.0	32	9	49	50
TOTALS	348	100	99	100

Table 3.2 presents a distribution of wastewater treatment plants (WWTPs) surveyed by EPA region and size group. This distribution reasonably represents the 10 EPA regions by size groups. EPA Regions IV (Southeast) and V (Lake Central) have the greatest number of plants while EPA Regions VII (Plains) and X (Northwest) have the smallest number of facilities.

A distribution of wastewater treatment plants sampled by level of treatment for the two surveys is shown in Table 3.3. The EPA survey approximates the various levels of treatment that are representative treatment systems across the nation. The AMSA survey indicates a high percentage of primary and activated sludge plants and a low percentage of trickling filter and advanced waste treatment (AWT) plants. No aerated lagoons nor oxidation ditches were sampled in the AMSA survey.

Care was taken in the EPA survey not to sample plants that were already included in the AMSA data base. However, nine plants were duplicated in the EPA survey but these plants were enlarged, upgraded in level of treatment, or a combination of enlargement or upgrading since the AMSA survey was conducted. Therefore, the inherent characteristics of these nine plants were significantly changed.

3.4 DATA BASE ANOMALIES

During the data collection phase of the EPA survey it was revealed that the cost accounting systems for wastewater treatment plants were

TABLE 3.2

EPA SURVEY

NUMBER OF WASTEWATER TREATMENT PLANTS SURVEYED BY EPA REGION AND SIZE GROUP

EPA Region	1.0-5.0 mgd	5.1-20.0 mgd	>20.0 mgd	TOTALS
I	18	5	0	23
II	24	11	4	39
III	24	7	3	34
IV	39	17	3	59
V	32	16	9	57
VI	25	8	4	37
VII	13	3	2	18
VIII	14	5	2	21
IX	27	11	4	42
X	11	6	1	18
TOTALS	227	89	32	348

TABLE 3.3

NUMBER OF WASTEWATER TREATMENT PLANTS SURVEYED BY LEVEL OF TREATMENT

Level of Treatment	EPA Survey		AMSA Survey	
	Number	Percent	Number	Percent
Primary	63	18	29	29
Secondary				
-- Trickling Filter	68	19	8	8
-- Activated Sludge	131	38	49	50
-- Aerated Lagoon	6	2	0	0
-- Oxidation Ditch	7	2	0	0
Advanced (AWT)	73	21	13	13
TOTALS	348	100	99	100

considerably detailed. Utility accounting procedures varied among the selected facilities.

It was observed that the general levels for fringe benefits vary as to local custom and the socioeconomic profile of the community. The fringe benefits (retirement, social security, health insurance, etc.) percentage of total payroll varied from a low of approximately 10 percent to a high of 35 percent. In this study fringe benefits were included as part of personnel costs.

Administrative and support services costs were often omitted where the sewerage facility was an agency of the municipal government. Administrative costs for autonomous bodies like sewer commissions or special sanitation districts were usually available and were apportioned among the various facilities if there was more than one treatment plant.

A frequent inconsistency occurred with respect to the terminology used for contractual services. Contractual services, as defined in this study, are work done by outside forces, rental of equipment, service contracts, etc. Many municipalities included under contractual services any purchase of materials, supplies, or services, which was made through a municipal contract. This required the investigator to segregate the individual costs into classifications consistent with the study data base. In general, the costs of major equipment replacements (e.g. pumps, blowers, etc.) were not included in the data base, but in some instances the investigator experienced difficulty in excluding these items.

Cost accounting procedures and data for sewer systems were usually not as well developed as for plants. Greater cost detail was usually available at the larger facilities because a permanent crew was assigned to perform routine sewer maintenance work. In the smaller municipalities personnel were often assigned only when needed and in many cases manhour and recorded payroll figures were often the superintendent's estimate. In some instances, sewer maintenance was often a function of the Department of Public Works or another department, which made actual sewer system operations, maintenance, and minor repair costs difficult to estimate. Where this situation occurred, the local official offered his estimate in the apportionment of costs to labor, materials, contracted work, etc.

3.5 COST INDEXING PROCEDURE

The O&M cost data collected in the EPA survey range in time from late 1975 to early 1977. The AMSA cost data ranges over a longer time span: late 1972 to late 1975. Prior to performing data analyses, these current cost data were converted to constant dollars. Several indices were considered in translating these O&M costs to a common dollar base. The EPA O&M cost index was selected primarily because it reasonably estimates actual wastewater treatment plant O&M costs. All treatment plant costs reported in the EPA survey and the AMSA survey were converted to third quarter 1977 dollars using the EPA O&M cost index. A description of this index is provided in Appendix C and Table C.1 indicates the procedure used in normalizing the recorded costs.

Finding a suitable index to convert current dollar amounts for operations, maintenance, and minor repair (OM&R) to sewer systems was difficult. A thorough search revealed no appropriate OM&R index. However, in the absence of a good conversion measure, the most suitable index apparently is the EPA complete urban sewer system (CUSS) cost index. Even though the CUSS index is predicated on construction of sewer systems, it was reasoned that much of the operations and maintenance work on sewer systems is repair and minor replacement work. Therefore, the EPA CUSS index was used to adjust current OM&R costs of sewer systems to a common dollar base.

4.0 SURVEY RESULTS AND FINDINGS: WASTEWATER TREATMENT PLANTS

4.1 OPERATING COST PARAMETERS

4.1.1 Operational Capacity: Average Daily Flow versus Design Flow

Approximately three-fourths of all wastewater treatment plants (WWTPs) included in the EPA survey were operating at less than their hydraulic design capacity or at underloaded conditions. In this study underloaded plants are defined as the plants in which actual average daily wastewater flows are less than 90 percent of engineering design flow. Table 4.1 indicates that about 16 percent of the plants surveyed were operating within the 90 to 110 percent range of the design capacity. Only eight percent of this nationwide survey reported average daily flows exceeding the design requirements by more than 10 percent. All types of plants are fairly representative of the foregoing national distribution except that the trickling filter plants are proportionately higher at overloaded conditions. An in-depth review of the data indicates that a considerable lapse in time has occurred since the last plant modification for a high percentage of the overloaded trickling filter plants.

Table 4.2 presents operational capacity data for the AMSA survey. Approximately one-fourth of all plants in the AMSA survey were operating at overloaded conditions. Eighteen percent of the WWTPs are operating at design capacity while about 59 percent are treating flows at less than

TABLE 4.1

EPA SURVEY

DISTRIBUTION OF OPERATIONAL CAPACITY OF WASTEWATER TREATMENT PLANTS BY LEVEL OF TREATMENT

Level of Treatment	Operating @ Design (90-110%)	Operating @ Overload (>110%)	Operating @ Underload (<90%)	Totals
Primary	8	7	48	63
Secondary				
-- Trickling Filter	13	9	46	68
-- Activated Sludge	24	10	97	131
-- Oxidation Ditch	0	1	6	7
-- Aerated Lagoon	0	0	6	6
Advanced (AWT)	10	2	61	73
TOTALS	55	29	264	348
Percent	16	8	76	100

TABLE 4.2

AMSA SURVEY

OPERATIONAL CAPACITY OF WASTEWATER TREATMENT PLANTS BY LEVEL OF TREATMENT

Level of Treatment	Operating @ Design (90-110%)	Operating @ Overload (>110%)	Operating @ Underload (<90%)	Totals
Primary	4	12	13	29
Secondary				
-- Trickling Filter	0	2	6	8
-- Activated Sludge	11	7	31	49
Advanced (AWT)	3	2	8	13
TOTALS	18	23	58	99
Percent	18	23	59	100

hydraulic design capacity. The most significant point relative to hydraulic design appears to be the high number of primary treatment plants that are overloaded (12 of 23 equals 52 percent). Above average population growth in most of the communities with overloaded primary treatment plants has been one of the reasons for the high number (12) of AMSA primary facilities operating beyond design specifications. In addition, nearly all primary plants are old, and by their hydraulic capacities, these plants are not able to conform to the existing water quality effluent standards.

Table 4.3 presents average (arithmetic mean) operating costs for various treatment levels by operational capacity for the EPA survey. Except for primary treatment plants, overloaded plants have lower average operating costs per million gallons treated than WWTPs operating at their hydraulic design. Also, plants that are operating at less than design capacity (<90 percent) have higher operating costs than plants treating wastes at design flow. Regardless of treatment level, treatment plants operating at less than 50 percent of hydraulic design capacity incur substantially higher O&M costs per million gallons treated. Table 4.4 presents similar data for the plants sampled in the AMSA survey.

4.1.2 Component Treatment Expenditures

Tables 4.5, 4.6, and 4.7 present average percent distributions of various component treatment expenditures for small, medium, and large plants, respectively. Personnel costs, i.e., labor wages, salaries, and benefits, comprise about one-half of all WWTP expenditures for primary,

TABLE 4.3

EPA SURVEY

AVERAGE OPERATING COST FOR VARIOUS TREATMENT LEVELS BY OPERATIONAL CAPACITY

(Dollars Per Million Gallons Treated Per Year)

Actual Flow as Percent of Design Flow	Level of Treatment			
		Secondary		
	Primary	Trickling Filter	Activated Sludge	Advanced
Overload (>110%)	147[a]	133	176	b
At Design (90-110%)	131	170	192	303
Underload at				
70-89%	133	176	198	376
50-69%	132	184	315	377
<50%	281	417	436	796

---

[a] The values appearing in this table were determined from the following equation:

$$\text{Dollars Per Million Gallons Treated Per Year} = \frac{\text{Total Annual O\&M Costs in Dollars}}{\text{Actual Flow (mgd)} \times 365}$$

[b] No AWT plants reporting overload condition.

TABLE 4.4

AMSA SURVEY

AVERAGE OPERATING COST FOR VARIOUS TREATMENT LEVELS BY OPERATIONAL CAPACITY

(Dollars Per Million Gallons Treated Per Year)

Actual Flow as Percent of Design Flow	Level of Treatment			
		Secondary		
	Primary	Trickling Filter	Activated Sludge	Advanced
Overload (>110%)	81[a]	46	122	c
At Design (90-110%)	109	b	194	111
Underload at				
70-89%	177	148	227	529
50-69%	216	232	261	547
<50%	239	b	328	c

---

[a] The values appearing in this table were determined from the following equation:

$$\text{Dollars Per Million Gallons Treated Per Year} = \frac{\text{Total Annual O\&M Costs in Dollars}}{\text{Actual Flow (mgd) x 365}}$$

[b] No Trickling Filter plants operating at design or at <50% of design.

[c] No AWT plants reporting cost at overload conditions or at <50% of design.

TABLE 4.5

EPA SURVEY

AVERAGE PERCENT DISTRIBUTION OF VARIOUS EXPENDITURES TO TOTAL COSTS BY TREATMENT LEVEL FOR 1.0-5.0 MGD ACTUAL FLOW

Object of Expenditure Category	Level of Treatment			
		Secondary		
	Primary	Trickling Filter	Activated Sludge	Advanced (AWT)
Personnel	59	57	54	47
Power[a]	(14)	(13)	(22)	(20)
Total Utilities	15	17	23	24
Chemical Disinfection[b]	(4)	(3)	(2)	(1)
Total Chemicals	10	9	6	10
Equipment	3	5	4	5
Materials	5	6	6	3
Contractual	4	3	3	5
Other	4	3	4	6
TOTAL	100	100	100	100
Number of Plants Surveyed	40	61	95	22

---

[a] Power costs are also included in total utility costs.

[b] Chemical disinfection (usually chlorine) costs are also included in total chemical costs.

TABLE 4.6

EPA SURVEY

AVERAGE PERCENT DISTRIBUTION OF VARIOUS EXPENDITURES TO TOTAL COSTS BY TREATMENT LEVEL FOR 5.1-20.0 MGD ACTUAL FLOW

Object of Expenditure Category	Level of Treatment			
		Secondary		
	Primary	Trickling Filter	Activated Sludge	Advanced (AWT)
Personnel	55	57	48	40
Power[a]	(17)	(12)	(27)	(11)
Total Utilities	18	15	30	15
Chemical Disinfection[b]	(3)	(4)	(3)	(7)
Total Chemicals	10	10	9	15
Equipment	5	5	4	15
Materials	7	6	6	4
Contractual	3	3	1	8
Other	2	4	2	3
TOTAL	100	100	100	100
Number of Plants Surveyed	12	17	30	3

---

[a] Power costs are also included in total utility costs.

[b] Chemical disinfection (usually chlorine) costs are also included in total chemical costs.

TABLE 4.7

EPA SURVEY

AVERAGE PERCENT DISTRIBUTION OF VARIOUS EXPENDITURES TO TOTAL COSTS BY TREATMENT LEVEL FOR >20.0 MGD ACTUAL FLOW

Object of Expenditure Category	Level of Treatment			
		Secondary		
	Primary	Trickling Filter	Activated Sludge	Advanced (AWT)
Personnel	65	60	47	44
Power[a]	(8)	(10)	(14)	(20)
Total Utilities	9	15	18	25
Chemical Disinfection[b]	(2)	(8)	(3)	(5)
Total Chemicals	7	16	8	15
Equipment	1	1	2	4
Materials	2	3	9	3
Contractual	7	3	8	6
Other	9	2	8	3
TOTAL	100	100	100	100
Number of Plants Surveyed	4	4	12	3

---

[a] Power costs are also included in total utility costs.

[b] Chemical disinfection (usually chlorine) costs are also included in total chemical costs.

trickling filter, and activated sludge plants regardless of size. In general, personnel costs for AWT plants constitute less than one-half of all operating expenses (usually in the 40-47 percent range).

Power costs are noticeably higher in activated sludge plants than in primary treatment and trickling filter plants regardless of size. Total chemical costs are relatively the same (8 to 10 percent) for the various levels of treatment (except for AWT plants) and size of plants. Due to the nature of AWT plants, a proportionately higher percent of expenditures is allocated to chemicals than at the other levels of treatment. Other object of expenditure categories, such as equipment, materials, and contractual services, contribute proportionately smaller expenditure amounts.

Table 4.8 reflects the distribution of various expenditures for all WWTPs in the EPA survey whereas Table 4.9 shows the same information for the AMSA survey. In both surveys the distribution of expenditures for primary treatment plants and trickling filter plants are very similar. However, the distribution of reported operating costs for the activated sludge plants and the AWT plants vary significantly.

According to the information in Table 4.8 from the EPA survey, the percentage of personnel costs declines as the level of treatment increases. For example, personnel costs represent about 59 percent of total operating costs at primary treatment plants; this percentage declines to 58 percent at trickling filter plants and to 52 percent at

TABLE 4.8

EPA SURVEY

AVERAGE PERCENT DISTRIBUTION OF VARIOUS EXPENDITURES TO TOTAL COSTS BY TREATMENT LEVEL FOR ALL SIZE PLANTS

Object of Expenditure Category	Level of Treatment			
		Secondary		
	Primary	Trickling Filter	Activated Sludge	Advanced (AWT)
Personnel	59	58	52	46
Power[a]	(14)	(13)	(22)	(19)
Total Utilities	15	16	24	23
Chemical Disinfection[b]	(4)	(3)	(2)	(2)
Total Chemicals	10	9	7	12
Equipment	3	5	4	6
Materials	5	6	6	3
Contractual	4	3	3	5
Other	4	3	4	5
TOTAL	100	100	100	100
Number of Plants Surveyed	56	82	137	28

---

[a] Power costs are also included in total utility costs.

[b] Chemical disinfection (usually chlorine) costs are also included in total chemical costs.

TABLE 4.9

AMSA SURVEY

AVERAGE PERCENT DISTRIBUTION OF VARIOUS EXPENDITURES TO TOTAL COSTS BY TREATMENT LEVEL FOR ALL SIZE PLANTS

Object of Expenditure Category	Level of Treatment			
		Secondary		
	Primary	Trickling Filter	Activated Sludge	Advanced (AWT)
Personnel	59	60	43	41
Power[a]	(10)	(8)	(20)	(18)
Total Utilities	11	12	24	20
Chemical Disinfection[b]	(4)	(<1)	(2)	(3)
Total Chemicals	14	13	21	25
Materials	9	8	6	6
Contractual	3	1	3	1
Other	4	6	3	7
TOTAL [c]	100	100	100	100
Number of Plants Surveyed	25	8	45	13

---

[a] Power costs are also included in total utility costs.

[b] Chemical disinfection (usually chlorine) costs are also included in total chemical costs.

[c] The AMSA survey did not report a separate "equipment" costs category as did the EPA Survey; presumably equipment costs are spread among the materials, contractual services, and other categories.

activated sludge plants. It drops further to 46 percent at AWT plants. Because of process requirements, the percentage of power costs are significantly higher at activated sludge plants and AWT plants than at primary treatment plants and trickling filter plants. Total chemical costs appear to average about 9 percent for all levels of treatment although AWT plants indicate a 12 percent distribution. Equipment, materials, contractual, and other object of expenditure categories all range between 3 and 6 percent for all treatment levels.

The AMSA survey which includes proportionately larger WWTPs generally portrays similar findings as reported in the EPA survey. In this respect Table 4.9 shows the following trends: (1) a decline in the percentage of personnel costs as the level of treatment increases; (2) a substantially greater cost for power at activated sludge and AWT plants as opposed to primary and trickling filter plants; and (3) a significantly higher percentage of total chemical costs at activated sludge and AWT plants than at primary and trickling filter plants.

4.1.3 Average Cost Per Employee

Average cost per employee is defined as total personnel costs per staff member. Total personnel costs include not only wages and/or salaries but also fringe benefits earned by the employee and paid by the municipality. Table 4.10 presents these data for the EPA survey while Table 4.11 indicates the results for the AMSA survey. In general, both surveys show a trend toward higher personnel costs per employee for the

TABLE 4.10

EPA SURVEY

AVERAGE COST PER EMPLOYEE FOR VARIOUS TREATMENT LEVELS AND SIZE GROUPS

		Secondary[a]		
	Primary	Trickling Filter	Activated Sludge	Advanced (AWT)
Flow = 1.0-5.0 mgd				
Dollars Per Employee	16,405[b]	13,574	13,994	14,373
Number of WWTP	39	61	94	23
Flow = 5.1-20.0 mgd				
Dollars Per Employee	13,172	16,658	14,606	15,297
Number of WWTP	12	18	31	3
Flow > 20.0 mgd				
Dollars Per Employee	13,816	18,286	15,499	15,724
Number of WWTP	5	4	10	3
All WWTPs				
Dollars Per Employee	15,481	14,470	14,213	14,608
Total Number of WWTP	56	83	135	29

---

[a] Secondary Plants in addition to Trickling Filter and Activated Sludge:

Type	1.0-5.0 mgd	5.1-20.0 mgd
. Oxidation Ditch	\$ 10,674 (n=5)	\$ 11,028 (n=1)
. Aerated Lagoon	\$ 7,656 (n=2)	\$ 11,199 (n=1)

[b] The values appearing in this table were determined from the following equation:

$$\text{Average Cost Per Employee} = \frac{\text{Total Personnel Costs in Dollars}}{\text{Total Number of Employees}}$$

Total Personnel Costs include fringe benefits.

TABLE 4.11

AMSA SURVEY

AVERAGE COST PER EMPLOYEE FOR VARIOUS TREATMENT LEVELS AND SIZE GROUPS

	Primary	Secondary Trickling Filter	Secondary Activated Sludge	Advanced (AWT)
Flow = 1.0-5.0 mgd				
Dollars Per Employee	8,914[a]	b	7,468	12,516
Number of WWTP	4	b	6	5
Flow = 5.1-20.0 mgd				
Dollars Per Employee	15,076	17,889	20,776	4,686
Number of WWTP	9	2	15	2
Flow > 20.0 mgd				
Dollars Per Employee	18,934	11,289	27,084	13,546
Number of WWTP	13	3	24	4
All WWTPs				
Dollars Per Employee	16,057	13,929	22,366	11,467
Total Number of WWTP	26	5	45	11

---

[a] Average Cost Per Employee = $\frac{\text{Total Personnel Costs in Dollars}}{\text{Total Number of Employees}}$

Total Personnel Costs include fringe benefits.

[b] No trickling filter WWTPs were reported for the small plant category.

larger size facilities. This phenomenon might be explained: larger plants require more specialization (greater division of labor), usually have labor unions representing hourly wage earners, and are located in metropolitan areas. In addition, larger plants usually have on their staff more highly qualified or more skilled personnel which normally are more expensive. The larger plants also tend to do more of their own work, particularly for such items as mechanical/electrical problems and laboratory analyses, rather than contract it to outside services. For these reasons, it is not surprising that larger plants have higher employee costs than smaller WWTPs. Average cost per employee for advanced treatment levels might be expected to be higher than similar costs for primary treatment plants. This hypothesis is not supported by the information shown in either table. Regardless of treatment level the EPA survey (Table 4.10) indicates that the average cost per employee is nearly the same (actually a 9 percent variance between high and low rates). However, the AMSA survey (Table 4.11) shows a large disparity of employee costs between activated sludge and AWT plants. Some of this difference might be explained since most AWT plants are highly automated.

4.1.4 Distribution of Functional Costs

Table 4.12 presents a distribution of functional costs to total O&M costs by level of treatment (EPA survey). Functional costs are costs attributable to a major process in a group of related major processes. For example, the major functional processes of an activated sludge plant are primary, solids handling, and secondary. In this instance the processing of both primary sludge and secondary sludge are grouped

TABLE 4.12

EPA SURVEY

AVERAGE PERCENTAGE OF FUNCTIONAL COSTS TO TOTAL O&M COSTS BY LEVEL OF TREATMENT

Level of Treatment	Sample Size(n)	Ratio of Functional Costs at			
		Primary	Solids Handling	Secondary	Advanced
Primary	31	80	20	n.a.[a]	n.a.
Secondary					
-- Trickling Filter	42	33	30	37	n.a.
-- Activated Sludge	72	35	26	39	n.a.
Advanced	15	15	20	47	18

Total Plants Surveyed = 160

Average Design Flow = 10 mgd

Range = 0.3 mgd to 200 mgd

---

[a] n.a. denotes 'not applicable'.

and reported as solids handling costs. Costs associated with treating the liquid stream are primary (removing settleable solids) and secondary (biologically and chemically removing pollutants from primary-treated wastewater). Thirty-one primary treatment plants reported functional costs. Eighty (80) percent of total plant O&M costs were recorded as primary costs and 20 percent were recorded as solids handling costs. Forty-two trickling filter plants reported functional costs. A nearly equal distribution of costs among the three functional areas was recorded, viz., 33 percent for primary costs, 30 percent for solids handling costs, and 37 percent for secondary costs. Functional costs were reported for 72 activated sludge plants. Thirty-five percent of the total plant O&M costs were recorded as primary costs, 26 percent were recorded as solids handling costs, and 39 percent were classified as secondary treatment costs. Fifteen advanced waste treatment plants reported functional costs. Fifteen percent of the total plant operating costs were recorded as primary treatment costs, 20 percent were indicated as solids handling costs, 47 percent were classified as secondary treatment costs, and 18 percent were specifically identified as advanced treatment costs.

Table 4.13 illustrates the same general distribution of functional costs as reported by the AMSA survey. The major difference in the functional cost distributions between the two surveys is the higher allocation to secondary process at all levels of treatment in the AMSA survey. Conversely, for every treatment level in the AMSA survey primary

TABLE 4.13

AMSA SURVEY

AVERAGE PERCENTAGE OF FUNCTIONAL COSTS TO TOTAL O&M COSTS BY LEVEL OF TREATMENT

Level of Treatment	Sample Size(n)	Ratio of Functional Costs at			
		Primary	Solids Handling	Secondary	Advanced
Primary	7	60	40	n.a.[a]	n.a.
Secondary					
-- Trickling Filter	1	22	20	58	n.a.
-- Activated Sludge	17	27	20	53	n.a.
Advanced	5	13	19	52	16

Total Plants Surveyed = 30

Average Design Flow = 70 mgd

Range = 1.0 mgd to 999 mgd

---

[a] n.a. denotes 'not applicable'.

process costs and solids handling costs are comparably lower than in the EPA survey.

4.1.5 Cost Allocation: Operating Versus Supporting

Table 4.14 presents average operating costs as percentages of total O&M costs for various levels of treatment and by wastewater treatment plant size groups. The values listed in this table are actual average operating costs ("inside-the-fence") which exclude administrative or supporting services type costs. By subtracting these values from 100, the resultant values would be the average administrative and supporting services costs. For all levels of treatment, as the size of treatment plant increases, the proportion of operating costs to total O&M costs likewise increases. In addition, as the level of treatment is upgraded, i.e., primary treatment to secondary treatment to advanced treatment, the percent of average operating costs increases steadily.

4.2 RELATIVE O&M INDICES FOR VARIOUS ULTIMATE DISPOSAL METHODS

Table 4.15 presents index values for average cost estimates to remove a dry ton of suspended solids (SS) for various methods of ultimate sludge disposal. The index values appearing in this table were determined by dividing the average O&M cost per dry ton of SS removed for a specific disposal method by the average O&M cost per dry ton of SS removed for all methods. This relative index value is used for comparing the SS removal efficiency and related expenses of various solids disposal methods. (These values or estimates should not be confused with the cost to process a dry ton of sludge.)

TABLE 4.14

EPA SURVEY

AVERAGE OPERATING COSTS AS PERCENTAGES OF TOTAL O&M COSTS[a]

(All numbers in percentages)

Actual Flow (mgd)	Primary	Secondary Trickling Filter	Secondary Activated Sludge	Advanced
0.1 - 5.0	82	85	86	89
5.0 - 20.0	83	85	88	92
<20.0	88	88	90	94
All Plants	83	86	87	92
Number Sampled	33	39	86	16

---

[a] The values appearing in this table were determined from the following equation:

$$\text{Percent Operating Costs} = \frac{\text{Total Operating Costs in Dollars}}{\text{Total O\&M Costs (includes Operating + Supporting Administrative Cost) in Dollars}}$$

TABLE 4.15

EPA SURVEY

INDEX VALUES FOR AVERAGE O&M COST PER DRY TON OF SS REMOVED FOR VARIOUS LEVELS OF TREATMENT BY ULTIMATE SLUDGE DISPOSAL METHODS

Various Methods of Ultimate Sludge Disposal	Primary	Secondary		Advanced
		Trickling Filter	Activated Sludge	
AIR				
Incineration	1.01[a]	1.48	1.39	1.20
WATER				
Ocean Dumping	b	b	1.13	b
LAND				
Air Drying Beds	0.69	0.89	1.32	0.87
Land Spreading	0.95	1.03	1.15	1.00
Landfill/Burying	1.12	0.98	0.91	0.91
Average O&M Cost Per Dry Ton of SS Removed for All Methods	$170[c]	$214	$257	$410
Number of Disposal Systems Sampled	63	68	131	73

---

[a] The values appearing in this table were determined from the following equation:

Index Value = Average O&M Costs Per Dry Ton of SS Removed for a Specific Method of Ultimate Sludge Disposal ÷ Average O&M Cost Per Dry Ton of SS Removed for All Methods.

[b] No costs reported for this level of treatment.

[c] Computed:

$$\text{Dollars Per Dry Ton of SS} = \frac{\text{Total Annual O\&M Costs in Dollars of All Systems}}{\text{Total Tons of SS Removed Per Year of All Systems}}$$

As an ultimate method of disposal, incineration is the most costly alternative for all levels of treatment except primary treatment. Air drying beds are the least costly method for all levels of treatment except for activated sludge treatment. Table 4.16 shows comparable trends for the AMSA survey, viz., incineration is generally the most costly ultimate sludge disposal method while the various land application methods are generally the least costly disposal alternatives. In general, all of the cost estimates for the various solids handling methods in the EPA survey are slightly higher than those cost values obtained from the AMSA survey. This result is probably due to the size of the WWTPs in both surveys. For example, the average size plant in the AMSA survey is seven times the size of the average plant in the EPA survey (70 mgd vs 10 mgd). This analysis suggests that smaller treatment plants incur proportionately higher solids handling costs per level of operating efficiency than do larger plants.

4.3 EFFECT OF INDUSTRIAL WASTE LOADINGS ON O&M COSTS

In this study industrial waste loadings are defined as those flows contributed to municipal wastewater treatment plants by various manufacturing establishments, commercial businesses, and profit-making enterprises without regard to quality of plant influent. Some industries, of course, pretreat their wastewater prior to releasing it to the municipal sewerage system. The specific quality of industrial flows was not analyzed in this study, but the aggregate contribution of all industrial flows was recorded and analyzed as a proportion of the total plant influent.

TABLE 4.16

AMSA SURVEY

INDEX VALUES FOR O&M COST PER DRY TON OF SS REMOVED FOR VARIOUS LEVELS OF TREATMENT BY ULTIMATE SLUDGE DISPOSAL METHODS

Various Methods of Ultimate Sludge Disposal	Primary	Secondary		Advanced
		Trickling Filter	Activated Sludge	
AIR				
Incineration	1.07[a]	2.85	1.64	b
WATER				
Ocean Dumping	1.16	b	1.51	b
LAND				
Air Drying Beds	0.79	0.84	1.06	0.93
Land Spreading	1.17	1.19	0.79	b
Landfill/Burying	1.06	0.85	0.94	1.22
Average O&M Cost Per Dry Ton of SS Removed for All Methods	$145[c]	$201	$227	$361
Number of Disposal Systems Sampled	29	8	49	13

---

[a] The values appearing in this table were determined from the following equation:

Index Value = Average O&M Costs Per Dry Ton of SS Removed for a Specific Method of Ultimate Sludge Disposal ÷ Average O&M Cost Per Dry Ton of SS Removed for All Methods.

[b] No costs reported for this level of treatment.

[c] Computed:

$$\text{Dollars Per Dry Ton of SS} = \frac{\text{Total Annual O\&M Costs in Dollars of All Systems}}{\text{Total Tons of SS Removed Per Year of All Systems}}$$

It was hypothesized that industrial waste loadings would impact costs at a given WWTP in two ways: (1) as the amount (percentage) of industrial flow increases, the total O&M costs would also show an increase, and (2) average O&M costs for treating industrial wastes would increase per unit as greater quantities of industrial pollutants are removed at progressively higher treatment levels. Admittedly, these hypotheses are somewhat generalized, but the particular objective of this comparative analysis is to identify and determine the relative impacts (effects) of industrial waste contributions on O&M costs at municipal treatment plants. Although both surveys failed to disclose the character of industrial wastes at the sampled facilities, it was assumed that the proportion of industrial waste flow to total flow would be a determinant of total O&M costs.

Table 4.17 shows the number of plants sampled in the two surveys by the level of industrial flow contribution. Municipal plants treating wastes were grouped into four categories: those WWTPs receiving no industrial wastes at all; those WWTPs receiving up to 10 percent of their total flow; those WWTPs receiving between 10 and 25 percent industrial wastes; and those WWTP receiving greater than 25 percent of their total flow in industrial wastes. In comparison to the EPA survey, the AMSA survey included WWTPs that were more evenly distributed in the four industrial waste categories.

Results of both surveys refute the first hypothesis, viz., that as the percent of industrial flow increases, the total O&M costs would

TABLE 4.17

NUMBER OF WASTEWATER TREATMENT PLANTS SURVEYED BY INDUSTRIAL CONTRIBUTION

Industrial Flow as Percent of Total Annual Flow	EPA Survey		AMSA Survey	
	Number	Percent	Number	Percent
No Industrial Contribution	177	51	35	36
Less than 10 Percent	39	11	27	27
10 - 25 Percent	74	21	23	23
Greater than 25 Percent	58	17	14	14
TOTALS	348	100	99	100

also increase. Tables 4.18 (EPA survey) and 4.19 (AMSA survey) indicate that plants with increasing industrial flow percentages do not incur higher average O&M costs per million gallons of wastewater treated.

The second hypothesis appears to be substantiated by the data presented in both surveys. From Tables 4.18 and 4.19, average O&M costs per million gallons of treated effluent increase as greater quantities of industrial pollutants are removed at progressively higher treatment levels. For example, in Table 4.18 municipal plants that have 10 to 25 percent of their total flows as industrial waste flow show $143 per million gallons treated for primary plants, $178 per million gallons treated for trickling filter plants, $225 per million gallons treated for activated sludge plants, and $247 per million gallons treated for AWT plants. Similar trends for other industrial waste categories are evident in both surveys.

4.4 PER CAPITA TRENDS AND OPERATING COSTS

4.4.1 Per Capita Flow Trends

According to Table 4.20 the average flow per capita (in gallons per capita per day) increases as the size of plant increases. The values appearing in Table 4.20 were determined by dividing the actual flow (mgd) less industrial contributions by the service population. Population equivalent (PE) flow loadings to account for commercial establishments and public facilities were not computed nor employed in this analysis. Actual flow data for both surveys were obtained for the most recent year without considering whether or not the year in question was a "normal"

TABLE 4.18

EPA SURVEY

AVERAGE O&M COST FOR TREATMENT AS AFFECTED BY INDUSTRIAL WASTES

	Dollars Per Million Gallons Treated			
		Secondary		
Industrial Flow as Percent of Total Annual Flow	Primary	Trickling Filter	Activated Sludge	Advanced
No Industrial Flow	\$163[a]	\$213	\$311	\$486
Number of Plants	34	42	86	15
Less Than 10 Percent	\$154	\$144	\$242	\$681
Number of Plants	10	10	16	3
10-25 Percent	\$143	\$178	\$225	\$247
Number of Plants	15	18	34	7
Greater Than 25 Percent	\$163	\$185	\$236	\$186
Number of Plants	8	11	30	9

---

[a] The values appearing in this table were determined from the following equation:

$$\text{Dollars Per Million Gallons Treated} = \frac{\text{Total Annual O\&M Costs in Dollars}}{\text{Total Actual Flow (mgd) x 365}}$$

TABLE 4.19

AMSA SURVEY

AVERAGE O&M COST FOR TREATMENT AS AFFECTED BY INDUSTRIAL WASTES

	Dollars Per Million Gallons Treated			
		Secondary		
Industrial Flow as Percent of Total Annual Flow	Primary	Trickling Filter	Activated Sludge	Advanced
No Industrial Flow	$188[a]	$153	$238	$477
Number of Plants	9	4	18	4
Less Than 10 Percent	$ 81	$ 84	$227	$ 0
Number of Plants	7	4	16	0
10-25 Percent	$ 91	$ 0	$171	$354
Number of Plants	8	0	12	3
Greater Than 25 Percent	$ 63	$ 0	$161	$ 62
Number of Plants	6	0	7	1

---

[a] The values appearing in this table were determined from the following equation:

$$\text{Dollars Per Million Gallons Treated} = \frac{\text{Total Annual O\&M Costs in Dollars}}{\text{Total Actual Flow (mgd)} \times 365}$$

TABLE 4.20

AVERAGE FLOW PER CAPITA FOR WASTEWATER TREATMENT PLANTS SURVEYED BY SIZE GROUP

Size Group: Actual Flow (Million Gallons Per Day)	Average Flow Per Capita (Gallons Per Capita Per Day)	
	EPA Survey	AMSA Survey
0.1-5.0	121[a]	110
5.1-20.0	130	126
>20.0	145	139

---

[a] The values appearing in this table were determined from the following equation:

$$\text{Average Flow Per Capita} = \frac{\text{Actual Flow (mgd) - Industrial Flow (mgd)}}{\text{Service Population}}$$

flow year. In other words, the actual flows used in this study were not evaluated or classified as "wet" year flows (due to higher than average precipitation), "dry" year flows (due to lower than average precipitation), or normal year flows.

Because many of the larger WWTPs have heavier commercial flows, it is assumed that these flows contributed to the sizeable increase in the gpcd value from the middle group to the greater than 20 mgd size category. In addition, some of the larger, older treatment plants in the eastern U.S. still process storm wastes, i.e., have combined sanitary and storm wastes. Thus, the combined flows of sanitary and storm flows also contributed to the noticeably higher gpcd value for the larger size class.

4.4.2 Per Capita Operating Costs

Table 4.21 presents average operating cost per capita for varying levels of treatment by WWTP size group. These per capita values do not include any allowances for amortization of capital debt or any provision for debt service requirements. In general, it can be stated that per capita costs decline for all levels of treatment as treatment plant size increases. Table 4.21 also indicates that per capita costs increase as the level of treatment progresses from primary to secondary to advanced treatment systems. On a cost per capita basis, the most costly treatment systems to operate are the smaller AWT plants (cf. $19.60 per capita per year). Conversely, the least costly treatment systems to operate are the large primary treatment plants (cf. $2.89 per capita per year).

TABLE 4.21

EPA SURVEY

AVERAGE OPERATING COST PER CAPITA FOR VARYING TREATMENT LEVELS BY WWTP SIZE GROUP

(Costs in Dollars Per Capita Per Year)

		Secondary		
Actual Flow (MGD)	Primary	Trickling Filter	Activated Sludge	Advanced
0.1 - 5.0	\$7.87[a] n=44	\$9.35 n=57	\$15.97 n=105	\$19.60 n=23
5.1 - 20.0	\$7.19 n=15	\$9.83 n=14	\$10.15 n=35	\$12.01 n=4
>20.0	\$2.89 n=4	\$6.15 n=4	\$ 8.72 n=13	\$11.77 n=3
All Plants	\$7.40 n=63	\$9.27 n=75	\$14.02 n=153	\$17.81 n=30

---

[a] The values appearing in this table were determined from the following equation:

$$\text{Costs in Dollars Per Capita Per Year} = \frac{\text{Total Annual O\&M Costs in Dollars}}{\text{Service Population}}$$

These calculations did not include debt service provisions.

The AMSA survey findings concerning average cost per capita are presented in Table 4.22. Generally, the same conclusions that are made about the EPA survey hold true for the AMSA survey. However, the cost per capita per year for the medium size class of trickling filter plants is higher than the small class ($6.74 versus $5.23), but this situation may be biased due to a low sample frequency of only three plants in each category. Also, the annual cost per capita of medium size AWT plants ($9.43) is lower than the annual cost per capita of medium size activated sludge plants ($12.63). Again, the aberration might be attributed to the low number of AWT plants (only two) in the sample. Other than this discrepancy, the AMSA survey findings regarding annual per capita operating costs are very comparable with those found in the nationwide EPA survey.

Table 4.23 presents the same type of data that was reported in Table 4.21, except average operating costs per capita are presented for each EPA region rather than by WWTP size class. Of the sample data from the EPA survey, EPA Regions V and IX indicate the highest annual per capita operating costs for primary treatment plants at $8.90 and $8.92, respectively. The lowest annual per capita operating costs for primary treatment plants are in EPA Regions VI and VIII at $3.08 and $3.55, respectively. For trickling filter plants, EPA Regions II and IV rank the highest in annual per capita operating costs at $18.60 and $10.16, while the lowest per capita costs for trickling filter WWTP are in EPA Regions VI ($5.31) and VIII ($6.03). EPA Regions I and VIII show the

TABLE 4.22

AMSA SURVEY

AVERAGE OPERATING COST PER CAPITA FOR VARYING TREATMENT LEVELS BY WWTP SIZE GROUP (Costs in Dollars Per Capita Per Year)

Actual Flow (MGD)	Primary	Secondary		Advanced
		Trickling Filter	Activated Sludge	
0.1 - 5.0	$8.51[a] n=7	$5.23 n=3	$23.40 n=12	$29.43 n=2
5.1 - 20.0	$4.83 n=10	$6.74 n=3	$12.63 n=11	$ 9.43 n=2
>20.0	$4.67 n=13	$2.17 n=2	$ 7.11 n=25	$ 7.38 n=3
All Plants	$5.62 n=30	$5.03 n=8	$12.45 n=48	$14.27 n=7

---

[a] The values appearing in this table were determined from the following equation:

$$\text{Costs in Dollars Per Capita Per Year} = \frac{\text{Total Annual O\&M Costs in Dollars}}{\text{Service Population}}$$

These calculations did not include debt service provisions.

TABLE 4.23

EPA SURVEY

AVERAGE OPERATING COST FOR VARYING TREATMENT LEVELS BY EPA REGIONS

(Dollars Per Capita Per Year)

		Secondary		
EPA Region	Primary	Trickling Filter	Activated Sludge	Advanced
I	$6.94 n=6	$9.29 n=3	$22.74 n=11	$35.21 n=2
II	$7.95 n=5	$18.60 n=10	$13.03 n=18	$18.64 n=5
III	$4.46 n=4	$9.80 n=7	$12.25 n=19	$32.32 n=3
IV	$8.40 n=10	$10.16 n=14	$18.21 n=26	$16.15 n=1
V	$8.90 n=10	$7.70 n=6	$13.86 n=29	$16.41 n=11
VI	$3.08 n=2	$5.31 n=14	$7.44 n=18	$ [a] n=
VII	$5.09 n=5	$6.81 n=5	$10.19 n=3	$14.29 n=2
VIII	$3.55 n=3	$6.03 n=7	$22.72[b] n=6	$ [a] n=
IX	$8.92 n=11	$8.64 n=6	$9.47 n=16	$8.05 n=6
X	$7.60 n=7	$7.27 n=3	$14.32 n=7	$ [a] n=
National Average	$7.40 n=63	$9.27 n=75	$14.02 n=153	$17.81 n=30

---

[a] Per capita operating costs not reported in these regions.

[b] Abnormally high due to inclusion of two mountain resort areas; when these two Colorado resort areas are excluded, the average per capita cost is $8.01.

highest ($22.74 and $22.72) per capita treatment costs for activated sludge plants. (Note: EPA Region VIII's per capita cost per year is abnormally high due to a small sample (6) and of this sample two plants are located in mountain resort communities. If these two plants are excluded, EPA Region VIII's per capita cost drops to $8.01 which would make it the lowest region along with EPA Region VI.) The highest annual per capita operating cost for AWT systems is in EPA Region I ($35.21) and the lowest is in EPA Region IX ($8.05). The high annual per capita cost at EPA Region I is atypical; this value is based on only two samples. Therefore, this per capita per year cost should be used with caution.

4.5 OPERATING EFFICIENCIES

4.5.1 Average Flow Treatment Costs

Table 4.24a indicates average (arithmetic mean) cost per million gallons treated for varying levels of treatment by WWTP size. The findings of the EPA survey show, as expected, that the cost of treating a million gallons of wastewater increases as the level of treatment increases. Primary treatment plants average $159 per million gallons treated, trickling filter plants $196, activated sludge plants $268, and AWT plants $398. In all levels of treatment, as the WWTP group size increases, the average cost of treating one million gallons of wastewater decreases. This result basically reinforces the concept of economies of scale.

Table 4.24b presents a corresponding distribution of average costs for level of treatment and size categories except that costs are reporte

TABLE 4.24a
EPA SURVEY
AVERAGE COST PER MILLION GALLONS TREATED

Level of Treatment	1.0-5.0 mgd	5.1-20.0 mgd	>20.0 mgd	All Plants
Primary	\$176[a] n=40	\$137 n=12	\$ 47 n=4	\$159 n=56
Secondary				
-- Trickling Filter	\$212 n=61	\$162 n=17	\$ 95 n=4	\$196 n=82
-- Activated Sludge	\$316 n=95	\$165 n=30	\$149 n=12	\$268 n=137
Advanced (AWT)	\$454 n=22	\$251 n=3	\$136 n=3	\$398 n=28

---

[a] The values appearing in this table were determined from the following equation:

$$\text{Average Cost Per Million Gallons} = \frac{\text{Total Annual O\&M Costs in Dollars}}{\text{Actual Flow (mgd)} \times 365}$$

TABLE 4.24b
EPA SURVEY
MEDIAN COST PER MILLION GALLONS TREATED

Level of Treatment	1.0-5.0 mgd	5.1-20.0 mgd	>20.0 mgd	All Plants
Primary	\$161[a]	\$ 98	\$ 40	\$126
Secondary				
-- Trickling Filter	\$182	\$113	\$46	\$163
-- Activated Sludge	\$240	\$155	\$123	\$219
Advanced (AWT)	\$458	\$221	\$139	\$366

---

[a] The values appearing in this table were determined from the following equation: Median Cost Per Million Gallons is the middle value in order of size by dividing Total Annual O&M Costs in Dollars by Actual Flow (mgd) times 365.

as median costs. These median values reflect similar trends as the average costs shown in Table 4.24a, viz., the median O&M cost of treating one million gallons of wastewater increases both as the level of treatment is upgraded and as the size of plant decreases in hydraulic design capacity.

The AMSA survey findings (Table 4.25a) exhibit the same patterns of average cost per million gallons treated as reported above in the EPA survey. The average cost per million gallons treated declines as the size (capacity) of the WWTP increases but the average cost per million gallons treated increases as the level of treatment also increases (quality upgrading). Similarly, the AMSA survey shows median values that demonstrate this same trend (Table 4.25b). One additional observation is made in comparing the data from the two surveys: the average costs presented in the AMSA survey are considerably less than those presented in the EPA survey. This phenomenon is probably due to the significantly larger size treatment plants in the AMSA survey as opposed to the EPA survey (70 mgd vs 10 mgd).

4.5.2 Average BOD Removal Costs

Perhaps an even better way to look at plant efficiency is to compare pollutant removal unit costs instead of an average cost per volume of wastewater treated. Table 4.26a shows average cost per pound of BOD removed for plants sampled in the EPA survey. Primary treatment removal costs are high in comparison to other treatment levels. (BOD removal

TABLE 4.25a
AMSA SURVEY
AVERAGE COST PER MILLION GALLONS TREATED

Level of Treatment	1.0-5.0 mgd	5.1-20.0 mgd	>20.0 mgd	All Plants
Primary	$102[a] n=4	$ 89 n=10	$ 64 n=13	$ 78 n=27
Secondary				
-- Trickling Filter	$136 n=3	$134 n=2	$ 74 n=3	$113 n=8
-- Activated Sludge	$341 n=7	$230 n=15	$139 n=24	$199 n=46
Advanced (AWT)	$435 n=5	$390 n=3	$110 n=4	$316 n=12

---

[a] The values appearing in this table were determined from the following equation:

$$\text{Average Cost Per Million Gallons} = \frac{\text{Total Annual O\&M Costs in Dollars}}{\text{Actual Flow (mgd)} \times 365}$$

TABLE 4.25b
AMSA SURVEY
MEDIAN COST PER MILLION GALLONS TREATED

Level of Treatment	1.0-5.0 mgd	5.1-20.0 mgd	>20.0 mgd	All Plants
Primary	$ 72[a]	$ 62	$ 50	$ 66
Secondary				
-- Trickling Filter	$ 92	$ 46	$ 69	$ 89
-- Activated Sludge	$305	$168	$120	$165
Advanced (AWT)	$349	$323	$ 99	$305

---

[a] The values appearing in this table were determined from the following equation: Median Cost Per Million Gallons is the middle value in order of size by dividing Total Annual O&M Costs in Dollars by Actual Flow (mgd) times 365.

TABLE 4.26a
EPA SURVEY
AVERAGE COST PER POUND BOD REMOVED

Level of Treatment	1.0-5.0 mgd	5.1-20.0 mgd	>20.0 mgd	All Plants
Primary	\$0.35[a] n=26	\$0.47 n=9	\$0.07 n=4	\$0.35 n=39
Secondary				
-- Trickling Filter	\$0.17 n=48	\$0.15 n=11	\$0.10 n=2	\$0.16 n=61
-- Activated Sludge	\$0.26 n=75	\$0.12 n=27	\$0.13 n=9	\$0.22 n=111
Advanced (AWT)	\$0.37 n=19	\$0.20 n=3	\$0.15 n=3	\$0.32 n=25

---

[a] The values appearing in this table were determined from the following equation:

$$\text{Average Cost Per Pound BOD Removed} = \frac{\text{Total Annual O\&M Costs in Dollars}}{\text{Total Pounds of BOD Removed Per Year}}$$

TABLE 4.26b
EPA SURVEY
MEDIAN COST PER POUND BOD REMOVED

Level of Treatment	1.0-5.0 mgd	5.1-20.0 mgd	>20.0 mgd	All Plants
Primary	\$0.19[a]	\$0.18	\$ .08	\$0.14
Secondary				
-- Trickling Filter	\$0.13	\$0.15	\$0.07	\$0.13
-- Activated Sludge	\$0.19	\$0.09	\$0.11	\$0.16
Advanced (AWT)	\$0.34	\$0.08	\$0.13	\$0.26

---

[a] The values appearing in this table were determined from the following equation: Median Cost Per Pound BOD Removed is the middle value in order of size by dividing Total Annual O&M Costs in Dollars by Total Pounds of BOD Removed Per Year.

costs for primary plants are high because these plants are basically designed to remove SS. The BOD removals at primary plants are coincident with SS removal performance.) Notwithstanding this difference it can be observed that average BOD removal costs increase as the level of treatment increases. Table 4.26b indicates that median BOD removal costs generally increase as the level of treatment increases. In addition, the median costs decline as the WWTP size increases. The larger average cost discrepancy between primary treatment and the other levels of treatment in Table 4.26a is not quite as profound in the median cost values of Table 4.26b.

Table 4.27a presents average costs per pound of BOD removed for 92 plants in the AMSA survey. In general, average costs decline as the size of plant increases; however, average costs do not consistently increase as the level of treatment is upgraded. For example, the average cost to remove a pound of BOD for primary treatment plants as well as activated sludge plants is $0.19 whereas the average cost to do the same job at an AWT plant is $0.73. A partial explanation for the high AWT BOD removal cost is the small sample size; perhaps this would have been lower if data were obtained from more plants. In addition, the BOD removal average appears abnormally low for trickling filter plants. This, too, might be attributable to the small number of plants available in the sample. Although the median costs per pound of BOD removed as shown in Table 4.27b reflect similar trends as the mean costs, the absolute values are somewhat lower. This fact implies that the arithmetic mean values are

TABLE 4.27a
AMSA SURVEY
AVERAGE COST PER POUND BOD REMOVED

Level of Treatment	1.0-5.0 mgd	5.1-20.0 mgd	>20.0 mgd	All Plants
Primary	$0.08[a] n=4	$0.25 n=10	$0.18 n=13	$0.19 n=27
Secondary				
-- Trickling Filter	$0.07 n=3	$0.14 n=2	$0.03 n=3	$0.07 n=8
-- Activated Sludge	$0.24 n=7	$0.24 n=15	$0.14 n=24	$0.19 n=46
Advanced (AWT)	$1.36 n=5	$0.45 n=2	$0.08 n=4	$0.73 n=11

---

[a] The values appearing in this table were determined from the following equation:

$$\text{Average Cost Per Pound BOD Removed} = \frac{\text{Total Annual O\&M Costs in Dollars}}{\text{Total Pounds of BOD Removed Per Year}}$$

TABLE 4.27b
AMSA SURVEY
MEDIAN COST PER POUND BOD REMOVED

Level of Treatment	1.0-5.0 mgd	5.1-20.0 mgd	>20.0 mgd	All Plants
Primary	$0.04[a]	$0.18	$0.12	$0.12
Secondary				
-- Trickling Filter	$0.07	$0.07	$0.03	$0.05
-- Activated Sludge	$0.18	$0.10	$0.09	$0.11
Advanced (AWT)	$0.36	$0.23	$0.07	$0.19

---

[a] The values appearing in this table were determined from the following equation: Median Cost Per Pound BOD Removed is the middle value in order of size by dividing Total Annual O&M Costs in Dollars by Total Pounds of BOD Removed Per Year.

probably inflated by unusually high average removal costs at only a few plants.

As increasing quantities of BOD are removed from a given volume of wastewater, greater technical difficulties are encountered which are, of course, directly proportional to O&M costs. Most AWT plants are not designed to remove additional BOD but to remove specific nutrients such as phosphorus, nitrogen, and ammonia. The cost analysis in this section presumes that O&M costs for removal of these nutrients are directly attributal to BOD.

4.5.3 Average SS Removal Costs

Table 4.28a presents average suspended solids (SS) removal costs for the EPA survey. These cost data are similar in trend to the BOD removal costs disclosed in Table 4.26a. Primary treatment removal costs are high in comparison to other treatment levels. Excluding primary treatment, the average SS removal costs increase as the level of treatment increases, i.e. trickling filter plants average $0.16 per pound SS removed, activated sludge $0.21, and AWT plants $0.33. Technically, trickling filter and activated sludge plants are the same level of treatment, but the absolute pollutant removals of activated sludge plants are usually better (i.e., lower) than those of tricking filter plants. Table 4.28b indicates that median SS removal costs generally increase as the level of treatment increases. The median costs also decline as the WWTP size increases.

TABLE 4.28a
EPA SURVEY
AVERAGE COST PER POUND SS REMOVED

Level of Treatment	1.0-5.0 mgd	5.1-20.0 mgd	>20.0 mgd	All Plants
Primary	$0.43[a] n=27	$0.17 n=9	$0.03 n=4	$0.33 n=40
Secondary				
-- Tricking Filter	$0.17 n=48	$0.13 n=11	$0.11 n=2	$0.16 n=61
-- Activated Sludge	$0.26 n=74	$0.11 n=27	$0.10 n=9	$0.21 n=110
Advanced (AWT)	$0.37 n=18	$0.22 n=3	$0.18 n=3	$0.33 n=24

---

[a] The values appearing in this table were determined from the following equation:

$$\text{Average Cost Per Pound SS Removed} = \frac{\text{Total Annual O\&M Costs in Dollars}}{\text{Total Pounds of SS Removed Per Year}}$$

TABLE 4.28b
EPA SURVEY
MEDIAN COST PER POUND SS REMOVED

Level of Treatment	1.0-5.0 mgd	5.1-20.0 mgd	>20.0 mgd	All Plants
Primary	$0.18[a]	$0.14	$0.02	$0.13
Secondary				
-- Trickling Filter	$0.14	$0.13	$0.10	$0.13
-- Activated Sludge	$0.19	$0.09	$0.09	$0.16
Advanced (AWT)	$0.29	$0.09	$0.16	$0.25

---

[a] The values appearing in this table were determined from the following equation: Median Cost Per Pound SS Removed is the middle value in order of size by dividing Total Annual O&M Costs in Dollars by Total Pounds of SS Removed Per Year.

The average cost per pound of suspended solids removed was computed for 92 plants in the AMSA survey (Table 4.29a). Larger plants tend to show lower average SS removal costs, and as the level of treatment is upgraded, higher average SS removal costs are generally incurred. Trickling filter process costs are lower than those experienced by primary treatment plants. Table 4.29b presents median cost values per pound SS removed. In general, all these averages are lower than the mean values as illustrated in Table 4.29a. This suggests that a few plants with abnormally high removal costs have distorted the mean averages. As increasing quantities of SS are removed from a given concentration and volume of wastewater, greater technical difficulties are encountered which are directly proportional to O&M costs.

Most AWT plants are not designed to remove additional SS only but to remove specific nutrients such as phosphorus, nitrogen, and ammonia. The cost analysis in this section presumes that O&M costs for removal of these nutrients are directly attributable to SS.

4.5.4 Significant O&M Relationships

Appendix D contains tabular information on the specific plants sampled in the EPA survey. The treatment systems are listed by group size with level of treatment specified for each facility (Table D.1). Table D.2 indicates the number of plants sampled by specific treatment processes for both surveys.

TABLE 4.29a
AMSA SURVEY
AVERAGE COST PER POUND SS REMOVED

Level of Treatment	1.0-5.0 mgd	5.1-20.0 mgd	>20.0 mgd	All Plants
Primary	\$0.06[a] n=4	\$0.20 n=10	\$0.08 n=13	\$0.12 n=27
Secondary				
-- Trickling Filter	\$0.11 n=3	\$0.10 n=2	\$0.04 n=3	\$0.08 n=8
-- Activated Sludge	\$0.24 n=7	\$0.22 n=15	\$0.12 n=24	\$0.17 n=46
Advanced (AWT)	\$0.96 n=5	\$0.40 n=2	\$0.05 n=4	\$0.53 n=11

---

[a] The values appearing in this table were determined from the following equation:

$$\text{Average Cost Per Pound SS Removed} = \frac{\text{Total Annual O\&M Costs in Dollars}}{\text{Total Pounds of SS Removed Per Year}}$$

TABLE 4.29b
AMSA SURVEY
MEDIAN COST PER POUND SS REMOVED

Level of Treatment	1.0-5.0 mgd	5.1-20.0 mgd	>20.0 mgd	All Plants
Primary	\$0.04[a]	\$0.06	\$0.04	\$0.05
Secondary				
-- Trickling Filter	\$0.06	\$0.03	\$0.05	\$0.05
-- Activated Sludge	\$0.13	\$0.14	\$0.08	\$0.11
Advanced (AWT)	\$0.27	\$0.22	\$0.04	\$0.17

---

[a] The values appearing in this table were determined from the following equation: Median Cost Per Pound SS Removed is the middle value in order of size by dividing Total Annual O&M Costs in Dollars by Total Pounds of SS Removed Per Year.

Potentially significant O&M relationships have been plotted using a polynomial regression statistical package developed by the Health Sciences Computing Facility, University of California at Los Angeles. All statistically meaningful relationships of plant variables are graphically presented in Appendix E and listed in Tables E.1, E.2, and E.3. Those plant relationships that appear to be statistically non-significant are listed in Table E.4. Potentially significant O&M relationships are defined as those relationships that meet the following criteria: 1) the sample size (n) must comprise at least five data points to be meaningful; 2) the correlation coefficient (r) is equal to or greater than 0.67. However, if the number of samples (n) is greater than 100, an r value of 0.60 is acceptable; and 3) the F-Test value, when compared in the F distribution table, is greater than those indicated values at the 95 percent or 99 percent level of significance. The higher a given F-Test value the greater the probability that the relationship is significant. Definitions of these terms along with the graphical relationships appear in Appendix E.

4.6 LEVEL OF TREATMENT UPGRADING COSTS

Sanitary engineering planners are often asked, "What will it cost to upgrade a given wastewater treatment plant from an existing level of treatment to a higher level to meet more stringent effluent standards?" Table 4.30 presents percent O&M cost differentials for upgrading treatment plants. To obtain these percent differentials, differences in actual operating costs were determined by combining relevant cost data

TABLE 4.30

PERCENT O&M COST DIFFERENTIALS FOR UPGRADING A WASTEWATER TREATMENT FACILITY[a]

(Percentage of Dollars Per Million Gallons Treated)

Actual Flow (mgd)[b]	Levels of Upgrading From Primary To Secondary	 Secondary To Advanded	 Primary To Advanced
1.0 - 5.0	68	59[c]	157
5.1 - 20.0	62	30	117
>20.0	52	17	73
All Plants	64	33	125

---

[a] EPA and AMSA Surveys combined. Percent cost differentials shown above were based on 155 plants: 40 primary; 93 secondary (activated sludge); and 22 advanced systems.

[b] Only wastewater treatment plants that were operating between 70-110 percent of design flow were included in this particular analysis.

[c] The percentage values appearing in this table were determined from the following equation:

Percent O&M Cost Differential = Higher level of treatment cost in dollars per million gallons treated less lower level of treatment cost in dollars per million gallons treated divided by the lower level of treatment cost in dollars per million gallons treated.

For example, to compute the percent increase in upgrading a secondary plant to an AWT in the 1-5 mgd class: $\frac{\$382/mg - \$241/mg}{\$241/mg} = 0.59$

from both surveys for three levels of upgrading: primary to secondary (activated sludge); secondary to advanced (AWT); and primary to advanced. These percent differentials also have been calculated for the three size groups. As presented in Table 4.30, the percent O&M cost differential declines as the size of the plant increases. For all levels of upgrading, the small size plants (1.0-5.0 mgd class) incurred the highest O&M cost differentials. In the secondary to advanced category, percent O&M cost differentials were not as large as the other two upgrading categories for the medium and large size plants. Disregarding plant size, the actual O&M cost differential for upgrading a primary WWTP to a secondary plant averaged 64 percent. The O&M cost differential between activated sludge plants and AWT systems was calculated at 33 percent, and the actual O&M differential for upgrading from primary treatment to advanced waste treatment averaged 125 percent. Another dimension to expanding WWTPs is enlargement. Table 4.30 does not present enough information to yield accurate O&M cost differentials for enlarging a plant. An approximation, however, might be ventured. Suppose an existing 4 mgd activated sludge plant were to be upgraded to an advanced treatment plant and also enlarged to 8 mgd. According to Table 4.30, the O&M cost differential for the upgraded, enlarged facility would be in the range of 59 percent to 89 percent.

4.7 ECONOMIES OF SCALE DETERMINATION

In Section 4.5 considerable evidence documents the concept of economies of scale, which basically infers that as the size of the treatment plant increases, the average cost per unit of treatment declines. This inverse relationship has been well documented in wastewater management studies over the past several years. Nevertheless, economic theory dictates that economies of scale do not continue without limit. At some point (which is often determined by technology) the limits of efficient plant operation are reached. A rapidly expanding municipal wastewater facility or growing sanitation district begins to stretch too thin the coordinating powers of management and resource allocation. When this occurs, diseconomies of scale become evident and the long run average unit cost curve begins to rise. Hence, bigger is not necessarily better or less expensive at this juncture.

This analysis attempts to estimate the hydraulic capacity at which wastewater treatment plants begin to become less economical. A computer analysis was employed to determine the slope of the curve. The following assumptions were made to assist in the analysis and to limit the biases that could occur:

1) the AMSA data base was combined with the EPA data base to provide an adequate data base for larger plants;
2) only secondary activated sludge plants with average daily flows in the 1.0 mgd to 200 mgd range were considered;
3) of these standard treatment systems only those plants with actual flows in the range of 70 to 110 percent of hydraulic design capacity were considered;
4) the minimum accceptable pollutant removal performance for BOD and SS was 85 percent or 30 milligrams per liter effluent discharge, whichever resulted in the higher absolute value;

5) cost per unit was measured in dollars per million gallons treated which is computed by dividing total annual O&M costs in dollars by actual annual flow in mgd; and

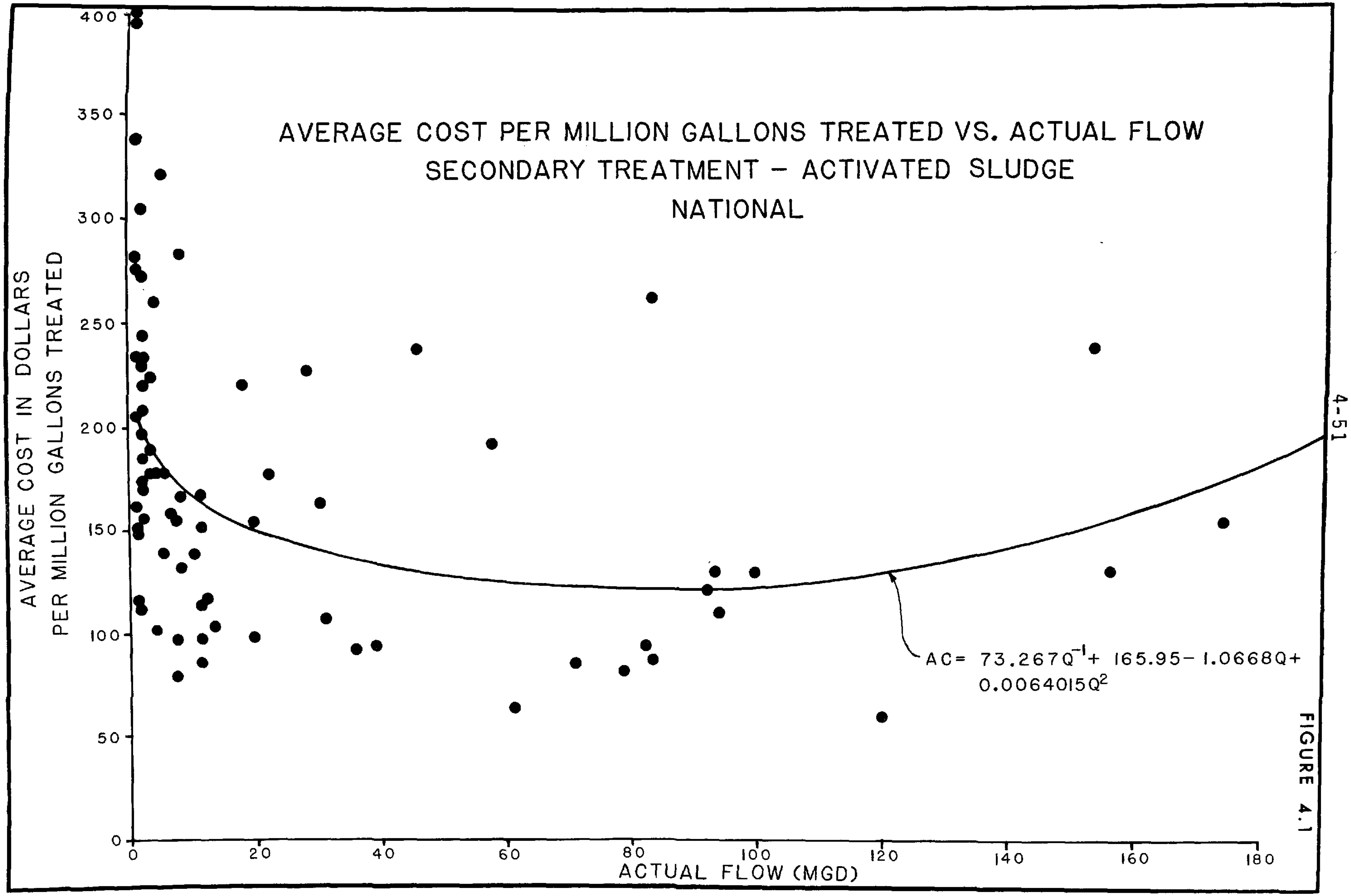
6) O&M costs were defined as those necessary and essential operating costs (or "inside-the-fence" costs) which are exclusive of administrative or supporting type costs.

Seventy-four activated sludge plants comprised the data base for the economies of scale determination. The results of the polynomial regression analysis indicate that the nonlinear best fit equation for the average cost (AC) curve from the combined surveys is:

$$AC = 73.267\ Q^{-1} + 165.95 - 1.0668\ Q + 0.0064015\ Q^{2},$$

where Q is actual flow in mgd. The F-Test value is 13.39 which is significant at the 99 percent confidence level (see Appendix E, page E-1, for a complete explanation of this important statistic). Figure 4.1 shows the shape of the average cost curve for the economies of scale determination.

From this analysis of O&M costs only it appears that the optimum size of an activated sludge treatment plant is approximately 85 mgd. Secondary plants less than 85 mgd have not achieved full economic efficiency but are advancing toward optimum O&M conditions as the WWTP is enlarged. Conversely, activated sludge treatment plants greater than 85



AVERAGE COST PER MILLION GALLONS TREATED VS. ACTUAL FLOW
SECONDARY TREATMENT – ACTIVATED SLUDGE
NATIONAL

FIGURE 4.1

mgd design capacity have probably reached the point where economies of scale begin to diminish, i.e., diseconomies commence.

Care must be exercised in the application of these findings. For example, a 120 mgd WWTP in this category could be operating efficiently in one community due to external factors or local conditions but in another setting or environment it might very well be operating inefficiently. The O&M variables that could alter or influence a specific community's average cost curve over the long run might include labor wages paid, power costs, assimilative capacity of the receiving stream, operational mode of activated sludge process, and major maintenance problems.

4.8 INCREMENTAL AWT COSTS

As previously defined in Section 2.3, the advanced wastewater treatment processes normally involve chemical treatment and filtration of secondary effluent. The preponderance of AWT plants with nutrient removal sampled in this study were required by NPDES permit to remove phosphorus. A fewer number of AWT plants provided for specific removal of nitrogen and ammonia. These same AWT plants, of course, removed additional amounts of BOD and SS as they were performing the specific process of nutrient removal.

The incremental or additional O&M costs to remove a pound of BOD or a pound of SS for two general classes of AWT systems are presented in Tables 4.31a and 4.31b. The actual O&M costs shown are for secondary

TABLE 4.31a

AVERAGE COST PER POUND BOD REMOVED[a]

Actual Flow (mgd)	Secondary Activated Sludge	Secondary With Nutrient Removal	Greater Than Secondary With Nutrient Removal
0.1 - 5.0	\$0.13[b] n=53	\$0.28 n=6	\$1.29 n=5
5.1 - 20.0	\$0.10 n=31	\$0.20 n=3	\$0.10 n=1
>20.0	\$0.10 n=34	\$0.11 n=4	\$0.20 n=1
All Plants	\$0.11 n=118	\$0.21 n=13	\$0.97 n=7

---

[a] EPA and AMSA Surveys combined. Not enough data were obtained from plants with Zero Discharge to present relevant removal costs.

[b] The values appearing in this table were determined from the following equation:

$$\text{Average Cost Per Pound BOD Removed} = \frac{\text{Total Annual O\&M Costs in Dollars}}{\text{Total Pounds of BOD Removed Per Year}}$$

TABLE 4.31b

AVERAGE COST PER POUND SS REMOVED[a]

Actual Flow (mgd)	Secondary Activated Sludge	Secondary With Nutrient Removal	Greater Than Secondary With Nutrient Removal
0.1 - 5.0	\$0.07[b] n=53	\$0.24 n=6	\$0.91 n=5
5.1 - 20.0	\$0.07 n=31	\$0.23 n=3	\$0.05 n=1
>20.0	\$0.08 n=34	\$0.15 n=4	\$0.11 n=1
All Plants	\$0.07 n=118	\$0.21 n=13	\$0.68 n=7

---

[a] EPA and AMSA Surveys combined. Not enough data were obtained from plants with Zero Discharge to present relevant removal costs.

[b] The values appearing in this table were determined from the following equation: Median Cost Per Pound SS Removed is the middle value in order of size by dividing Total Annual O&M Costs in Dollars by Total Pounds of SS Removed Per Year.

(activated sludge) treatment with nutrient removal--usually phosphorus nitrogen, and ammonia--and greater than secondary (activated sludge) treatment with nutrient removal. In general, the latter classification is considered a dedicated effort or total commitment to AWT while the former category is basically a waste activated sludge plant with added process units to remove a specific nutrient or nutrients.

Using the activated sludge plants as a base, O&M cost comparisons can be made with the two general classes of AWT systems. Except for the medium size plants (5.1-20.0 mgd), O&M costs for removing BOD increased from the base secondary treatment systems to secondary with nutrient removal and to greater than secondary with nutrient removal. The obvious reason for this exception is the sample size--actual operating costs for only one plant were obtained from the medium and large size classes for greater than secondary treatment with nutrient removal category. Another apparent observation in Table 4.31a is that BOD removal costs decline as the size of plant increases. When all WWTPs are considered regardless of size, the actual O&M cost to remove a pound of BOD progresses markedly upward from the base of $0.11 per pound for conventional secondary treatment systems to $0.21 per pound for secondary plants with nutrient removal to $0.97 per pound for WWTPs classed as greater than secondary with nutrient removal.

Similar trends are evident for SS removals (Table 4.31b). In general, actual O&M costs decline as the size of plant increases and average operating costs increase as more nutrients and pollutants are removed from wastewater. When all treatment plants are considered without regard to size, the average operating cost to remove a pound of SS increases significantly from the base of $0.07 per pound for a standard secondary treatment system to $0.21 per pound for secondary plants with nutrient removal to $0.68 per pound for plants greater than secondary with nutrient removal.

5.0 SURVEY RESULTS AND FINDINGS: SEWER SYSTEMS

5.1 SEWER SYSTEM DEFINITIONS AND STATISTICAL SUMMARY

5.1.1 Sewer System Definitions

Sewer collection systems have been classified into two general categories. They are defined as follows:

A. A sewer system owned and operated by a municipality or authority but tributary to a wastewater treatment plant owned and operated by a different municipality. This category of sewer systems was further subdivided into:

   1. Separate sewer system which collects and transmits the admixture of sanitary, commercial, and industrial wastes. In this report such systems are referred to as "Separate Sewer Systems."
   2. Combined sewer system which collects and transmits the above liquid wastes and storm water. In this report such systems are referred to as "Combined Sewer Systems."
   3. A sewer system which is partly separate and partly combined and is referred to as "Mixed Sewer System."

B. A sewer system owned and operated by the same municipality or authority which owns and operates the wastewater treatment plant to which said sewers are tributary. This category was further subdivided into:

   1. Sewer systems which collect and transmit only the admixture of sanitary, commercial, and industrial wastes. In this

report these systems are referred to as "WWTP + Separate Sewer System."

2. Combined systems which collect and transmit the above admixture and storm water. In this report these systems are referred to as "WWTP + Combined Sewer System."
3. Any combination of the above types of sewer systems are referred to as "WWTP + Mixed Sewer Systems."

5.1.2 Statistical Summary

Table 5.1 shows the distribution of sewer systems sampled in the EPA survey by the type of system. Separate Sewer Systems comprise 18 systems (12 percent) of the total types of systems sampled. Only two Combined Sewer Systems were surveyed and the same number of Mixed Sewer Systems were sampled. WWTP + Separate Sewer Systems comprise 94 systems (61 percent) of the total systems sampled in this nationwide OM&R study. WWTP + Combined Sewer System consist of eight samples (5 percent) and the WWTP + Mixed Sewer System contain 31 systems (20 percent).

A brief statistical summary of the sewer systems sampled in the EPA survey is shown in Table 5.2. Of the 155 sewer systems sampled, approximately 3.67 million persons are served, with an "average system" serving about 24,000 people. The total length of all gravity sewers reported is 18,753 miles; the average length of all gravity sewers is 139 miles. This survey reports 735 miles of force mains with the average force main system running about 18 miles. A total pumping capacity of

TABLE 5.1

EPA SURVEY

DISTRIBUTION OF SEWER SYSTEMS SAMPLED

Type of System	System Sampled	
	Number	Percent
Separate Sewer System	18	12
Combined Sewer System	2	1
Mixed Sewer System	2	1
WWTP + Separate Sewer System	94	61
WWTP + Combined Sewer System	8	5
WWTP + Mixed Sewer System	31	20
Total Systems Sampled	155	100

TABLE 5.2

EPA SURVEY

STATISTICAL SUMMARY OF SEWER SYSTEM DATA

	Total	Average for Total Number Reporting
Service Population n=154[a]	3,674,000	24,000
Length of Gravity Sewers (miles) n=135	18,753	139
Length of Force Mains (miles) n=42	735	18
Capacity of Lift Stations (mgd) n=85	1,708	20
Horsepower of Lift Stations (hp) n=83	53,071	639

---

[a] A population estimate was not provided for one sewer system.

1,708 mgd with an aggregate horsepower output of 53,071 hp was reported for 85 lift stations.

5.2 OM&R COSTS PER CAPITA

Operations, maintenance, and minor repair (OM&R) costs per capita for the six various classifications of sewer systems are presented in Table 5.3. Total costs per capita range from $3.66 for the plant plus the mixed sewer system to $14.53 for the separate sewer system. The most prevalent type of sewer system sampled, the WWTP plus the Separate Sewer System, averages $6.35 per capita.

The large disparity in per capita costs between autonomously-operated sewer systems and sewer systems operated in conjunction with treatment plants is not easily explained. It is reasoned, however, that the sewer system which is integrated into a treatment plant operation experiences lower OM&R costs because of better (more efficient) utilization of personnel. In addition, the plant operation provides a broader base to charge O&M costs as opposed to the sewer system entity. It is also plausible to expect better records management at those systems which are directly tied into a treatment plant due mainly to available resources. In some cases, however, it was revealed that power costs for pumping stations were charged to the wastewater treatment plant account. When this occurred, a break out of power charges to the lift function was not possible.

TABLE 5.3
EPA SURVEY
AVERAGE COST PER CAPITA FOR VARIOUS TYPES OF SEWER SYSTEMS

Type of System	Average Cost Per System (Dollars Per Capita)
Separate Sewer (n=17)	14.53[a]
Combined Sewer (n=2)	14.43
Mixed Sewer (n=2)	4.37
WWTP + Separate Sewer (n=92)	6.35
WWTP + Combined Sewer (n=7)	4.16
WWTP + Mixed Sewer (n=30)	3.66

---

[a] The values appearing in this table were determined from the following equation:

$$\text{Dollars Per Capita} = \frac{\text{Total Annual OM\&R Costs in Dollars}}{\text{Service Population}}$$

5.3 OM&R COSTS PER MILE

5.3.1 Gravity Sewers

Table 5.4 shows the total annual OM&R and component costs per mile of gravity sewer for the six specific types of sewer systems. These cost estimates represent national averages. The Separate Sewer System appears to have the highest total cost per mile, $2,783. (Even though the combined sewer system average cost is higher at $3,565, this estimate is questionable due to only two sample systems.) The lowest OM&R cost per mile of gravity sewer systems is $1,154, representing the plant and the Mixed Sewer System. Personnel costs are the highest component costs for nearly every type of sewer system ranging from 34 percent to 53 percent of the total cost of OM&R. Costs of materials and contractual work contribute significant amounts for the various sewer systems. Power costs and other costs are minor component expenditures for gravity sewers regardless of type of sewer system.

5.3.2 Force Mains

Table F.1 which appears in Appendix F lists those sewer systems that reported force main data. Unfortunately, the cost information and physical data were not in sufficient detail to produce meaningful cost per mile relationships for force mains.

5.4 ANALYSIS OF PUMPING STATIONS

Of the 85 facilities reporting pumping station data, only 18 provided sufficient information to develop meaningful cost relationships.

TABLE 5.4

EPA SURVEY

OM&R COST PER MILE OF GRAVITY SEWERS FOR VARIOUS TYPES OF SEWER SYSTEMS

(Costs in Dollars Per Mile)

	Total	Component Costs[b]				
Type of System	Cost[a]	Personnel	Power	Materials[c]	Contractual	Other
Separate Sewer	2,783	1,289	201	388	491	414
--Number in Sample	15					
Combined Sewer	3,565	1,861	58	640	d	1,006
--Number in Sample	2					
Mixed Sewer	1,272	427	217	398	219	11
--Number in Sample	2					
WWTP + Separate Sewer	1,618	839	231	246	136	166
--Number in Sample	81					
WWTP + Combined Sewer	2,142	981	522	164	324	151
--Number in Sample	4					
WWTP + Mixed Sewer	1,154	614	133	180	89	138
--Number in Sample	27					

---

[a] The values appearing in this column were determined from the following equation:

$$\text{Average Cost in Dollars Per Mile} = \frac{\text{Total Annual OM\&R Costs in Dollars}}{\text{Total Length (miles) Gravity Sewers}}$$

[b] $$\text{Component Costs Per Mile} = \frac{\text{Respective Component Cost in Dollars}}{\text{Total Length (miles) Gravity Sewers}}$$

[c] Chemicals, if any, are included as materials.

[d] No cost reported.

Table 5.5 presents various pumping station cost relationships. In this analysis only sewer systems reporting the number of pumps, total installed pump capacity and/or total installed horsepower, total cost of operation and maintenance, and/or major component costs were included. The median values presented in this table are probably better estimates than the average values due to abnormally high pumping costs at a few facilities.

Table 5.6 shows component costs as a percentage of the total OM&R costs for selected pumping stations. Only 15 facilities or 10 percent of those sampled supplied data to the degree necessary to establish these relationships. Unit costs for power vary considerably throughout the country. In the State of New York, for example, the highest cost per kilowatt-hour is 2.5 times the lowest for privately-owned electric utilities. Obviously, this large disparity greatly affects power cost relationships. Another factor which affects power cost relationships is the head against which the sewage is pumped.

Graphical relationships for total OM&R cost of pumping stations versus total installed capacity (mgd) and versus total installed horsepower indicated no significant trend. This is not alarming because total dynamic head which would tie these data together was not readily available.

TABLE 5.5

EPA SURVEY

PUMPING STATIONS COST RELATIONSHIPS

(Cost in Dollars Per mgd or Dollars Per hp)

	Number of Facilities	Number of Pumps	Maximum	Average[a]	Median	Minimum
Total Cost/mgd	18	245[b]	$47,648[c]	$5,430	$1,659	$ 456
Total Cost/hp	11	212	604	159	61	23
Power Cost/mgd	15	176[d]	24,903[c]	2,898	956	182
Power Cost/hp	15	176	422	44	31	6
Personnel Cost/mgd	9	113	14,126[c]	3,696	1,431	256
Personnel Cost/hp	8	100	187	77	48	3

---

[a] The average values appearing in this column were determined from the following equations:

	Average Costs	
For:	Per Million Gallons Per Day	Per Horsepower
Total Cost =	$\frac{\text{Total OM\&R Costs in Dollars}}{\text{Total Flow (Q) Lifted in mgd}}$	$\frac{\text{Total OM\&R Costs in Dollars}}{\text{Total Horsepower}}$
Power Cost =	$\frac{\text{Total Power Costs in Dollars}}{\text{Total Flow (Q) Lifted in mgd}}$	$\frac{\text{Total Power Costs in Dollars}}{\text{Total Horsepower}}$
Personnel Cost =	$\frac{\text{Total Personnel Costs in \$}}{\text{Total Flow (Q) Lifted in mgd}}$	$\frac{\text{Total Personnel Costs in \$}}{\text{Total Horsepower}}$

[b] Average hydraulic lift capacity of the 245 pumps is 2.1 million gallons per day.

[c] This facility has many samll pump stations with high discharge heads and is located in a high power and labor cost area.

[d] Average hydraulic lift capacity of the 176 pumps is 2.2 million gallons per day.

TABLE 5.6

EPA SURVEY

PUMPING STATIONS
COMPONENT COSTS AS PERCENT OF TOTAL COSTS

Component	Percent[a]
Personnel	47.8
Power	35.5
Equipment	12.5
Chemicals	1.4
Contractual	1.0
Other	1.8
	100.0

Number in Sample = 15

---

[a] Component percent = $\frac{\text{Total Component Cost in Dollars}}{\text{Total O\&M Cost of Pumping Stations}}$

5.5 COST ALLOCATION: OPERATING VERSUS SUPPORTING

Table 5.7 presents the proportion of total OM&R sewer costs for all types of sewer systems by operating costs and by administrative, supporting services costs. This allocation combines the costs of gravity sewers, force mains, and lift stations. Over two-thirds of all total OM&R costs are classified as operating costs for every type of sewer system. Administrative and supporting costs represent the balance but range from 15 to 31 percent of the total OM&R costs.

Appendix F contains a listing of gravity sewers and force mains that were sampled in the EPA survey (Table F.1). A listing of the pump stations that were sampled appear in Table F.2. Potentially significant OM&R relationships have been plotted using a polynomial regression statistical package. These geographical relationships are in Appendix G.

TABLE 5.7

EPA SURVEY

AVERAGE OPERATING AND ADMINISTRATIVE SUPPORT COSTS AS PERCENTAGES OF TOTAL OM&R COSTS

Type of System	Operating Costs (Percent)	Administrative and Supporting Services Costs (Percent)
Separate Sewer	69	31
Combined Sewer	85	15
Mixed Sewer	a	a
WWTP + Separate Sewer	84	16
WWTP + Combined Sewer	70	30
WWTP + Mixed Sewer	83	17

---

[a] Not Calculated.

APPENDIX A

METHODOLOGY USED IN EPA SURVEY

APPENDIX A

METHODOLOGY USED IN EPA SURVEY

A.1 SAMPLE SELECTION - TREATMENT PLANTS

To ensure that the wastewater treatment plants sampled were representative of the "real world," the existing plants in the U.S. were identified by size and type. The U.S. EPA 1976 Needs Survey included an assessment of existing facilities by design flow, level of treatment, and unit processes. This information was tabulated and used to establish the state and regional distribution of plant sizes and types (see Tables A.1 through A.10).

Table A.11 presents a national distribution of wastewater plants by EPA regions indicating type of process. This table is the basis for developing a representative sample of plants from across the United States. Basic assumptions used in the sample selection procedure are as follows:

1) Only plants of 1 mgd or greater would be considered.
2) Each EPA region can be accurately represented by one or more states within that region.
3) Plants would be categorized into one of six categories: primary; secondary (trickling filter, activated sludge, aerated lagoon, or oxidation ditch); and advanced waste treatment (AWT).

TABLE A.1 REGION I DISTRIBUTION OF WASTEWATER TREATMENT PLANTS IN OPERATION GREATER THAN ONE MILLION GALLONS PER DAY BY SIZE AND PROCESS, 1976

	PROCESS[a]					
	TRICKLING FILTER	ACTIVATED SLUDGE	AERATED LAGOON	OTHER[b]	STATE TOTALS	REGIONAL TOTALS
1.0 - 5.0 MGD						
STATE						
CT	9	23	0	2	34)	
ME	0	17	2	0	19)	
MA	3	15	0	8	26)	96
NH	0	5	1	3	9)	
RI	0	1	0	0	1)	
VT	2	5	0	0	7)	
5.1-20.0 MGD						
STATE						
CT	3	15	0	0	18)	
ME	0	3	0	0	3)	
MA	1	8	0	2	11)	34
NH	0	0	0	0	0)	
RI	0	2	0	0	2)	
VT	0	0	0	0	0)	
>20.0 MGD						
STATE						
CT	0	3	0	0	3)	
ME	0	0	0	0	0)	
MA	0	1	0	0	1)	6
NH	0	1	0	0	1)	
RI	0	1	0	0	1)	
VT	0	0	0	0	0)	
PROCESS TOTALS	18	100	3	15	136	136

Notes: [a] Primary treatment plants are excluded.

[b] Other implies advanced waste treatment (AWT) and other secondary treatment schemes not otherwise defined as trickling filter, activated sludge, or lagoon.

Source: 1976 Update of Needs Municipal Facilities, Environmental Protection Agency

TABLE A.2 REGION II DISTRIBUTION OF WASTEWATER TREATMENT PLANTS IN OPERATION GREATER THAN ONE MILLION GALLONS PER DAY BY SIZE AND PROCESS, 1976

	PROCESS[a]					
	TRICKLING FILTER	ACTIVATED SLUDGE	AERATED LAGOON	OTHER[b]	STATE TOTALS	REGIONAL TOTALS
1.0 - 5.0 MGD						
STATE						
NJ	22	40	0	10	72)	
NY	18	32	2	16	68)	
PR	0	1	0	0	1)	141
VI	0	0	0	0	0)	
5.1-20.0 MGD						
STATE						
NJ	2	7	0	3	12)	
NY	0	12	1	6	19)	
PR	0	0	0	0	0)	31
VI	0	0	0	0	0)	
>20.0 MGD						
STATE						
NJ	1	2	0	1	4)	
NY	0	17	0	1	18)	
PR	0	0	0	1	1)	23
VI	0	0	0	0	0)	
PROCESS TOTALS	43	111	3	38	195	195

Notes: [a] Primary treatment plants are excluded.
[b] Other implies advanced waste treatment (AWT) and other secondary treatment schemes not otherwise defined as trickling filter, activated sludge, or lagoon.

Source: 1976 Update of Needs Municipal Facilities, Environmental Protection Agency

TABLE A.3 REGION III DISTRIBUTION OF WASTEWATER TREATMENT PLANTS IN OPERATION GREATER THAN ONE MILLION GALLONS PER DAY BY SIZE AND PROCESS, 1976

	----PROCESS[a]----					
	TRICKLING FILTER	ACTIVATED SLUDGE	AERATED LAGOON	OTHER[b]	STATE TOTALS	REGIONAL TOTALS
1.0 - 5.0 MGD						
STATE						
DE	0	0	0	0	0)	
DC	0	0	0	0	0)	
MD	2	4	3	2	11)	149
PA	13	80	0	18	111)	
VA	8	11	0	4	23)	
WV	1	2	0	1	4)	
5.1-20.0 MGD						
STATE						
DE	0	0	0	1	1)	
DC	0	0	0	0	0)	
MD	1	5	0	4	10)	44
PA	6	15	0	2	23)	
VA	1	6	0	1	8)	
WV	0	2	0	0	2)	
>20.0 MGD						
STATE						
DE	0	1	0	0	1)	
DC	0	1	0	0	1)	
MD	0	3	0	1	4)	21
PA	2	5	0	0	7)	
VA	1	5	0	2	8)	
WV	0	0	0	0	0)	
PROCESS TOTALS	35	140	3	36	214	214

Notes:

[a] Primary treatment plants are excluded.

[b] Other implies advanced waste treatment (AWT) and other secondary treatment schemes not otherwise defined as trickling filter, activated sludge, or lagoon.

Source: 1976 Update of Needs Municipal Facilities, Environmental Protection Agency

TABLE A.4 REGION IV DISTRIBUTION OF WASTEWATER TREATMENT PLANTS IN OPERATION GREATER THAN ONE MILLION GALLONS PER DAY BY SIZE AND PROCESS, 1976

	PROCESS[a]					
	TRICKLING FILTER	ACTIVATED SLUDGE	AERATED LAGOON	OTHER[b]	STATE TOTALS	REGIONAL TOTALS
1.0 - 5.0 MGD						
STATE						
AL	21	11	16	3	51)	335
FL	17	54	0	10	81)	
GA	17	28	2	4	51)	
KY	1	8	0	4	13)	
MS	3	8	5	6	22)	
NC	12	16	0	4	32)	
SC	9	24	3	7	43)	
TN	9	19	1	13	42)	
5.1-20.0 MGD						
STATE						
AL	5	6	0	2	13)	108
FL	2	18	0	10	30)	
GA	3	14	0	2	19)	
KY	0	3	0	0	3)	
MS	1	1	3	0	5)	
NC	4	16	0	1	21)	
SC	0	4	0	4	8)	
TN	3	4	0	2	9)	
>20.0 MGD						
STATE						
AL	0	2	0	2	4)	30
FL	1	2	0	5	8)	
GA	0	6	0	0	6)	
KY	0	1	0	1	2)	
MS	0	1	0	0	1)	
NC	1	2	0	0	3)	
SC	0	1	0	0	1)	
TN	0	6	0	0	5)	
PROCESS TOTALS	109	254	30	80	473	473

Notes: [a] Primary treatment plants are excluded.
[b] Other implies advanced waste treatment (AWT) and other secondary treatment schemes not otherwise defined as trickling filter, activated sludge, or lagoon.

Source: 1976 Update of Needs Municipal Facilities, Environmental Protection Agency

TABLE A.5 REGION V DISTRIBUTION OF WASTEWATER TREATMENT PLANTS IN OPERATION GREATER THAN ONE MILLION GALLONS PER DAY BY SIZE AND PROCESS, 1976

	PROCESS[a]					
	TRICKLING FILTER	ACTIVATED SLUDGE	AERATED LAGOON	OTHER[b]	STATE TOTALS	REGIONAL TOTALS
<u>1.0 - 5.0 MGD</u>						
STATE						
IL	18	37	1	25	81)	297
IN	13	24	0	3	40)	
MI	4	14	0	12	30)	
MN	3	10	2	2	17)	
OH	5	59	0	18	82)	
WI	3	32	1	11	47)	
<u>5.1-20.0 MGD</u>						
STATE						
IL	3	15	0	7	25)	96
IN	2	16	1	0	19)	
MI	0	10	0	4	14)	
MN	2	3	0	1	6)	
OH	0	17	1	4	22)	
WI	2	6	0	2	10)	
<u>>20.0 MGD</u>						
STATE						
IL	0	7	0	0	7)	39
IN	1	5	0	1	7)	
MI	0	8	0	1	9)	
MN	0	3	0	0	3)	
OH	0	5	0	5	10)	
WI	0	3	0	0	3)	
<u>PROCESS TOTALS</u>	56	274	6	96	432	432

Notes:
[a] Primary treatment plants are excluded.
[b] Other implies advanced waste treatment (AWT) and other secondary treatment schemes not otherwise defined as trickling filter, activated sludge, or lagoon.

Source: 1976 Update of Needs Municipal Facilities, Environmental Protection Agency

TABLE A.6 REGION VI DISTRIBUTION OF WASTEWATER TREATMENT PLANTS IN OPERATION GREATER THAN ONE MILLION GALLONS PER DAY BY SIZE AND PROCESS, 1976

	PROCESS[a]					
	TRICKLING FILTER	ACTIVATED SLUDGE	AERATED LAGOON	OTHER[b]	STATE TOTALS	REGIONAL TOTALS
<u>1.0 - 5.0 MGD</u>						
STATE						
AR	9	1	13	1	24)	
LA	2	17	6	1	26)	
NM	2	2	2	1	7)	217
TX	16	14	2	1	33)	
OK	27	82	14	4	127)	
<u>5.1-20.0 MGD</u>						
STATE						
AR	3	1	0	0	4)	
LA	1	3	0	0	4)	
NM	0	0	0	0	0)	41
TX	4	3	0	0	7)	
OK	4	18	3	1	26)	
<u>>20.0 MGD</u>						
STATE						
AR	0	1	0	0	1)	
LA	0	1	0	0	1)	
NM	0	1	0	0	1)	18
TX	1	1	0	0	2)	
OK	2	8	0	2	13)	
<u>PROCESS TOTALS</u>	72	153	40	11	276	276

Notes: [a] Primary treatment plants are excluded.
[b] Other implies advanced waste treatment (AWT) and other secondary treatment schemes not otherwise defined as trickling filter, activated sludge, or lagoon.

Source: 1976 Update of Needs Municipal Facilities, Environmental Protection Agency

TABLE A.7 REGION VII DISTRIBUTION OF WASTEWATER TREATMENT PLANTS IN OPERATION GREATER THAN ONE MILLION GALLONS PER DAY BY SIZE AND PROCESS, 1976

	PROCESS[a]					
	TRICKLING FILTER	ACTIVATED SLUDGE	AERATED LAGOON	OTHER[b]	STATE TOTALS	REGIONAL TOTALS
1.0 - 5.0 MGD						
STATE						
IA	11	1	1	0	13)	
KS	12	7	0	4	23)	
MO	13	11	12	3	39)	84
NE	4	2	2	1	9)	
5.1-20.0 MGD						
STATE						
IA	4	1	0	3	8)	
KS	6	1	0	2	9)	
MO	1	0	0	1	2)	22
NE	0	3	0	0	3)	
>20.0 MGD						
STATE						
IA	2	0	0	1	3)	
KS	1	0	0	0	1)	
MO	0	1	0	1	2)	8
NE	0	1	0	1	2)	
PROCESS TOTALS	54	28	15	17	114	114

Notes: [a] Primary treatment plants are excluded.

[b] Other implies advanced waste treatment (AWT) and other secondary treatment schemes not otherwise defined as trickling filter, activated sludge, or lagoon.

Source: 1976 Update of Needs Municipal Facilities, Environmental Protection Agency

TABLE A.8 REGION VIII DISTRIBUTION OF WASTEWATER TREATMENT PLANTS IN OPERATION GREATER THAN ONE MILLION GALLONS PER DAY BY SIZE AND PROCESS, 1976

	PROCESS[a]					
	TRICKLING FILTER	ACTIVATED SLUDGE	AERATED LAGOON	OTHER[b]	STATE TOTALS	REGIONAL TOTALS
1.0 - 5.0 MGD						
STATE						
CO	10	16	3	0	29)	65
MT	0	2	2	1	5)	
ND	1	0	7	0	8)	
SD	4	0	2	0	6)	
UT	10	1	0	0	11)	
WY	1	3	2	0	6)	
5.1-20.0 MGD						
STATE						
CO	6	4	0	0	10)	19
MT	0	1	0	1	2)	
ND	0	0	0	0	0)	
SD	1	1	1	0	3)	
UT	3	0	1	0	4)	
WY	0	0	0	0	0)	
>20.0 MGD						
STATE						
CO	0	2	0	0	2)	3
MT	0	0	0	0	0)	
ND	0	0	0	0	0)	
SD	0	0	0	0	0)	
UT	1	0	0	0	1)	
WY	0	0	0	0	0)	
PROCESS TOTALS	37	30	18	2	87	87

Notes: [a] Primary treatment plants are excluded.
[b] Other implies advanced waste treatment (AWT) and other secondary treatment schemes not otherwise defined as trickling filter, activated sludge, or lagoon.

Source: 1976 Update of Needs Municipal Facilities, Environmental Protection Agency

TABLE A.9 REGION IX DISTRIBUTION OF WASTEWATER TREATMENT PLANTS IN OPERATION GREATER THAN ONE MILLION GALLONS PER DAY BY SIZE AND PROCESS, 1976

	PROCESS[a]					
	TRICKLING FILTER	ACTIVATED SLUDGE	AERATED LAGOON	OTHER[b]	STATE TOTALS	REGIONAL TOTALS
1.0 - 5.0 MGD						
STATE						
AZ	3	3	5	2	13)	
CA	35	54	10	24	123)	
HI	1	7	0	0	8)	154
NV	3	4	2	1	10)	
GM	0	0	0	0	0)	
TR	0	0	0	0	0)	
5.1-20.0 MGD						
STATE						
AZ	0	1	1	0	2)	
CA	7	17	1	11	36)	
HI	1	0	0	0	1)	40
NV	0	0	0	0	0)	
GM	0	1	0	0	1)	
TR	0	0	0	0	0)	
>20.0 MGD						
STATE						
AZ	2	1	0	0	3)	
CA	1	10	0	3	14)	
HI	0	0	0	0	0)	18
NV	0	1	0	0	1)	
GM	0	0	0	0	0)	
TR	0	0	0	0	0)	
PROCESS TOTALS	53	99	19	41	212	212

Notes: [a] Primary treatment plants are excluded.
[b] Other implies advanced waste treatment (AWT) and other secondary treatment schemes not otherwise defined as trickling filter, activated sludge, or lagoon.

Source: 1976 Update of Needs Municipal Facilities, Environmental Protection Agency

TABLE A.10 REGION X DISTRIBUTION OF WASTEWATER TREATMENT PLANTS IN OPERATION GREATER THAN ONE MILLION GALLONS PER DAY BY SIZE AND PROCESS, 1976

	PROCESS[a]					
	TRICKLING FILTER	ACTIVATED SLUDGE	AERATED LAGOON	OTHER[b]	STATE TOTALS	REGIONAL TOTALS
1.0 - 5.0 MGD						
STATE						
AK	0	1	0	0	1)	53
ID	4	2	0	0	6)	
OR	6	20	1	2	29)	
WA	7	10	0	0	17)	
5.1-20.0 MGD						
STATE						
AK	0	0	0	0	0)	21
ID	2	3	0	1	6)	
OR	3	6	0	1	10)	
WA	2	1	1	1	5)	
>20.0 MGD						
STATE						
AK	0	0	0	0	0)	5
ID	0	0	0	0	0)	
OR	1	1	0	0	2)	
WA	0	1	0	2	3)	
PROCESS TOTALS	25	45	2	7	79	79

Notes: [a] Primary treatment plants are excluded.
[b] Other implies advanced waste treatment (AWT) and other secondary treatment schemes *not otherwise* defined as trickling filter, activated sludge, or lagoon.

Source: 1976 Update of Needs Municipal Facilities, Environmental Protection Agency

TABLE A.11 NATIONAL DISTRIBUTION OF WASTEWATER TREATMENT PLANTS IN OPERATION GREATER THAN ONE MILLION GALLONS PER DAY BY PROCESS, 1976

	PROCESS[a]					
	TRICKLING FILTER	ACTIVATED SLUDGE	AERATED LAGOON	OTHER[b]	TOTAL PLANTS	PERCENT OF NATION
EPA REGION						
I	18	100	3	15	136	6.1
II	43	111	3	38	195	8.1
III	35	140	3	36	214	9.7
IV	109	254	30	80	473	21.3
V	56	274	6	96	432	19.5
VI	72	153	40	11	276	12.4
VII	54	28	15	17	114	5.1
VIII	37	30	18	2	87	3.9
IX	53	99	19	41	212	9.6
X	25	45	2	7	79	3.6
NATIONAL PLANTS	502	1234	139	343	2218	
TOTAL PERCENT	22.6	55.6	6.2	15.6		100.0

Notes: [a] Primary treatment plants are excluded.

[b] Other implies advanced waste treatment (AWT) and other secondary treatment schemes not otherwise defined as trickling filter, activated sludge, or lagoon.

Source: 1976 Update of Needs Municipal Facilities, Environmental Protection Agency

Categories for treatment plant classification were selected to reflect those areas thought to have similar cost relationships. In addition, the degree of detail provided by the 1976 Needs Survey data limited the classification of existing plants to these relatively broad categories. Regional data were collected within representative states in an attempt to minimize travel costs and limit the number of governmental entities involved.

One rationale considered in attempting to develop cost relationships was the lack of accounting precision in the smaller plants. Several reasons for this assertion became evident during the course of the survey:

1) It is difficult to accurately record costs and hours worked by functional areas at a small plant in which personnel may work only a portion of their time at any one task;
2) There is often less flexibility of support at treatment facilities requiring only a portion of personnel time and consequently a greater variability in recording appropriate costs and hours worked;
3) Smaller plants with smaller budgets were more likely to have a greater variability in cost reporting between similar types of process trains due to the more significant impact of equipment failure, plant upset, staff turnover or other operational interferences; and

4) In general, budgeting and accounting records are not as accurately or thoroughly tabulated in smaller communities, making data collection more difficult and time consuming.

From the percentages presented in Table A.11, the number of facilities to be surveyed by EPA region could be determined. Due to financial limitations it was decided to survey approximately 300 secondary and advanced waste treatment plants. Table A.12 shows the desired number of plants that require sampling by EPA region. In addition to the 300 secondary and AWT plants, a representative selection of wastewater treatment plants that provide only primary treatment would be surveyed. Therefore, a few (4-6) primary treatment plants for each EPA region were added to the secondary and AWT base of 300 plants. From the state breakdown for each region, each state could be tested for its similarity to regional characteristics. Other supplemental factors such as geography, terrain, urbanization, climate, and state water quality organization were evaluated for each state and compared with the region.

After considering the above factors, the representative states were reviewed to insure that regional sampling requirements could be obtained within those states and still provide a large degree of flexibility. The states selected are listed in Table A.13 and shown in Figure A.1. Areas remote from the continental U.S. in both distance and characteristics were excluded from consideration. These areas include Alaska, Hawaii, Puerto Rico, Virgin Islands, American Samoa, Guam, the Trust

TABLE A.12 DESIRED DISTRIBUTION OF NATIONAL SAMPLE OF WASTEWATER TREATMENT PLANTS BY EPA REGION AND PROCESS

	---------------PROCESS[a]---------------					
	TRICKLING FILTER	ACTIVATED SLUDGE	AERATED LAGOON	OTHER[b]	TOTAL PLANTS	PERCENT OF NATION
EPA REGION						
I	3	13	1	2	19	6.3
II	6	15	1	5	27	9.0
III	5	18	1	5	29	9.6
IV	15	35	4	10	64	21.3
V	8	37	1	13	59	19.6
VI	10	20	5	1	36	12.0
VII	8	3	2	2	15	5.0
VIII	5	3	2	1	11	3.7
IX	8	13	3	5	29	9.6
X	3	7	1	1	12	3.9
NATIONAL PLANTS	71	164	21	45	301	
TOTAL PERCENT	23.6	54.5	7.0	14.9		100.0

Notes: [a] Primary treatment plants are excluded.
[b] Other implies advanced waste treatment (AWT) and other secondary treatment schemes not otherwise defined as trickling filter, activated sludge, or lagoon.

Source: 1976 Update of Needs Municipal Facilities, Environmental Protection Agency

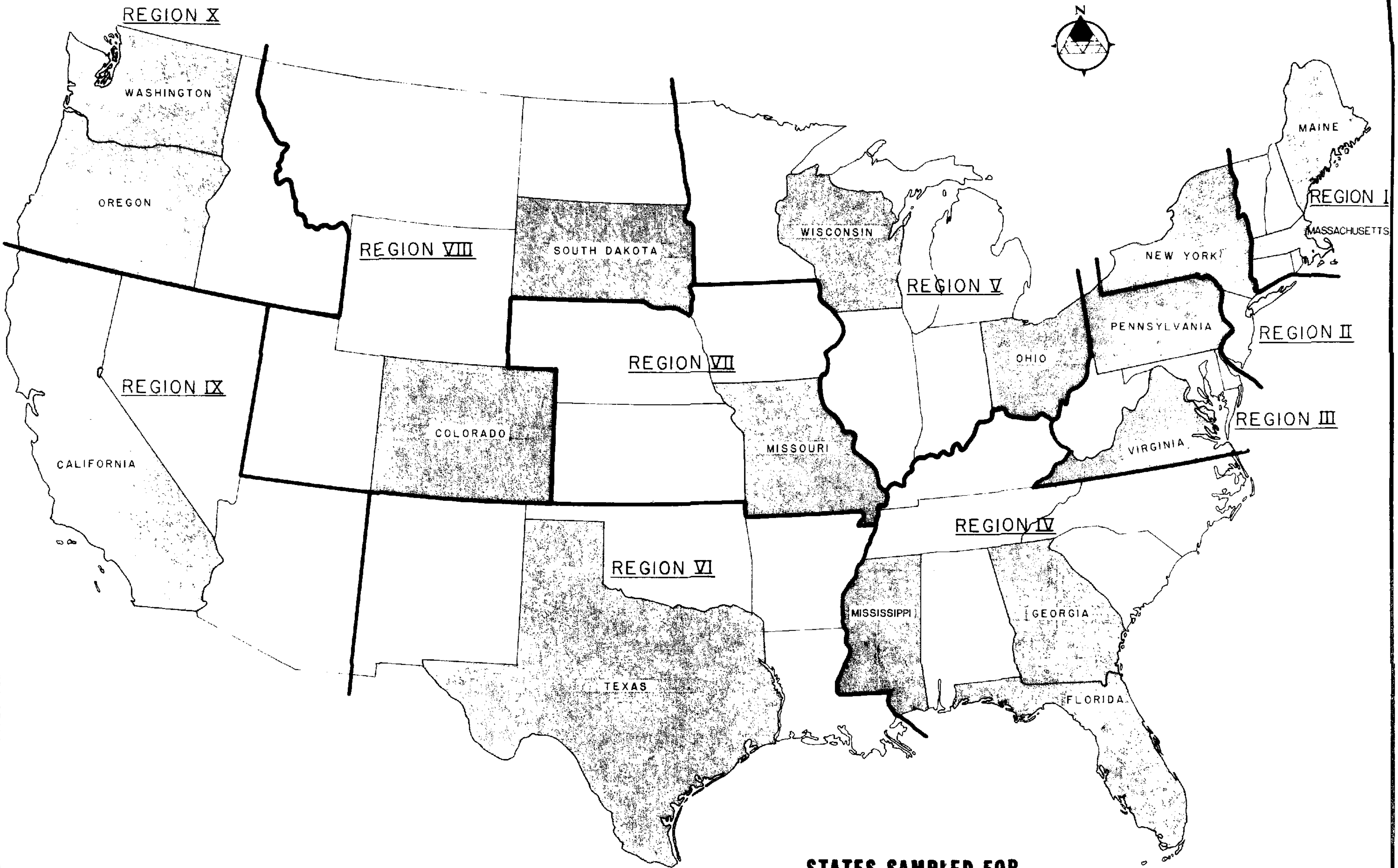
Territories of the Pacific, and all other territories or possessions of the United States.

Figures A.2 through A.18 illustrate the geographical distribution of the sampled wastewater treatment plants in the selected states. The type of plant and size class are also noted in addition to the general location within the selected state.

TABLE A.13

Region	Sample State	Other States in Region
Region I	Maine Massachusetts	Connecticut, New Hampshire Rhode Island, Vermont
Region II	New York	New Jersey, Puerto Rico Virgin Islands
Region III	Pennsylvania Virginia	Delaware, District of Columbia, Maryland, West Virginia
Region IV	Florida Georgia Mississippi	Alabama, Kentucky, North Carolina, South Carolina, Tennessee
Region V	Ohio Wisconsin	Illinois, Indiana, Michigan, Minnesota
Region VI	Texas	Arkansas, Louisiana, New Mexico, Oklahoma
Region VII	Missouri	Iowa, Kansas, Nebraska
Region VIII	Colorado South Dakota	North Dakota, Montana, Utah, Wyoming
Region IX	California	Arizona, Hawaii, Nevada, Guam, Trust Territories, American Samoa
Region X	Oregon Washington	Alaska, Idaho

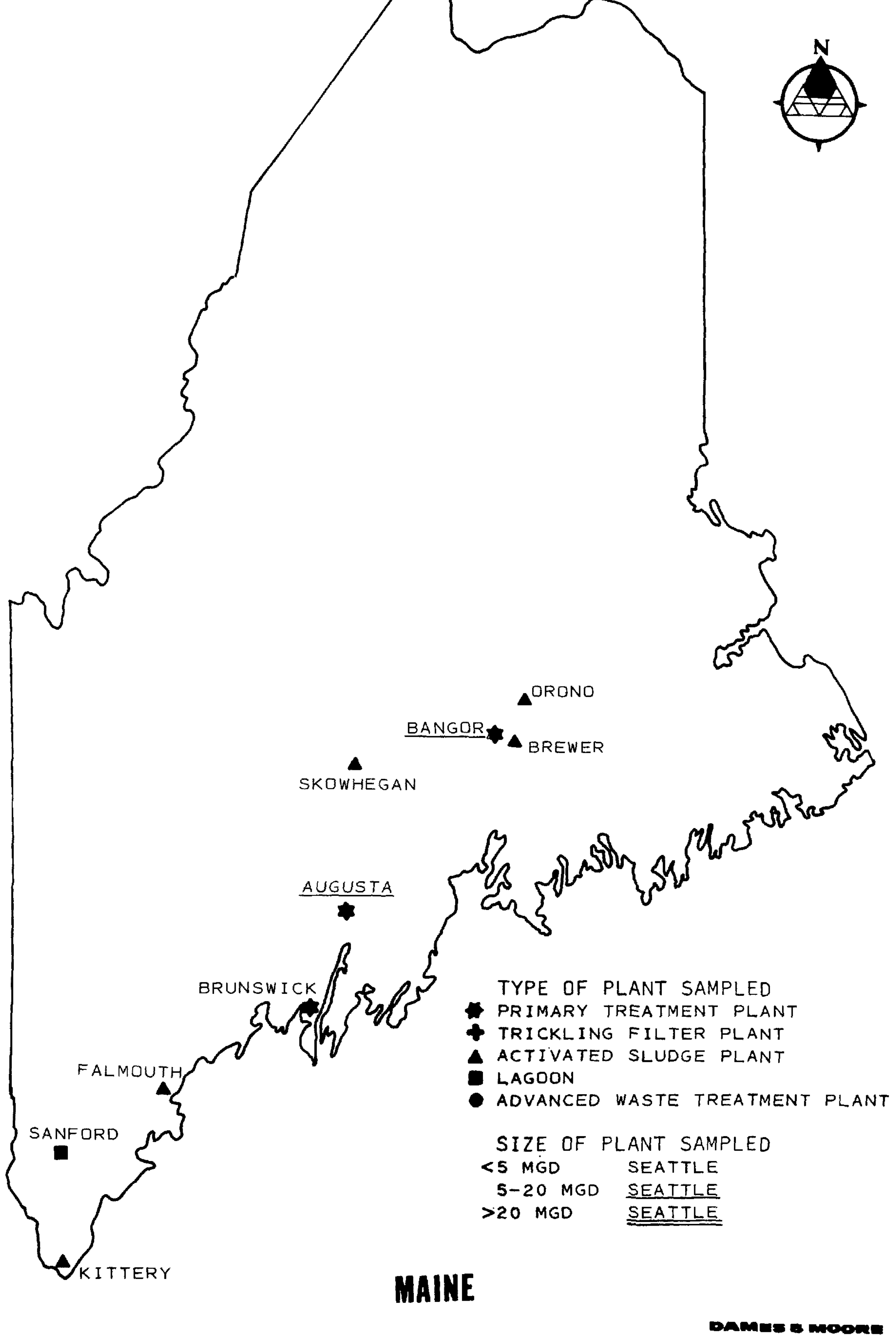
FIGURE A.1

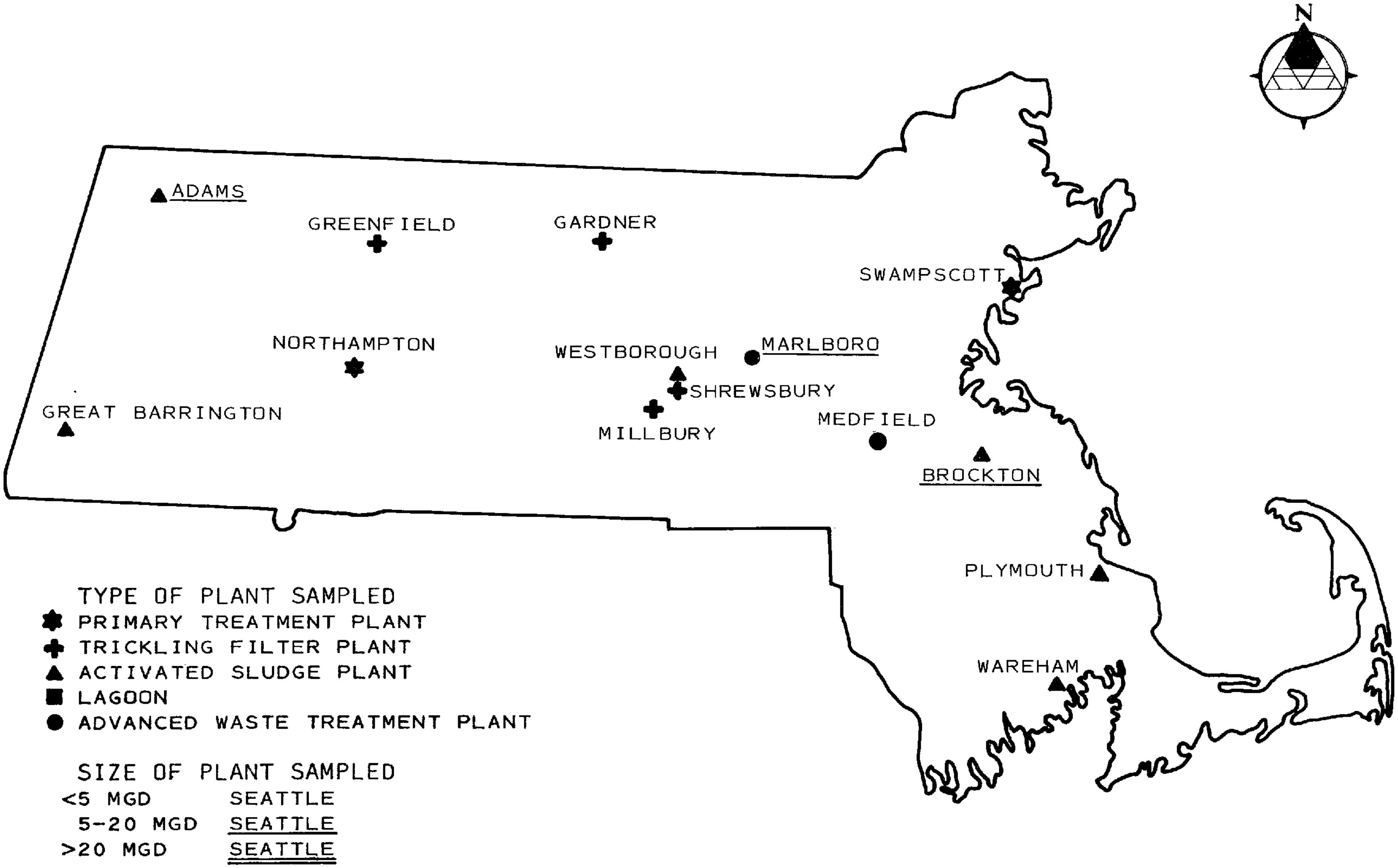


STATES SAMPLED FOR
MUNICIPAL WASTEWATER TREATMENT
FACILITIES BY EPA REGIONS

DAMES & MOORE

FIGURE A.2


N
ORONO
BANGOR
BREWER
SKOWHEGAN
AUGUSTA
BRUNSWICK
FALMOUTH
SANFORD
KITTERY
TYPE OF PLANT SAMPLED
✱ PRIMARY TREATMENT PLANT
✚ TRICKLING FILTER PLANT
▲ ACTIVATED SLUDGE PLANT
■ LAGOON
● ADVANCED WASTE TREATMENT PLANT
SIZE OF PLANT SAMPLED
<5 MGD SEATTLE
5-20 MGD SEATTLE
>20 MGD SEATTLE
MAINE
DAMES & MOORE



MASSACHUSETTS

FIGURE A.3

DAMES & MOORE

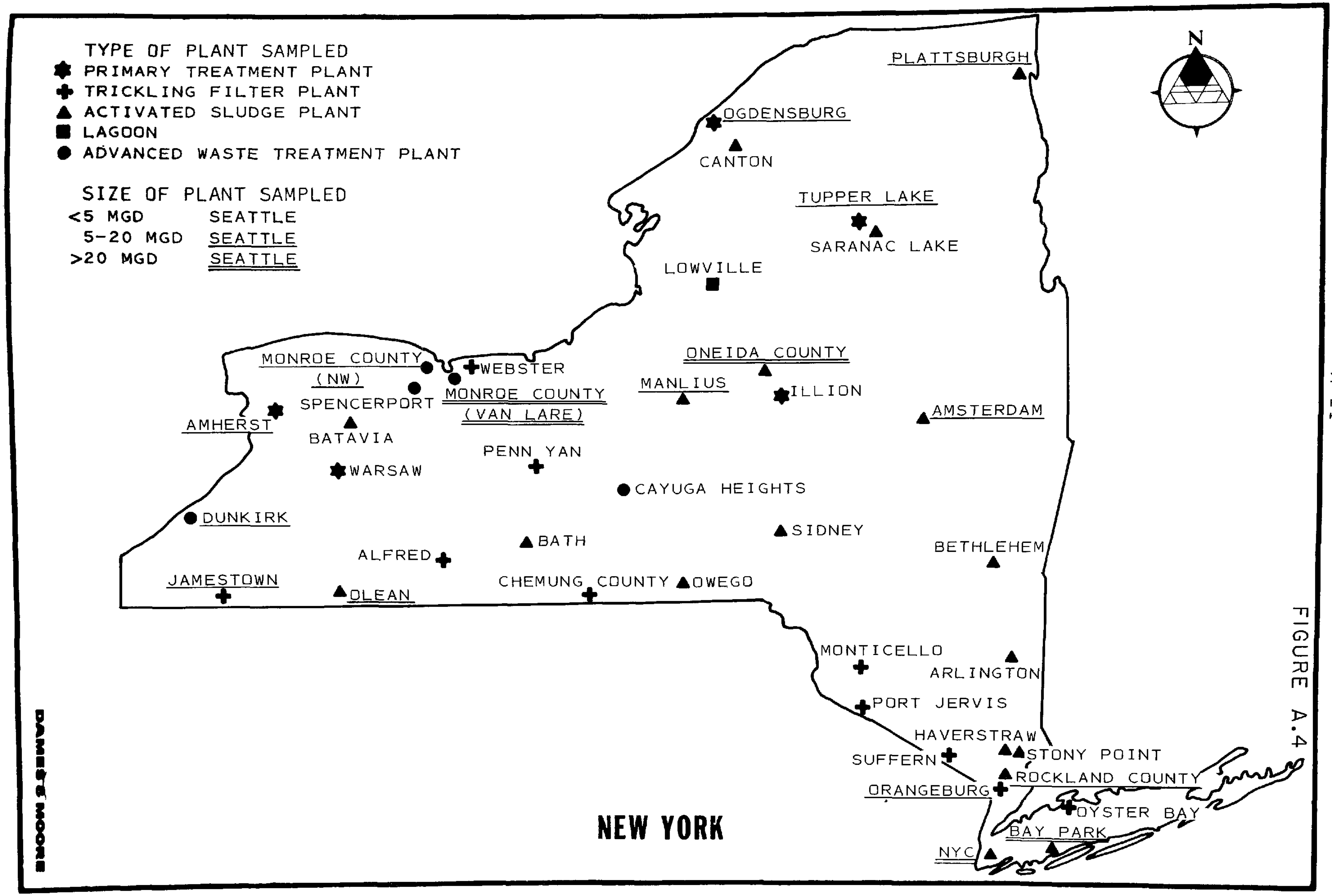
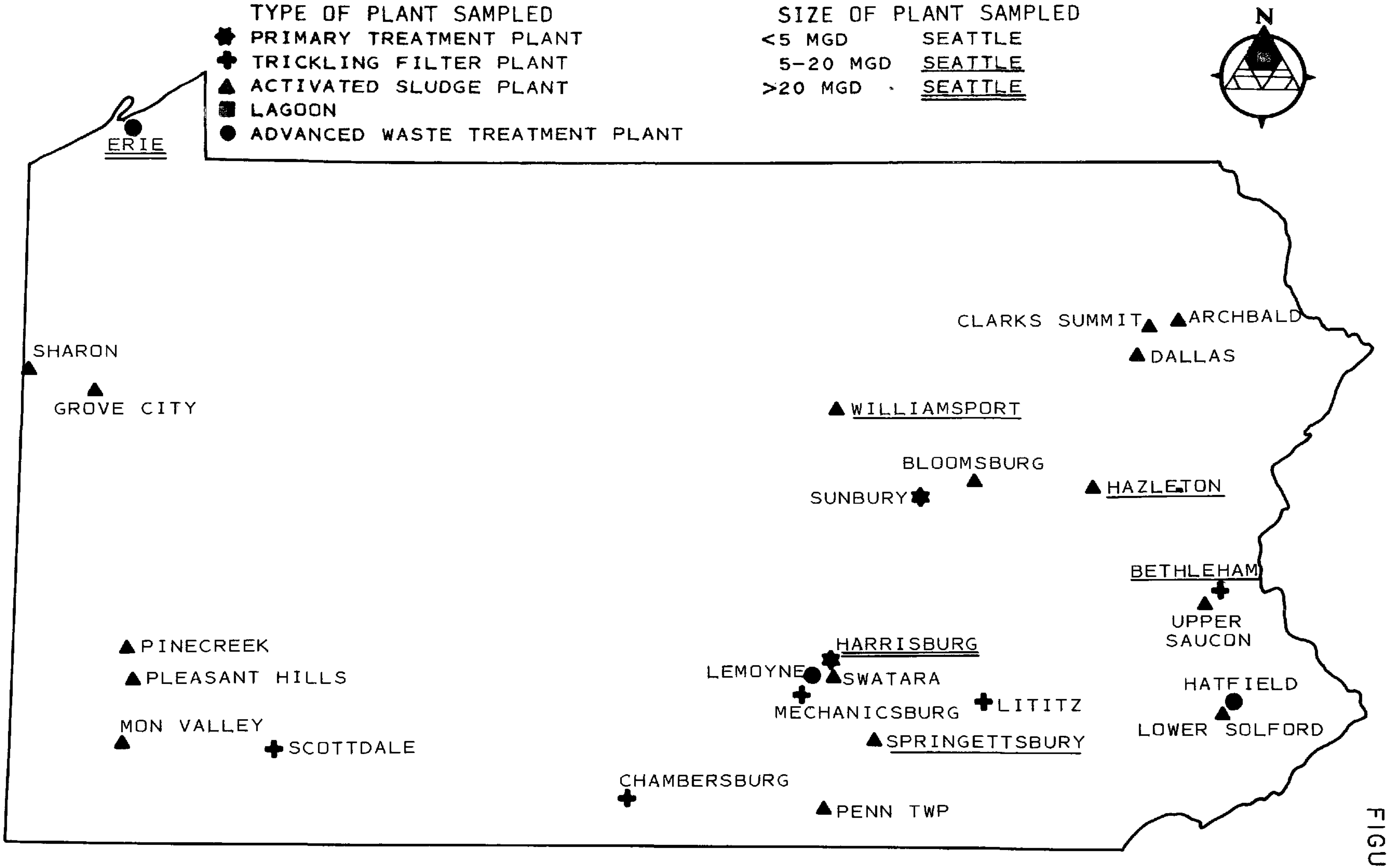

TYPE OF PLANT SAMPLED
PRIMARY TREATMENT PLANT
TRICKLING FILTER PLANT
ACTIVATED SLUDGE PLANT
LAGOON
ADVANCED WASTE TREATMENT PLANT
SIZE OF PLANT SAMPLED
<5 MGD SEATTLE
5-20 MGD SEATTLE
>20 MGD SEATTLE
N
PLATTSBURGH
OGDENSBURG
CANTON
TUPPER LAKE
SARANAC LAKE
LOWVILLE
ONEIDA COUNTY
MANLIUS
ILLION
AMSTERDAM
MONROE COUNTY (NW)
WEBSTER
SPENCERPORT
MONROE COUNTY (VAN LARE)
AMHERST
BATAVIA
PENN YAN
WARSAW
CAYUGA HEIGHTS
DUNKIRK
SIDNEY
BETHLEHEM
BATH
ALFRED
JAMESTOWN
OLEAN
CHEMUNG COUNTY
OWEGO
MONTICELLO
ARLINGTON
PORT JERVIS
HAVERSTRAW
STONY POINT
SUFFERN
ROCKLAND COUNTY
ORANGEBURG
OYSTER BAY
BAY PARK
NYC
NEW YORK
DAMES & MOORE

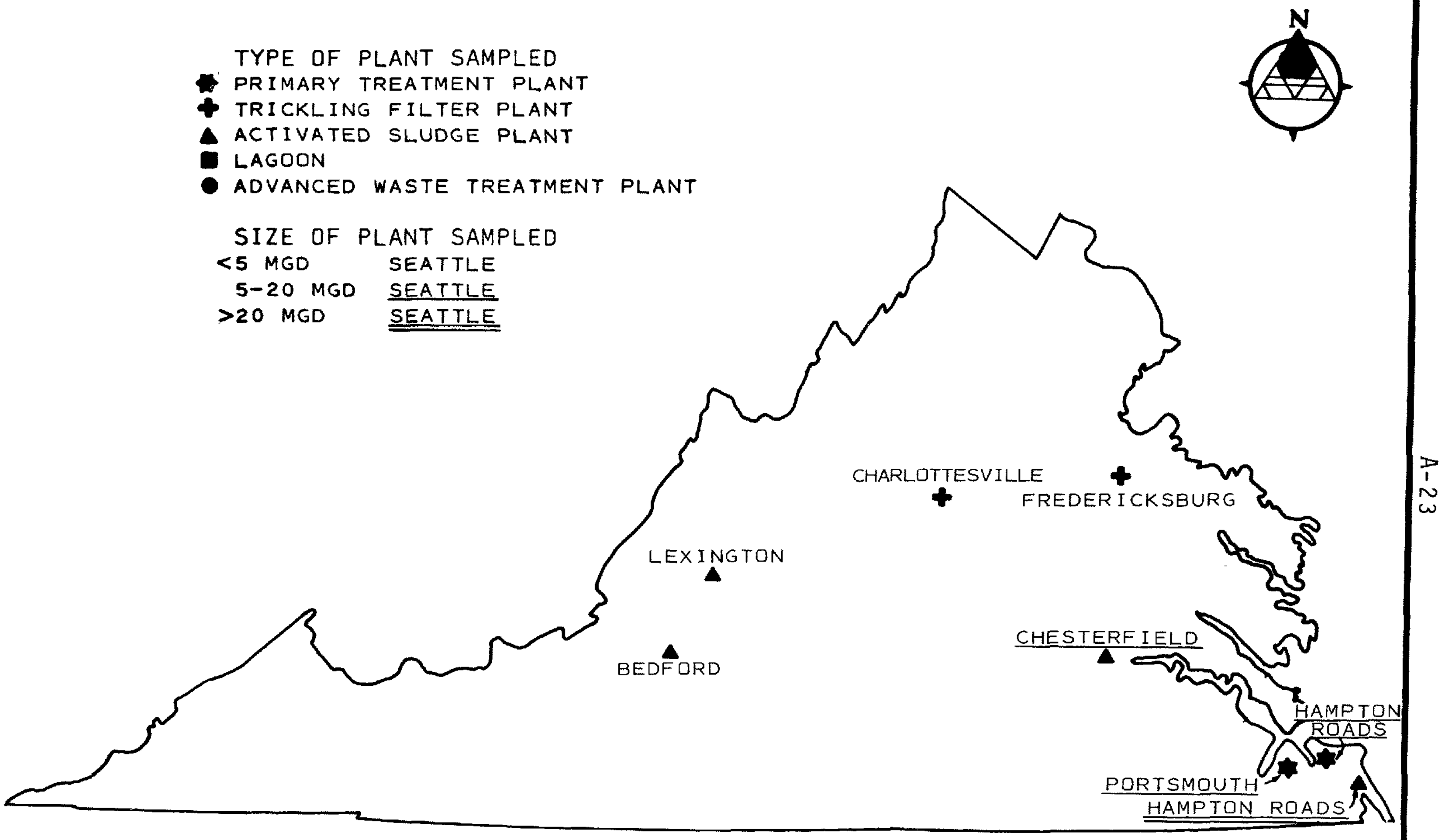
FIGURE A.4



PENNSYLVANIA

FIGURE A.5

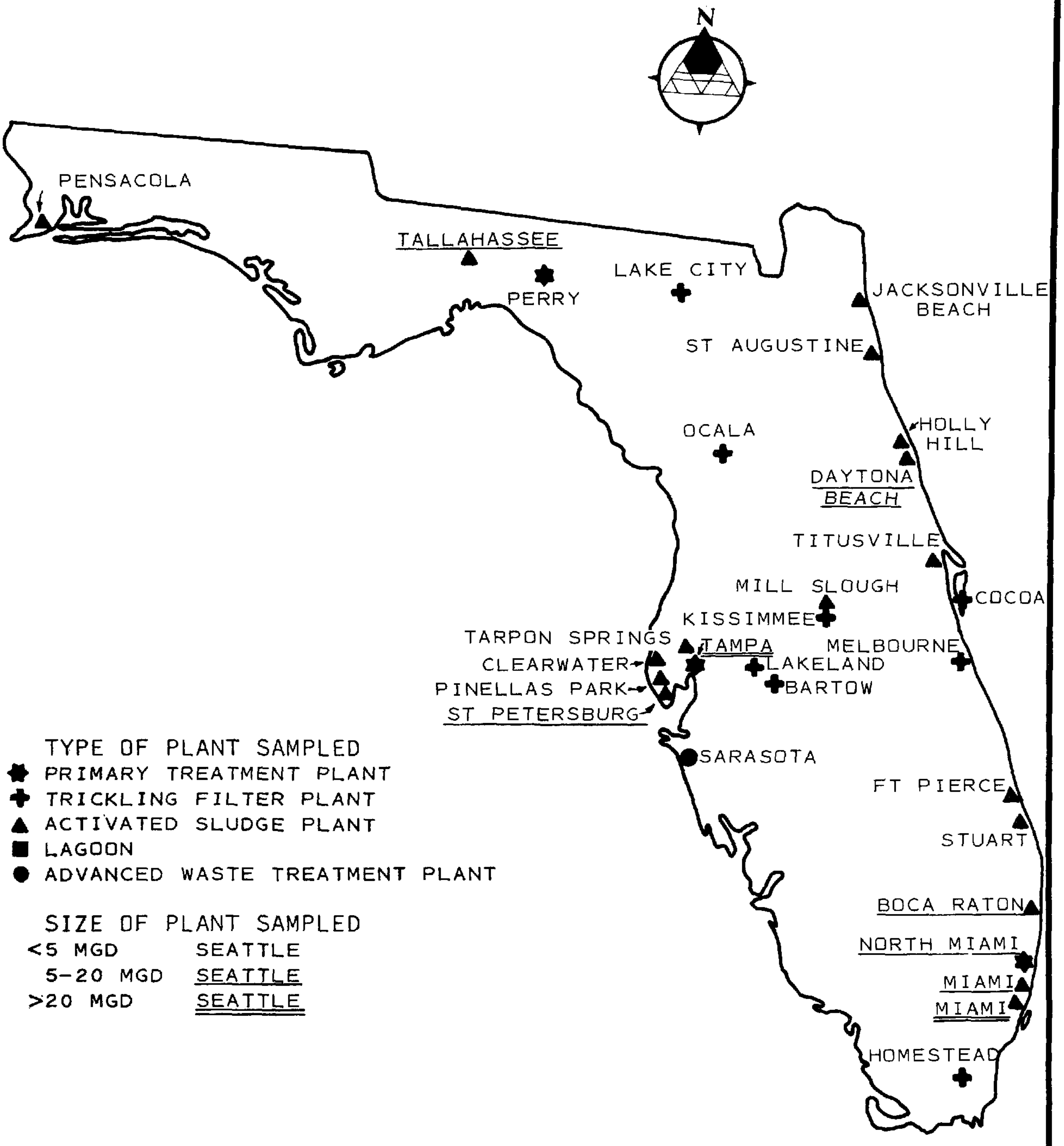
DAMES & MOORE



VIRGINIA

FIGURE A.6

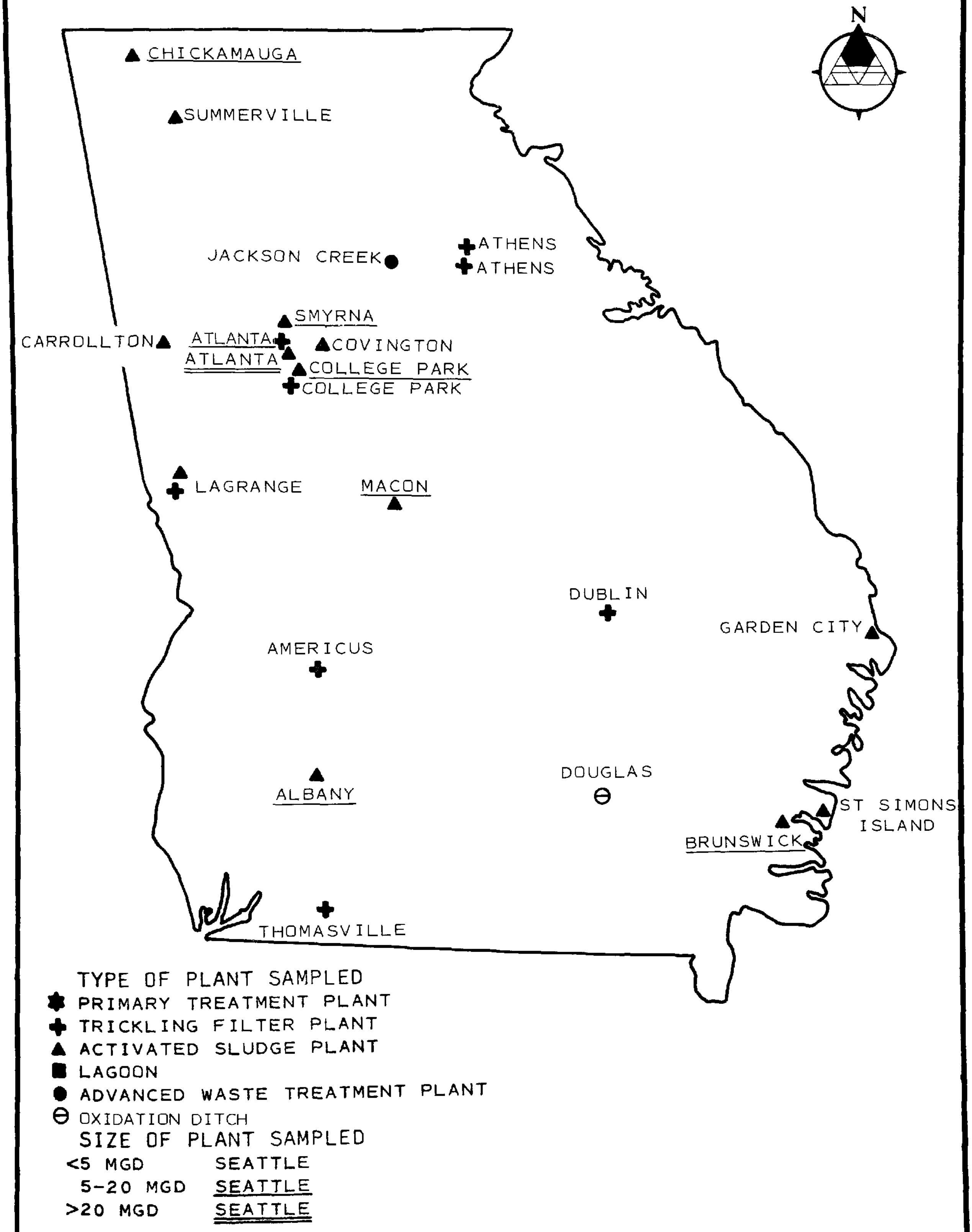
FIGURE A.7



FLORIDA

DAMES & MOORE

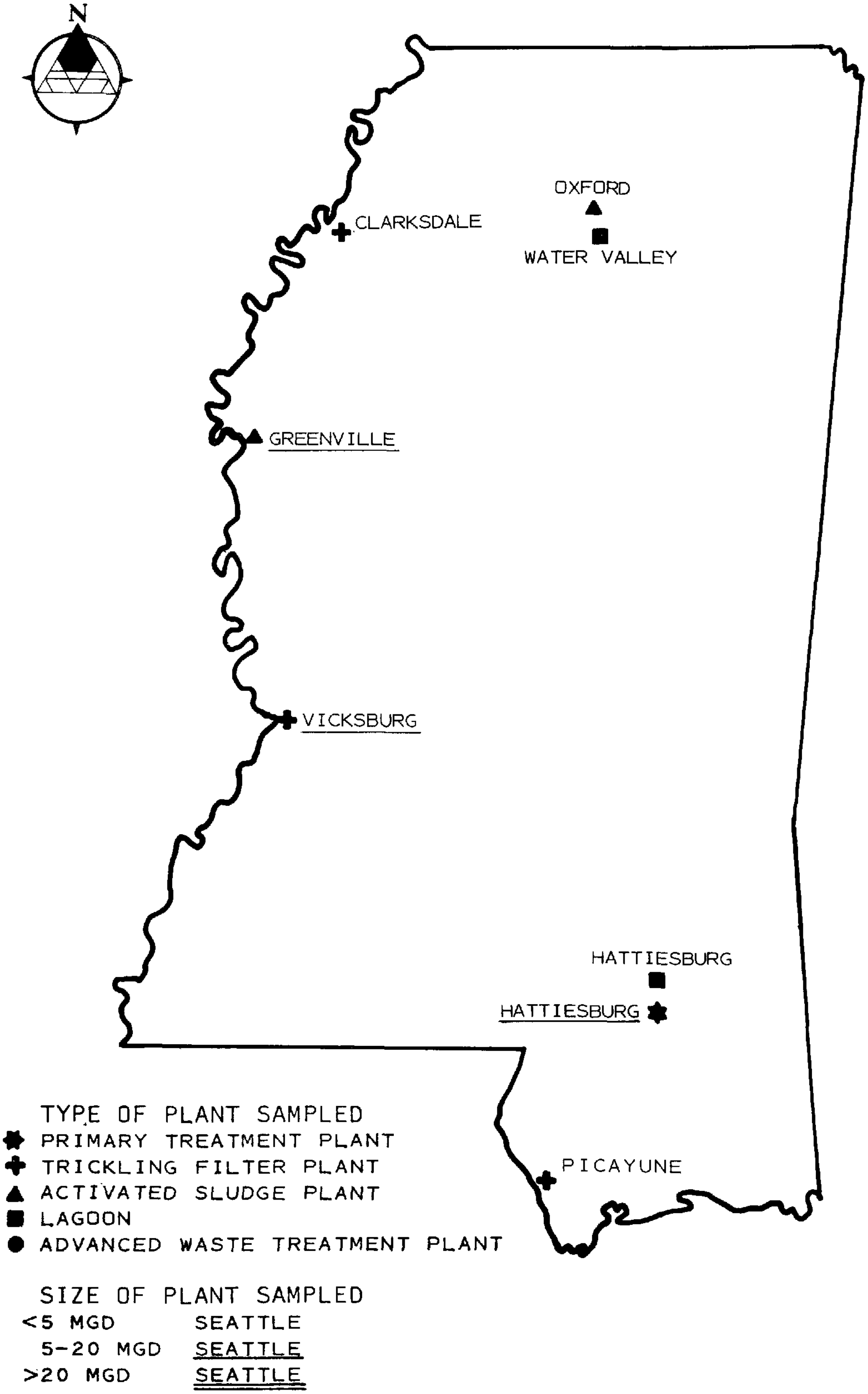
FIGURE A.8



GEORGIA

DAMES & MOORE

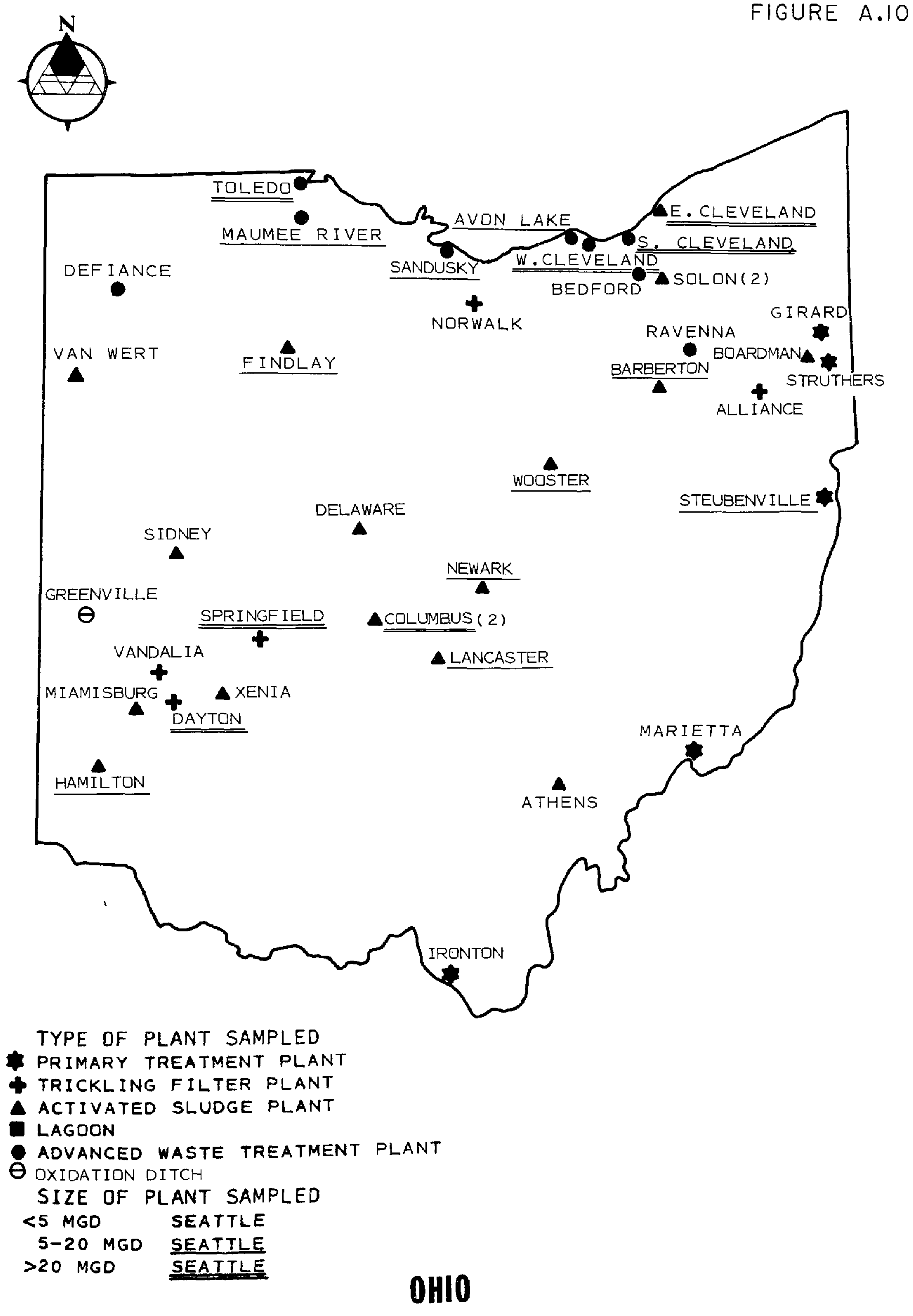
FIGURE A.9



MISSISSIPPI

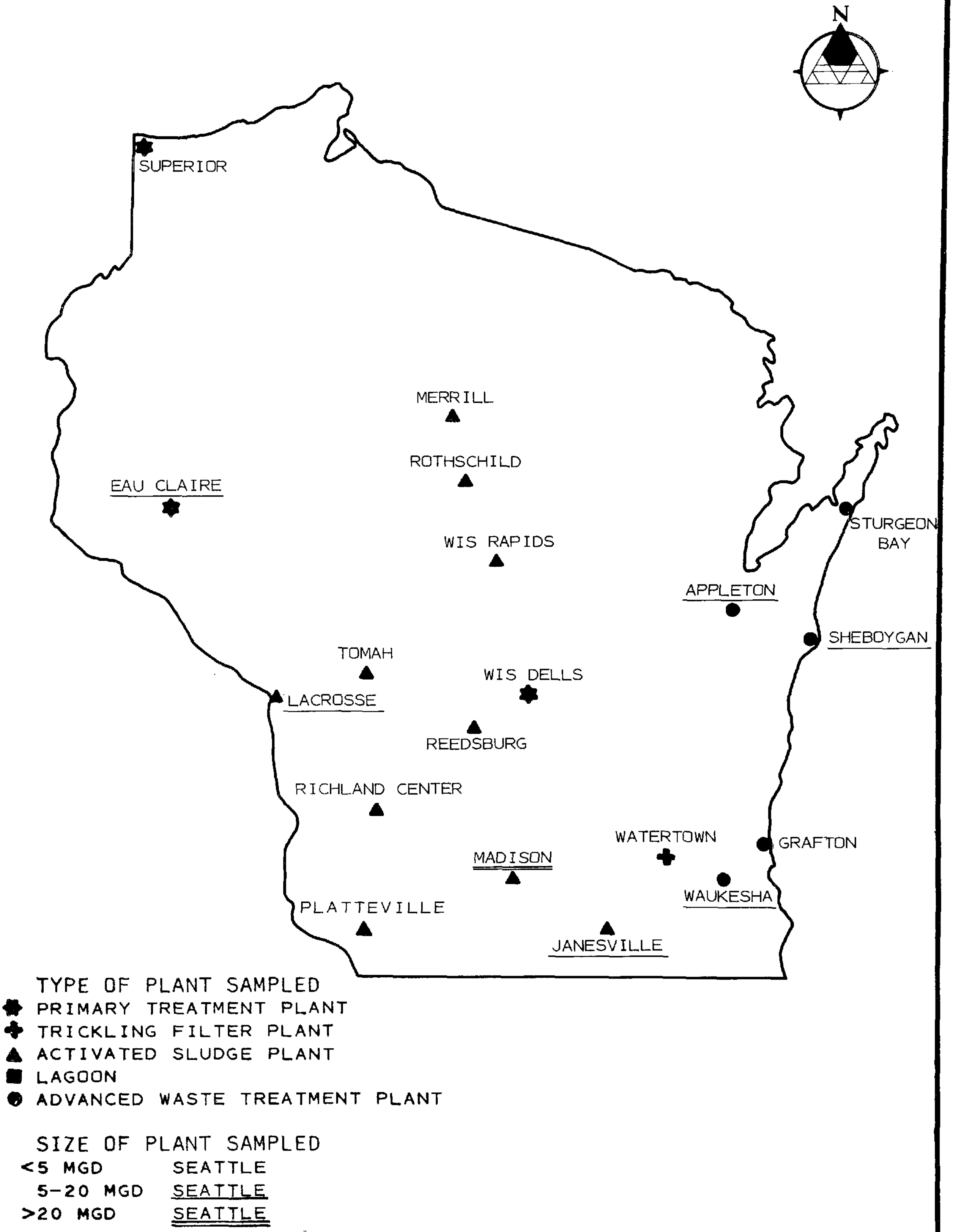
FIGURE G. 7— 1

FIGURE A.10



DAMES & MOORE

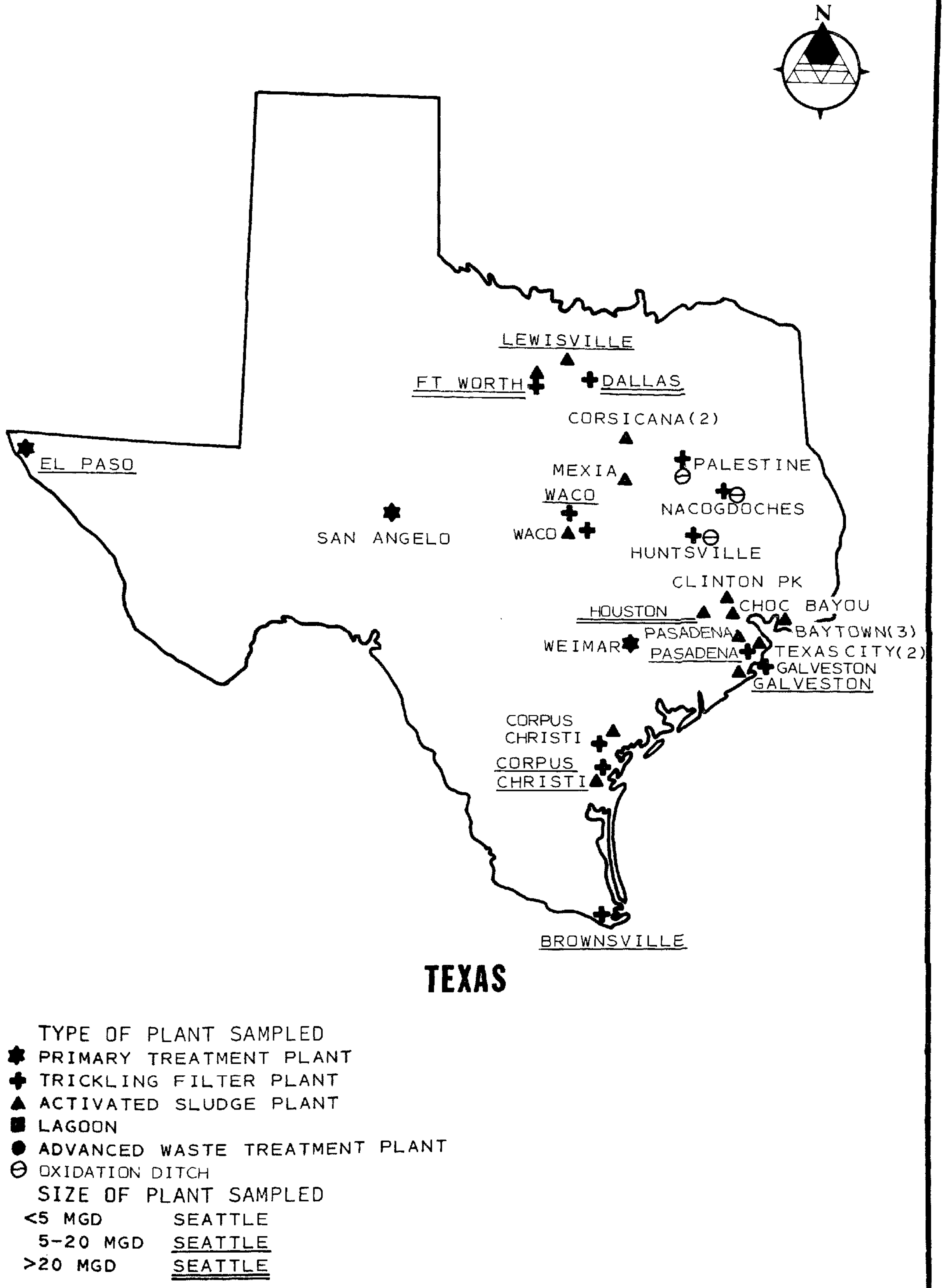
FIGURE A.11



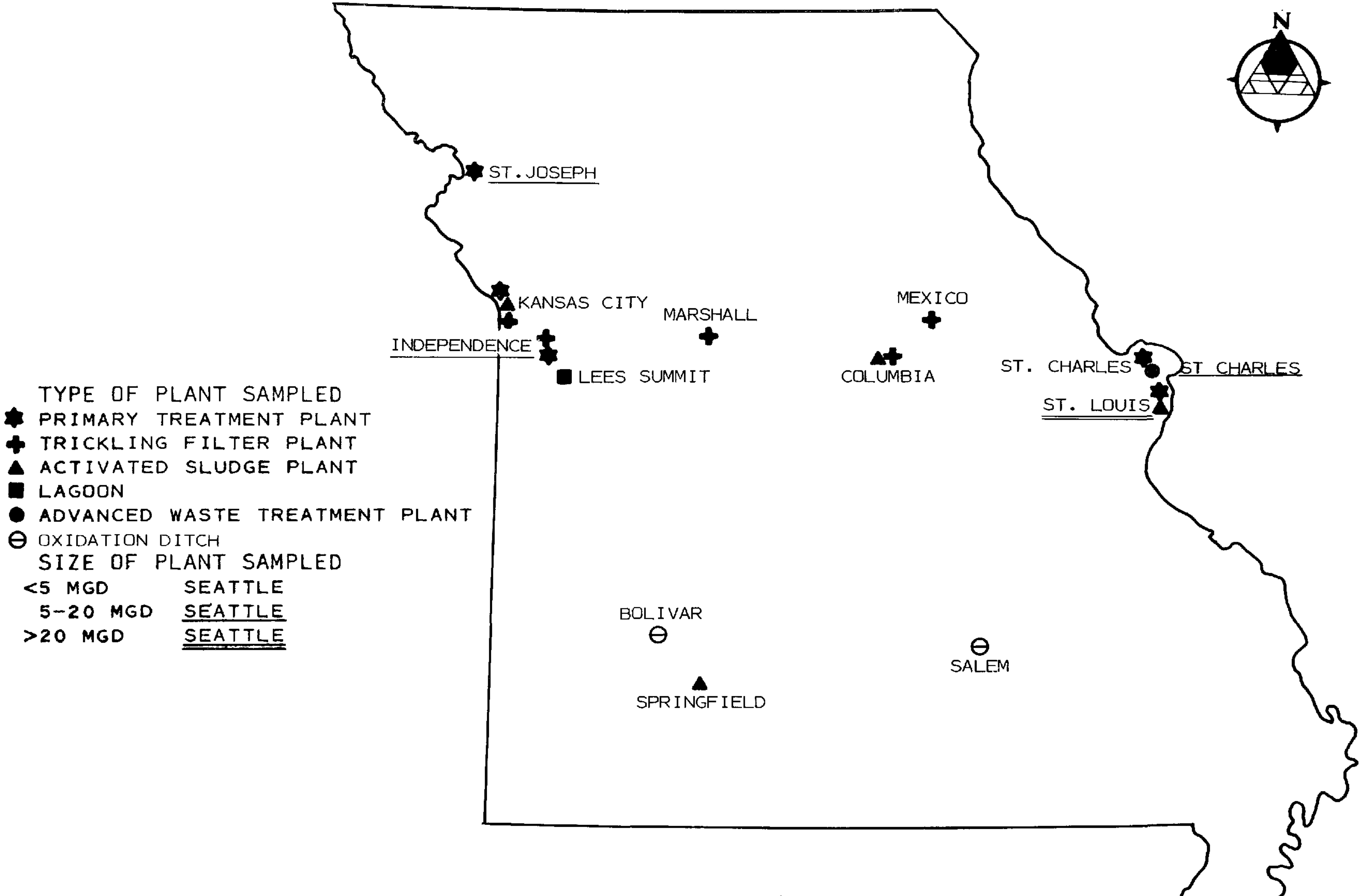
WISCONSIN

DAMES & MOORE

FIGURE A.12



DAMES & MOORE

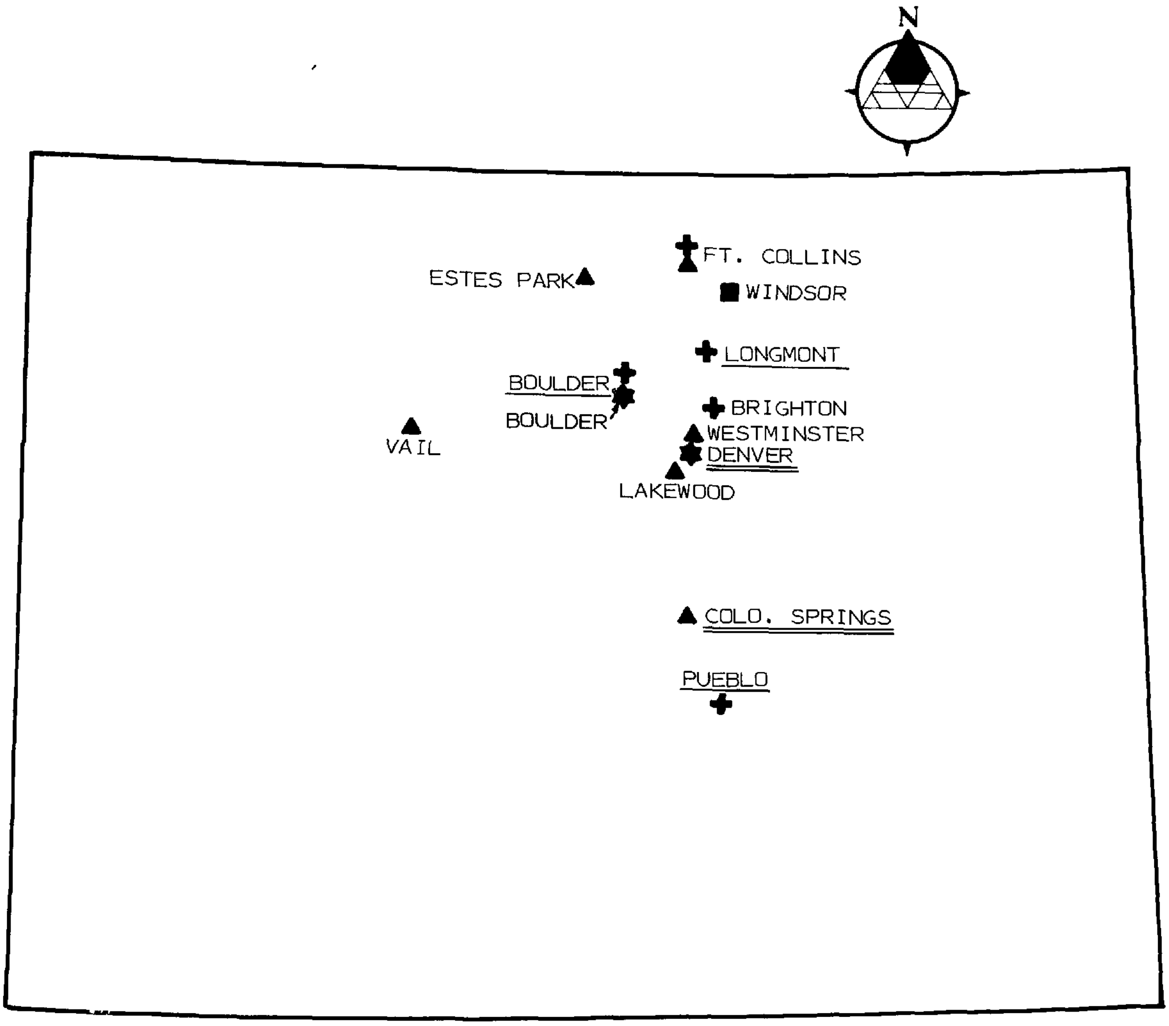


MISSOURI

FIGURE A.13

DAMES & MOORE

FIGURE A.14



TYPE OF PLANT SAMPLED

- ✱ PRIMARY TREATMENT PLANT
- ✚ TRICKLING FILTER PLANT
- ▲ ACTIVATED SLUDGE PLANT
- ■ LAGOON
- ● ADVANCED WASTE TREATMENT PLANT

SIZE OF PLANT SAMPLED

<5 MGD	SEATTLE
5-20 MGD	SEATTLE
>20 MGD	SEATTLE

COLORADO

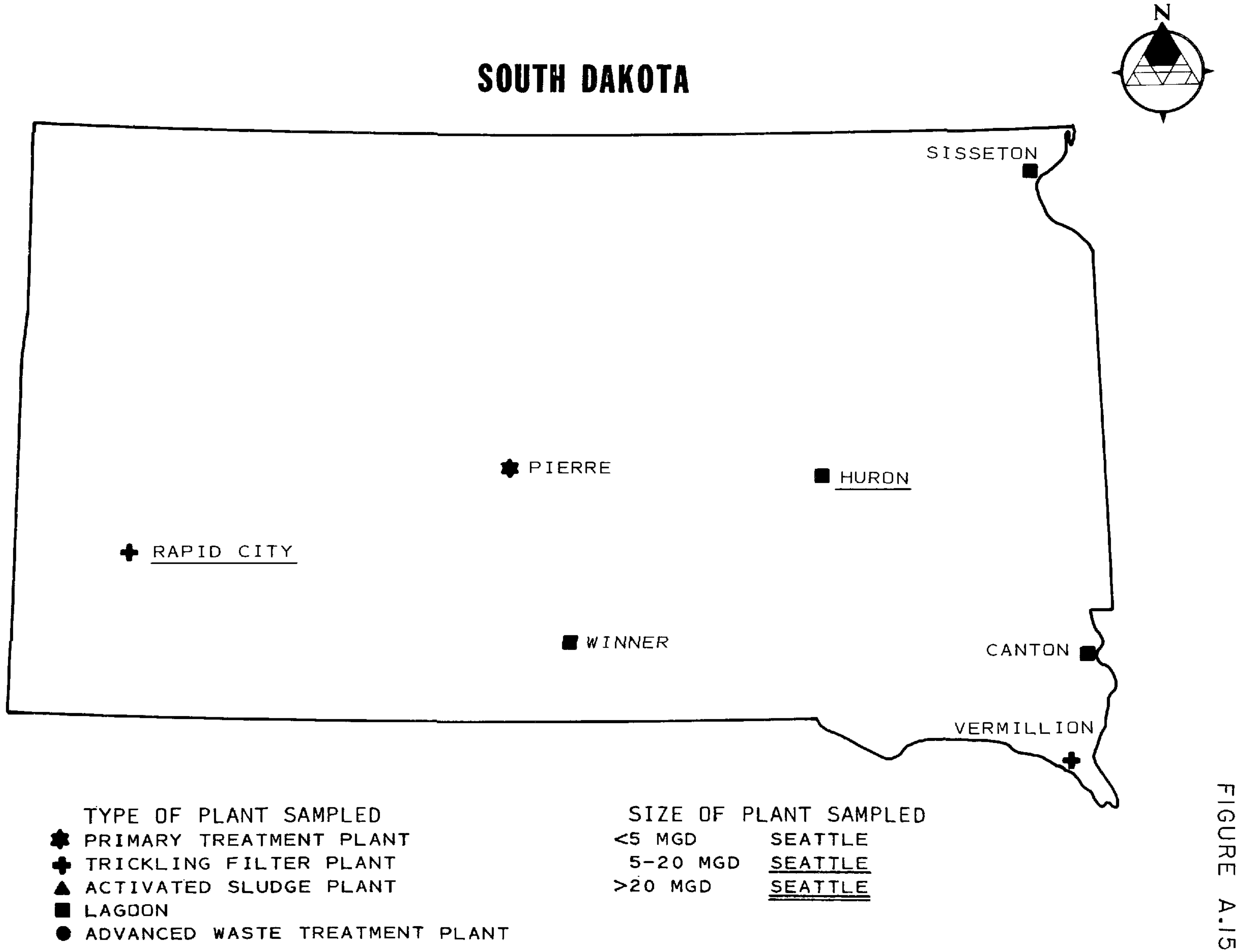

N
SOUTH DAKOTA
SISSETON
PIERRE
HURON
RAPID CITY
WINNER
CANTON
VERMILLION
TYPE OF PLANT SAMPLED
✱ PRIMARY TREATMENT PLANT
✚ TRICKLING FILTER PLANT
▲ ACTIVATED SLUDGE PLANT
■ LAGOON
● ADVANCED WASTE TREATMENT PLANT
SIZE OF PLANT SAMPLED
<5 MGD SEATTLE
5-20 MGD SEATTLE
>20 MGD SEATTLE

FIGURE A.15

FIGURE A.16

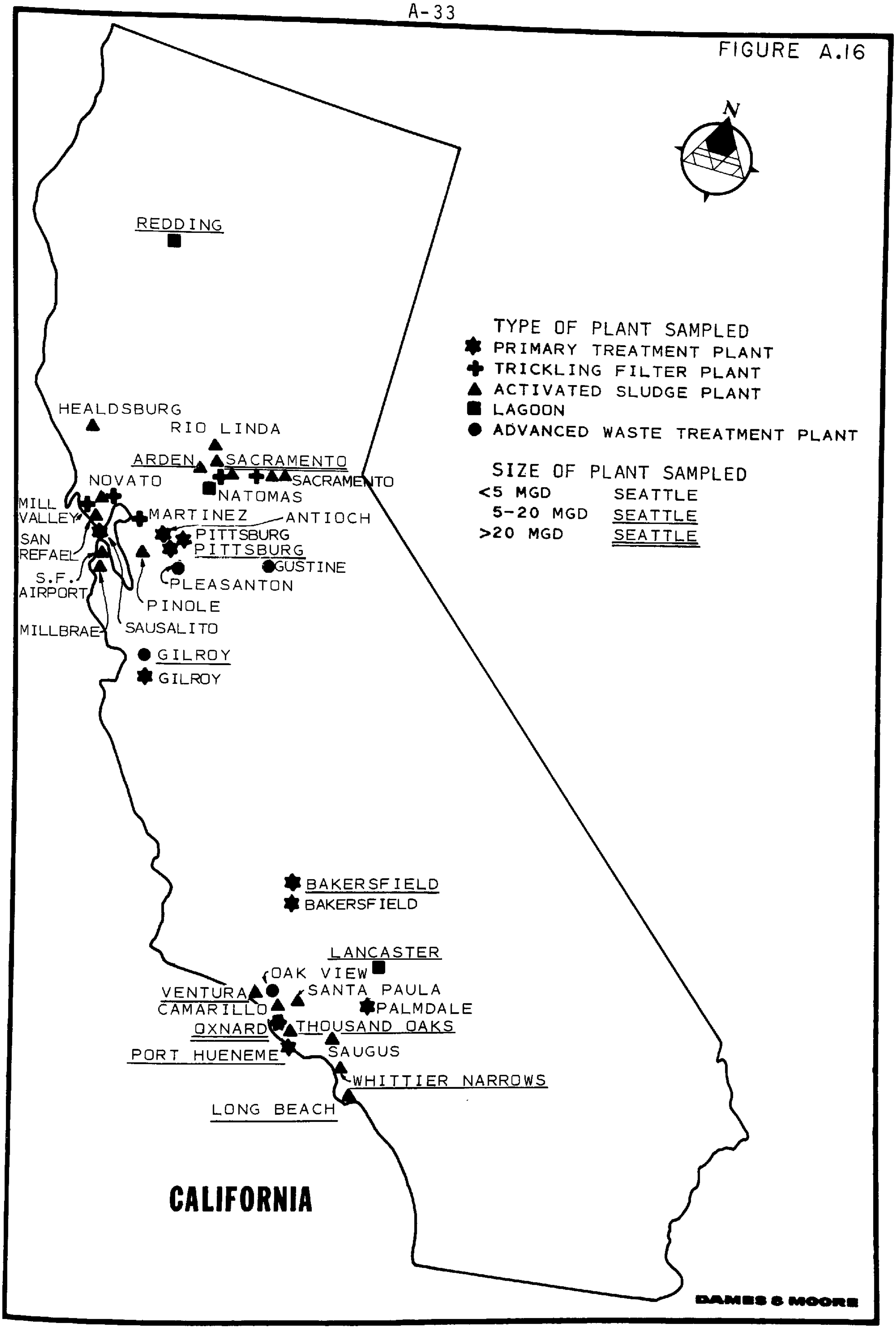
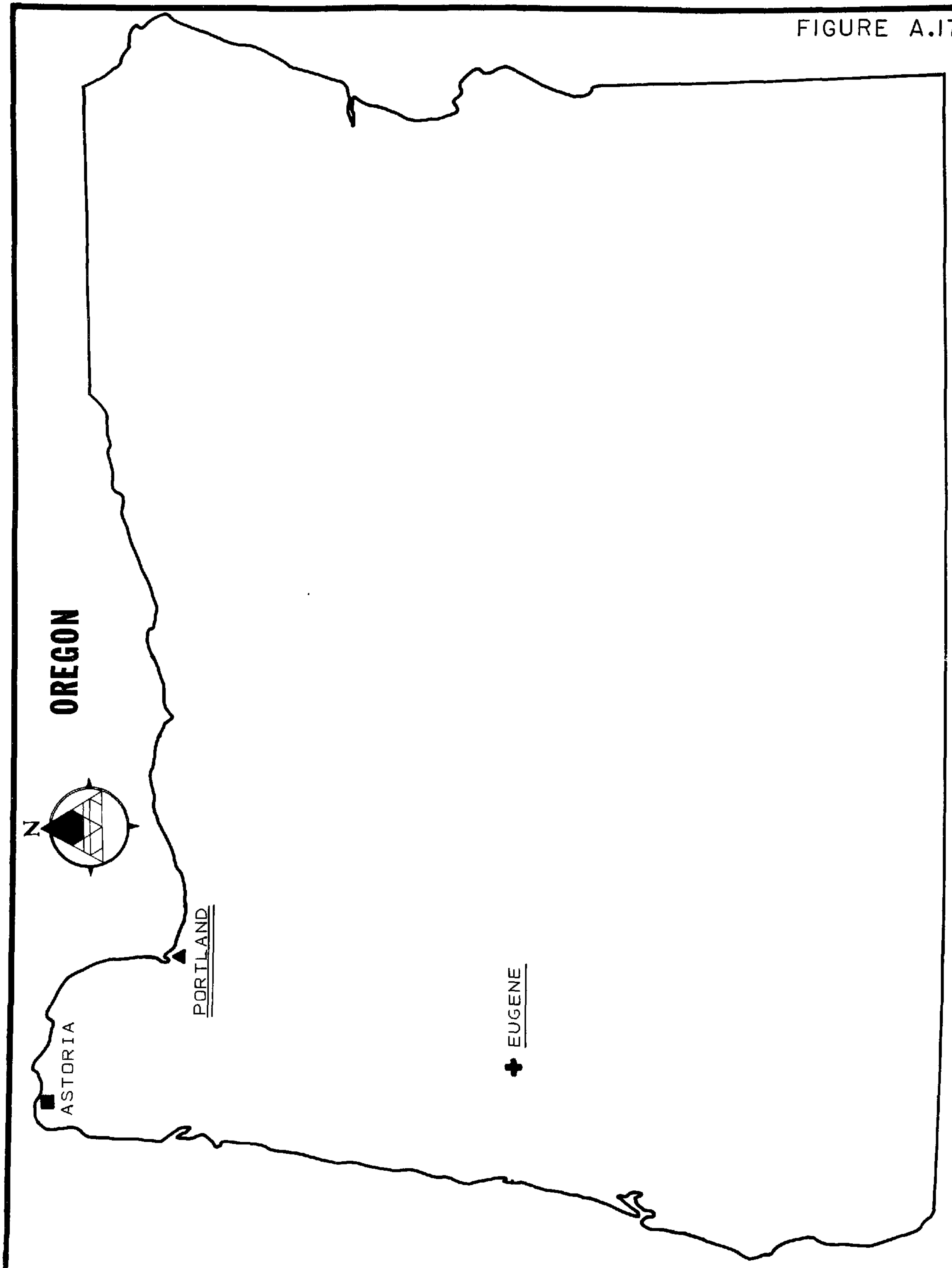

N
REDDING
HEALDSBURG
RIO LINDA
ARDEN
SACRAMENTO
SACRAMENTO
NATOMAS
NOVATO
MILL VALLEY
MARTINEZ
ANTIOCH
SAN REFAEL
PITTSBURG
PITTSBURG
GUSTINE
S.F. AIRPORT
PLEASANTON
PINOLE
MILLBRAE
SAUSALITO
GILROY
GILROY
BAKERSFIELD
BAKERSFIELD
LANCASTER
OAK VIEW
VENTURA
SANTA PAULA
CAMARILLO
PALMDALE
OXNARD
THOUSAND OAKS
PORT HUENEME
SAUGUS
WHITTIER NARROWS
LONG BEACH
TYPE OF PLANT SAMPLED
✱ PRIMARY TREATMENT PLANT
✚ TRICKLING FILTER PLANT
▲ ACTIVATED SLUDGE PLANT
■ LAGOON
● ADVANCED WASTE TREATMENT PLANT
SIZE OF PLANT SAMPLED
<5 MGD SEATTLE
5-20 MGD SEATTLE
>20 MGD SEATTLE
CALIFORNIA
DAMES & MOORE

FIGURE A.17



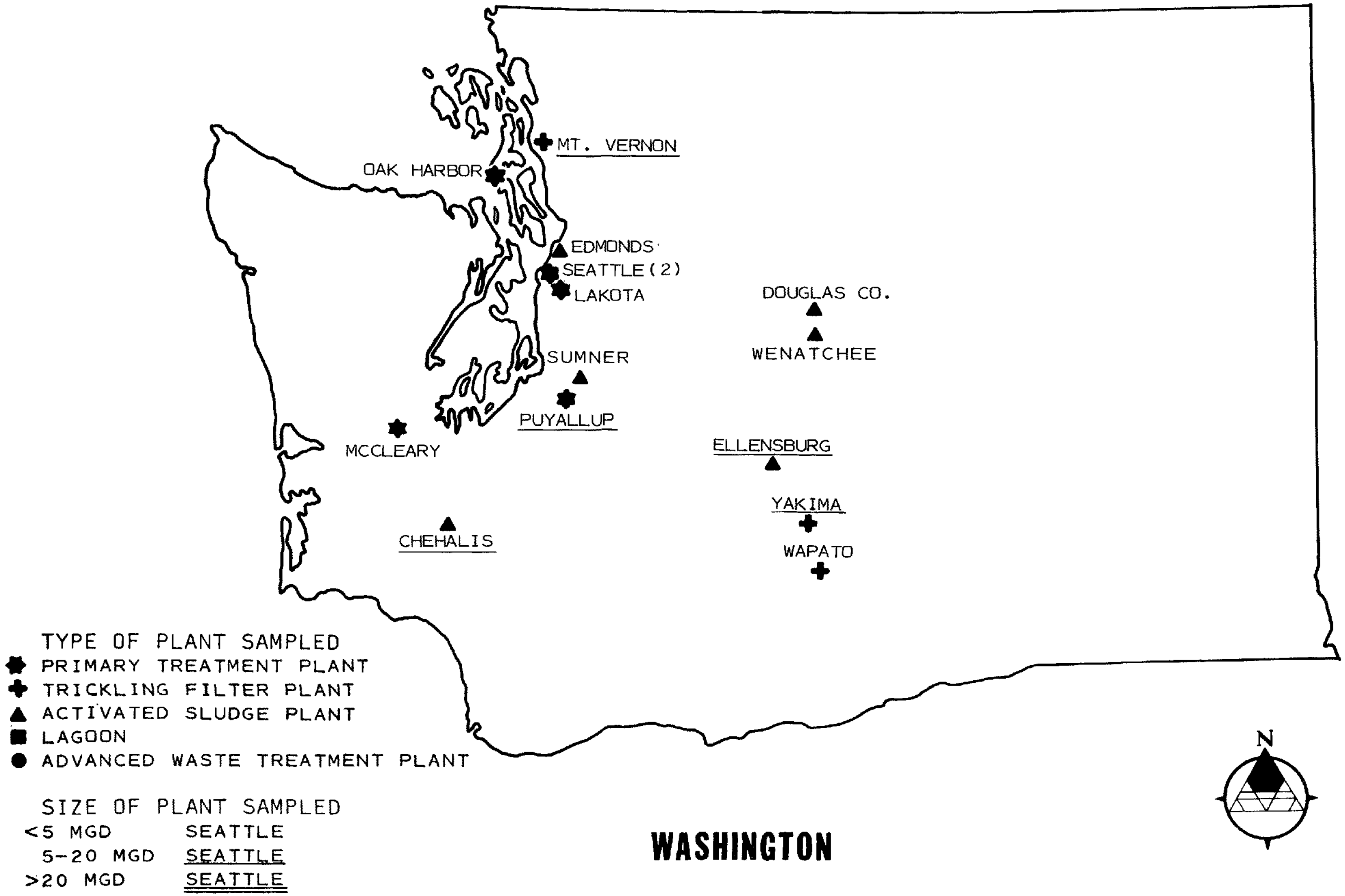
TYPE OF PLANT SAMPLED

- ✱ PRIMARY TREATMENT PLANT
- ✚ TRICKLING FILTER PLANT
- ▲ ACTIVATED SLUDGE PLANT
- ■ LAGOON
- ● ADVANCED WASTE TREATMENT PLANT

SIZE OF PLANT SAMPLED

<5 MGD	SEATTLE
5–20 MGD	SEATTLE
>20 MGD	SEATTLE

DAMES & MOORE



WASHINGTON

FIGURE A.18

A.2 DATA COLLECTION PROCEDURES

A.2.1 Methods of Contact

In order to minimize the effort required to locate proper facilities from which to obtain data and to contact proper authorities, an approach was devised based on the Federal-state-local hierarchy of the Water Pollution Control Grants or NPDES permit programs. After determining the sample characteristics and states to be considered in each region, Dames & Moore survey personnel contacted the Operation and Maintenance (O&M) Branch in each EPA region. From the information available in these regional offices and from the NPDES Permit files, potential facilities were selected by Dames & Moore investigators and reviewed by the regional O&M staff for appropriateness. An attempt was made to avoid selecting only those facilities that were operated well and properly maintained.

In some regions this information was more readily available from the state offices than from regional EPA offices and the facility selection was performed at that level. In those cases where facilities were selected at the regional level, the states concerned were consulted.

After sample facilities were approved at the regional and state levels, the authority names, addresses, and phone numbers of the predesignated municipalities were obtained from either the O&M offices, or the NPDES or Grants files. Each facility was contacted and informed of the nature of the project and the required information. Appointments were made with the appropriate municipal officials and a visit to each facility was scheduled.

A.2.2 Data Collection Worksheets

To standardize the format of the data collected and to simplify data processing, a worksheet was developed that itemized the information desired (see Figure A.19). In addition, to insure flexibility and thoroughness, a supplemental worksheet was provided to accommodate exceptional information or comments (see Figure A.20). The comment worksheet could only be used in conjunction with the treatment system data worksheet or the sewer system data worksheet.

Treatment System Data Worksheet

The Treatment System Data worksheet (Figure A.19) is divided into three basic segments: identity data; flow, quality, process and pumping data; and fiscal data. In addition, each line of the treatment worksheet and accompanying comment worksheet is uniquely identified by a three-digit identification number identifying the EPA region and state of the facility. Table A.14 lists the identification number groupings for each region and state.

For each facility line A includes the name, location (city, county, state, zip code), the Authority/Facility number from the 1976 Needs Survey, and the NPDES permit number. In addition, a two-digit code, (explained in Section A.2.3) is entered describing the type of facility being recorded. Line B lists the operating authority, staff size, service population, year of latest modification, and the ending date of the year the data represent.

DATA COLLECTOR ____________________
DATE COLLECTED ____________________

TREATMENT SYSTEM DATA

DATE KEYPUNCHED ____________________
KEYPUNCHED BY ____________________
VERIFIED? ____________________

(1) FACILITY NAME (2) CITY (3) STATE (4) COUNTY (5) ZIP (6) TYPE (7) A-F NO (8) NPDES NO (9) COMMENT

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

A

(10) OPERATING AUTHORITY (11) YEAR ENDING (12) STAFF (13) SERVICE POP. (14) YEAR MOD.

B

FLOW (MGD) (15) PERMIT (16) ACTUAL (17) PEAK (18) DATE (19) DESIGN (20) IND (21) TRT. LEVEL (22) PROCESSES

C ● ● ● ● ●

(23) QUALITY (a) INFLUENT (mg/l) EFFLUENT (b) PERMIT 7 DAY (mg/l) (c) 7 DAY (mg/l) (d) 30 DAY (mg/l) (e) 30 DAY (Lbs) (f) MAX (mg/l) (g) ACTUAL MIN (mg/l) (h) AVE. (mg/l) (i) AVE (Lbs) / DESIGN (mg/l) (j) MAX (mg/l) (k) INFLUENT (l) EFFLUENT (m) (Lb/day) (n) COMMENT

D ● ● ● ● ● ● ● ●
E ● ● ● ● ● ● ● ●
F
G
H

PUMPING (24) INFLUENT NO. (25) MGD (26) ≤HP (27) LIQUID STREAM NO (28) ≤HP (29) SOLIDS HANDLING NO (30) ≤HP (31) COMMENT

J

(32) COSTS (a) CODE (b) COMMENT (c) TOTAL (d) PERSONNEL (e) POWER (f) TOTAL UTILITIES (g) CHEMICAL DISINFECTION (h) CHEMICAL TOTAL (i) EQUIPMENT (j) MATERIALS (k) CONTRACTUAL (l) OTHER

K
K
K
K
K
K
K
K
K
K
K
K
K
K
K
K

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

FIGURE A.19

ID NO. COMMENT

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

FIGURE A.20

TABLE A.14

IDENTIFICATION NUMBERS

Region	State	ID#'s
I	Massachusetts	100-149
	Maine	150-199
II	New York	200-299
III	Pennsylvania	300-349
	Virginia	350-399
IV	Florida	400-434
	Georgia	450-499
	Mississippi	435-449
V	Ohio	500-549
	Wisconsin	550-599
VI	Texas	600-699
VII	Missouri	700-799
VIII	Colorado	800-879
	South Dakota	880-899
IX	California	900-999
X	Oregon Washington	000-099

Line C itemizes plant flow, treatment level, and unit processes. Coding for the latter two items is explained in the next section.

Lines D through H are for quality information and are patterned after the NPDES permit reporting requirements. Line D is for BOD, line E for suspended solids, and lines F through H for other critical parameters. Quality information is obtained for actual influent values, permit effluent limitations, actual effluent values, and design influent and effluent levels. Flow data as submitted by the facility operator was accepted without further investigation.

Line J contains information on the number and total horsepower of influent pumps, liquid stream pumps, and solids handling pumps. In addition, total flow capacity of the influent pumps is included.

Fiscal information is entered on line K. Costs are broken out into personnel, power, total utilities, chemicals for disinfection, total chemicals, equipment, materials or supplies, contractual services, and other. Additional K lines are available to facilitate data collection for the degree of detail contained in the municipality's financial records.

Sewer System Data Worksheet

The Sewer System Data worksheet (Figure A.21) is divided into two basic segments: identity data and physical data with cost. The identi-

DATA COLLECTOR ____________________

DATE COLLECTED ____________________

SEWER SYSTEM DATA

DATE KEYPUNCHED ____________________

KEYPUNCHED BY ____________________

VERIFIED? ____________________

(1) FACILITY NAME | (2) CITY | (3) STATE | (4) COUNTY | (5) ZIP | (6) TYPE | (7) A/F NO | (8) NPDES NO. | (9) COMMENT

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

A

(10) OPERATING AUTHORITY | (11) YEAR ENDING | (12) STAFF | (13) SERVICE POP. | (14) YEAR MOD.

B

(15) COSTS | (a) CODE | (b) DIAMETER MIN | (c) DIAMETER MAX | (d) LENGTH/CAP | (e) ΣHP | (f) COMMENT | (g) TOTAL | (h) PERSONNEL | (i) POWER | (j) EQUIPMENT & MATERIALS | (k) CHEMICALS | (l) CONTRACTUAL | (m) OTHER

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

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C

C

C

C

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C

C

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

FIGURE A.21

fication numbering system and lines A and B are similar to that for the Treatment System Data.

C lines may be used for the size and length of gravity sewers and force mains, pumping stations, and fiscal data. Flexibility is built-in to the data format to obtain as detailed information for cost centers as is contained in the municipality's financial records.

A.2.3 Data Coding

Information required for lines A and B of the Treatment System and Sewer System Data worksheets with the exception of block 6, Type of Facility, did not require coding. Two-digit codes were developed to indicate the type of facility being reviewed, including sewage treatment plants with various combinations of sewers tributary thereto. Where treatment plants were owned and operated by one municipality and sewers by another municipality, separate identification numbers are used and the type code adjusted accordingly. Table A.15 lists the various codes.

TABLE A.15

Code	Type of Facility
10	Wastewater Treatment Plant (WWTP) Only
01	Interceptor Sewers - Separate[a] (Major Transmission)
02	Interceptor Sewers - Combined[b] (Major Transmission)
03	Collection Sewers - Separate (Not Included in 01)
04	Collection Sewers - Combined (Not Included in 02)
05	Complete Sewer System - Separate (01 + 03)
06	Complete Sewer System - Combined (02 + 04)
07	Complete Sewer System - Mixed
11	10 + 01 WWTP + Separate Interceptor Sewers
12	10 + 02 WWTP + Combined Interceptor Sewers
15	10 + 05 WWTP + Complete Sewer System - Separate
16	10 + 06 WWTP + Complete Sewer System - Combined
17	10 + 07 WWTP + Complete Sewer System - Mixed

---

[a] Separate Interceptor Sewer implies sanitary wastes only.

[b] Combined Interceptor Sewer implies sanitary wastes and storm water wastes.

Line C, block 21 of the treatment system data worksheet describes the level of treatment. For level of treatment, a two-digit code describing the design treatment level provided by the installed processes is indicated in the following table.

TABLE A.16

Code	
00	Raw Discharge
01	Primary (BOD/SS Eff. >50/50)
02	Advanced Primary (BOD/SS Eff. 50/50 - 30/30)
03	Secondary (BOD/SS Eff. 30/30 - 25/25)
04	Greater Than Secondary (BOD/SS only)
05	Nutrient Removal (BOD/SS <Secondary)
06	Secondary Treatment with Nutrient Removal
07	Greater Than Secondary with Nutrient Removal
08	Zero Discharge

Line C, block 22 provides spaces to list the various processes employed in the facility. Processes for treating both liquid and solid components of the sewage are included. Table A.17 lists the codes and processes considered applicable to the study.

Where codes AO, BO, etc. were used a comment describing the process was required, and they were only to be used where one of the listed processes did not adequately describe the process employed.

TABLE A.17

WASTEWATER TREATMENT CODES

Code	Process
AO	Pre-Treatment - General
	A1 - Pumping, Raw Wastewater
	A2 - Preliminary Treatment - Bar Screen
	A3 - Preliminary Treatment - Grit Removal
	A4 - Preliminary Treatment - Comminutors/Barminutors
	A5 - Preliminary Treatment - Others
	A6 - Prechlorination
	A7 - Flow Equalization Basins
	A8 - Preaeration
BO	Sedimentation - General
	B1 - Primary Sedimentation
	B2 - Clarification
	B3 - Tube Settlers
CO	Trickling Filter - Unspecified
	C1 - Trickling Filter - Rock Media
	C2 - Trickling Filter - Plastic Media
	C3 - Trickling Filter - Redwood Slat
	C4 - Trickling Filter - Other Media
	C5 - Rotating Biological Filter (Bio-Disc, Bio-Surf)
	C6 - Activated Bio- Filter Contactors
DO	Activated Sludge - Unspecified
	D1 - Activated Sludge - Conventional
	D2 - Activated Sludge - High Rate
	D3 - Activated Sludge - Contact Stabilization
	D4 - Activated Sludge - Extended Aeration
	D5 - Pure Oxygen Activated sludge
	D6 - Oxidation Ditch
EO	Filtration - Unspecified
	E1 - Microstrainers - Raw Sewage or Primary Effluent
	E2 - Microstrainers - Secondary or Tertiary Effluent
	E3 - Sand Filters
	E4 - Mix-Media Filters
FO	Nutrient Removal/Chemical Treatment
	F1 - Biological Nitrification
	F2 - Biological Denitrification
	F3 - Ion Exchange
	F4 - Breakpoint Chlorination

TABLE A.17 (Continued)

Code	Process
FO	Nutrient Removal/Chemical Treatment - (continued)
	F5 - Ammonia Stripping F6 - Recarbonation F7 - Neutralization F8 - Activated Carbon - Granular F9 - Activated Carbon - Powdered G1 - Lime Treatment of Raw Wastewater G2 - Tertiary Lime Treatment G3 - Alum Addition G4 - Ferri-Chloride Addition G5 - Polymer Addition G6 - Other Chemical Additions
HO	Disinfection - General
	H1 - Chlorination for Disinfection H2 - Ozonation for Disinfection H3 - Other Disinfection H4 - Dechlorination H5 - Reaeration - General
JO	Other Treatment - General
	J1 - Land Treatment of Primary Effluent J2 - Land Treatment of Secondary Effluent (30/30) J3 - Stabilization Ponds J4 - Aerated Lagoons J5 - Polishing Ponds
KO	Effluent Disposal
	K1 - Effluent Pumping K2 - Outfall to Other Plants K3 - Recycling and Reuse K4 - Irrigation K5 - Ocean Outfall K6 - Surface Water Outfall K7 - Land Disposal K8 - Complete Retention K9 - Other Disposal (Comment)
LO	Sludge Handling (Comment)
	L1 - Sludge Holding Tank L2 - Sludge Lagoons L3 - Air Drying (Sludge Drying Beds) M1 - Aerobic Digestion - Air M2 - Aerobic Digestion - Oxygen M3 - Anaerobic Digestion M4 - Digestion Gas Utilization

TABLE A.17 (Concluded)

Code	Process
LO	Sludge Handling (Comment) - (continued)
	M5 - Chlorine Oxidation of Sludge (Purifax)
	N1 - Dewatering - Mechanical - Vacuum Filter
	N2 - Dewatering - Mechanical - Centrifuge
	N3 - Dewatering - Mechanical - Filter Press
	N4 - Dewatering - Others
	N5 - Gravity Thickening
	N6 - Flotation Thickening
	N7 - Heat Treatment
	P1 - Incineration - Multiple Hearth
	P2 - Incineration - Fluidized Beds
	P3 - Incineration - Rotary Kiln
	P4 - Incineration - General/Other (Comment)
	P5 - Pyrolysis
	P6 - Co-incineration with Solid Waste
	P7 - Co-pyrolysis with Solid Waste
	P8 - Wet Air Oxidation
	P9 - Recalcination
QO	Ultimate Sludge Disposal
	Q1 - Compositing
	Q2 - Land Spreading of Liquid Sludge
	Q3 - Land Spreading of Thickened Sludge
	Q4 - Trenching
	Q5 - Ocean Dumping
	Q6 - Other Sludge Handling
	Q7 - Sludge Transferred to Another Facility
	Q8 - Sludge Used by Others
	Q9 - Landfill
RO	Miscellaneous
	R1 - Laboratory
	R2 - Controls
	R3 - Maintenance
	R4 - Other Miscellaneous Items (Comment)

Lines F, G, and H are to be used for permit quality parameters other than BOD or SS but which the discharge permit requires treatment. Use of these lines required an accompanying comment to identify the parameter.

Line J - Pumping - listed not only influent and sludge handling pumping but also other pumping in the liquid stream which pumps substantially all of the flow through the process train such as pumps between primary and secondary units, effluent pumps, etc. No pumps which are an integral part of a process were included.

The K lines are to be used for fiscal data. Table A.18 lists the coding for block 32(a).

TABLE A.18

FISCAL CODES

Code	Item
T0	General Acccounting
T1	Administration, Support Services, Etc.
T2	Operation & Maintenance (actual "inside-the-fence" costs)
T3	Total O&M costs, including administration, support services, etc. (T1 + T2)
T4	Primary Treatment
T5	Secondary Treatment
T6	Advanced Waste Treatment (AWT)
T7	Other
T8	Solids Handling

Code T0, General Accounting, and Code T7, Other, must be accompanied by a comment to adequately describe the item of work on which costs are being reported.

Data required for lines A and B of Figure A.21, Sewer System Data worksheet, are similar to that required for lines A and B of Figure A.19, on the Treatment System Data worksheet. Line C of Figure A.21 (Sewer System Data worksheet) is used for listing engineering design and financial data for sewer systems. Provisions are made for a range of diameters, length of gravity sewers and force mains, number of pumps, and summation of discharge capacity and horsepower within the sewer system. Table A.19 lists the coding and items to be used on line C.

TABLE A.19

SEWER SYSTEM CODES

Code	Item
01	Gravity Sewers
02	Force Mains
03	Pump Stations
04	Combined Flow Appurtenances
05	Separate Flow Appurtenances
06	Treatment or Control Devices
07	Other
10	Total O&M Costs (20 + 30), including Administration, Support Services
20	Operating Cost (includes Maintenance and Minor Repair)
30	Administration, Support Services, Etc.

APPENDIX B

ASSOCIATION OF METROPOLITAN SEWERAGE AGENCIES SURVEY

APPENDIX B

AMSA SURVEY

B.1 BACKGROUND

In 1975 the Association of Metropolitan Sewerage Agencies (AMSA) conducted a survey of wastewater treatment plant operations and maintenance among its membership. This survey was very thorough and required considerable data relative to treatment processes, design parameters, and process efficiencies. The 38-page questionnaire emphasized operational performance data with O&M costs receiving only secondary importance. The plant equipment inventory section requested information on design parameters as well as number, type, model, and manufacturer of equipment installed in the various processes. It requested flow and strength of sewage applied to each process plus a description of each process and mode of operation.

The operational data reporting section was so arranged that flow and other parameters were to be reported as influent or effluent of each liquid treatment process. In general to satisfy the data collection requirements of the AMSA form, wastewater samples would have to be taken and reported at four locations throughout a conventional activated sludge plant. Quality parameters considered were BOD, SS, COD, Total N, Total P, and NH_3. Other operational data requested related to specific processes which are tests usually performed by the operator for process control.

The solids handling section of the AMSA questionnaire required data regarding the quantity of screenings, grit and scum removal, feed to digesters, digester performance analyses, and sludge quantity. Chemical dosage information was requested by process and type of chemicals used.

Plant operating personnel were categorized into one of the following classes: management, operations, engineering, maintenance, training, and other. Only in-plant personnel were to be considered. Operational costs were requested by cost centers, viz., primary, secondary, solids handling and AWT (if any). No sewer system data were requested.

During the organizational stage of the EPA O&M survey, contact was made with AMSA officials to ascertain the status of their extensive O&M survey. It was learned that the data had been collected in 1975 but had yet to be analyzed and consequently no report had been prepared. In exchange for processing the AMSA data and reporting the findings to AMSA officials, Dames & Moore project personnel received approval to incorporate the AMSA results in this O&M study.

B.2 AMSA DATA BASE

The AMSA data were reviewed and extracted to fit the format of the EPA survey worksheet (see Figure A.19). Of the 139 municipal AMSA questionnaires, 99 contained sufficient data for a cost performance analysis. Thirty-seven (37) municipal agencies in 25 states provided data for the 99 wastewater treatment plants. These 99 facilities ranged in size from 0.3 mgd to 999 mgd design flow and contained primary, secondary (trickling filter and activated sludge), and advanced wastewater treatment plants. The aggregate design capacity of these facilities is 6.9 billion gallons per day with an actual flow of 6.0 billion gallons per day. Nearly 38 million people are served by these 99 plants.

Table B.1 lists those AMSA facilities that are part of the analysis of this report. The cost data which represent fiscal years ranging from late 1972 to late 1975 were in general agreement with the cost reporting requirements of the EPA survey. The AMSA operating data, however, were in much greater detail than required in the EPA survey.

TABLE B.1

AMSA SAMPLE TREATMENT SYSTEMS

ID NO	FACILITY NAME	CITY	STATE	OPERATING AUTHORITY	DESIGN FLOW	LEVEL OF TREATMENT
199	HARTFORD WPCP	HARTFORD	CT	METRO DIST BUREAU OF P W	60.0	03
100	NUT ISLAND STP	QUINCY	MA	BOSTON METRO DISTRICT COM	112.0	01
101	DEER ISLAND STP	WINTHROP	MA	BOSTON METRO DISTRICT COM	343.0	01
298	PASSAIC VALLEY STP	NEWARK	NJ	PASSAIC VALLEY SEW COM	300.0	01
200	NORTH WWTP	ALBANY	NY	ALBANY COUNTY SEW. DIST.	35.0	03
201	BOWERY BAY WPCP	QUEENS	NY	NEW YORK CITY DWR	70.0	03
202	ROCKAWAY STP	ROCKAWAY	NY	NEW YORK CITY DWR	30.0	03
203	TALLMAN ISLAND WPCP	NEW YORK	NY	NEW YORK CITY DWR	55.0	03
204	NEWTOWN CREEK WPCP	BROOKLYN	NY	NEW YORK CITY DWR	310.0	03
205	JAMAICA PCP	QUEENS	NY	NEW YORK CITY DWR	100.0	03
206	OWLS HEAD STP	BROOKLYN	NY	NEW YORK CITY DWR	160.0	03
207	CONEY ISLAND WPCP	BROOKLYN	NY	NEW YORK CITY DWR	110.0	03
208	26TH WARD STP	BROOKLYN	NY	NEW YORK CITY DWR	60.0	03
209	WARDS ISLAND WPCP	NEW YORK	NY	NEW YORK CITY DWR	250.0	03
210	HUNTS POINT WPCP	BRONX	NY	NEW YORK CITY	150.0	03
211	PORT RICHMOND WPCP	STATEN ISLAND	NY	NEW YORK CITY DWR	10.0	01
212	OAKWOOD BEACH WPCP	STATEN ISLAND	NY	NEW YORK CITY DWR	15.0	03
213	GATE-CHILI-OGDEN TP	ROCHESTER	NY	MONROE CO. PURE WATERS D.	4.0	01
214	NW QUADRANT STP	HILTON	NY	MONROE CO. DPW	15.0	06
396	WESTERN BRANCH WWTP	UPPER MARLBORO	MD	WASHINGTON SUB. SAN. COMM	5.0	03
397	PARKWAY WWTP	LAUREL	MD	WASHINGTON SUB. SAN.COMM.	7.5	04
398	PISCATAWAY WWTP	ACCOKEEK	MD	WASH SUB SAN COMM	30.0	03
399	PISCATAWAY MODEL PL	ACCOKEEK	MD	WASH SUB SAN COMM	5.0	07
300	NORTHEAST WPCP	PHILADELPHIA	PA	CITY OF PHILADELPHIA	175.0	03
301	SOUTHEAST WPCP	PHILADELPHIA	PA	CITY OF PHILADELPHIA	130.0	01
302	SOUTHWEST WPCP	PHILADELPHIA	PA	CITY OF PHILADELPHIA	136.0	01
303	PITTSBURGH WWTP	PITTSBURGH	PA	ALLEGHENY COUNTY SAN AUTH	200.0	03
360	BOAT HARBOR STP	NEWPORT NEWS	VA	HAMPTON ROADS SAN DIST	11.0	01
361	LAMBERTS POINT STP	NORFOLK	VA	HAMPTON ROADS SAN DIST	20.0	01
362	ARMY BASE STP	NORFOLK	VA	HAMPTON ROADS SAN DIST	11.0	01
363	CHESAPEAKE-ELIZ STP	VIRGINIA BEACH	VA	HAMPTON ROADS SAN DIST	24.0	03
364	JAMES RIVER STP	NEWPORT NEWS	VA	HAMPTON ROADS SAN DIST	11.0	03
365	WILLIAMSBURG STP	WILLIAMSBURG	VA	HAMPTON ROADS SAN DIST	9.6	03
492	MORRIS FOREMAN WWTP	LOUISVILLE	KY	LOUISVILLE METRO SEWER DT	105.0	01
491	N BUFFALO STP	GREENSBORO	NC	CITY OF GREENSBORO	18.0	03
488	DRY CREEK WWTP	MADISON	TN	NASHVILLE-DAVIDSON CTY	6.0	03
594	STREAMWOOD WRP	STREAMWOOD	IL	MSD CHICAGO	3.0	07
595	LEMONT STP	LEMONT	IL	MSD CHICAGO	1.2	07
596	HANOVER PARK WRP	HANOVER PARK	IL	MSD CHICAGO	6.0	04
597	WEST-SOUTHWEST STW	CICERO	IL	MSD CHICAGO	999.0	03
598	NORTH SIDE STP	SKOKIE	IL	MSD CHICAGO	333.0	03
599	CALUMET SEW. TRT WK	CHICAGO	IL	MSD CHICAGO	220.0	03
593	FORT WAYNE WPCP	FORT WAYNE	IN	FORT WAYNE CITY UTILITIES	32.0	06
585	CLOQUET STP	CLOQUET	MN	W. LAKE SUPERIOR SAN DIST	1.5	01
591	FAIRMONT STP	DULUTH	MN	W. LAKE SUPERIOR SAN DIST	.7	02
592	GARY NEW DULUTH STP	DULUTH	MN	W. LAKE SUPERIOR SAN.DIST	.3	02
500	AKRON WPCS	AKRON	OH	CITY OF AKRON	87.0	06
550	SOUTH SHORE WWTP	OAK CREEK	WI	CITY OF MILWAUKEE	120.0	06
551	JONES ISLAND STP	MILWAUKEE	WI	CITY OF MILWAUKEE	200.0	03
697	EAST BANK STP	NEW ORLEANS	LA	JEFF PARISH SAN DIST	23.0	01

TABLE B.1 (Concluded)

AMSA SAMPLE TREATMENT SYSTEMS

ID NO	FACILITY NAME	CITY	STATE	OPERATING AUTHORITY	DESIGN FLOW	LEVEL OF TREATMENT
698	WEST BANK STP	ALGIERS	LA	NEW ORLEANS S AND W BD	10.0	03
699	MICHOUD STP	NEW ORLEANS	LA	NEW ORLEANS S 8 W BOARD	2.5	03
693	TULSA COAL CREEK	TULSA	OK	TULSA WSD	5.0	03
694	TULSA SOUTHSIDE	TULSA	OK	TULSA WSD	21.0	01
695	TULSA NORTHSIDE	TULSA	OK	TULSA WSD	11.0	02
696	TULSA FLAT ROCK	TULSA	OK	TULSA WSD	6.0	02
600	GOVALLE STP	AUSTIN	TX	CITY OF AUSTIN	40.0	03
603	HASKELL ST. TP	EL PASO	TX	EL PASO WATER UTIL. PUB.	25.0	03
607	CENTRAL REG. WWTS	GRAND PRAIRIE	TX	TRINITY RIVER AUTH. TEX.	30.0	03
608	SALADO CREEK STP	SAN ANTONIO	TX	CITY OF SAN ANTONIO	24.0	03
609	RILLING ROAD STP	SAN ANTONIO	TX	CITY OF SAN ANTONIO	94.0	03
610	LEON CREEK STP	SAN ANTONIO	TX	CITY OF SAN ANTONIO	12.0	03
700	BIG BLUE RIVER STP	KANSAS CITY	MO	CITY OF KANSAS CITY	100.0	01
701	TODD CREEK STP	KANSAS CITY	MO	CITY OF KANSAS CITY	1.0	03
702	PLATTE CO. STP	KANSAS CITY	MO	CITY OF KANSAS CITY	1.0	03
703	S. LITTLE BLUE STP	KANSAS CITY	MO	CITY OF KANSAS CITY	5.0	02
704	WESTSIDE STP	KANSAS CITY	MO	CITY OF KANSAS CITY	35.0	01
801	MDSD #1 STP	COMMERCE CITY	CO	METRO DENVER SAN DIST #1	117.0	03
997	RODGER ROAD PLANT	TUCSON	AR	TUCSON, CITY OF	37.0	03
998	91ST AVE WWTP	PHOENIX	AR	CITY OF PHOENIX	60.0	03
999	23RD AVE WWTP	PHOENIX	AR	CITY OF PHOENIX	45.0	03
901	CHINO REG PLANT #2	CHINO	CA	CHINO BASIN MUN WATER DIS	3.0	03
903	REG. TERT. PLT NO 1	ONTARIO	CA	CHINO BASIN MUN WATER DIS	16.0	07
905	TERMINAL ISLAND TP	SAN PEDRO	CA	CITY OF LOS ANGELES	14.0	01
906	SPEC. DISTRICT 1 TP	OAKLAND	CA	EAST BAY M.U.D.	128.0	01
911	SAN JOSE/SANTA CLAR	SAN JOSE	CA	CITY OF SAN JOSE	160.0	03
912	JOINT WATER POL CTL	CARSON	CA	CO SAN DIST LOS ANGELES	385.0	01
913	DIST 14 WWTP	LANCASTER	CA	CO SAN DIST LOS ANGELES	4.5	01
914	DIST 26 WWTP	SAUGUS	CA	CO SAN DIST LOS ANGELES	5.0	04
915	SAN JOSE CREEK WWTP	WHITTIER	CA	CO SAN DIST LOS ANGELES	37.0	04
916	DISTRICT 20 WWTP	PALMDALE	CA	CO SAN DIST LOS ANGELES	3.0	02
917	LONG BEACH WWTP	LONG BEACH	CA	CO SAN DIST LOS ANGELES	12.0	03
918	LOS COYOTES	CERRITOS	CA	CO SAN DIST LOS ANGELES	12.0	03
919	DISTRICT 32 WWTP	VALENCIA	CA	CO SAN DIST LOS ANGELES	1.5	03
921	POMONA WWTP	POMONA	CA	CO SAN DIST LOS ANGELES	10.0	03
923	WHITTIER NARROWS WW	EL MONTE	CA	CO SAN DIST LOS ANGELES	12.0	03
991	MILILANI STP	MILILANI	HI	CITY AND CO. OF HONOLULU	2.0	03
992	WAHIAWA STP	WAHIAWA	HI	CITY AND CO. OF HONOLULU	2.0	03
993	WAIPAHU LAGOON	WAIPAHU	HI	CITY AND CO. OF HONOLULU	3.0	02
994	KANEOHE STP	KANEOHE	HI	CITY AND CO. OF HONOLULU	4.0	03
995	KAILUA SEWAGE PLANT	KAILUA	HI	CITY AND CO. OF HONOLULU	7.0	03
996	PEARL CITY STP	PEARL CITY	HI	CITY AND CO. OF HONOLULU	5.0	01
000	FOREST GROVE WWTP	FOREST GROVE	OR	UNIFIED SEW. AG. WASH. CO	5.0	03
001	ALOHA WWTP	HILLSBORO	OR	UNIFIED SEW. AG. WASH. CO	5.2	04
002	TRYON CREEK STP	LAKE OSWEGO	OR	CITY OF PORTLAND	5.0	03
003	COLUMBIA BLVD WWTP	PORTLAND	OR	CITY OF PORTLAND	100.0	03
052	ALKI STP	SEATTLE	WA	METRO SEATTLE	10.0	01
053	WEST POINT STP	SEATTLE	WA	METRO SEATTLE	125.0	01
054	RENTON STP	RENTON	WA	METRO SEATTLE	36.0	03

APPENDIX C

COST INDEXING PROCEDURE

APPENDIX C

COST INDEXING PROCEDURE

C.1 NEED FOR COMMON DOLLAR BASE

The operations and maintenance cost data that were collected across the United States reflect several time periods. Whenever possible, the most current cost data were obtained. Not all municipalities conveniently end their fiscal year on December 31st. According to the information received from the survey about one-third of all municipalities terminate their fiscal year other than on a calendar year basis. Consequently, the O&M cost data that were originally collected represent current dollars...not constant dollars for the same period of time. Recorded costs range from late 1975 to early 1977 for the EPA survey and late 1972 to late 1975 for the AMSA survey. In order to perform economic analyses and make cost comparisons, it was essential to convert all costs to a constant dollar basis.

C.2 ALTERNATIVE INDICES FOR PLANT COSTS

A number of indices exist that might be used to convert the O&M wastewater treatment plant costs to a common dollar base. Some of the indices that were considered include the EPA operation and maintenance cost index, the fuel and utilities component of the National Consumer Price Index (CPI), the Bureau of Labor Statistics (BLS) water and sewerage services index, the BLS industrial commodities Wholesale Price Index (WPI), factory maintenance cost index as published regularly in

Factory magazine, and the Business Week price index. Because the EPA operation and maintenance cost index most nearly reflects actual wastewater treatment plant operational costs, it was chosen to convert the recorded current O&M costs to a constant dollar base.

C.3 DESCRIPTION OF EPA OPERATIONS & MAINTENANCE PLANT INDEX

The EPA O&M plant index was developed from an extensive study conducted in 1966-67. This index comprises six separate sub-indexes that are based on the actual costs of operating and maintaining a 5 million gallon per day conventional activated sludge plant. These six sub-indexes which are composited to form the single annual O&M escalation index include the categories of labor, chemical, power, maintenance, other cost, and added input. These various components of the EPA O&M plant index were distributed as follows:

Component	Allocation (Percent)
Labor	47.1
Chemical	9.8
Power	19.8
Maintenance	10.5
Other Costs	12.5
Added Input (Training)	0.3
Total	100.0

Since 1974 EPA's Municipal Construction Division has produced quarterly updates of the O&M plant cost index. During the seven previous years (1967-73) the index was released annually. Over the 10 year period the annual O&M costs for a typical 5 mgd activated sludge plant have escalated 122 percent (3rd quarter 1977).

C.4 APPLICATION OF EPA O&M PLANT INDEX

Fields 32c through 321 of the Treatment System Data worksheet provide for recording O & M costs by object of expenditure. Refer to Appendix A, Figure A.19 for a representation of the form. The recorded dollar amounts in columns 32c through 321 were converted to a third quarter 1977 base (constant dollars) using the appropriate EPA O&M sub-index. Table C.1 outlines the appropriate EPA O&M sub-index employed to update the recorded cost in these 10 fields.

C.5 SEWER COST CONVERSION

Finding a suitable index to convert current dollar amounts for operations, maintenance, and minor repair (OM&R) to sewer systems was difficult. An extensive search revealed no appropriate OM&R index exists. However, in the absence of a good conversion measure, such as the EPA O&M Plant Index for WWTPs, the most suitable sewer index appears to be the EPA complete urban sewer system (CUSS) cost index. Even though the CUSS index is based on construction of sewer systems, it is rationalized that much of the operations and maintenance work on sewer systems is repair and minor replacement work. Therefore, the EPA sewer CUSS index

TABLE C.1 O&M PLANT COST INDEX CONVERSION SCHEME

Costs as Recorded in Field 32[a]		Appropriate Sub-Index for Conversion to Common Base
Column	Title	
c	Total	(1) Automatically totals columns (d) through (l) <u>OR</u> (2) Apply Average O&M Escalation Index when only dollars occur in column (c)
d	Personnel	Labor Index
e	Power	Power Index
f	Total Utilities	Power Index
g	Chemical Disinfection	Chlorine Index
h	Chemical Total	Chemical Cost (Overall) Index
i	Equipment	Maintenance Index
j	Materials	BLS Industrial Commodities Index
k	Contractual	Labor Index
l	Other	Other Cost Index

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[a] See Appendix A, Figure A.19 (Treatment System Data worksheet).

was used to convert current OM&R costs of sewer systems to a 3rd quarter 1977 dollar base (constant dollars). The input factors of this index include wages for labor and material costs for ready mix concrete, reinforced concrete pipe, low grade S4S lumber, and asphalt paving.

APPENDIX D

WASTEWATER TREATMENT PLANTS

D.1 Treatment Systems Listed by Group Size and Level of Treatment

D.2 Number of Plants Surveyed by Process

EPA SURVEY

O&M SAMPLE TREATMENT SYSTEMS

0.1 - 5.0 MGD

ID NO	FACILITY NAME	CITY	STATE	OPERATING AUTHORITY	DESIGN FLOW	LEVEL OF TREATMENT
102	MILLBURY WPC PLANT	MILLBURY	MA	MILLBURY SEWER COMM.	.9	03
103	SHREWSBURY WPCP	SHREWSBURY	MA	SHREWSBURY SEWER COMM.	1.3	03
105	PLYMOUTH WWTP	PLYMOUTH	MA	PLYMOUTH SEWER DEPT.	1.8	04
106	WAREHAM WWTP	WAREHAM	MA	WAREHAM BRD. SEW. COMM.	1.8	04
107	SWAMPSCOTT WPCP	SWAMPSCOTT	MA	SWAMPSCOTT, TOWN OF	2.2	01
108	WESTBOROUGH WWTP	WESTBOROUGH	MA	WESTBOROUGH W&S COMM.	1.1	04
109	NORTHAMPTON WWTP	NORTHAMPTON	MA	NORTHAMPTON DPW	4.3	01
110	GARDNER WWTP	GARDNER	MA	GARDNER DPW	3.8	03
111	GREENFIELD WWTP	GREENFIELD	MA	GREENFIELD BOARD OF PW	3.2	03
113	GREAT BARRINGTON TP	GREAT BARRINGTO	MA	GREAT BARRINGTON SD	3.2	03
115	MEDFIELD WWTP	MEDFIELD	MA	MEDFIELD SEWER COMM.	1.5	07
153	BREWER POLL.CONT.FA	BREWER	ME	BREWER,CITY OF	3.0	03
154	ORONO STP	ORONO	ME	ORONO, TOWN OF	1.8	03
157	BRUNSWICK STP	BRUNSWICK	ME	BRUNSWICK SD	2.5	01
158	FALMOUTH WPCP	FALMOUTH	ME	FALMOUTH, TOWN OF	1.5	03
160	SANFORD SEW.TRT.FAC	SANFORD	ME	SANFORD SD	5.0	03
161	KITTERY STP	KITTERY	ME	KITTERY, TOWN OF	1.5	03
165	SKOWHEGAN STP	SKOWHEGAN	ME	SKOWHEGAN, CITY OF	1.4	03
219	HAVERSTRAW JT REG	W HAVERSTRAW	NY	HAVERSTRAW,JT REG SEW BD	4.0	03
221	STONY POINT STP	STONY POINT	NY	STONY POINT,TN OF	1.0	03
222	ARLINGTON STP	POUGHKEEPSIE	NY	POUGHKEEPSIE,T.ARLINGTON	4.0	03
223	SUFFERN STP	SUFFERN	NY	SUFFERN,VILLAGE OF	1.5	03
224	MONTICELLO STP	MONTICELLO	NY	MONTICELLO,VILLAGE OF	2.5	03
227	TUPPER LAKE WPCP	TUPPER LAKE	NY	TUPPER LAKE, VILLAGE OF	1.1	01
228	SARANAC LAKE WPCP	SARANAC LAKE	NY	SARANAC LAKE, VILLAGE OF	3.0	03
229	CANTON WPCP	CANTON	NY	CANTON,VILLAGE OF	2.0	03
231	LOWVILLE WPCP	LOWVILLE	NY	LOWVILLE,VILLAGE OF	1.5	03
232	OWEGO WPCP # 2	APALACHIN	NY	OWEGO TN	2.0	03
233	SIDNEY WPCP	SIDNEY	NY	SIDNEY,VILLAGE OF	1.7	03
234	CHEMUNG CO SD #1	ELMIRA	NY	SIDNEY,VILLAGE OF	4.8	03
235	CAYUGA HGTS WPCP	CAYUGA HGTS	NY	CAYUGA HGTS,VILLAGE OF	2.0	06
239	ILLION WPCP	ILLION	NY	ILLION,VILLAGE OF	1.5	01
243	WARSAW WWTP	WARSAW	NY	WARSAW,VILLAGE OF	1.2	01
244	BATAVIA WPCP	BATAVIA	NY	BATAVIA,CITY OF	2.5	03
246	ALFRED WWTP	ALFRED	NY	ALFRED,VILLAGE OF	1.0	04
247	BATH WWTP	BATH	NY	BATH,VILLAGE OF	1.0	03
248	PENN YAN WWTP	PENN YAN	NY	PENN YAN,VILLAGE OF	1.5	03
249	SPENCERPORT WWTP	SPENCERPORT	NY	SPENCERPORT VILLAGE OF	1.0	06
250	WEBSTER WWTP	WEBSTER	NY	WEBSTER,VILLAGE OF	2.5	03
251	OYSTER BAY STP	OYSTER BAY	NY	OYSTER BAY TOWN OF	1.2	03
252	BETHLEHEM WWTP	CEDAR HILL	NY	BETHLEHEM,TOWN OF	4.9	03
255	PORT JERVIS STP	PORT JERVIS	NY	NEW YORK CITY,EPA	5.0	03
304	LITITZ STP	LITITZ	PA	LITITZ BOROUGH	1.2	03
306	LEMOYNE BORO JT. AD	LEMOYNE	PA	LEMOYNE BORO MUN. AUTH.	2.1	06
307	MECHANICSBURG STP	MECHANICSBURG	PA	MECHANICSBURG MUN. AUTH.	1.2	03
308	CHAMBERSBURG WWTP	CHAMBERSBURG	PA	CHAMBERSBURG BORO MUN. AU	3.0	03
310	UPPER SAUCON TWP WW	CENTER VALLEY	PA	UPPER SAUCON VAL. MUN. AU	.6	04
311	SWATARA TWP AUTH. W	SWATARA TWP	PA	SWATARA TWP AUTH.	3.0	03

TABLE D.1

TABLE D.1 CONTINUED

O&M SAMPLE TREATMENT SYSTEMS

0.1 - 5.0 MGD

ID NO	FACILITY NAME	CITY	STATE	OPERATING AUTHORITY	DESIGN FLOW	LEVEL OF TREATMENT
314	HATFIELD TWP AUT	HATFIELD	PA	HATFIELD TWP. MUN. AUTH.	3.6	06
315	PENN TWP WWTT	PENN TWP	PA	PENN TWP YORK CO. AUTH.	1.2	03
316	ARCHBALD STP	ARCHBALD	PA	LACKAWANNA RIVER BASIN SE	3.0	03
317	DALLAS AREA MUN. AU	KINGSTON TWP	PA	DALLAS AREA MUN. AUTH.	2.2	03
319	CLARKS-SUMMITTS. AB	CHINCHILLA	PA	CLARKS SUMMIT-S. ABINGTON	1.2	03
320	BLOOMSBURG STP	BLOOMSBURG	PA	BLOOMSBURG MUN. AUTH.	4.3	03
321	SUNBURY WWTP	SUNBURY	PA	SUNBURY, CITY OF MUN. AUT	3.5	01
323	LOWER SALFORD TWP W	HARLEYSVILLE	PA	LOWER SALFORD TWP AUTH.	.3	03
340	SCOTDALE STP	SCOTDALE	PA	WESTMORELAND-FAYETTE AUTH	1.0	04
341	PINECREEK STP	MCCANDLESS	PA	MCCANDLESS TWP.SAN. AUTH.	3.0	03
342	MON VALLEY STP	DONORA	PA	MON VALLEY SEWAGE AUTH	3.6	03
343	PLEASANT HILLS	PLEASANT HILLS	PA	PLEASANT HILLS AUTH.	3.0	04
344	GROVE CITY STP	GROVE CITY	PA	GROVE CITY BOROUGH OF	1.5	03
345	SHARON STP	SHARON	PA	UPPER SHENAGO VALLEY WPCA	3.0	03
366	FREDERICKSBURG STP	FREDERICKSBURG	VA	FREDERICKSBURG, CITY OF	3.5	03
369	MOORES CREEK STP	CHARLOTTESVILLE	VA	RIVANNA W & S AUTH.	3.3	03
371	LEXINGTON STP	LEXINGTON	VA	LEXINGTON, CITY OF	2.0	03
372	BEDFORD STP	BEDFORD	VA	BEDFORD, CITY OF	1.5	03
403	HOMESTEAD STP	HOMESTEAD	FL	HOMESTEAD CITY OF	2.3	04
405	FT.PIERCE CITY WWTP	FT.PIERCE	FL	FT.PIERCE CITY OF	5.0	03
406	KISS.MILL SLOUGH WW	KISSIMMEE	FL	KISSIMMEE CITY OF	1.0	04
407	KISSIMMEE 192 STP	KISSIMMEE	FL	KISSIMMEE CITY OF	1.7	04
408	STUART STP	STUART	FL	STUART CITY OF	4.0	03
409	GRANT ST STP	MELBOURNE	FL	MELBOURNE CITY OF	2.5	04
410	COCOA STP	COCOA	FL	COCOA CITY OF	2.0	04
413	HOLLY HILL STP	HOLLY HILL	FL	HOLLY HILL,CITY OF	1.3	04
414	SOUTH STP	TITUSVILLE	FL	TITUSVILLE,CITY OF	2.0	04
415	OCALA STP #1	OCALA	FL	OCALA, CITY OF	2.5	03
416	JACKSON. BEACH STP	JACKSON. BEACH	FL	JACKSONVILLE BEACH CITY	3.0	03
417	LAKE CITY STP PL#1	LAKE CITY	FL	LAKE CITY CITY OF	1.5	03
418	ST. AUGUSTINE FL.#1	ST. AUGUSTINE	FL	ST. AUGUSTINE CITY OF	3.0	03
419	PERRY STP	PERRY	FL	PERRY CITY OF	1.3	02
420	MUNICIPAL STP	BARTOW	FL	BARTOW CITY OF	2.8	04
422	TARPON SPRINGS STP	TARPON SPRINGS	FL	TARPON SPRINGS CITY OF	1.3	04
423	MARINA PLANT STP	CLEARWATER	FL	CLEARWATER CITY OF	2.7	04
426	PINELLAS PARK STP#2	PINELLAS PARK	FL	HILLSBOROUGH COUNTY	3.0	03
429	SOUTHGATE STP	SARASOTA	FL	FLA CITIES WATER CO	1.3	07
430	MONTCLAIR PLANT STP	PENSACOLA	FL	PENSACOLA CITY OF	1.1	04
437	AERATED LAGOON	WATER VALLEY	MS	WATER VALLEY CITY OF	1.7	03
438	NORTH LAGOON NO.2	HATTIESBURG	MS	HATTIESBURG CITY OF	1.0	03
443	OXFORD STP	OXFORD	MS	OXFORD CITY OF	3.5	03
445	CLARKSDALE STP	CLARKSDALE	MS	CLARKSDALE CITY OF	4.5	03
446	PICAYUNE STP	PICAYUNE	MS	PICAYUNE CITY OF	3.0	04
466	DUBLIN WPCP	DUBLIN	GA	DUBLIN, CITY OF	2.3	03
468	GARDEN CITY WPCP	GARDEN CITY	GA	GARDEN CITY, CITY OF	1.0	03
470	ST. SIMONS ISLAND W	ST. SIMONS ISLA	GA	GLYNN CO. ST. SIMONS DIST	1.0	03
471	DOUGLAS WPCP SE	DOUGLAS	GA	DOUGLAS, CITY OF	5.0	03
472	MUCKALEE CREEK WPCP	AMERICUS	GA	AMERICUS, CITY OF	2.0	03
473	COVINGTON WWTP	COVINGTON	GA	COVINGTON, CITY OF	3.0	03

TABLE D.1 CONTINUED

O&M SAMPLE TREATMENT SYSTEMS

0.1 - 5.0 MGD

ID NO	FACILITY NAME	CITY	STATE	OPERATING AUTHORITY	DESIGN FLOW	LEVEL OF TREATMENT
474	THOMASVILLE WPCP	THOMASVILLE	GA	THOMASVILLE, CITY OF	4.0	04
476	BLUE JOHN MUNICIPAL	LAGRANGE	GA	LAGRANGE, CITY OF	3.5	03
477	BLUE JOHN INDUSTRIA	LAGRANGE	GA	LAGRANGE, CITY OF	2.5	03
478	CARROLLTON WWTP	CARROLLTON	GA	CARROLLTON, CITY OF	5.0	03
480	SUMMERVILLE WWTP	SUMMERVILLE	GA	SUMMERVILLE, CITY OF	2.0	03
481	NORTH OCONEE WPC 2	ATHENS	GA	ATHENS, CITY OF	2.0	03
482	NORTH OCONEE WPC 1	ATHENS	GA	ATHENS, CITY OF	5.0	03
483	SOUTHEAST WPC PLANT	COLLEGE PARK	GA	COLLEGE PARK, CITY OF	1.2	03
486	JACKSON CREEK WPC	LILBURN	GA	GWINNETT CO. WPC	2.4	06
505	MARIETTA STP	MARIETTA	OH	MARIETTA, CITY OF	3.4	02
507	ALLIANCE STP	ALLIANCE	OH	ALLIANCE, CITY OF	4.7	03
508	STRUTHERS STP	STRUTHERS	OH	STRUTHERS, CITY OF	4.6	02
509	GIRARD STP	GIRARD	OH	GIRARD, CITY OF	3.5	02
510	BOARDMAN WWTP	BOARDMAN	OH	MAHONING CO. METRO. SD	5.0	03
511	RAVENNA STP	RAVENNA	OH	RAVENNA, CITY OF	1.9	07
517	SOLON CENTRAL STP	SOLON	OH	SOLON, CITY OF	2.4	03
518	BEDFORD STP	BEDFORD	OH	BEDFORD, CITY OF	3.2	07
519	SOLON NE STP	SOLON	OH	SOLON, CITY OF	.8	03
522	NORWALK STP	NORWALK	OH	NORWALK, CITY OF	3.5	03
525	DEFIANCE STP	DEFIANCE	OH	DEFIANCE, CITY OF	4.0	06
526	VAN WERT STP	VAN WERT	OH	VAN WERT, CITY OF	2.8	04
537	FORD ROAD WWTP	XENIA	OH	XENIA, CITY OF	3.0	03
538	VANDALIA WWTP	VANDALIA	OH	VANDALIA, CITY OF	1.2	03
540	MIAMISBURG STP	MIAMISBURG	OH	MIAMISBURG, CITY OF	2.2	03
542	SIDNEY WWTP	SIDNEY	OH	SIDNEY, CITY OF	2.5	03
544	ATHENS WWTP	ATHENS	OH	ATHENS, CITY OF	4.8	03
545	IRONTON STP	IRONTON	OH	IRONTON, CITY OF	2.0	01
548	GREENVILLE WWTP	GREENVILLE	OH	GREENVILLE, CITY OF	3.0	03
549	DELAWARE STP	DELAWARE	OH	DELAWARE, CITY OF	2.5	04
552	GRAFTON STP	GRAFTON	WI	GRAFTON W & S COMMISSION	1.0	06
555	PLATTEVILLE STP	PLATTEVILLE	WI	PLATTEVILLE	1.6	03
556	RICHLAND CENTER STP	RICHLAND CENTER	WI	RICHLAND CENTER, CITY OF	1.6	03
557	WATERTOWN STP	WATERTOWN	WI	WATERTOWN, CITY OF	2.5	03
558	REEDSBURG WWTP	REEDSBURG	WI	REEDSBURG, CITY OF	1.7	03
561	WISCONSIN DELLS STP	WISCONSIN DELLS	WI	WISCONSIN DELLS, CITY OF	.2	01
562	WISCONSIN RAPIDS TP	WISCONSIN RAPID	WI	WISCONSIN RAPIDS, CITY OF	4.0	03
563	STURGEON BAY WWTP	STURGEON BAY	WI	STURGEON BAY UTILITIES	1.2	06
564	ROTHSCHILD STP	ROTHSCHILD	WI	ROTHSCHILD, VIL. OF	1.3	03
565	MERRILL WWTP	MERRILL	WI	MERRILL, CITY OF	2.1	03
567	SUPERIOR STP	SUPERIOR	WI	SUPERIOR, CITY OF	5.0	01
569	TOMAH STP	TOMAH	WI	TOMAH, CITY OF	1.5	03
608	CORSICANA #1	CORSICANA	TX	CORSICANA DEPT OF UTILITY	1.0	03
609	CORSICANA #2	CORSICANA	TX	CORSICANA DEPT OF UTILITY	1.5	03
610	MEXIA STP	MEXIA	TX	MEXIA CITY OF	1.5	03
612	#2 WACO BRA	WACO	TX	BRAZOS RIVER AUTHORITY	2.8	03
613	TEMPLE-BELTON STP	WACO	TX	BRAZOS RIVER AUTHORITY	5.0	03
614	TOWN CREEK STP	PALESTINE	TX	PALESTINE DPW	1.8	03
615	WELLS CREEK STP	PALESTINE	TX	PALESTINE DPW	1.5	03

TABLE D.1 CONTINUED

O&M SAMPLE TREATMENT SYSTEMS

0.1 - 5.0 MGD

ID NO	FACILITY NAME	CITY	STATE	OPERATING AUTHORITY	DESIGN FLOW	LEVEL OF TREATMENT
616	PLANT # 1	NACOGDOCHES	TX	NACOGDOCHES CITY OF	2.0	03
617	PLANT # 2-A	NACOGDOCHES	TX	NACOGDOCHES CITY OF	2.8	03
618	N. STP	HUNTSVILLE	TX	HUNTSVILLE CITY OF	2.1	03
619	S STP	HUNTSVILLE	TX	HUNTSVILLE CITY OF	.8	03
620	WEIMAR STP	WEIMAR	TX	WEIMAR CITY OF	.5	01
622	CHOCOLATE BAYOU STP	HOUSTON	TX	HOUSTON DPW	1.6	03
624	CLINTON PARK STP	HOUSTON	TX	HOUSTON DPW	.8	03
626	DEEPWATER STP	PASEDENA	TX	PASEDENA CITY OF	4.0	03
628	E DIST STP	BAYTOWN	TX	BAYTOWN DPW	3.0	03
629	W MAIN STP	BAYTOWN	TX	BAYTOWN DPW	4.7	03
630	LAKEWOOD STP	BAYTOWN	TX	BAYTOWN DPW	.7	03
631	STP #2	TEXAS CITY	TX	TEXAS CITY UTIL DEPT	.8	03
632	STP #1	TEXAS CITY	TX	TEXAS CITY UTIL DEPT	4.5	03
634	WCID STP #1	DICKENSON	TX	GALVESTON CO WCID	4.2	03
635	WESTSIDE STP	CORPUS CHRISTI	TX	CORPUS CHRISTI	3.0	03
636	ALLISON STP	CORPUS CHRISTI	TX	CORPUS CHRISTI DEPT OF UT	2.0	03
640	AIRPORT STP	GALVESTON	TX	GALVESTON DEPT OF UTILITY	1.0	03
643	SAN ANGELO STP	SAN ANGELO	TX	SAN ANGELO WATER DEPT	5.0	01
703	MISSOURI R. STP	ST CHARLES	MO	ST. CHARLES CITY OF	3.0	01
704	MEXICO STP	MEXICO	MO	MEXICO CITY OF	2.4	03
705	PLANT #1	COLUMBIA	MO	COLUMBIA CITY OF	2.0	04
706	PLANT #2	COLUMBIA	MO	COLUMBIA CITY OF	2.5	03
707	SOUTHEAST STP	MARSHALL	MO	MARSHALL CITY OF	3.9	03
709	BOLIVAR STP	BOLIVAR	MO	BOLIVAR CITY OF	1.5	03
710	S. LITTLE BLUE STP	KANSAS CITY	MO	KANSAS CITY CITY OF	3.8	01
711	PLATTE CO. STP	KANSAS CITY	MO	KANSAS CITY CITY OF	1.0	03
712	TODD CK. STP	KANSAS CITY	MO	KANSAS CITY CITY OF	2.0	03
714	SPRING BRANCH STP	INDEPENDENCE	MO	INDEPENDENCE CITY OF	3.0	03
715	VALE LAGOON	LEES SUMMITT	MO	LEES SUMMITT CITY OF	2.1	03
716	N.W. STP	SPRINGFIELD	MO	SPRINGFIELD CITY OF	3.5	04
717	SALEM STP	SALEM	MO	SALEM CITY OF	.8	03
803	BRIGHTON WPCP	BRIGHTON	CO	BRIGHTON CITY OF	1.8	03
804	S. LAKEWOOD STP	DENVER	CO	S. LAKEWOOD SAN. DIST.	2.3	03
807	BIG DRY CK STP	WESTMINSTER	CO	WESTMINSTER, CITY OF	1.4	04
809	EAST PEARL ST WWTP	BOULDER	CO	BOULDER CITY OF	4.3	01
810	WINDSOR STP	WINDSOR	CO	WINDSOR CITY OF	.9	03
811	WWTP #1	FT. COLLINS	CO	FT. COLLINS CITY OF	4.6	03
812	WWTP #2	FT. COLLINS	CO	FT. COLLINS CITY OF	4.8	03
814	ESTES PARK STP	ESTES PARK	CO	ESTES PARK SAN. DIST.	.8	03
815	VAIL STP	VAIL	CO	VAIL W & SAN. DIST	1.5	03
891	WINNER STP	WINNER	SD	WINNER CITY OF	1.0	03
892	PIERRE STP	PIERRE	SD	PIERRE CITY OF	1.6	01
894	SISSETON STP	SISSETON	SD	SISSETON CITY OF	.4	03
895	CANTON STP	CANTON	SD	CANTON CITY OF	.4	03
896	VERMILLION STP	VERMILLION	SD	VERMILLION CITY OF	1.2	03
909	MEADOWVIEW STP	SACRAMENTO	CA	SACRAMENTO REG.CO.SAN.DIS	2.5	03
914	SAUGUS-NEWHALL WRP	SAUGUS (D. 26)	CA	LOS ANGELES CO. SAN. DIST	5.0	03
916	PALMDALE WRP D 20	PALMDALE	CA	LOS ANGELES CO. SAN. DIST	3.2	01

TABLE D.1 CONTINUED

O&M SAMPLE TREATMENT SYSTEMS

0.1 - 5.0 MGD

ID NO	FACILITY NAME	CITY	STATE	OPERATING AUTHORITY	DESIGN FLOW	LEVEL OF TREATMENT
925	DIST. NO. 6 TP	NORTH HIGHLANDS	CA	SACRAMENTO REG.CO.SAN.DIS	3.0	03
926	CORDOVA STP	RANCHO CORDOVA	CA	SACRAMENTO REG.CO.SAN.DIS	2.6	03
927	RIO LINDA TP	RIO LINDA	CA	SACRAMENTO REG.CO.SAN.DIS	.6	03
928	NATOMAS TP	SACRAMENTO	CA	SACRAMENTO REG.CO.SAN.DIS	1.7	03
929	HEALDSBURG TRT. FAC	HEALDSBURG	CA	HEALDSBURG, CITY OF	1.0	03
935	CAMARILLO W.REC.PLT	CAMARILLO	CA	CAMARILLO SAN. DIST.	4.8	04
936	OAK VIEW STP	VENTURA	CA	OAK VIEW SAN. DIST.	3.0	07
937	SANTA PAULA WW R FA	SANTA PAULA	CA	SANTA PAULA, CITY OF	2.4	04
951	GILROY-MORGAN HILL	GILROY	CA	GILROY, CITY OF	3.3	08
952	MILLBRAE WWTP	MILLBRAE	CA	MILLBRAE, CITY OF	3.0	04
953	SAN FRANCISCO I AIR	S.F. I. AIRPORT	CA	AIRPORTS COMMISSION	2.2	03
954	PINOLE WWTP	PINOLE	CA	PINOLE, CITY OF	2.0	03
955	MILL VALLEY WWTP	MILL VALLEY	CA	MILL VALLEY, CITY	1.5	04
956	SAN RAFAEL MAIN TP	SAN RAFAEL	CA	SAN RAFAEL SANITATION DIS	5.0	03
957	NOVATO PLANT	NOVATO	CA	SAN. DIST. 6 OF MARIN CO.	3.0	04
958	IGNACIO PLANT	NOVATO	CA	SAN. DIST. 6 OF MARIN CO.	1.2	04
959	MT. VIEW S.D. WWTP	MARTINEZ	CA	MT. VIEW S. D.	1.6	03
960	ANTIOCH W.POLL.C.P.	ANTIOCH	CA	ANTIOCH, CITY OF	2.5	01
962	PLEASANTON STP	PLEASANTON	CA	PLEASANTON, CITY OF	1.7	08
963	SAUSALITO-MARIN TP	SAUSALITO	CA	SAUSALITO-MARIN CITY S.D.	2.4	01
964	GUSTINE ST FACIL.	GUSTINE	CA	GUSTINE, CITY OF	3.2	08
970	WWTP NO. 1	BAKERSFIELD	CA	BAKERSFIELD, CITY OF	5.0	01
972	WWTP NO. 3	BAKERSFIELD	CA	BAKERSFIELD, CITY OF	3.5	02
973	MONTEZUMA STP	PITTSBURG	CA	PITTSBURG, CITY OF	3.5	01
003	LAKOTA WWTP	FEDERAL WAY	WA	LAKEHAVEN SEWER DIST	1.5	01
005	LK SERENE WWTP	EDMONDS	WA	ALDERWOOD MANOR WATER DIS	1.0	03
006	MCCLEARY STP	MCCLEARY	WA	MCCLEARY CITY OF	.3	01
009	SUMNER WWTP	SUMNER	WA	SUMNER CITY OF	2.0	03
011	OAK HARBOR STP	OAK HARBOR	WA	OAK HARBOR CITY OF	1.5	01
031	DOUGLAS CO STP #1	E WENATCHEE	WA	DOUGLAS CO SEW DIST	2.3	03
032	WENATCHEE WWT FAC	WENATCHEE	WA	WENATCHEE CITY OF	5.0	03
034	CARKEEK PARK STP	SEATTLE	WA	SEATTLE METRO	3.5	01
035	RICHMOND BEACH STP	SEATTLE	WA	SEATTLE METRO	3.2	01
050	ASTORIA STP	ASTORIA	OR	ASTORIA CITY OF	4.0	03
089	WAPATO WWTP	WAPATO	WA	WAPATO CITY OF	1.0	03

O&M SAMPLE TREATMENT SYSTEMS

5.1 - 20.0 MGD

ID NO	FACILITY NAME	CITY	STATE	OPERATING AUTHORITY	DESIGN FLOW,	LEVEL OF TREATMENT
104	MARLBORO E. AWTF	MARLBORO	MA	MARLBORO DPW	5.5	07
112	ADAMS WWTP	ADAMS	MA	ADAMS BOARD OF SEWER COMM	10.2	03
114	BROCKTON WWTP	BROCKTON	MA	BROCKTON DPW	12.0	03
151	AUGUSTA SAN.DIST.ST	AUGUSTA	ME	AUGUSTA SAN.DIST	6.8	01
152	BANGOR POLL.ABATEME	BANGOR	ME	BANGOR,CITY OF	9.0	01
215	NORTHWEST QUADRANT	HILTON	NY	MONROE CO.PURE WATERS DIV	15.0	06
217	ORANGETOWN STP	ORANGEBURG	NY	ORANGETOWN DPW	8.5	03
218	ROCKLAND COUNTY STP	ORANGEBURG	NY	ROCKLAND CO SD #1,BD OF G	10.0	03
225	AMSTERDAM STP	AMSTERDAM	NY	NYS ENV FACILITIES CORP	10.0	03
226	PLATTSBURGH WPCP	PLATTSBURGH	NY	PLATTSBURGH,CITY OF	16.0	03
230	OGDENSBURG WPCP	OGDENSBURG	NY	OGDENSBURG,CITY OF	6.5	01
236	MEADOWBROOK-LIMESTO	MANLIUS	NY	ONONDAGA CO.DEPT OF SAN	7.0	03
240	DUNKIRK WPC FAC	DUNKIRK	NY	DUNKIRK CITY OF	6.0	06
241	JAMESTOWN STP	POLAND (TN OF)	NY	JAMESTOWN CITY OF DPW	8.0	03
242	OLEAN WWTP	OLEAN	NY	OLEAN CITY OF	7.0	03
245	AMHERST STP # 16	AMHERST	NY	AMHERST,TOWN OF	12.0	01
305	SPRINGETTSBURY TWP	SPRINGETTSBURY	PA	SPRINGETTSBURY TWP SEW.	8.0	04
313	BETHLEHEM WWTP	BETHLEHEM	PA	BETHLEHEM, CITY OF	12.5	03
318	GREATER HAZLETON JS	HAZLETON	PA	GREATER HAZELTON JSA	5.8	03
346	CENTRAL PLANT STP	WILLIAMS PORT	PA	WILLIAMSPORT SANITARY AUT	7.2	03
362	ARMY BASE STP	NORFOLK	VA	HAMPTON ROADS SAN. DIST.	14.0	01
367	FALLING CREEK STP	CHESTERFIELD	VA	CHESTERFIELD CO	6.0	03
368	PINNER'S POINT STP	PORTSMOUTH	VA	PORTSMOUTH, CITY OF	15.0	01
400	BOCA RATON STP	BOCA RATON	FL	BOCA RATON CITY OF	10.0	03
402	GOULDS STP	GOULDS	FL	MIAMI-DADE W&S	6.0	04
404	NORTH MIAMI PLT #1	NORTH MIAMI	FL	NORTH MIAMI CITY OF	13.0	01
412	BETHUNE STP	DAYTONA BEACH	FL	DAYTONA BEACH,CITY OF	10.0	03
421	LAKELAND STP	LAKELAND	FL	SARASOTA CITY OF	10.0	04
425	NORTHEAST STP #2	ST.PETERSBURG	FL	ST.PETERSBURG CITY OF	8.0	04
431	SOUTHWEST STP	TALLAHASSEE	FL	TALLAHASSEE	8.8	04
435	VICKSBURG WWTP	VICKSBURG	MS	VICKSBURG CITY OF	7.5	04
436	LAGOON COMPLEX ONE	HATTIESBURG	MS	HATTIESBURG CITY OF	5.4	01
441	GREENVILLE STP	GREENVILLE	MS	GREENVILLE CITY OF	20.0	03
465	ALBANY WWTP	ALBANY	GA	ALBANY, CITY OF	20.0	03
467	ROCKY CREEK WPCP	MACON	GA	MACON-BIBB COUNTY W;S AUT	14.0	03
469	BRUNSWICK WPCP	BRUNSWICK	GA	BRUNSWICK, CITY OF	10.0	03
475	CHATTAHOOCHEE RIVER	SMYRNA	GA	COBB COUNTY W S S DEPT.	10.0	03
479	CHICKAMAUGA WW PLT	CHICKAMAUGA	GA	CHICKAMAUGA, CITY OF	5.2	03
484	FLINT RIVER WPC	COLLEGE PARK	GA	ATLANTA DEPT. OF ENV. AND	6.0	03
487	INTRENCHMENT CREEK	ATLANTA	GA	ATLANTA DEPT. OF ENV. AND	20.0	03
506	STEUBENVILLE STP	STEUBENVILLE	OH	STEUBENVILLE, CITY OF	6.5	02
512	BARBERTON STP	BARBERTON	OH	BARBERTON, CITY OF	8.0	03
520	AVON LAKE STP	AVON LAKE	OH	AVON LAKE, CITY OF	5.3	07
521	SANDUSKY STP	SANDUSKY	OH	SANDUSKY, CITY OF	12.5	07
524	MAUMEE RIVER STP	WATERVILLE	OH	LUCAS CO. SAN. ENGR.	6.0	06
527	FINDLAY STP	FINDLAY	OH	FINDLAY, CITY OF	7.5	03
528	WOOSTER WPCP	WOOSTER	OH	WOOSTER, CITY OF	5.5	03
539	HAMILTON WWTP	HAMILTON	OH	HAMILTON, CITY OF	12.0	03

TABLE D.1 CONTINUED

TABLE D.1 CONTINUED

O&M SAMPLE TREATMENT SYSTEMS

5.1 - 20.0 MGD

ID NO	FACILITY NAME	CITY	STATE	OPERATING AUTHORITY	DESIGN FLOW	LEVEL OF TREATMENT
541	NEWARK WWTP	NEWARK	OH	NEWARK, CITY OF	12.0	03
543	LANCASTER WPCF	LANCASTER	OH	LANCASTER, CITY OF	8.0	03
553	WAUKESHA STP	WAUKESHA	WI	WAUKESHA, CITY OF	8.5	06
554	JANESVILLE WPCP	JANESVILLE	WI	JANESVILLE WPC UTIL.	16.0	03
559	SHEBOYGAN WWTP	SHEBOYGAN	WI	SHEBOYGAN, CITY OF	15.0	05
560	APPLETON WWTP	APPLETON	WI	APPLETON, CITY OF	12.5	06
566	LACROSSE STP	LACROSSE	WI	LACROSSE, CITY OF	20.0	03
568	EAU CLAIRE WWTP	EAU CLAIRE	WI	EAU CLAIRE, CITY OF	7.0	01
604	LEWISVILLE WWTP	LEWISVILLE	TX	LEWISVILLE DPW	6.0	04
611	#1 WACO BRA	WACO	TX	BRAZOS RIVER AUTHORITY	18.0	03
627	VINCE BAYOU STP A&B	PASEDENA	TX	PASEDENA CITY OF	7.0	03
633	S.PLANT (MAIN PLANT	BROWNSVILLE	TX	BROWNSVILLE PUB	7.5	03
637	BROADWAY STP	CORPUS CHRISTI	TX	CORPUS CHRISTI	12.0	03
638	OSO STP	CORPUS CHRISTI	TX	CORPUS CHRISTI	12.0	03
639	MAIN PLANT	GALVESTON	TX	GALVESTON DEPT OF UTILITY	10.0	03
699	SOCORRO STP	EL PASO	TX	EL PASO WATER UTIL BOARD	20.0	03
702	MISSISSIPPI R. STP	ST. CHARLES	MO	ST. CHARLES CITY OF	5.5	06
708	ST. JOSEPH WWTP	ST. JOSEPH	MO	ST. JOSEPH CITY OF	13.1	01
713	ROCK CK. STP	INDEPENDENCE	MO	INDEPENDENCE CITY OF	6.5	01
802	LONGMONT STP	LONGMONT	CO	LONGMONT CITY OF	5.3	03
808	75TH ST WWTP	BOULDER	CO	BOULDER CITY OF	15.6	03
818	PUEBLO STP	PUEBLO	CO	PUEBLO, CITY OF	17.0	03
890	RAPID CITY STP	RAPID CITY	SD	RAPID CITY	13.5	03
893	HURON STP	HURON	SD	HURON CITY OF	6.0	03
913	LANCASTER WRP D 14	LANCASTER	CA	LOS ANGELES CO. SAN. DIST	6.0	04
917	LONG BEACH WRP	LONG BEACH	CA	LOS ANGELES CO. SAN. DIST	12.5	03
923	WHITTIER NARROWS WR	EL MONTE	CA	LOS ANGELES CO. SAN. DIST	12.5	03
924	ARDEN STP	SACRAMENTO	CA	SACRAMENTO REG.CO.SAN.DIS	10.0	03
930	CLEAR CREEK ST FACL	REDDING	CA	REDDING, CITY OF	8.8	03
945	VENTURA WATER RENOV	VENTURA	CA	VENTURA, CITY OF	14.0	04
946	HILL CANYON TP	THOUSAND OAKS	CA	THOUSAND OAKS, CITY OF	10.0	04
948	PORT HUENEME WTP	PORT HUENEME	CA	VENTURA REGIONAL CO. S.D.	6.0	01
950	GILROY-MORGAN HILL	GILROY	CA	GILROY, CITY OF	8.0	08
961	CAMP STONEMAN STP	PITTSBURG	CA	PITTSBURG, CITY OF	6.5	01
971	WWTP NO. 2	BAKERSFIELD	CA	BAKERSFIELD, CITY OF	16.0	01
001	EUGENE STP	EUGENE	OR	EUGENE DPW	17.1	03
002	MT VERNON WWTP	MT VERNON	WA	MT VERNON CITY OF	9.0	03
007	CHEHALIS TP	CHEHALIS	WA	CHEHALIS CITY OF	7.5	03
008	PUYALLUP STP	PUYALLUP	WA	PUYALLUP CITY OF	6.0	01
033	ELLENSBURG WWTP	ELLENSBURG	WA	ELLENSBURG CITY OF	15.0	03
061	YAKIMA WPC PLANT	YAKIMA	WA	YAKIMA CITY OF	18.0	03

TABLE D.1 CONTINUED

O&M SAMPLE TREATMENT SYSTEMS

> 20.0 MGD

ID NO	FACILITY NAME	CITY	STATE	OPERATING AUTHORITY	DESIGN FLOW	LEVEL OF TREATMENT
208	26TH WARD WPCP	BROOKLYN	NY	NEW YORK CITY	85.0	03
216	FRANK E VAN LARE WW	ROCHESTER	NY	MONROE CO.PURE WATERS DIV	100.0	06
238	ONEIDA CO WPCP	UTICA	NY	ONEIDA CO DPW	27.0	03
253	BAY PARK STP	E.ROCKAWAY	NY	NASSAU COUNTY DPW	60.0	03
309	HARRISBURG STP	HARRISBURG	PA	HARRISBURG SEW. AUTH.	27.8	01
322	ERIE WWTP	ERIE	PA	ERIE, CITY OF SEWER AUTH.	64.0	06
363	CHESAPEAKE-ELIZABET	VIRGINIA BEACH	VA	HAMPTON ROADS SAN. DIST.	24.0	03
401	VIRGINIA KEYS STP	MIAMI	FL	MIAMI-DADE WATER AND SEW.	70.0	03
427	HOOKERS PT STP	TAMPA	FL	TAMPA CITY OF	36.0	01
485	UTOY CREEK WPC PLT.	ATLANTA	GA	ATLANTA DEPT. OF ENV. AND	30.0	03
513	WESTERLY WWTP	CLEVELAND	OH	CLEVELAND REG. SD	38.0	05
514	EASTERLY WWTP	CLEVELAND	OH	CLEVELAND REG. SD	123.0	03
515	SOUTHERLY WWTP	CLEVELAND	OH	CLEVELAND REG. SD	96.0	03
523	TOLEDO WWTP	TOLEDO	OH	TOLEDO, CITY OF	102.0	03
535	JACKSON PIKE WWTP	COLUMBUS	OH	COLUMBUS, CITY OF	100.0	03
536	SOUTHERLY WWTP	COLUMBUS	OH	COLUMBUS, CITY OF	100.0	03
546	SPRINGFIELD WWTP	SPRINGFIELD	OH	SPRINGFIELD, CITY OF	25.0	03
547	DAYTON WWTP	DAYTON	OH	DAYTON, CITY OF	60.0	03
570	NINE SPRINGS WWTP	MADISON	WI	MADISON METRO. SEW. DIST.	27.5	03
605	VILLAGE CREEK STP	FT WORTH	TX	FT WORTH WATER DEPT	45.0	03
606	RIVERSIDE STP	FT WORTH	TX	FT WORTH WATER DEPT	22.0	03
607	CENTRAL STP	DALLAS	TX	DALLAS WATER UTILITY DEPT	100.0	03
625	N. SIDE STP	HOUSTON	TX	HOUSTON DPW	138.0	03
701	LEMAY STP	ST. LOUIS	MO	METRO SEWER DIST.	173.0	01
718	COLDWATER CK. STP	ST. LOUIS	MO	METRO. ST. LOUIS SEW. DIS	25.0	03
805	NORTHSIDE STP	DENVER	CO	DENVER C. & CO.	110.0	01
817	COLORADO SPRINGS TP	COLORADO SPRING	CO	COLORADO SPRINGS, CITY OF	30.0	03
907	CENTRAL TP	ELK GROVE	CA	SACRAMENTO REG.CO.SAN.DIS	30.0	03
908	NORTHEAST TP	CARMICHAEL	CA	SACRAMENTO REG.CO.SAN.DIS	21.0	03
910	CITY MAIN TP	SACRAMENTO	CA	SACRAMENTO REG.CO.SAN.DIS	70.0	03
947	OXNARD WTP	OXNARD	CA	VENTURA REGIONAL CO. S.D.	25.0	02
004	COLUMBIA BLVD WW TP	PORTLAND	OR	PORTLAND BUREAU OF WWT	200.0	03

DESIGN FLOW IN MILLION GALLONS PER DAY

CODE	LEVEL OF TREATMENT	CODE	LEVEL OF TREATMENT
00	RAW DISCHARGE	05	NUTRIENT REMOVAL (BOD/SS < SECONDARY)
01	PRIMARY (BOD/SS EFF. >50/50)	06	SECONDARY TREATMENT WITH NUTRIENT REMOVAL
02	ADVANCED PRIMARY (BOD/SS EFF. 50/50 - 30/30)	07	GREATER THAN SECONDARY WITH NUTRIENT REMOVAL
03	SECONDARY (BOD/SS EFF. 30/30 - 25/25)	08	ZERO DISCHARGE
04	GREATER THAN SECONDARY (BOD/SS ONLY)		

TABLE D.2

NUMBER OF PLANTS SURVEYED BY PROCESS DESCRIPTION

Process Description	Number of Wastewater Treatment Plants	
	D&M Survey	AMSA Survey
Pre-Treatment		
Pumping, Raw Wastewater	213	40
Preliminary Treatment - Bar Screen	226	84
Preliminary Treatment - Grit Removal	243	83
Preliminary Treatment - Comminutors/ Barminutors	197	20
Preliminary Treatment - Others	7	3
Prechlorination	40	3
Flow Equalization Basins	10	4
Preaeration	69	9
Sedimentation		
Primary Sedimentation	234	84
Clarification (Secondary & AWT)	275	71
Tube Settlers	1	0
Trickling Filter - Unspecified	0	1
Trickling Filter - Rock Media	93	9
Trickling Filter - Plastic Media	4	1
Trickling Filter - Redwood Slats	3	1
Trickling Filter - Other Media	1	0
Rotating Biological (Bio-Disc, Bio-Surf)	0	1
Activated Sludge - Unspecified	0	1
Activated Sludge - Conventional	101	50
Activated Sludge - High Rate	14	6
Activated Sludge - Contact Stabilization	38	3
Activated Sludge - Extended Aeration	26	2
Pure Oxygen Activated Sludge	2	0
Oxidation Ditch	7	0

TABLE D.2 (Continued)

Process Description (Continued)	Number of Wastewater Treatment Plants	
	D&M Survey	AMSA Survey
Filtration		
Microstrainers - Raw Sewage or Primary Effluent	0	1
Microstrainers - Secondary or Tertiary Effluent	6	1
Sand Filters	10	2
Mix-Media Filters	4	3
Nutrient Removal/Chemical Treatment		
Biological Nitrification	4	0
Biological Denitrification	2	0
Recarbonation	0	1
Activated Carbon - Granular	1	1
Activated Carbon - Powdered	1	0
Lime Treatment of Raw Wastewater	11	0
Tertiary Lime Treatment	2	1
Alum Addition	12	3
Ferri-Chloride Addition	11	2
Polymer Addition	16	3
Other Chemical Additions	6	1
Disinfection		
Chlorination for Disinfection	304	78
Ozonation for Disinfection	0	1
Other Disinfection	2	0
Dechlorination	8	0
Reaeration - General	7	2
Other Treatment		
Land Treatment of Secondary Effluent (30/30)	1	1
Stabilization Ponds	20	5

TABLE D.2 (Continued)

Process Description (Continued)	Number of Wastewater Treatment Plants D&M Survey	 AMSA Survey
Aerated Lagoons	16	1
Polishing Ponds	22	2
Effluent Disposal		
Effluent Pumping	21	4
Outfall to Other Plants	4	1
Recycling and Reuse	2	2
Irrigation	15	2
Ocean Outfall	27	19
Surface Water Outfall	293	66
Land Disposal	3	0
Complete Retention	7	1
Sludge Handling		
Sludge Holding Tank	51	11
Sludge Lagoons	19	8
Air Drying (Sludge Drying Beds)	131	43
Aerobic Digestion - Air	79	7
Aerobic Digestion - Oxygen	6	0
Anaerobic Digestion	182	60
Digestion Gas Utilization	99	18
Chlorine Oxidation of Sludge (Purifax)	2	5
Dewatering - Mechanical - Vacuum Filter	72	19
Dewatering - Mechanical - Centrifuge	34	16
Dewatering - Mechanical - Filter Press	7	2
Dewatering - Others	4	0
Gravity Thickening	76	45
Flotation Thickening	19	5
Heat Treatment	4	0
Incineration - Multiple Hearth	11	8

TABLE D.2 (Concluded)

Process Description (Concluded)	Number of Wastewater Treatment Plants	
	D&M Survey	AMSA Survey
Incineration - Fluidized Beds	5	1
Incineration - Rotary Kiln	1	0
Incineration - Other	5	2
Wet Air Oxidation	5	1
Recalcination	0	2
Ultimate Sludge Disposal		
Composting	7	6
Land Spreading of Liquid Sludge	58	1
Land Spreading of Thickened Sludge	52	9
Trenching	3	0
Ocean Dumping	2	18
Other Sludge Handling	7	2
Sludge Transferred to Another Facility	15	15
Sludge Used by Others	84	8
Landfill	140	50

APPENDIX E

WASTEWATER TREATMENT PLANT GRAPHICAL RELATIONSHIPS
POTENTIALLY SIGNIFICANT O&M RELATIONSHIPS

EPA Survey

Notes:

CORRELATION COEFFICIENT (r) is a measure of the degree of closeness of the linear relationship between two variables. It varies from zero (no relationship between the two variables) to ± 1 (perfect linear relationship). The sign of r is the same as that of a in the regression equation, $Y = a + bX$. Thus, if $r = -1$, all points are on the regression line sloping down to the right. The independent variable (X) accounts for the variability in the dependent variable (Y). For example, if $r = 0.73$, then 73 percent of the variance in Y is explained by X; the balance of 27 percent is simply not explained by the independent variable X and is left unaccounted for the relationship of the two designated variables.

F-TEST VALUE is used to test the goodness of the fit of a regression curve. The F-value can be compared with tabled values to give a test of the hypothesis that the correlation coefficient is zero against the alternative that the equation as a whole defines a significant relationship between the two variables. The F-value is the ratio of the mean square due to regression to the deviations mean square:

$$\text{F-value} = \frac{SSFE/K}{RSS/(N - K - 1)}$$

The ratio is compared to the corresponding value from an F-table with K and (N - K - 1) degrees of freedom, where N is the total number of points, K is the degrees of freedom due to regression, and N - K - 1 is the degrees of freedom due to deviations. (SSFE implies sum of square due to fitted equation; RSS means residual sum of squares.) In general, the higher a given F-value the greater the probability that the relationship is significant. Also, as the sample size increases, the relative probability of the F-test value being significant increases.

TABLE E.1

POTENTIALLY SIGNIFICANT O&M RELATIONSHIPS
STAFF SIZE VS ACTUAL FLOW

Title	Equation	Sample Size (n)	Correlation Coefficient (r)	F-Test Value
Primary Treatment National	$S = 0.90 \times Q + 3.25$	63	0.79	102.90
Trickling Filter (TF), National	$S = 1.19 \times Q + 2.59$	81	0.87	241.40
Activated Sludge (AS), National	$S = 1.94 \times Q + 2.38$	149	0.77	208.69
AWT, National	$S = 1.26 \times Q + 5.48$	32	0.94	223.93

Where S equals the size of the staff at the wastewater treatment plant, and Q equals the average daily flow in million gallons per day.

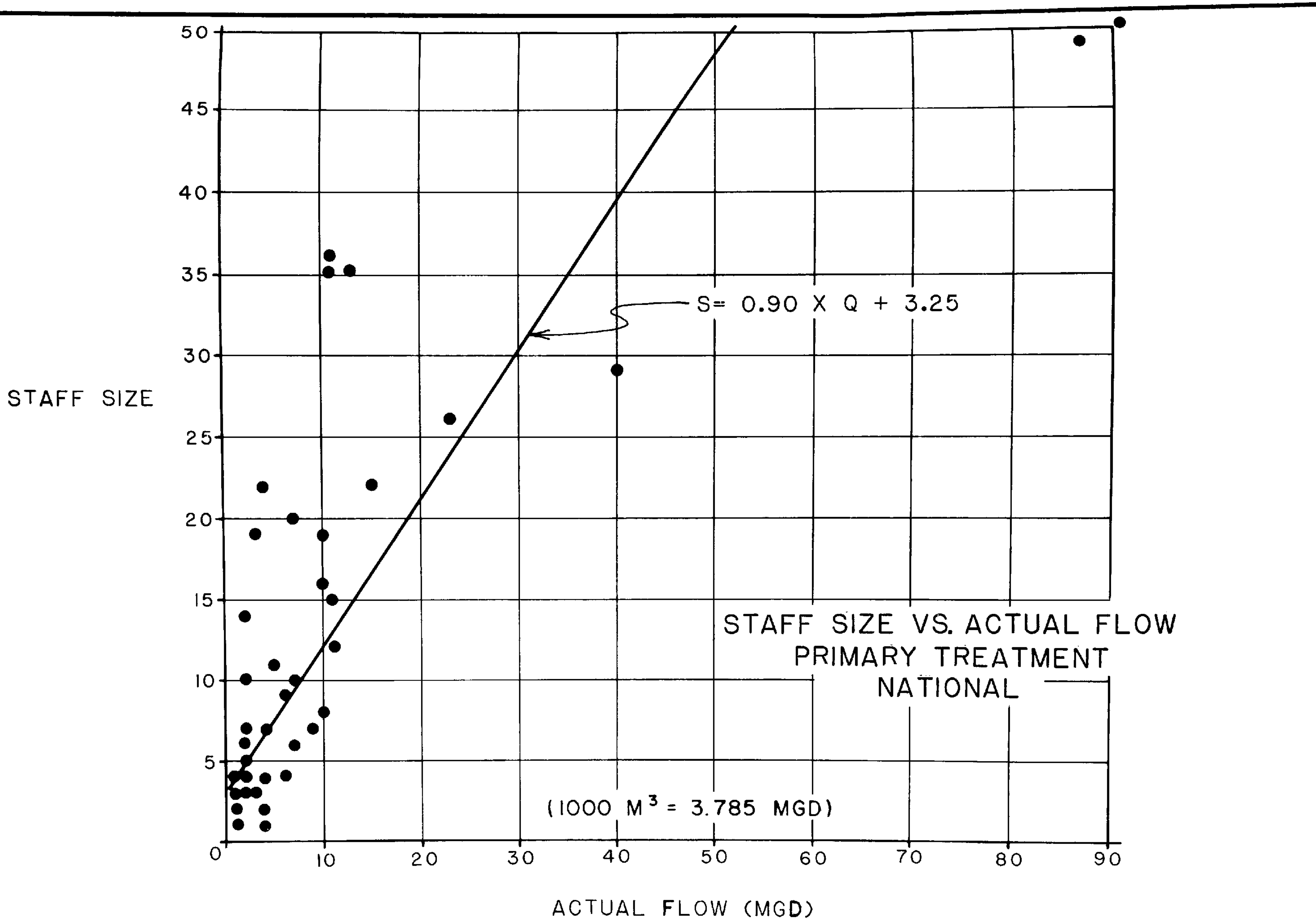
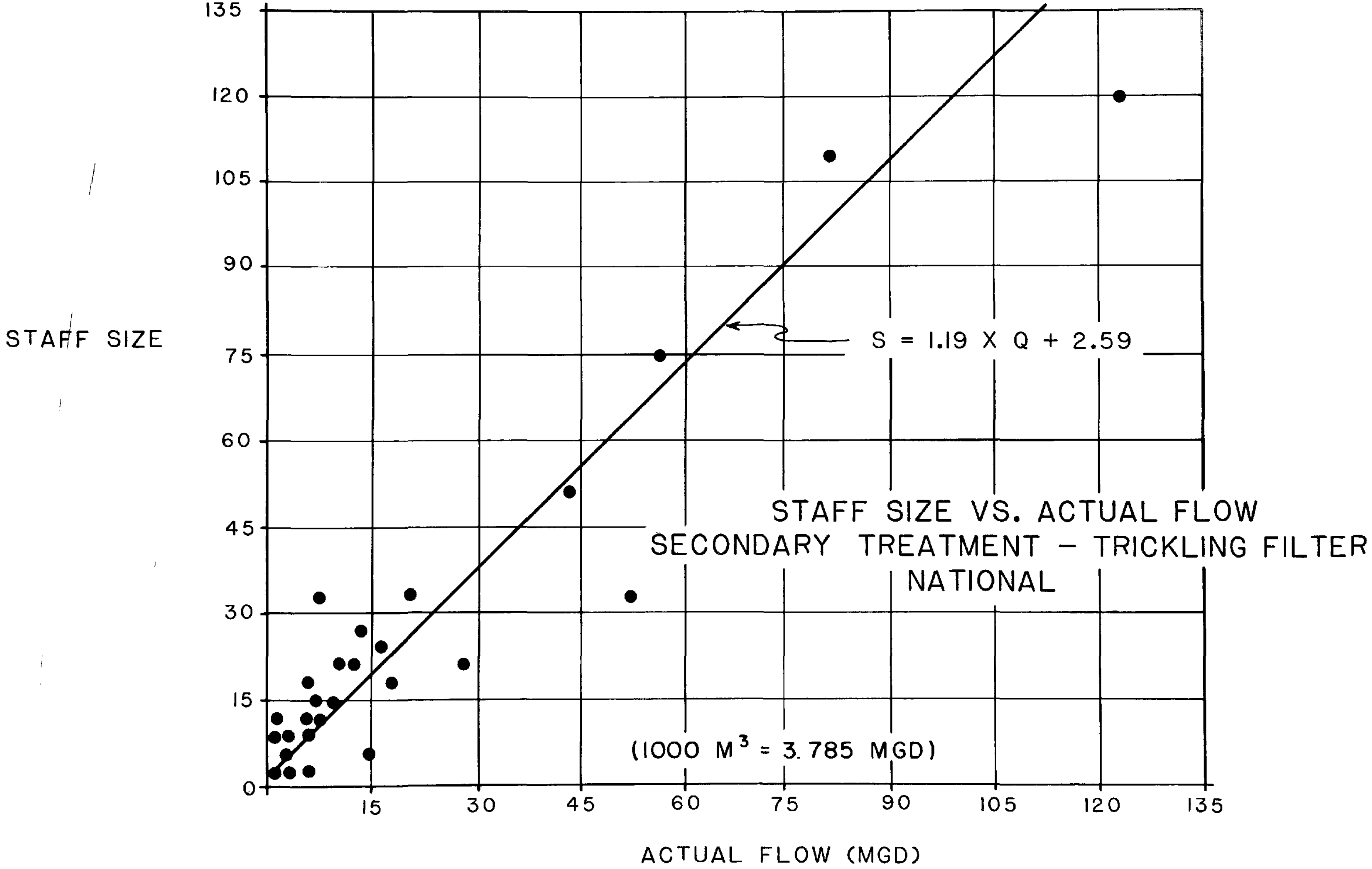
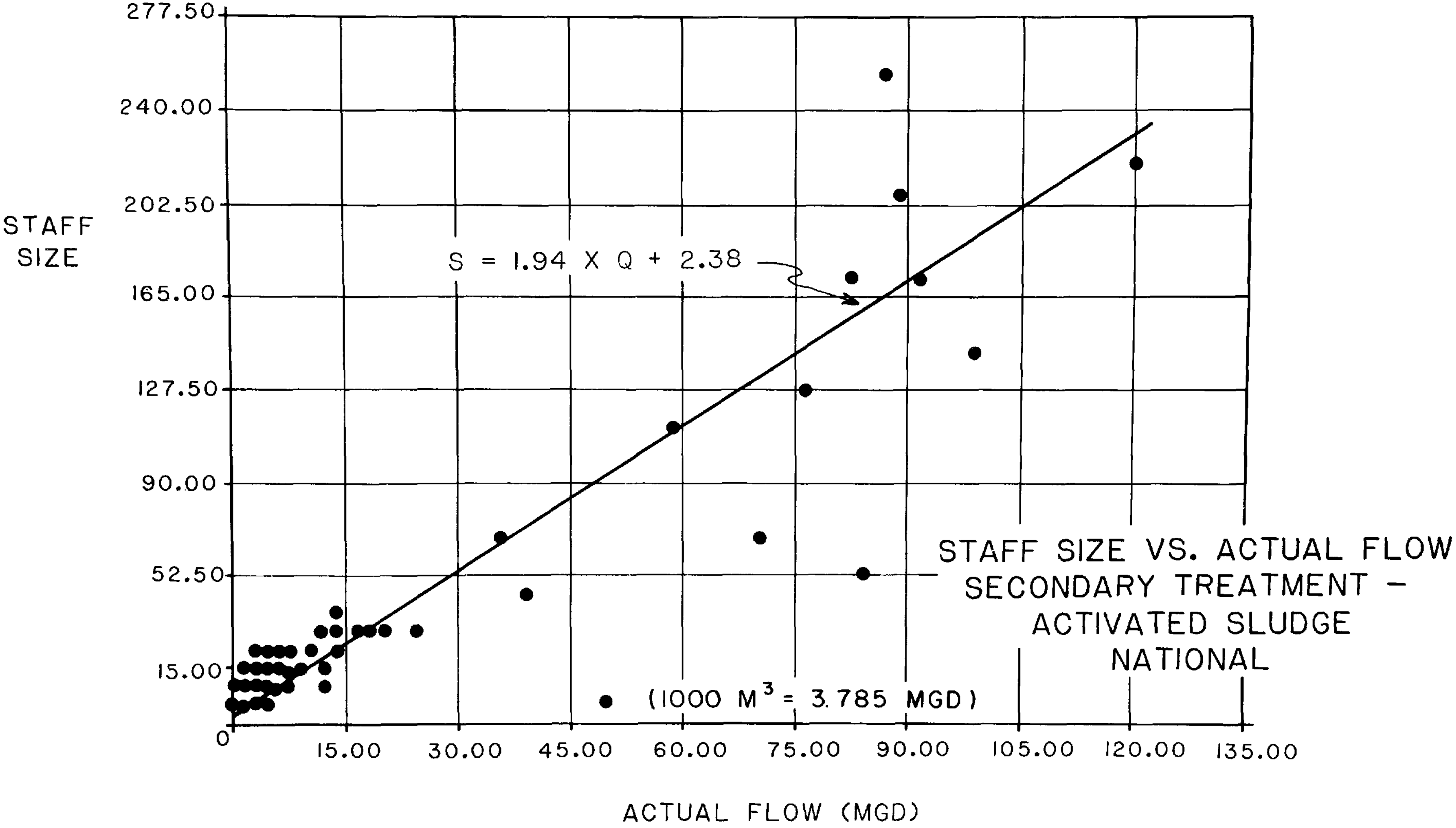

STAFF SIZE
ACTUAL FLOW (MGD)
50
45
40
35
30
25
20
15
10
5
0
10
20
30
40
50
60
70
80
90
S= 0.90 X Q + 3.25
STAFF SIZE VS. ACTUAL FLOW
PRIMARY TREATMENT
NATIONAL
(1000 M3 = 3.785 MGD)

FIGURE E. 1-1



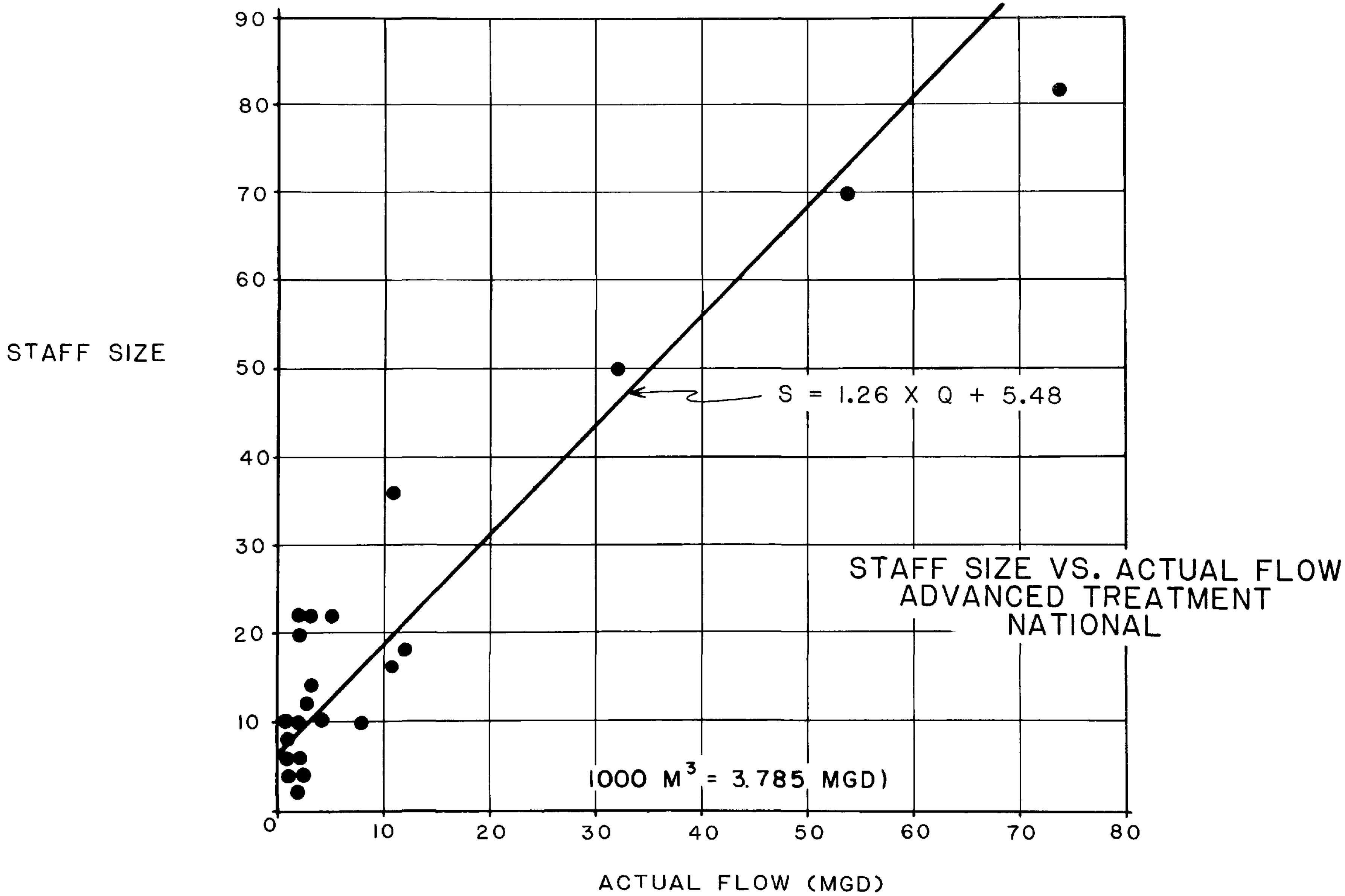
STAFF SIZE VS. ACTUAL FLOW
SECONDARY TREATMENT – TRICKLING FILTER
NATIONAL

FIGURE E. 1-2



STAFF SIZE VS. ACTUAL FLOW
SECONDARY TREATMENT –
ACTIVATED SLUDGE
NATIONAL

FIGURE E. 1-3



STAFF SIZE VS. ACTUAL FLOW
ADVANCED TREATMENT
NATIONAL

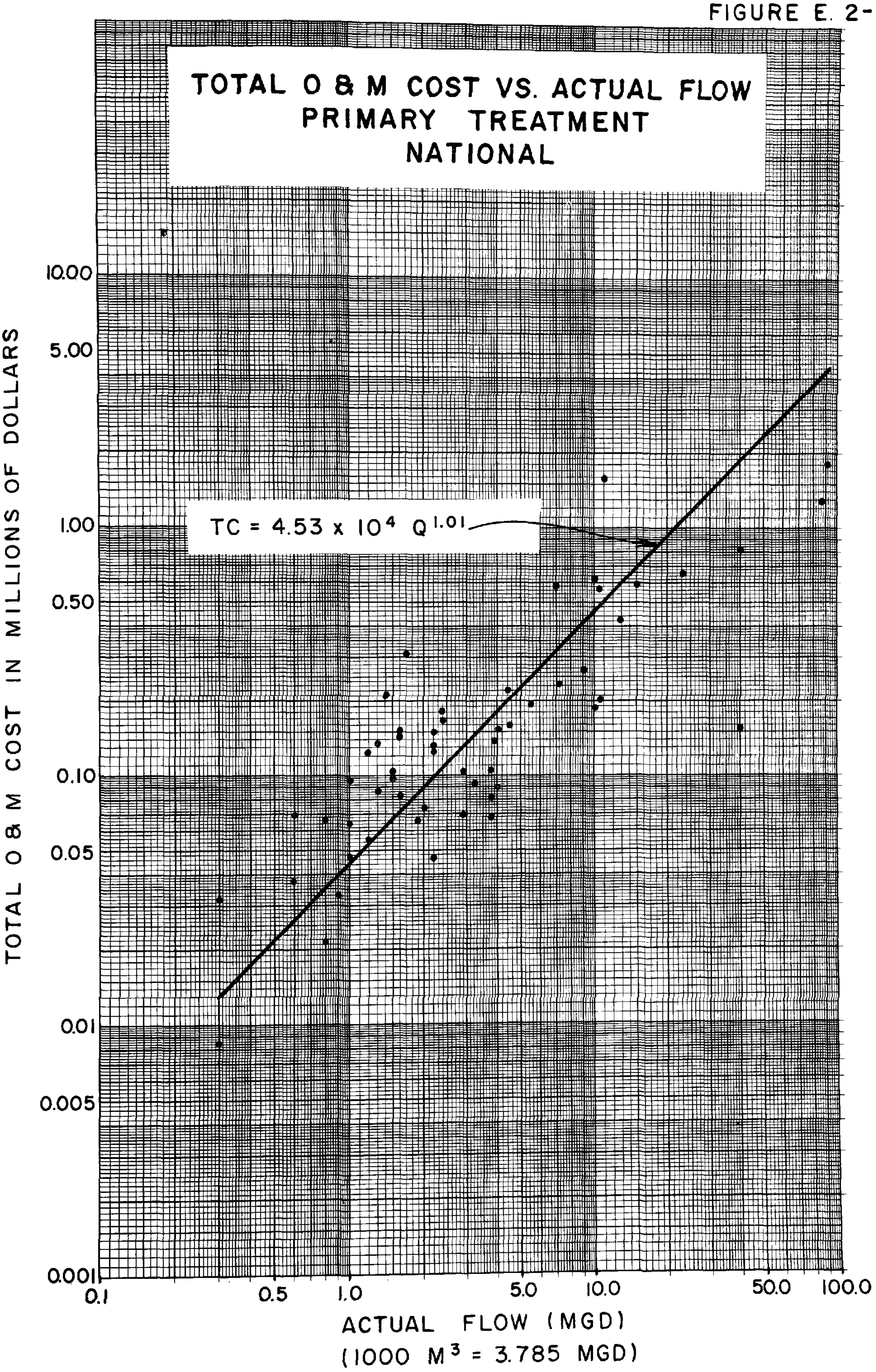
FIGURE E. 1-4

TABLE E.2

POTENTIALLY SIGNIFICANT O&M RELATIONSHIPS TOTAL O&M COSTS VS ACTUAL FLOW

Title	Equation	Sample Size (n)	Correlation Coefficient (r)	F-Test Value
Primary Treatment National	$TC = 4.53 \times 10^4 Q^{1.01}$	57	0.83	119.57
Trickling Filter (TF), National	$TC = 6.02 \times 10^4 Q^{0.94}$	71	0.86	194.15
Activated Sludge (AS), National	$TC = 8.25 \times 10^4 Q^{0.96}$	143	0.89	515.76
AWT, National	$TC = 6.85 \times 10^4 Q^{1.44}$	28	0.71	25.75
TF, Region II	$TC = 7.58 \times 10^4 Q^{1.10}$	9	0.77	10.31
TF, Region III	$TC = 6.14 \times 10^4 Q^{1.04}$	7	0.91	23.54
TF, Region IV	$TC = 4.66 \times 10^4 Q^{1.27}$	13	0.70	10.32
TF, Region V	$TC = 8.08 \times 10^4 Q^{0.70}$	5	0.95	25.13
TF, Region VI	$TC = 3.99 \times 10^4 Q^{0.90}$	12	0.95	96.03
TF, Region VIII	$TC = 2.51 \times 10^4 Q^{1.29}$	11	0.96	99.55
TF, Region IX	$TC = 8.55 \times 10^4 Q^{0.95}$	7	0.91	23.16
AS, Region II	$TC = 1.11 \times 10^5 Q^{0.82}$	15	0.95	112.19
AS, Region III	$TC = 1.08 \times 10^5 Q^{0.87}$	16	0.87	44.65
AS, Region IV	$TC = 7.27 \times 10^4 Q^{0.98}$	26	0.83	52.60
AS, Region V	$TC = 1.04 \times 10^5 Q^{0.87}$	20	0.95	176.73
AS, Region VI	$TC = 4.36 \times 10^4 Q^{1.14}$	18	0.93	109.73
AS, Region X	$TC = 9.55 \times 10^4 Q^{0.80}$	6	0.98	100.82

Where TC equals total O&M cost in dollars and
Q equals the average daily flow in million gallons per day.


TOTAL O & M COST VS. ACTUAL FLOW
PRIMARY TREATMENT
NATIONAL
TC = 4.53 x 10⁴ Q^1.01
TOTAL O & M COST IN MILLIONS OF DOLLARS
10.00
5.00
1.00
0.50
0.10
0.05
0.01
0.005
0.001
0.1
0.5
1.0
5.0
10.0
50.0
100.0
ACTUAL FLOW (MGD)
(1000 M³ = 3.785 MGD)

TOTAL O & M COST VS. ACTUAL FLOW SECONDARY TREATMENT-TRICKLING FILTER NATIONAL

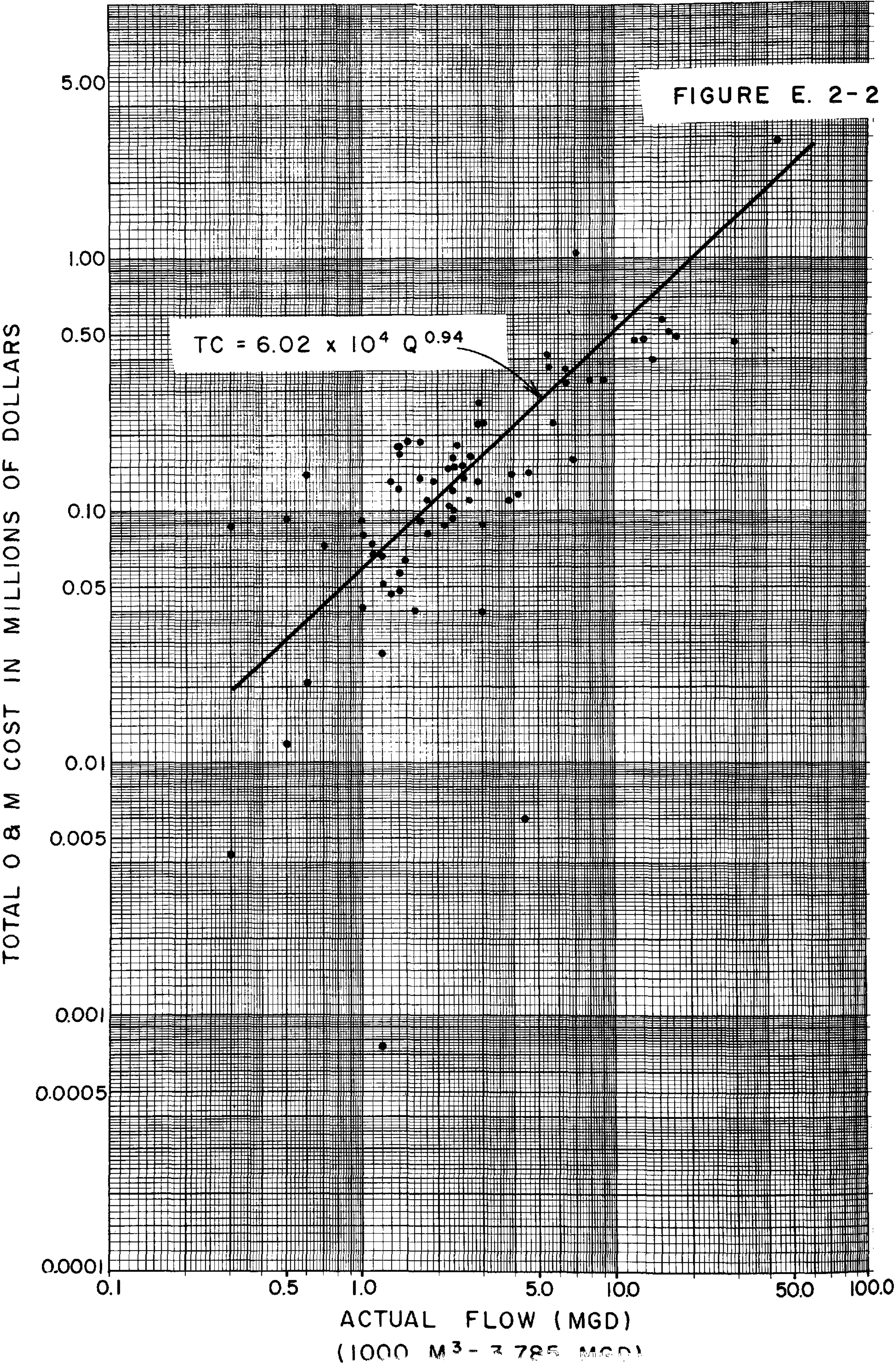


FIGURE E. 2-2

TOTAL O & M COST VS. ACTUAL FLOW SECONDARY TREATMENT-ACTIVATED SLUDGE NATIONAL

FIGURE E. 2-3

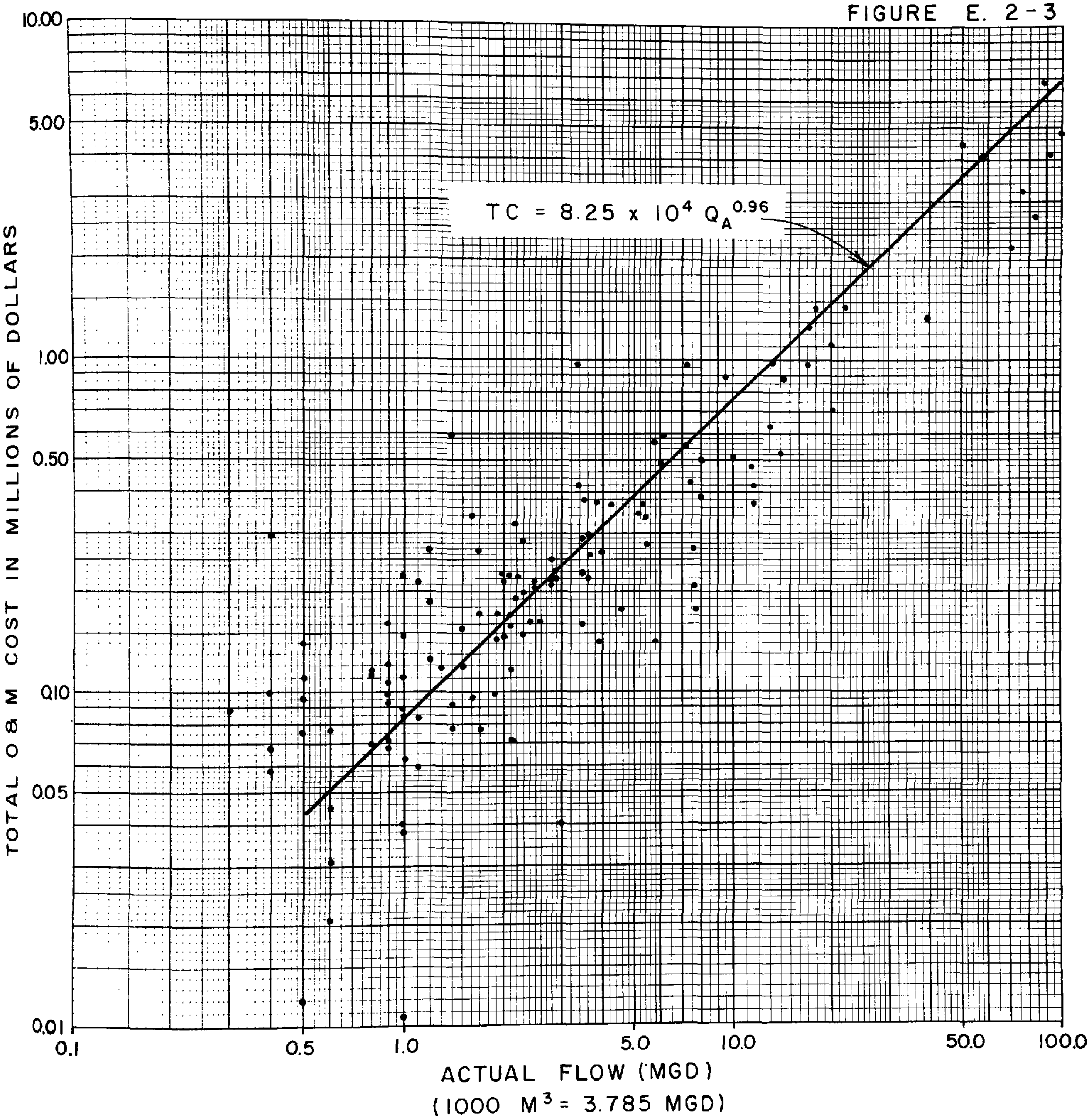
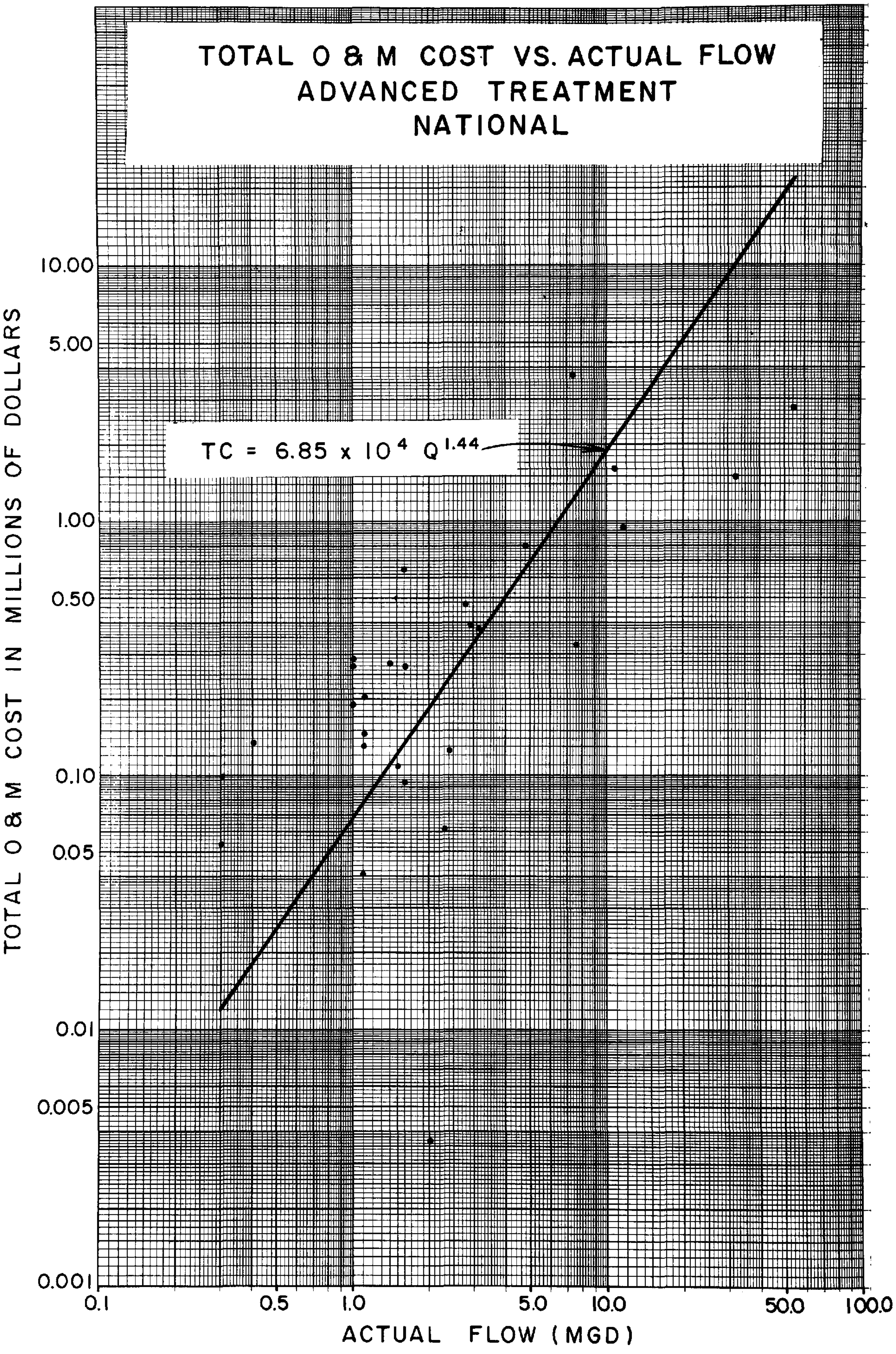
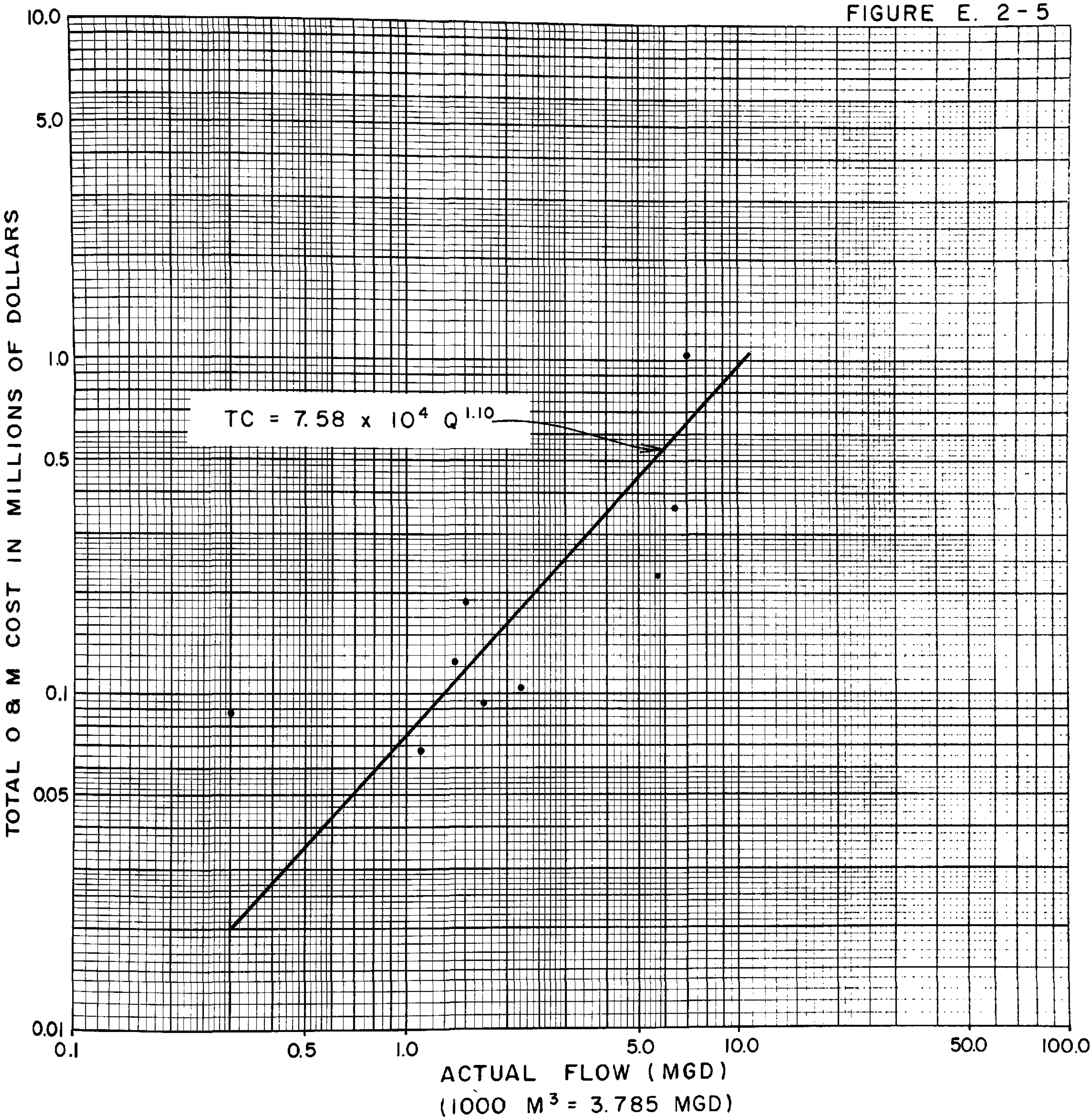


FIGURE E. 2-4


TOTAL O & M COST VS. ACTUAL FLOW
ADVANCED TREATMENT
NATIONAL
TC = 6.85 x 10⁴ Q^1.44
TOTAL O & M COST IN MILLIONS OF DOLLARS
10.00
5.00
1.00
0.50
0.10
0.05
0.01
0.005
0.001
0.1
0.5
1.0
5.0
10.0
50.0
100.0
ACTUAL FLOW (MGD)
(1000 M³= 3.785 MGD)

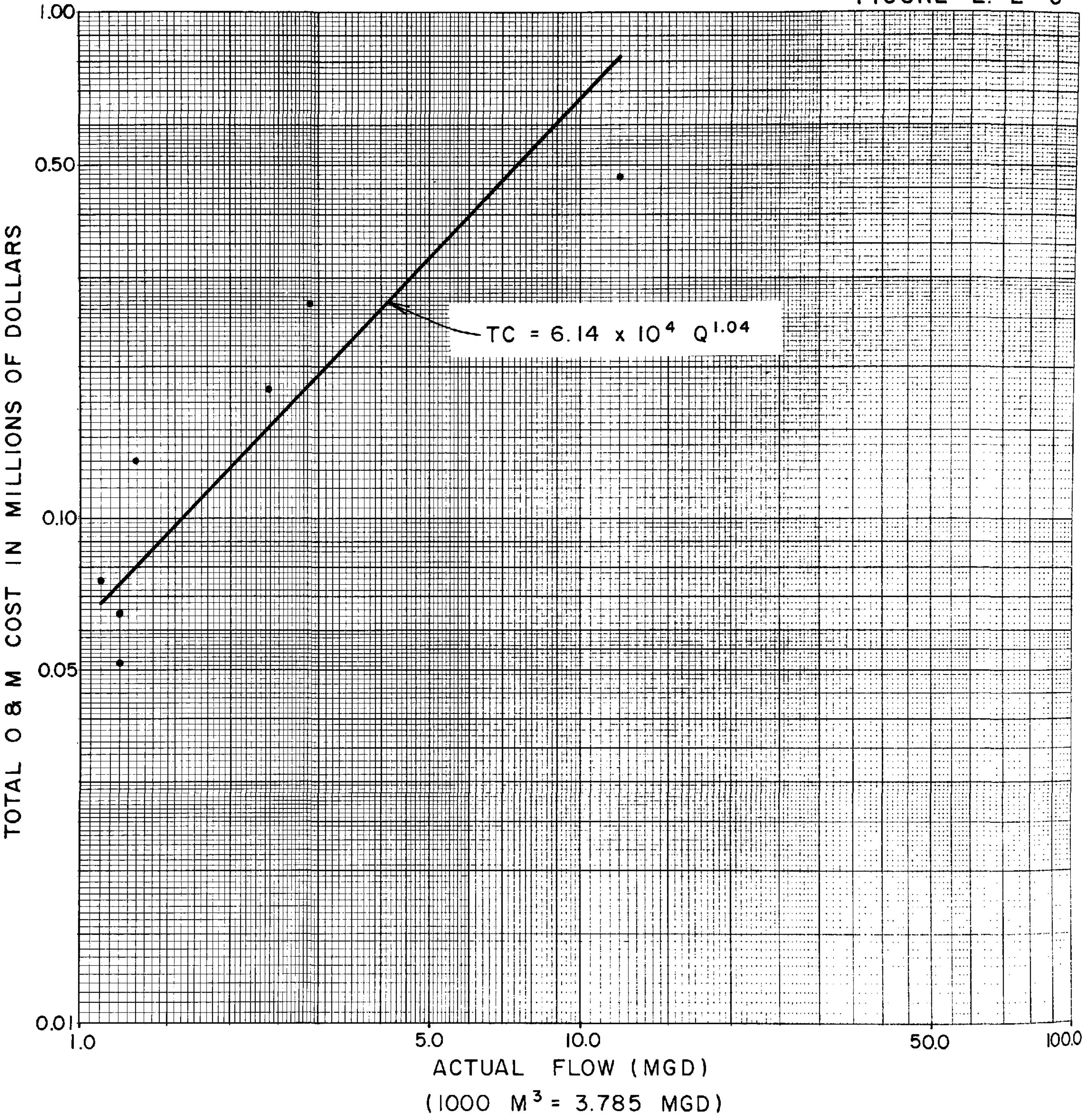
TOTAL O & M COST VS. ACTUAL FLOW
SECONDARY TREATMENT - TRICKLING FILTER
EPA REGION II

FIGURE E. 2-5



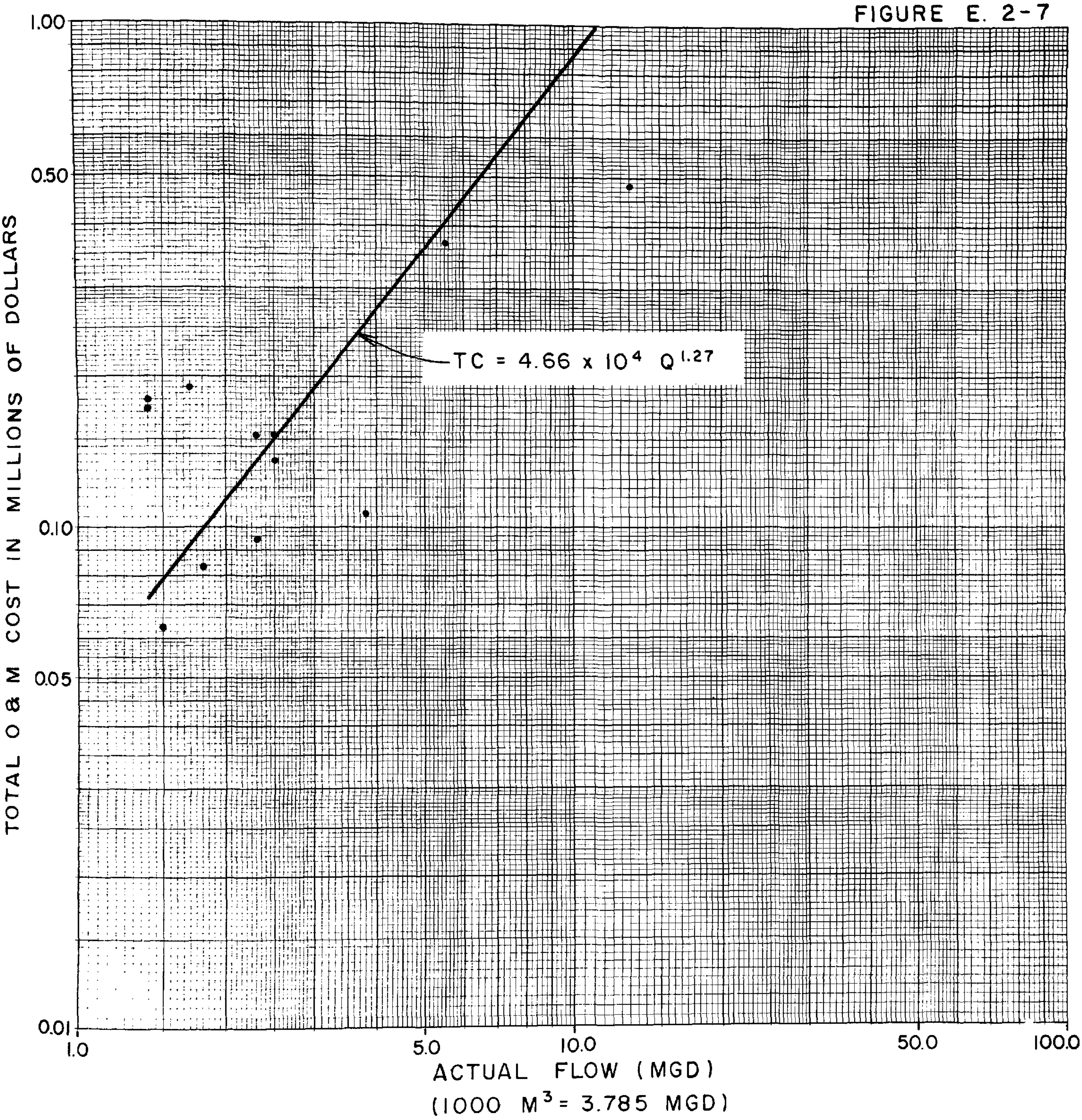
TOTAL O & M COST VS. ACTUAL FLOW SECONDARY TREATMENT-TRICKLING FILTER EPA REGION III

FIGURE E. 2-6



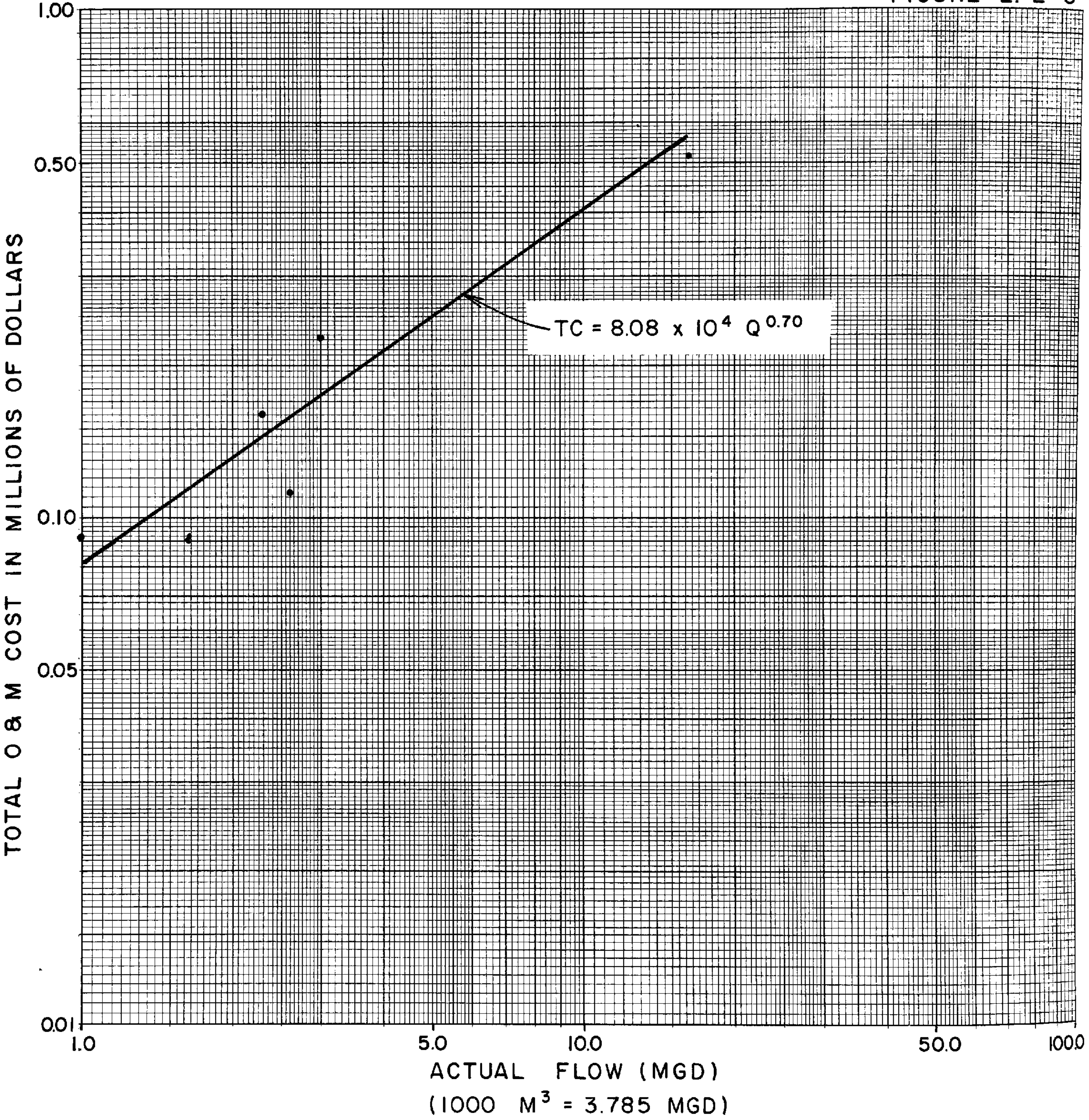
TOTAL O & M COST VS. ACTUAL FLOW
SECONDARY TREATMENT- TRICKLING FILTER
EPA REGION IV

FIGURE E. 2-7



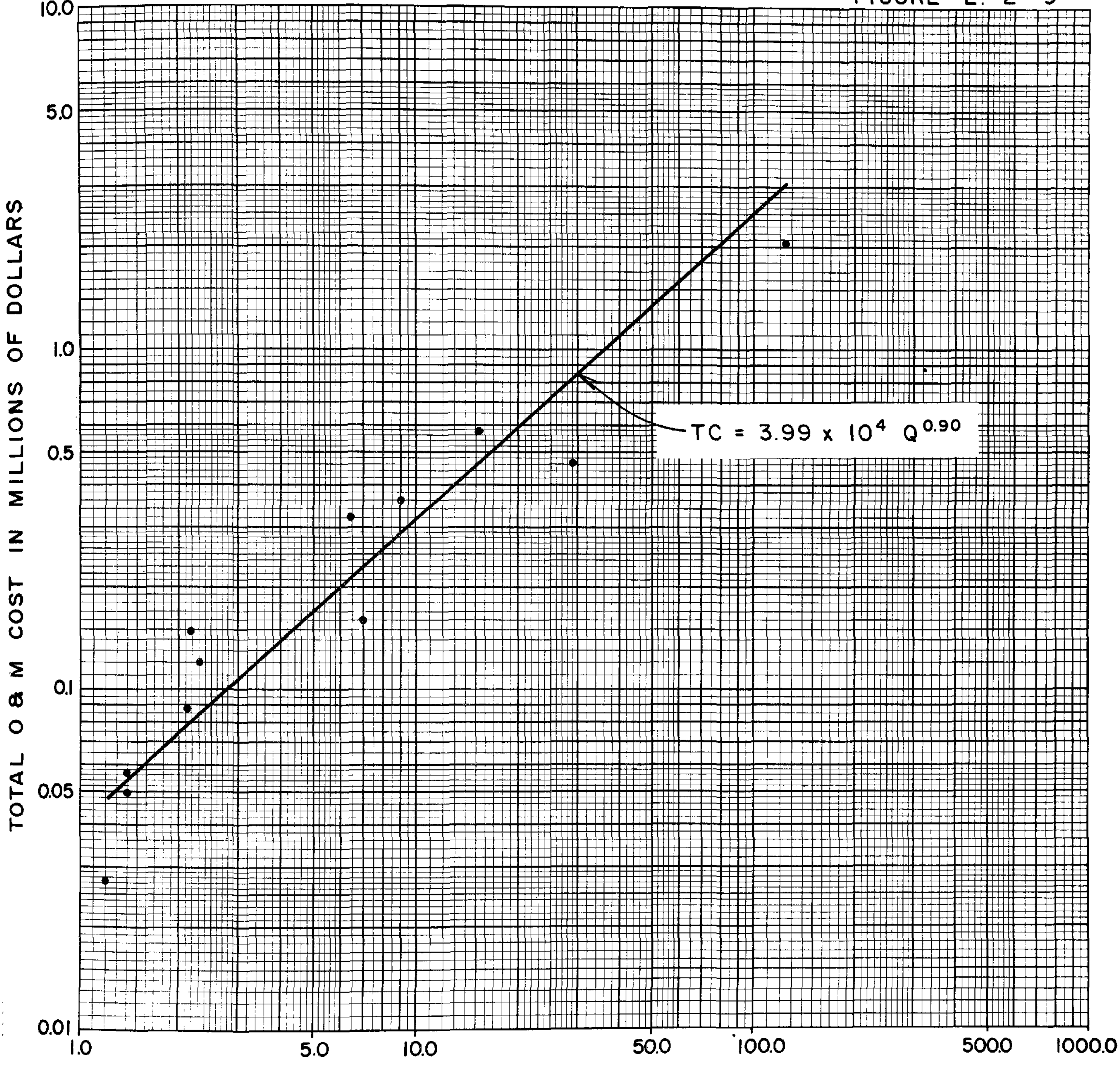
TOTAL O & M COST VS. ACTUAL FLOW
SECONDARY TREATMENT- TRICKLING FILTER
EPA REGION V

FIGURE E. 2-8



TOTAL O & M COST VS. ACTUAL FLOW
SECONDARY TREATMENT-TRICKLING FILTER
EPA REGION VI

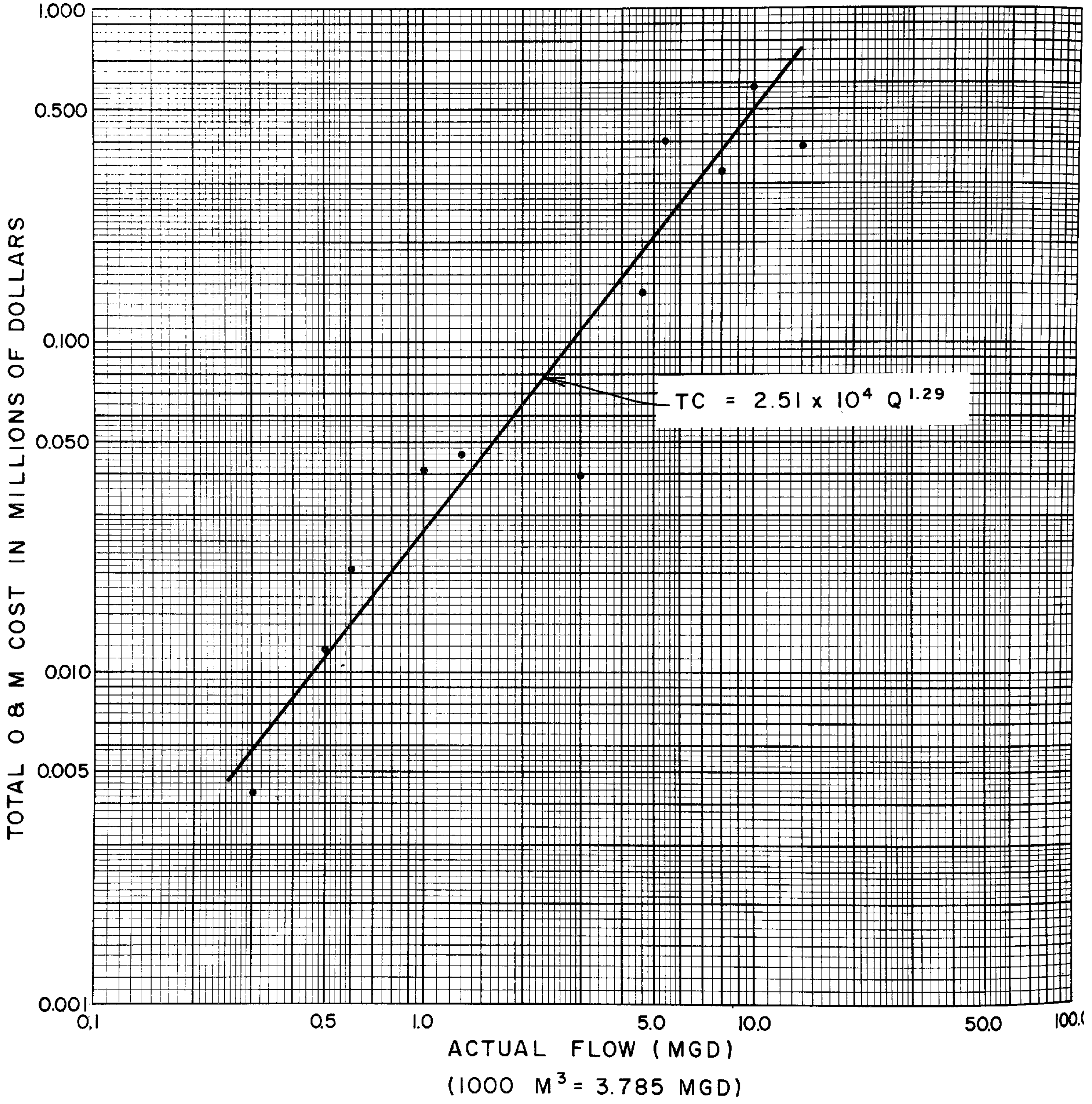
FIGURE E. 2-9



(1000 M^3 = 3.785 MGD)

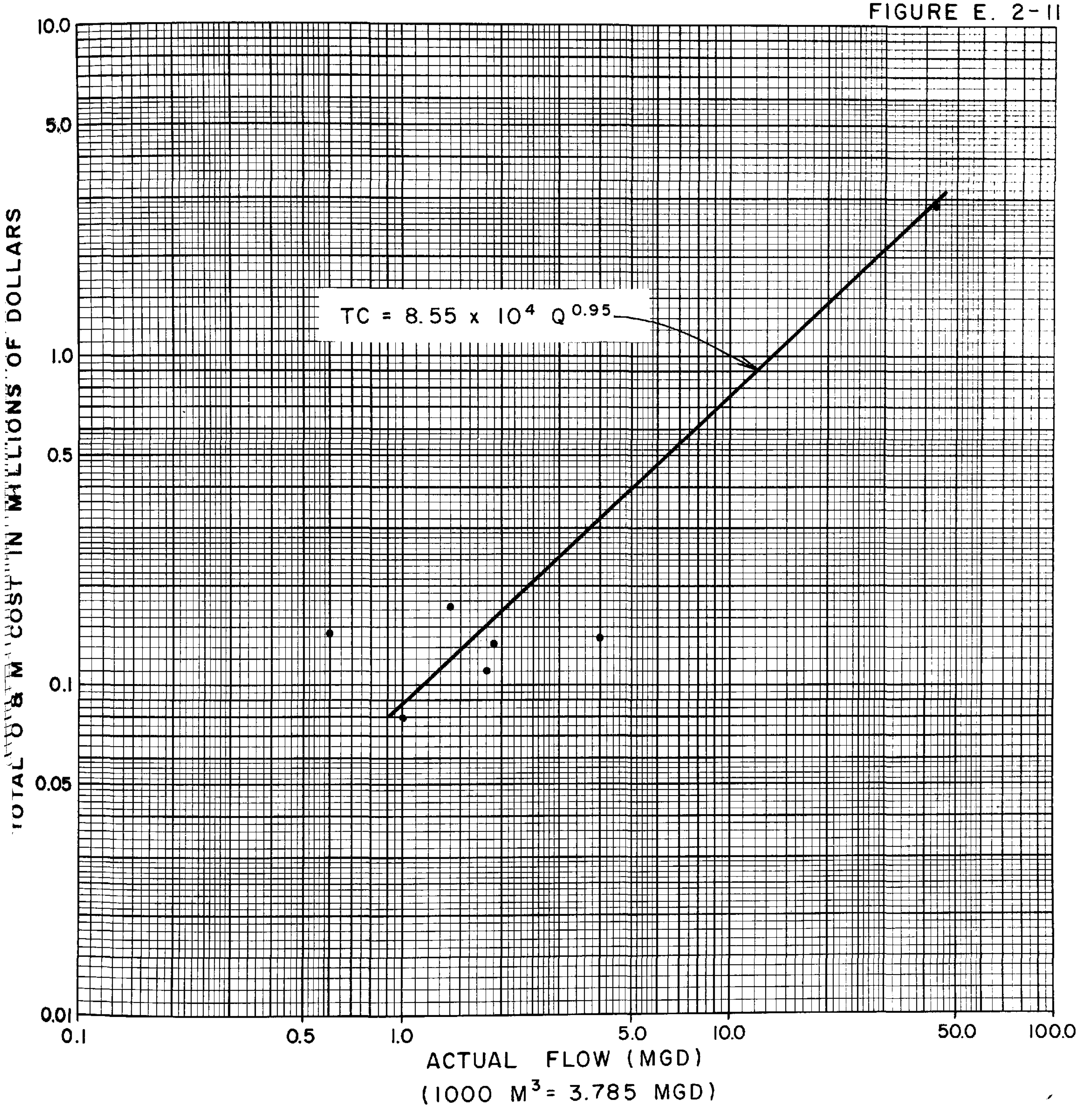
TOTAL O & M COST VS. ACTUAL FLOW
SECONDARY TREATMENT-TRICKLING FILTER
EPA REGION VIII

FIGURE E. 2-10



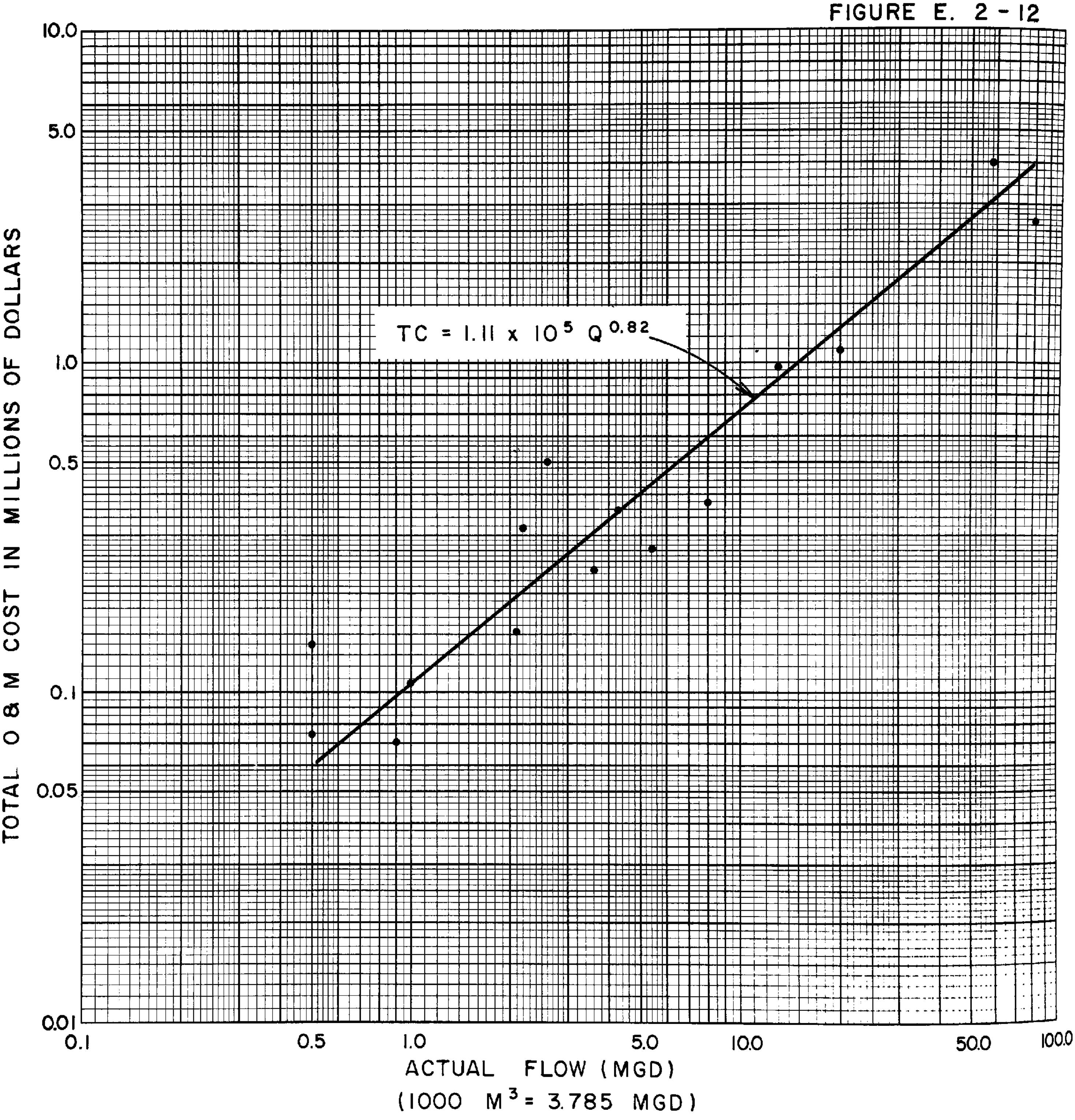
TOTAL O & M COST VS. ACTUAL FLOW
SECONDARY TREATMENT - TRICKLING FILTER
EPA REGION IX

FIGURE E. 2-11



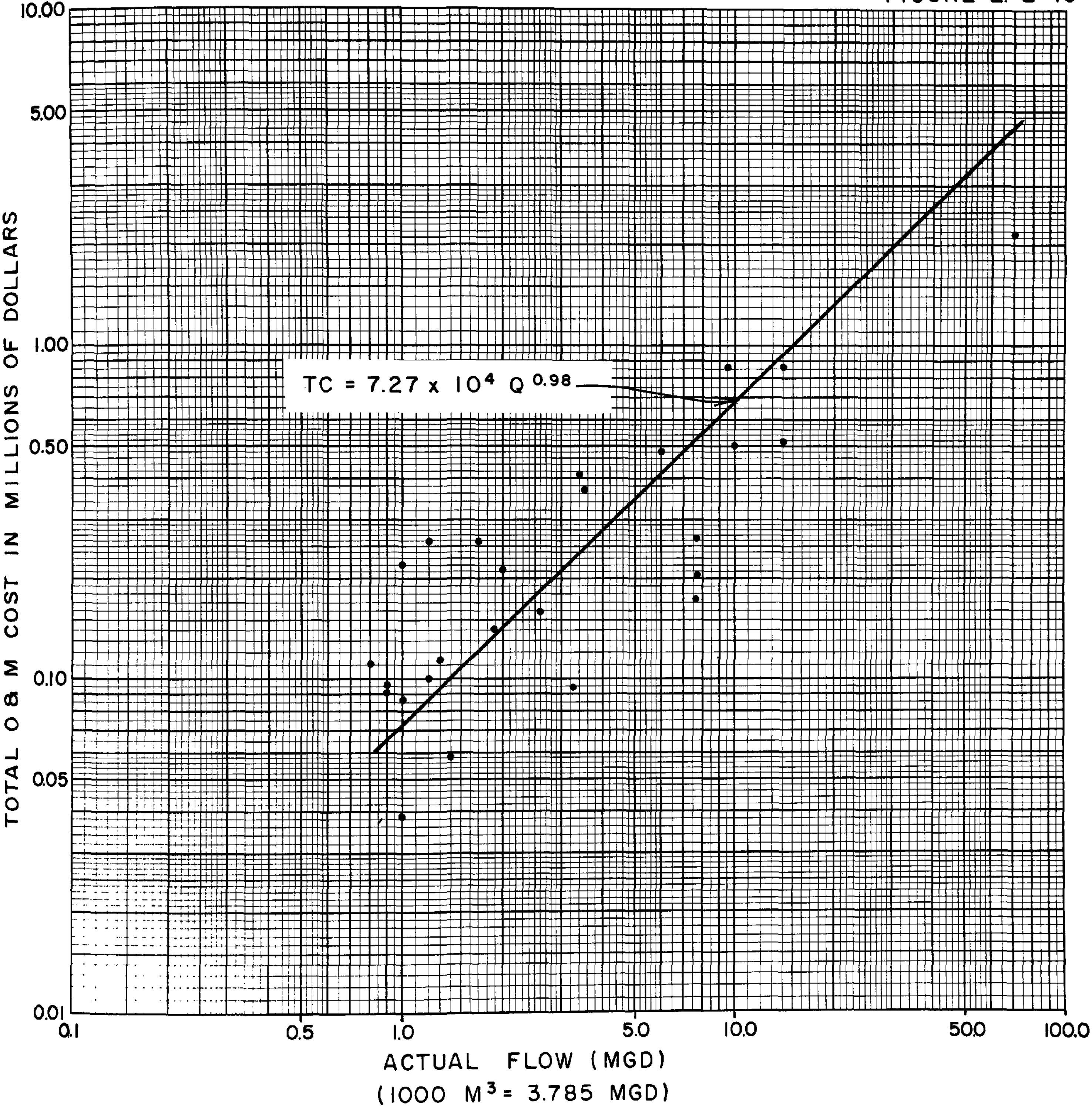
TOTAL O & M COST VS. ACTUAL FLOW
SECONDARY TREATMENT-ACTIVATED SLUDGE
EPA REGION II

FIGURE E. 2 - 12



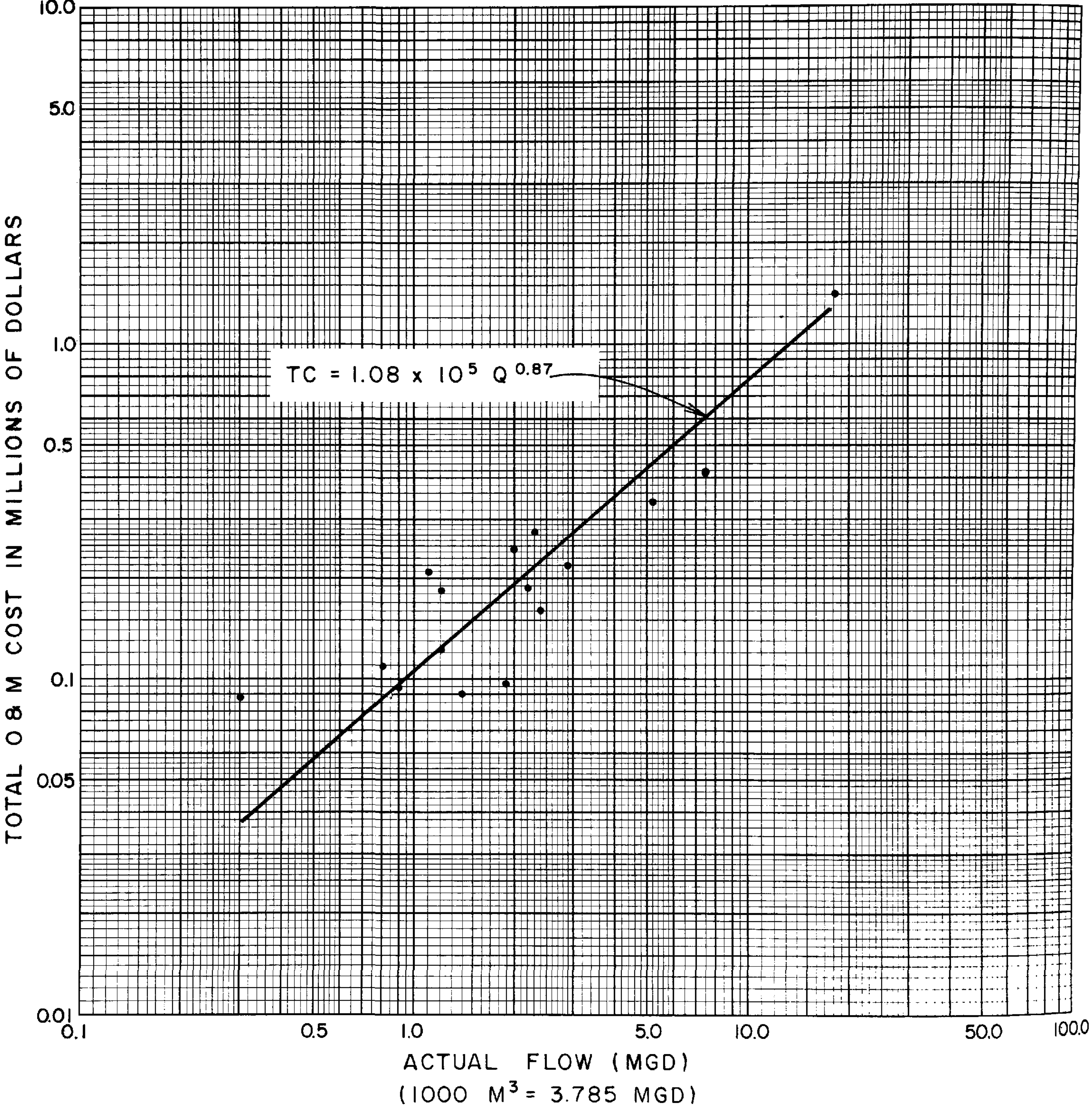
TOTAL O & M COST VS. ACTUAL FLOW SECONDARY TREATMENT-ACTIVATED SLUDGE EPA REGION IV

FIGURE E. 2-13



TOTAL O & M COST VS. ACTUAL FLOW SECONDARY TREATMENT-ACTIVATED SLUDGE EPA REGION III

FIGURE E. 2-14



TOTAL O & M COST VS ACTUAL FLOW
SECONDARY TREATMENT-ACTIVATED SLUDGE
EPA REGION V

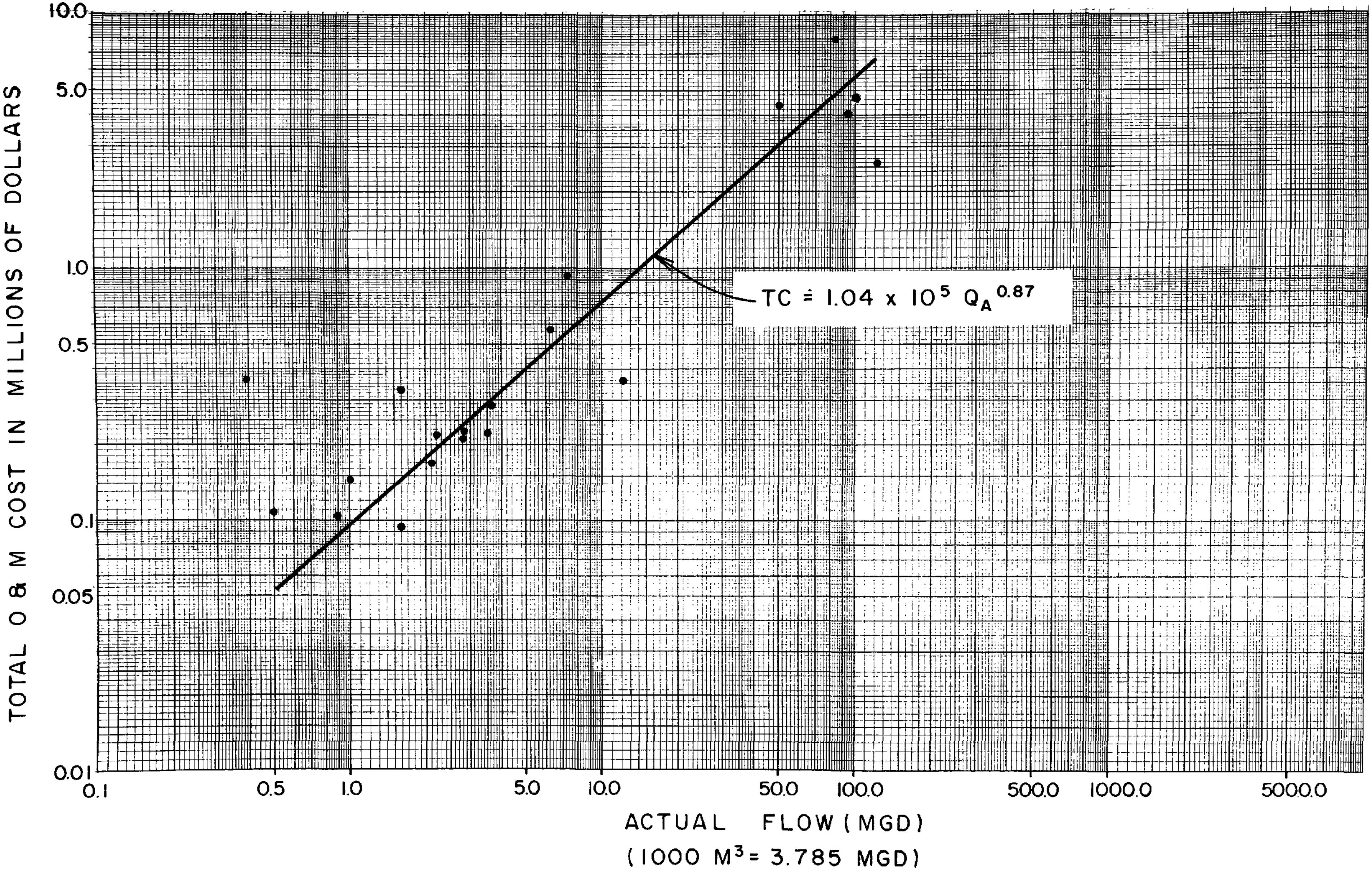
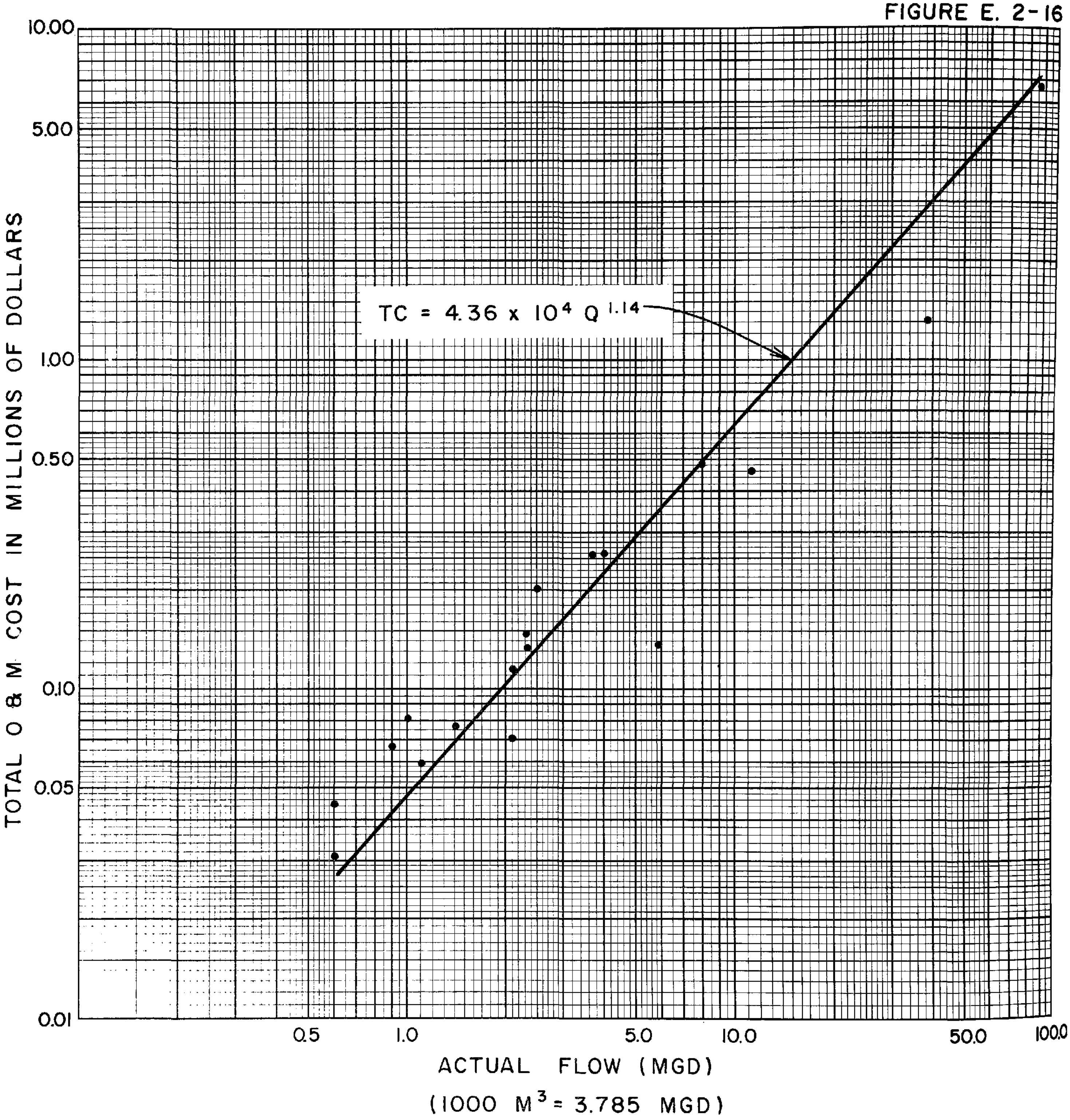


FIGURE E.2-15

TOTAL O & M COST VS. ACTUAL FLOW
SECONDARY TREATMENT-ACTIVATED SLUDGE
EPA REGION VI

FIGURE E. 2-16



TOTAL O & M COST VS. ACTUAL FLOW
SECONDARY TREATMENT-ACTIVATED SLUDGE
EPA REGION X

FIGURE E. 2-17

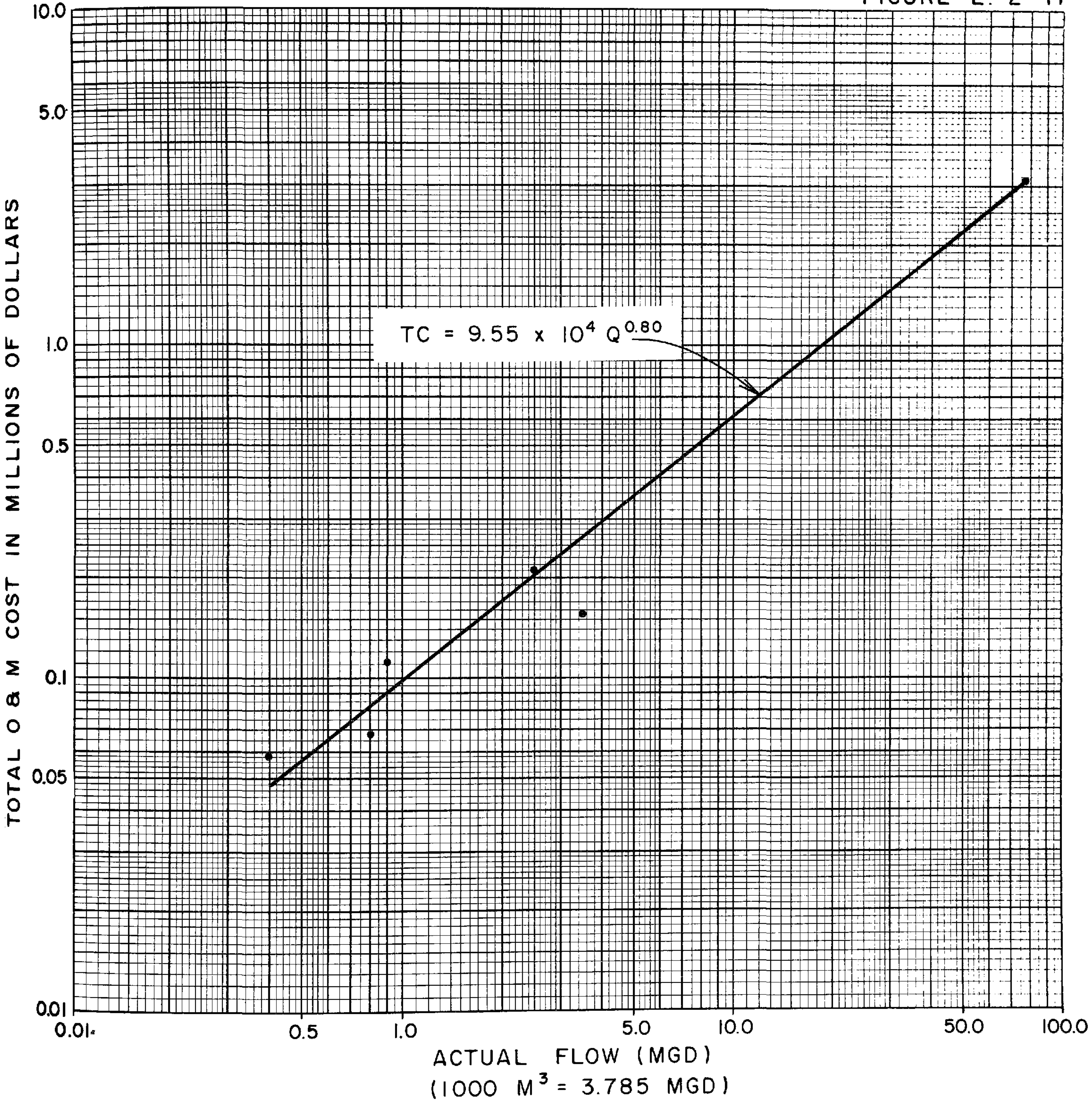


TABLE E.3

POTENTIALLY SIGNIFICANT O&M RELATIONSHIPS
TOTAL O&M COSTS VS STAFF SIZE

Title	Equation	Sample Size (n)	Correlation Coefficient (r)	F-Test Value
Primary Treatment National	$TC = 2.06 \times 10^4 S^{1.10}$	56	0.85	145.31
Trickling Filter (TF), National	$TC = 1.63 \times 10^4 S^{1.19}$	72	0.86	199.19
Activated Sludge (AS), National	$TC = 1.85 \times 10^4 S^{1.19}$	140	0.91	693.14
AWT, National	$TC = 3.32 \times 10^4 S^{1.02}$	30	0.97	464.19
Primary Region IV	$TC = 2.01 \times 10^4 S^{1.08}$	11	0.86	25.25
Primary Region V	$TC = 2.20 \times 10^4 S^{0.90}$	8	0.86	17.20
Primary Region IX	$TC = 3.79 \times 10^4 S^{1.08}$	11	0.76	12.27
Primary Region X	$TC = 2.90 \times 10^4 S^{0.97}$	7	0.90	21.38
TF, Region II	$TC = 3.35 \times 10^4 S^{1.02}$	9	0.93	47.31
TF, Region III	$TC = 1.39 \times 10^4 S^{1.35}$	7	0.86	14.70
TF, Region V	$TC = 3.41 \times 10^4 S^{0.83}$	5	0.99	125.76
TF, Region VI	$TC = 1.67 \times 10^4 S^{1.16}$	12	0.90	43.53
TF, Region VIII	$TC = 1.85 \times 10^4 S^{1.09}$	8	0.94	45.16
TF, Region IX	$TC = 3.35 \times 10^4 S^{1.11}$	7	0.94	40.18
AS, Region I	$TC = 6.20 \times 10^3 S^{1.73}$	11	0.85	22.67
AS, Region II	$TC = 1.99 \times 10^4 S^{1.15}$	15	0.98	304.45

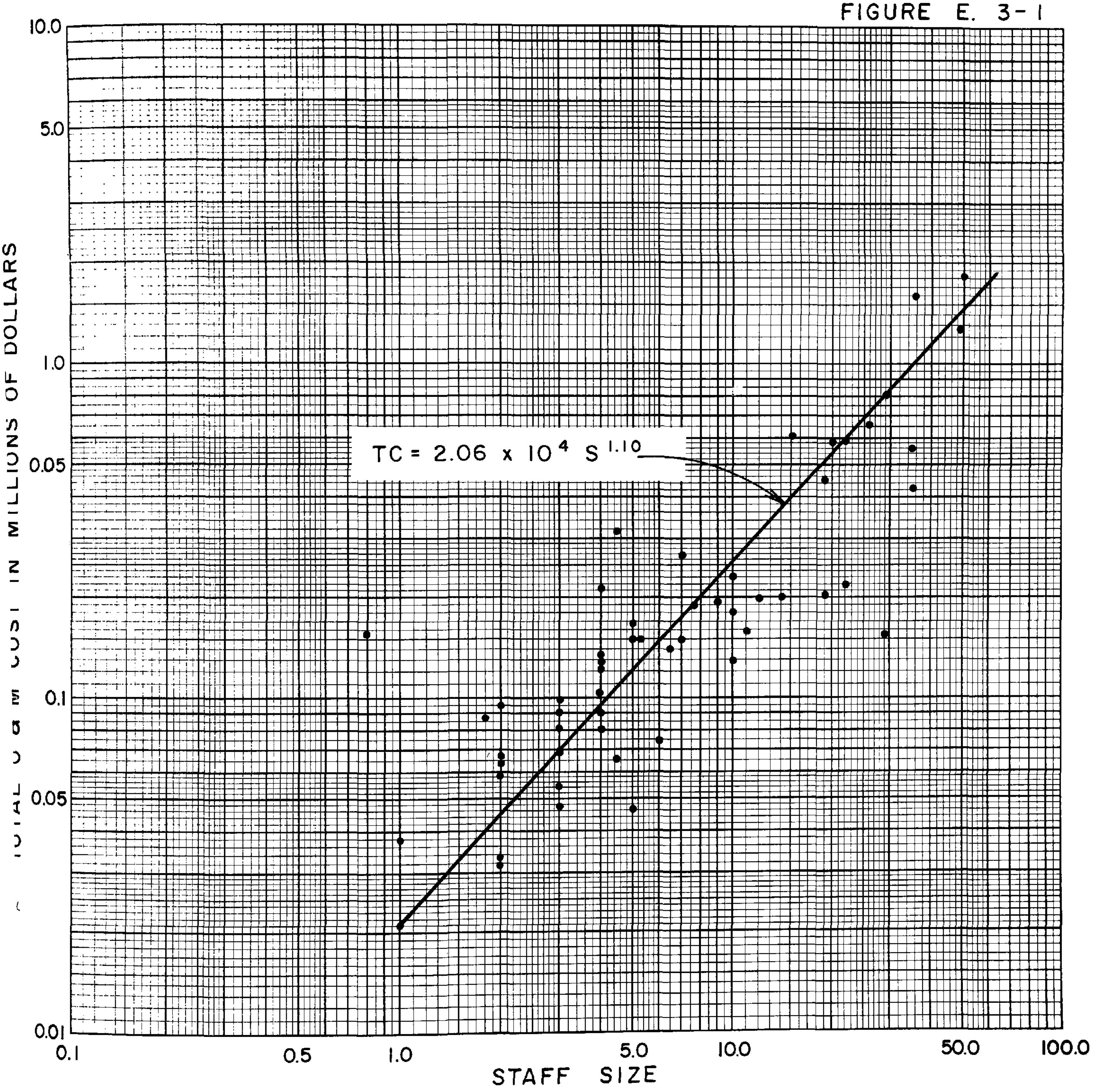
TABLE E.3 (Concluded)

Title	Equation	Sample Size (n)	Correlation Coefficient (r)	F-Test Value
AS, Region III	$TC = 1.61 \times 10^4 S^{1.20}$	16	0.82	28.17
AS, Region IV	$TC = 2.08 \times 10^4 S^{1.08}$	26	0.89	91.28
AS, Region V	$TC = 3.04 \times 10^4 S^{1.05}$	17	0.96	175.64
AS, Region VI	$TC = 1.04 \times 10^4 S^{1.36}$	18	0.90	72.17
AS, Region VIII	$TC = 2.76 \times 10^4 S^{1.10}$	6	0.95	34.81
AS, Region IX	$TC = 4.42 \times 10^3 S^{2.16}$	14	0.87	37.24
AS, Region X	$TC = 2.39 \times 10^4 S^{1.01}$	6	0.99	202.55
AWT, Region II	$TC = 1.73 \times 10^4 S^{1.23}$	5	0.99	167.65
AWT, Region V	$TC = 3.01 \times 10^4 S^{1.03}$	9	0.91	32.73
AWT, Region IX	$TC = 4.38 \times 10^4 S^{1.00}$	7	0.97	83.99

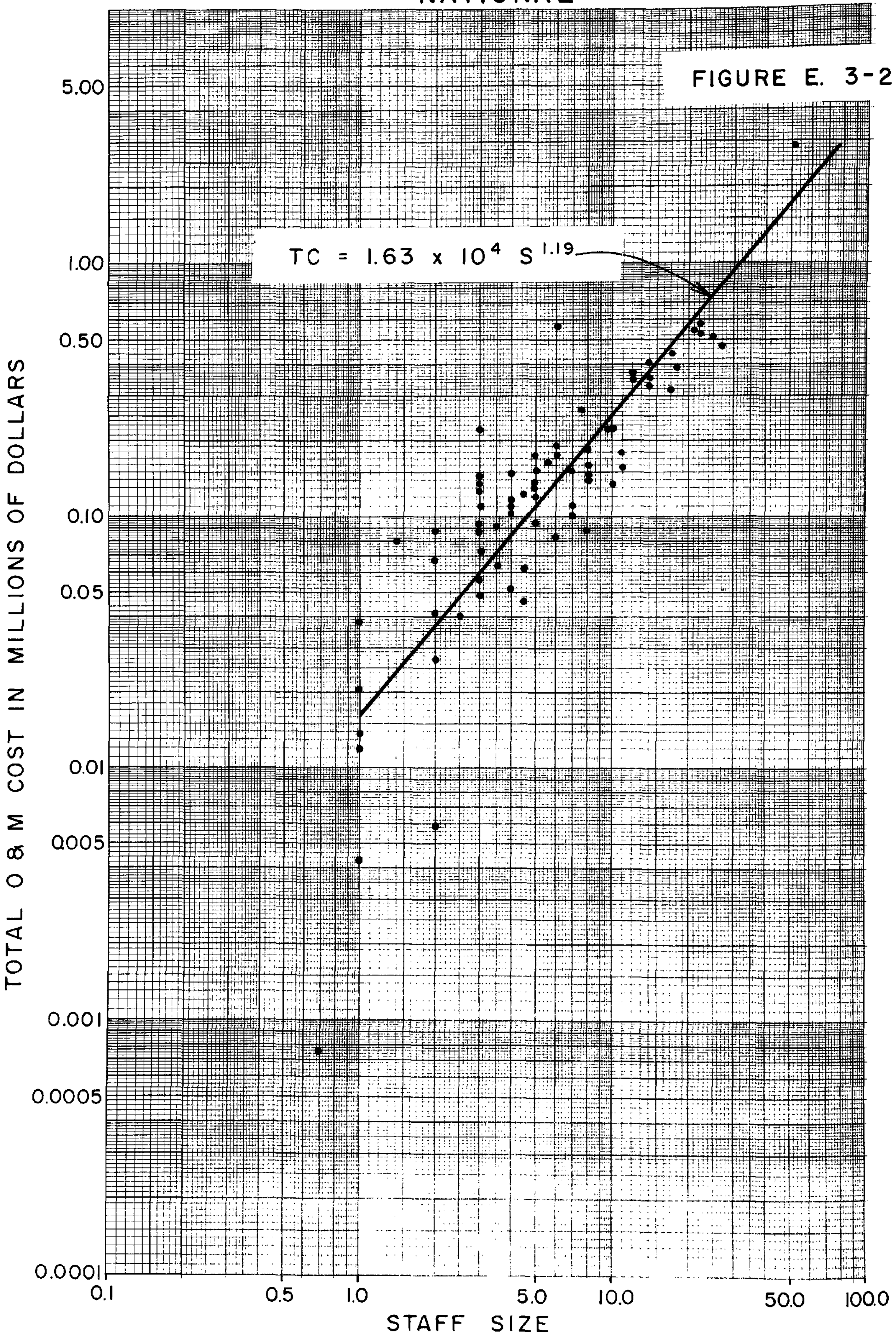
Where TC equals total O&M cost in dollars and
S equals the size of the staff at the wastewater treatment plant.

TOTAL O & M COST VS. STAFF SIZE
PRIMARY TREATMENT
NATIONAL

FIGURE E. 3-1

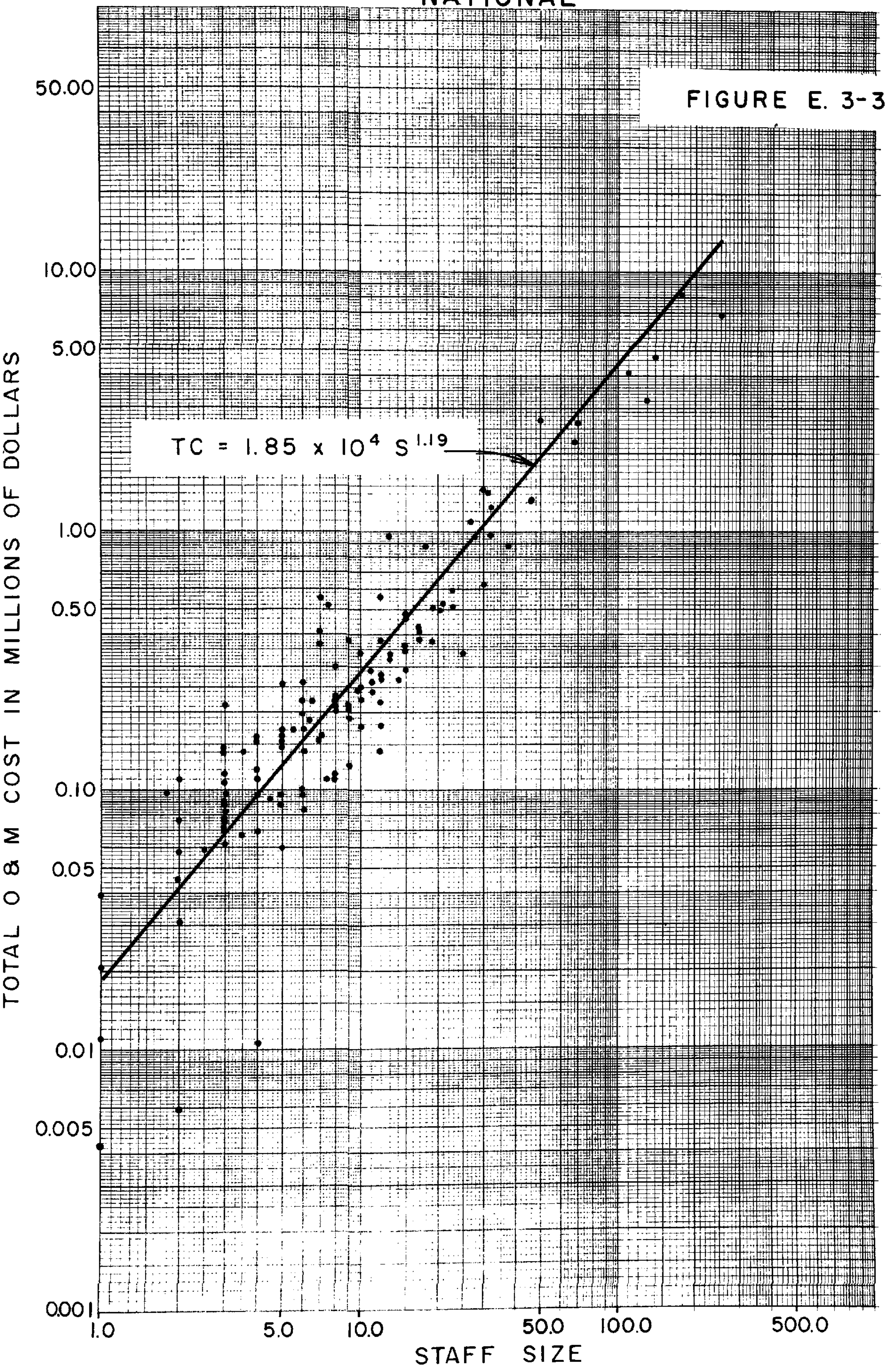


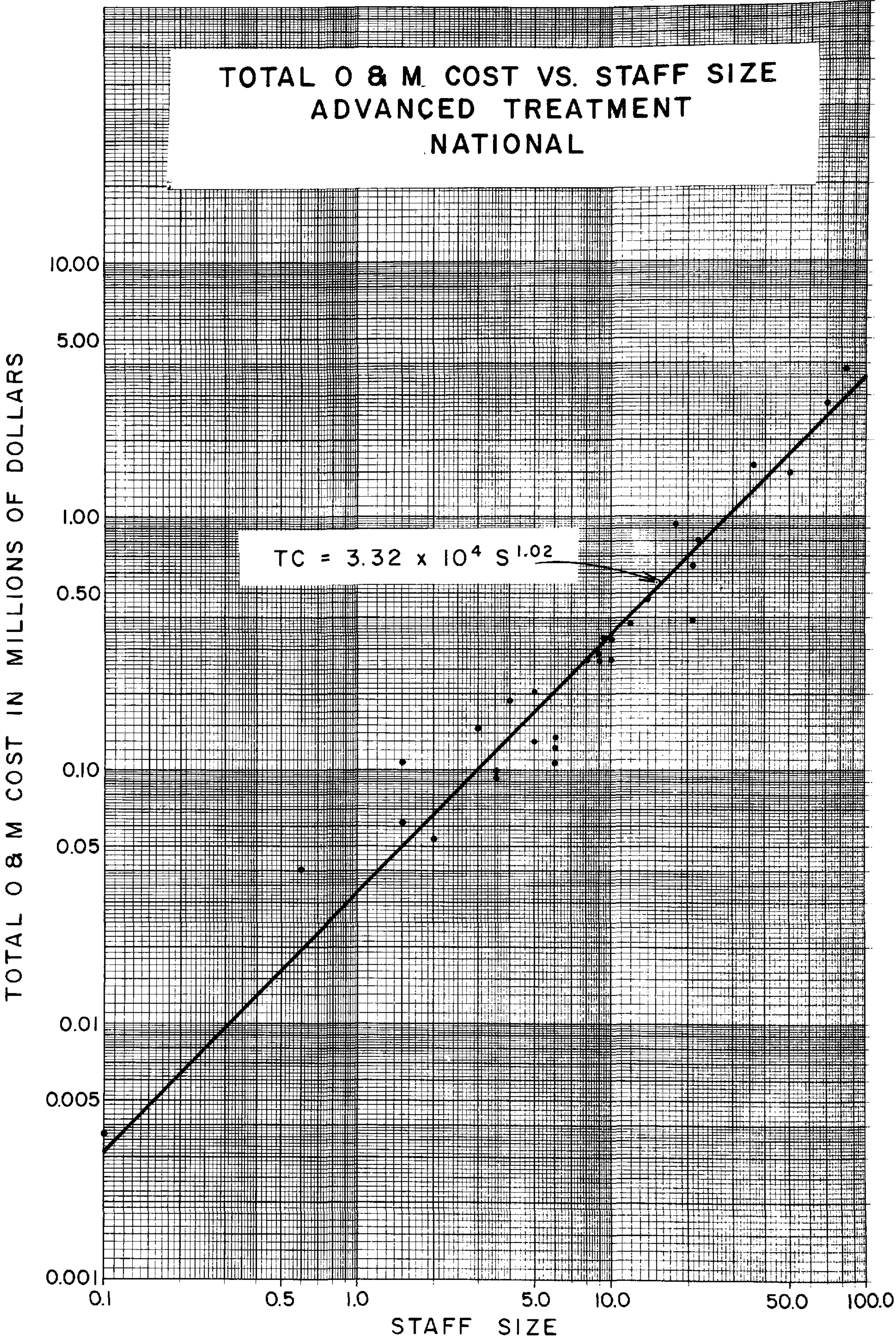
TOTAL O & M COST VS. STAFF SIZE SECONDARY TREATMENT - TRICKLING FILTER NATIONAL



TOTAL O & M COST VS. STAFF SIZE
SECONDARY TREATMENT-ACTIVATED SLUDGE
NATIONAL

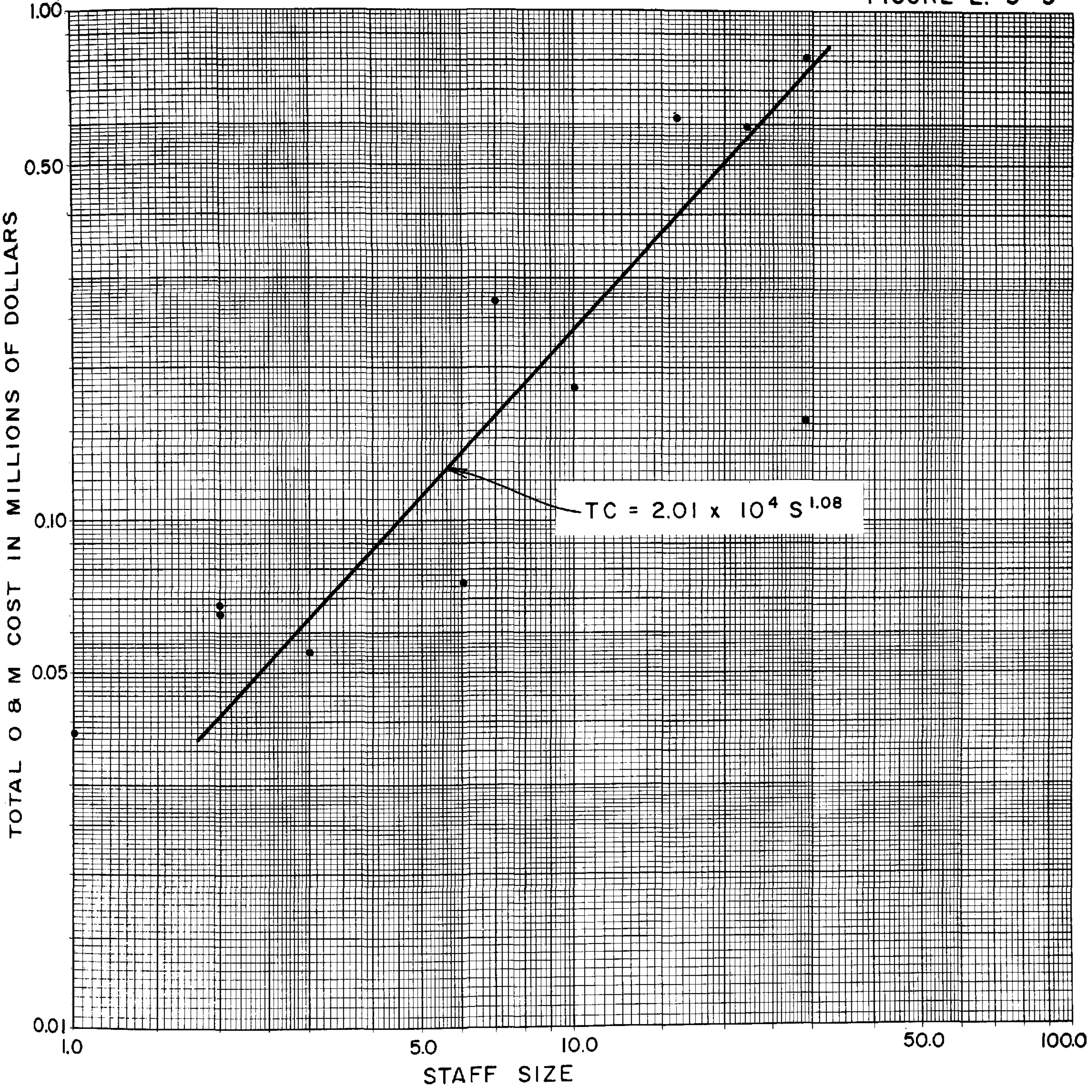
FIGURE E. 3-3




TOTAL O & M COST VS. STAFF SIZE
ADVANCED TREATMENT
NATIONAL
TC = 3.32 x 10^4 S^1.02
TOTAL O & M COST IN MILLIONS OF DOLLARS
10.00
5.00
1.00
0.50
0.10
0.05
0.01
0.005
0.001
STAFF SIZE
0.1
0.5
1.0
5.0
10.0
50.0
100.0

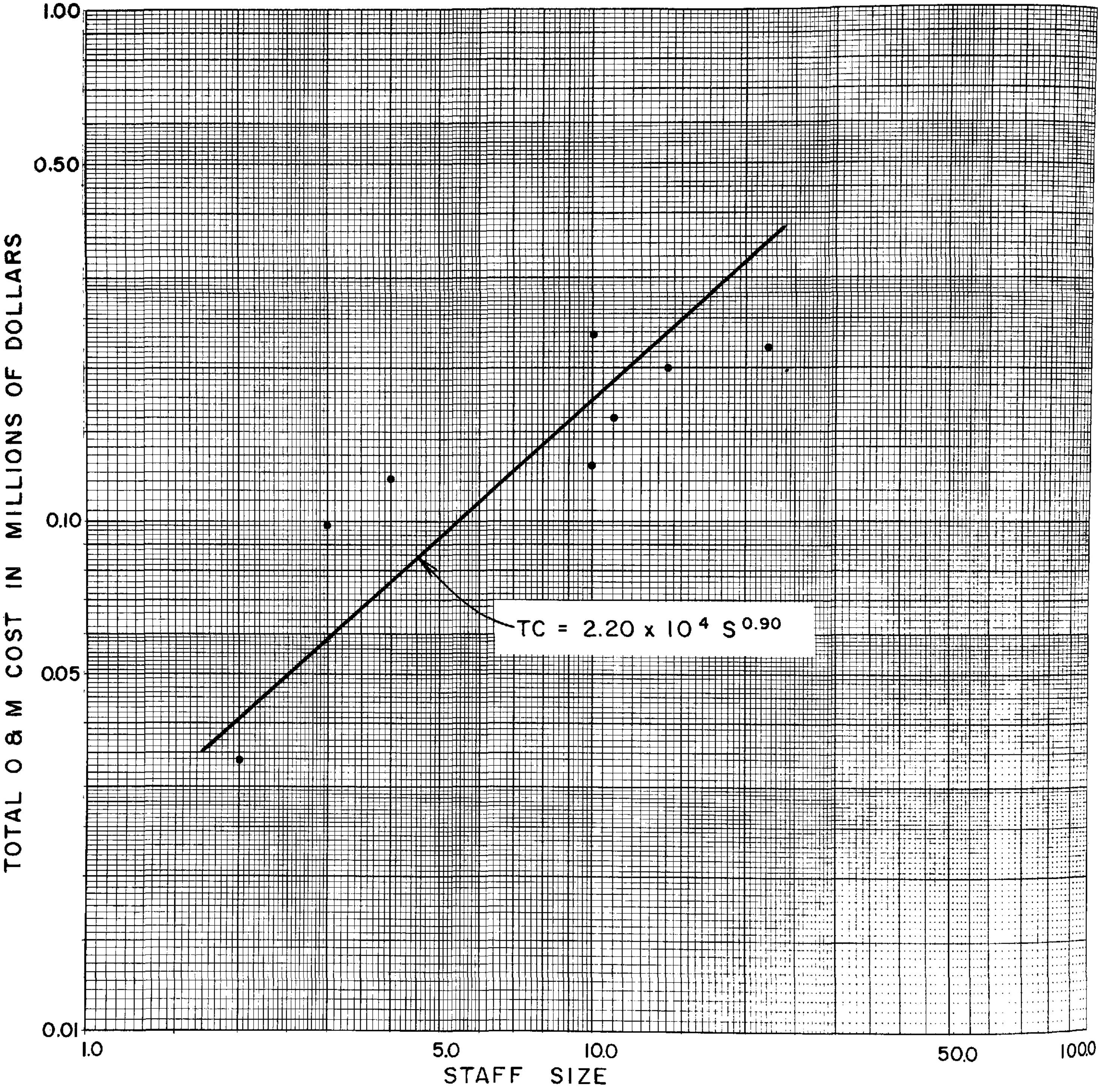
TOTAL O & M COST VS. STAFF SIZE
PRIMARY TREATMENT
EPA REGION IV

FIGURE E. 3-5



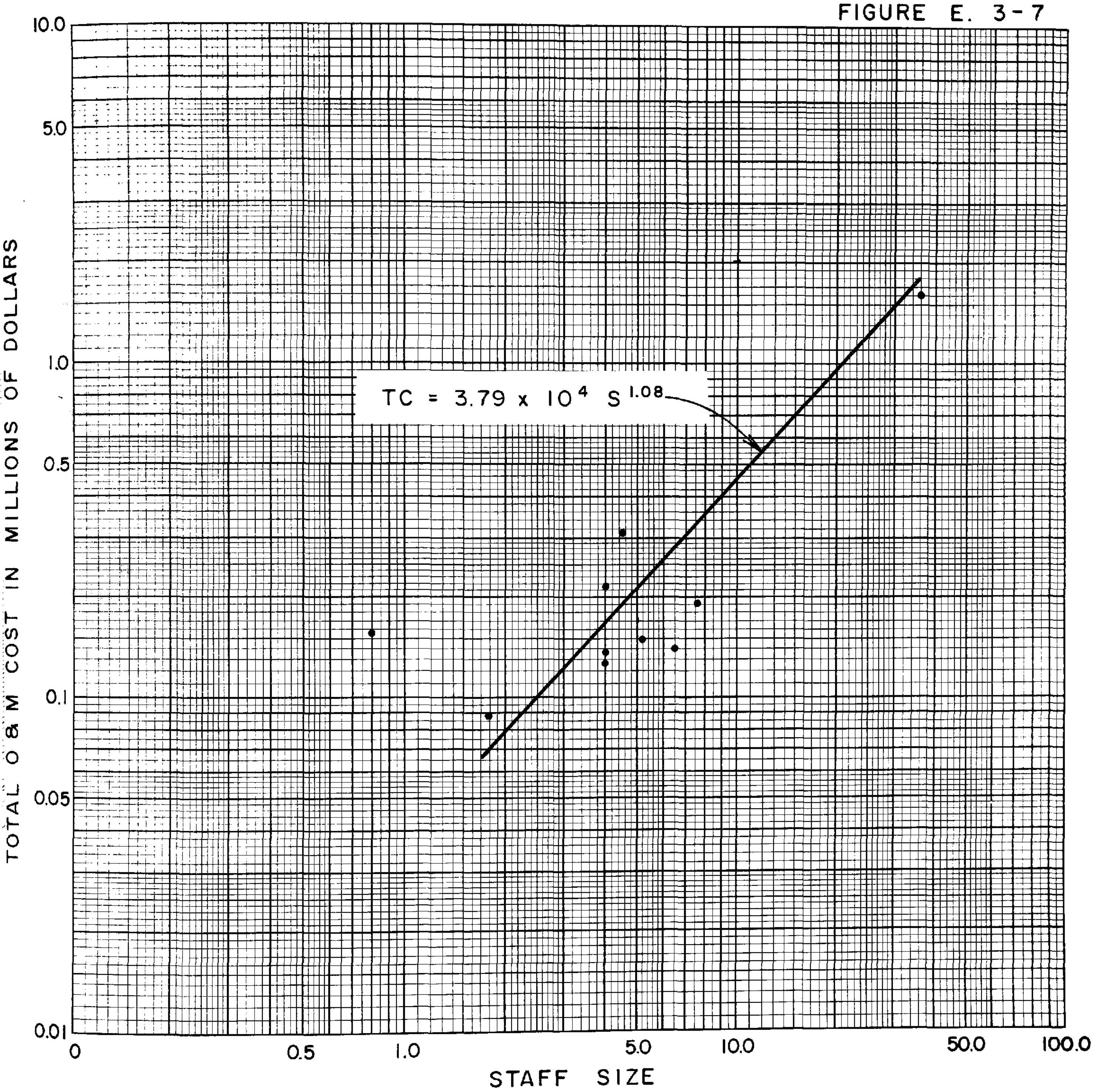
TOTAL O & M COST VS. STAFF SIZE
PRIMARY TREATMENT
EPA REGION V

FIGURE E. 3-6



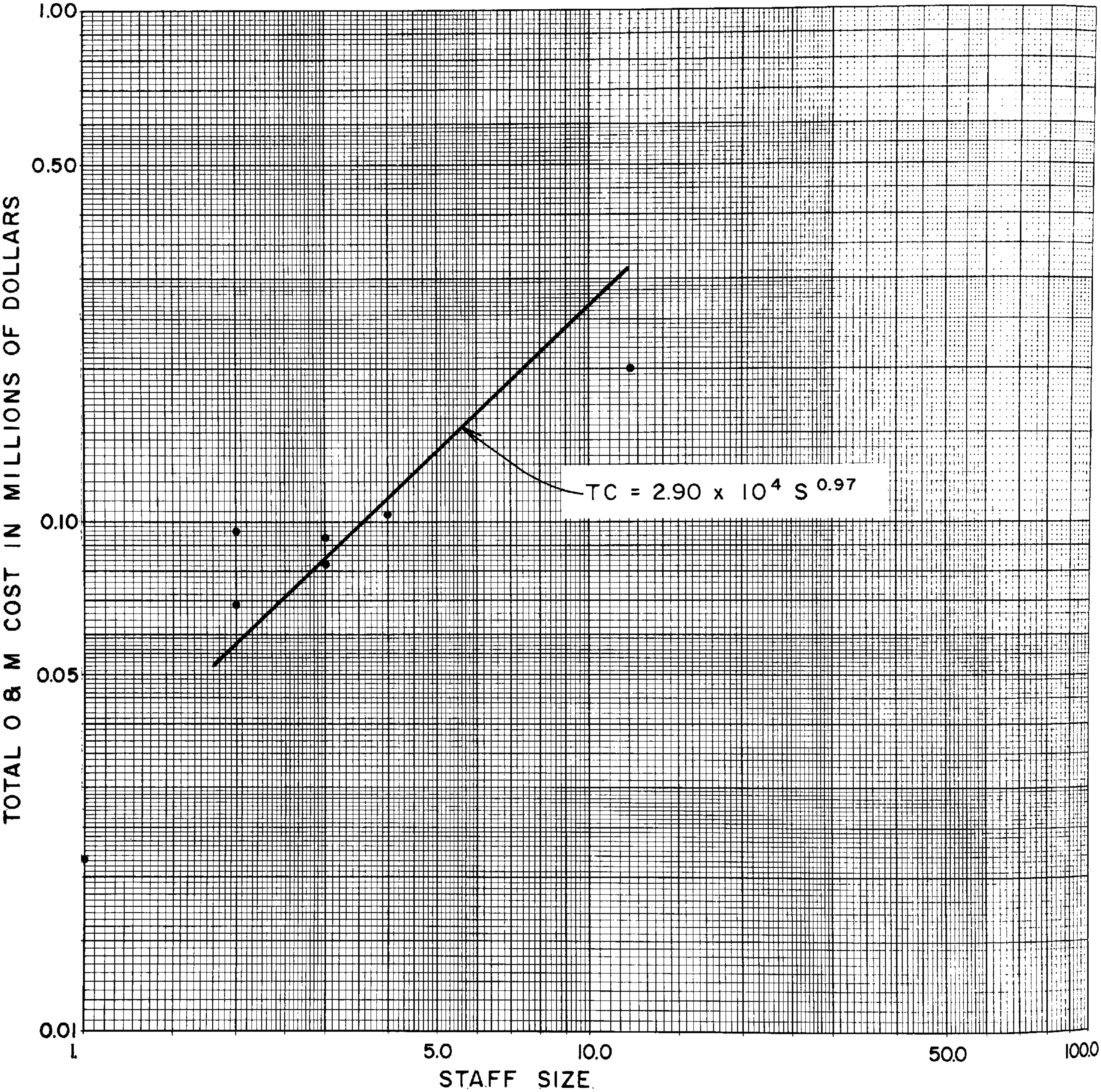
TOTAL O & M COST VS. STAFF SIZE
PRIMARY TREATMENT
EPA REGION IX

FIGURE E. 3-7



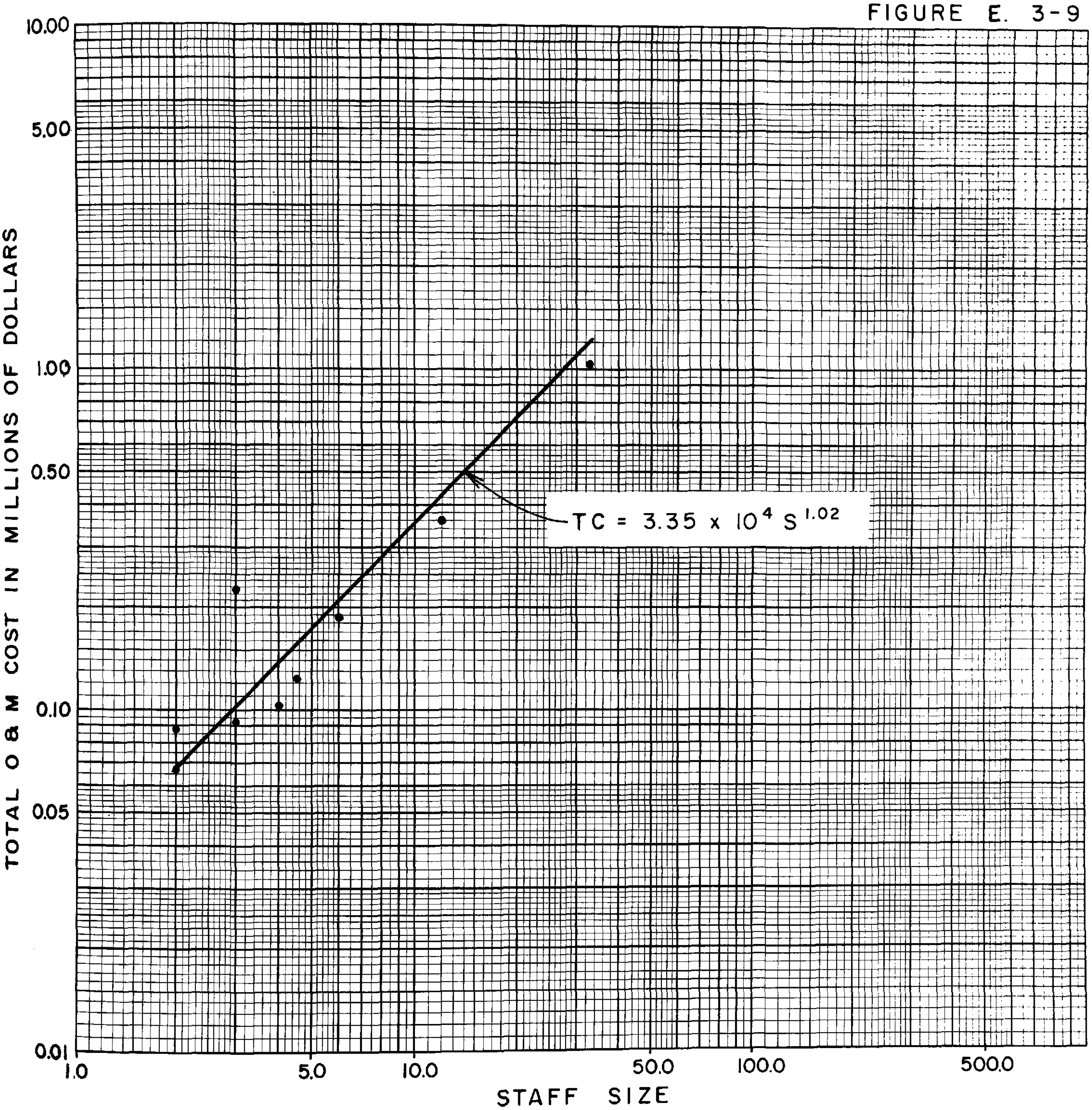
TOTAL O & M COST VS. STAFF SIZE
PRIMARY TREATMENT
EPA REGION X

FIGURE E. 3-8



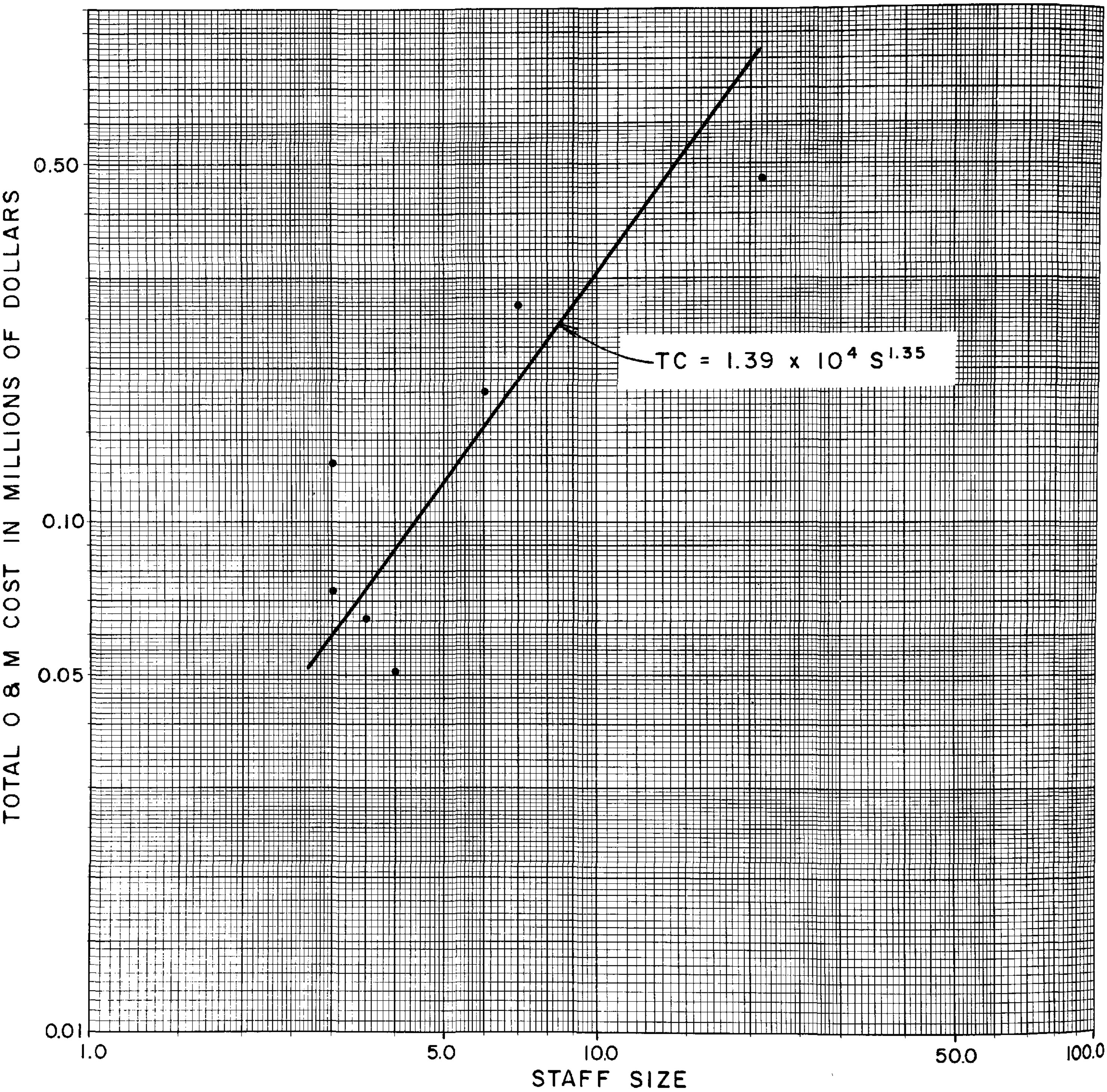
TOTAL O & M COST VS STAFF SIZE
SECONDARY TREATMENT - TRICKLING FILTER
EPA REGION II

FIGURE E. 3-9



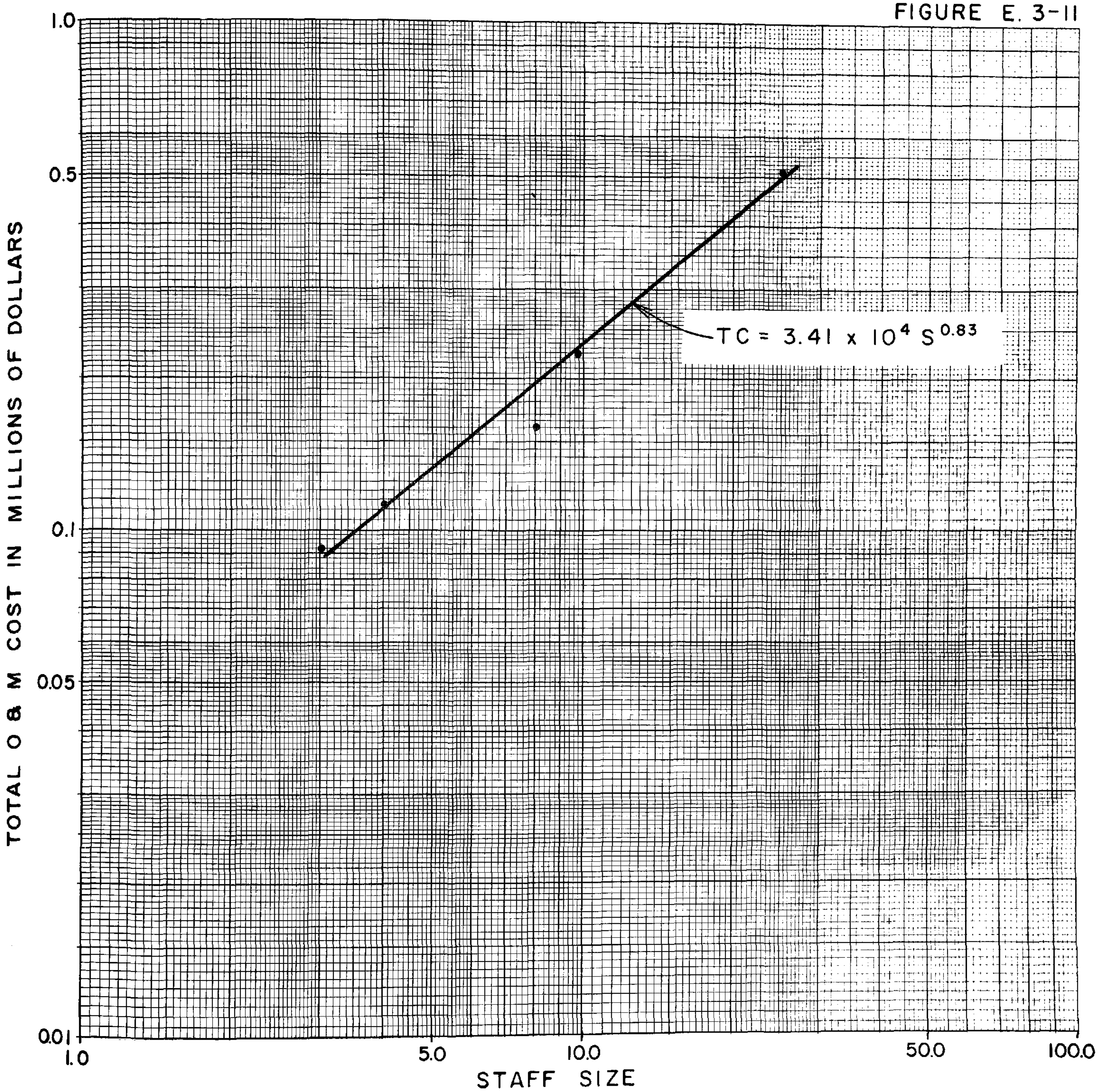
TOTAL O & M COST VS. STAFF SIZE
SECONDARY TREATMENT-TRICKLING FILTER
EPA REGION III

FIGURE E. 3-10



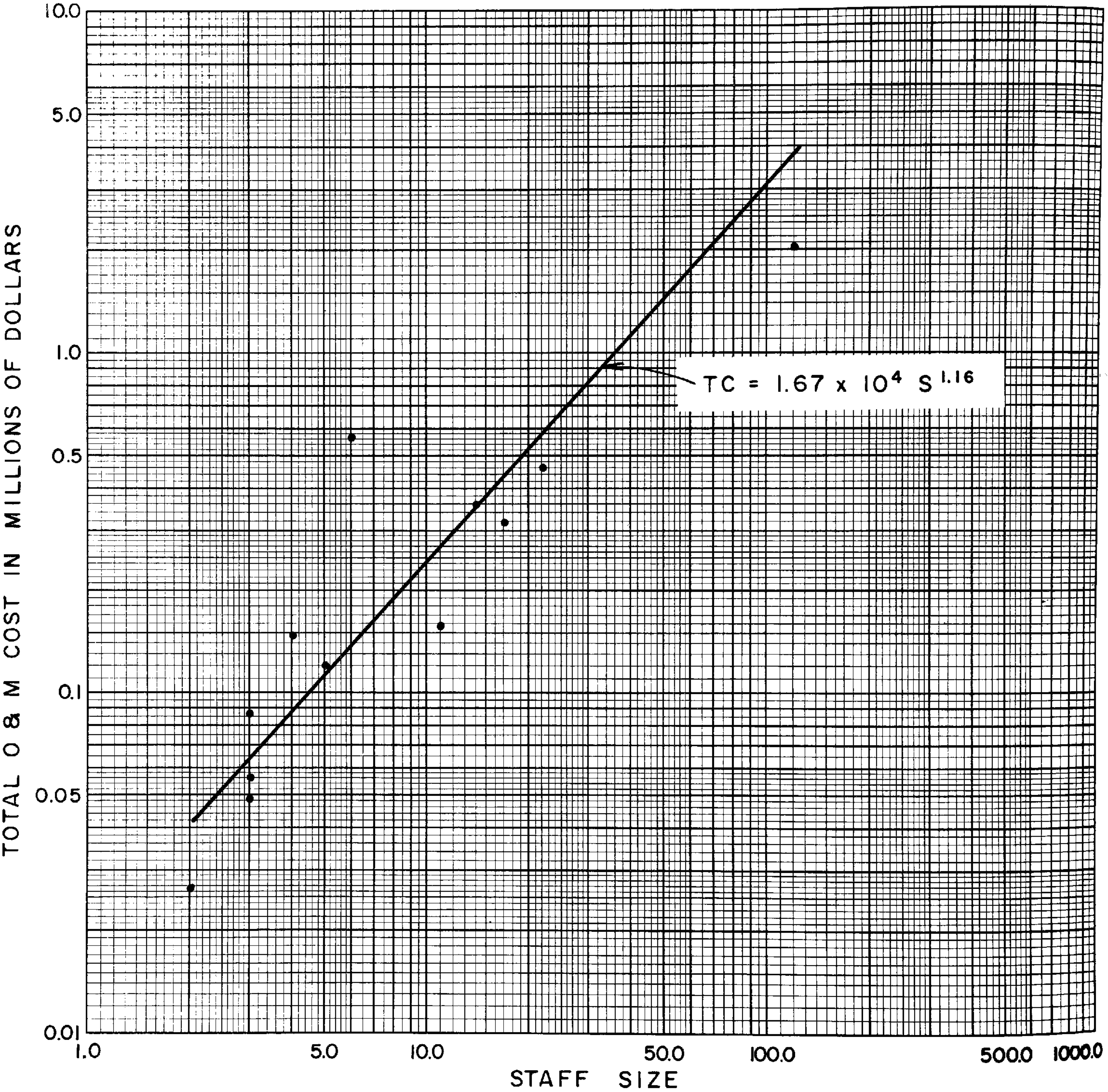
TOTAL O & M COST VS. STAFF SIZE
SECONDARY TREATMENT - TRICKLING FILTER
EPA REGION V

FIGURE E. 3-11



TOTAL O & M COST VS. STAFF SIZE
SECONDARY TREATMENT-TRICKLING FILTER
EPA REGION VI

FIGURE E. 3-12

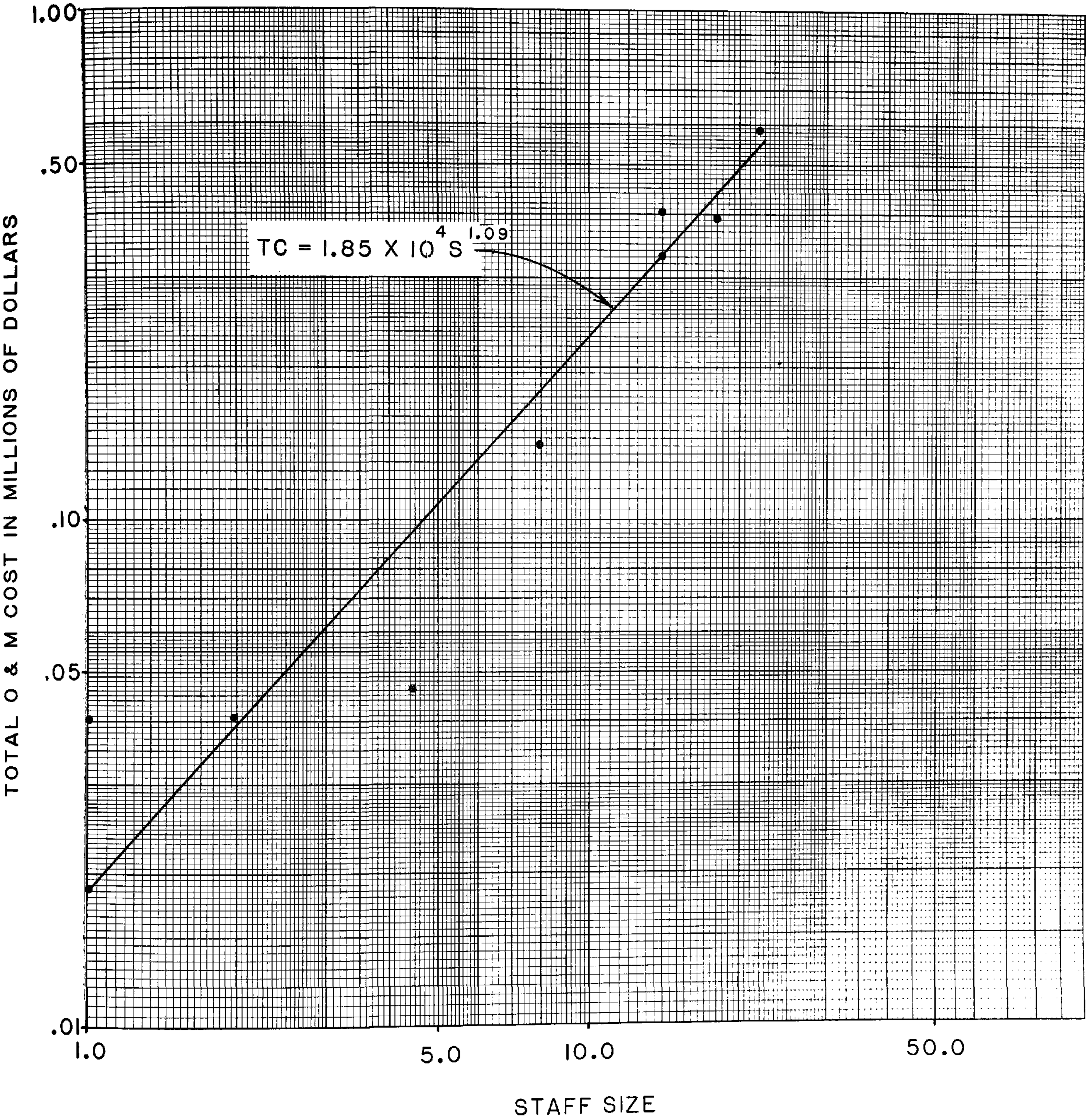


TOTAL O&M COST VS. STAFF SIZE

SECONDARY TREATMENT – TRICKLING FILTER

EPA REGION VIII

FIGURE E. 3-13

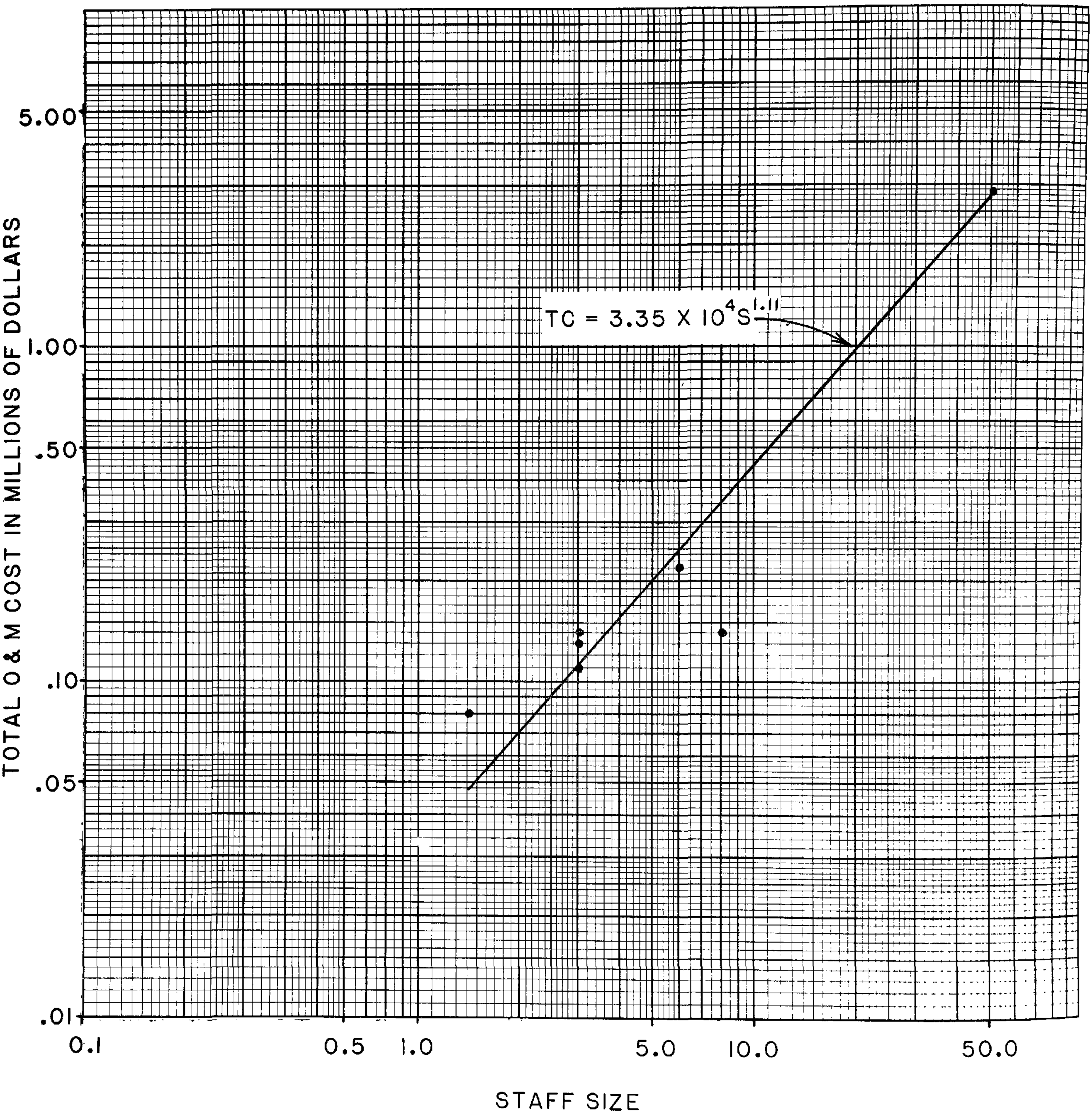


TOTAL O&M COST VS. STAFF SIZE

SECONDARY TREATMENT – TRICKLING FILTER

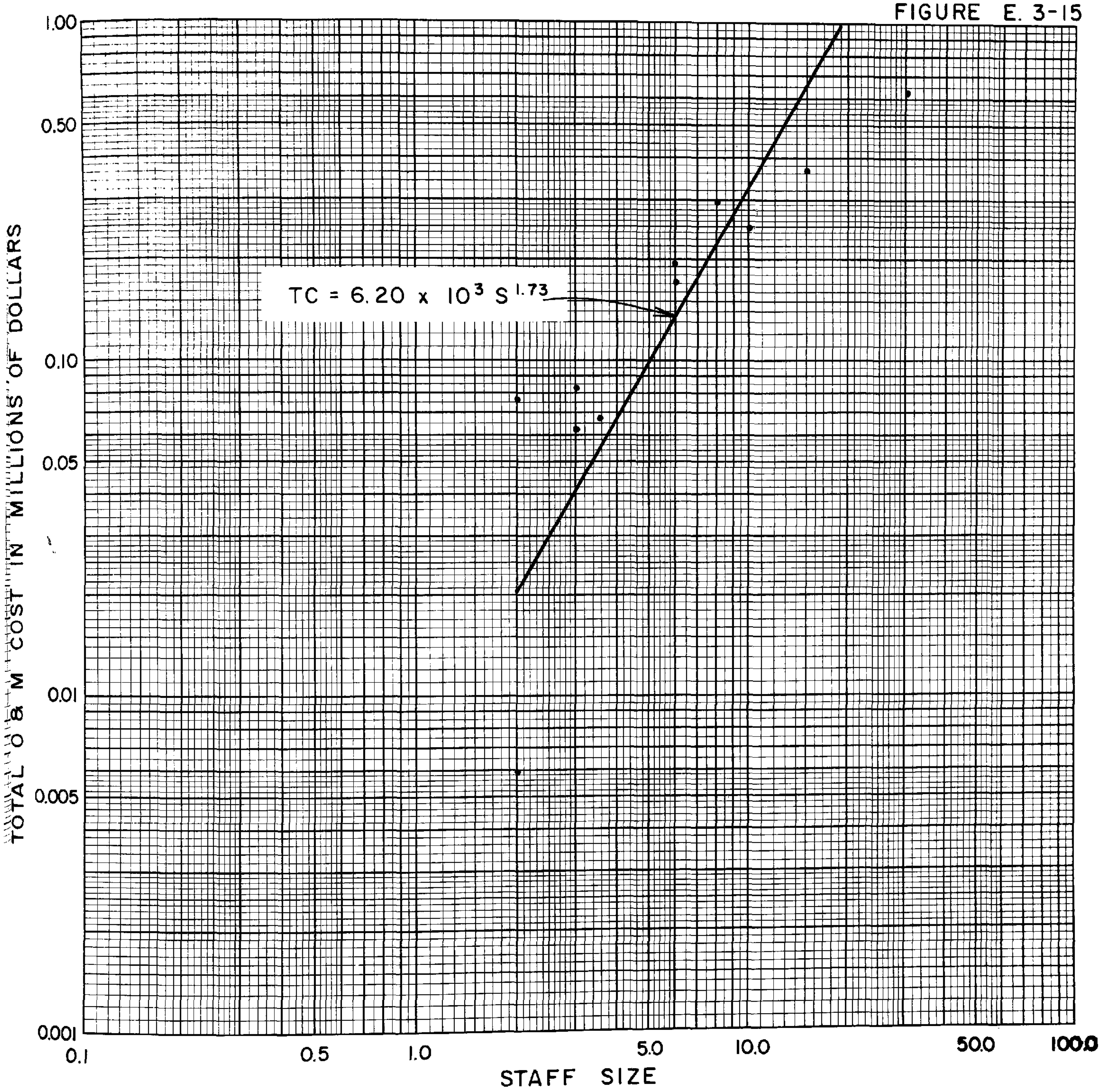
EPA REGION IX

FIGURE E. 3-14



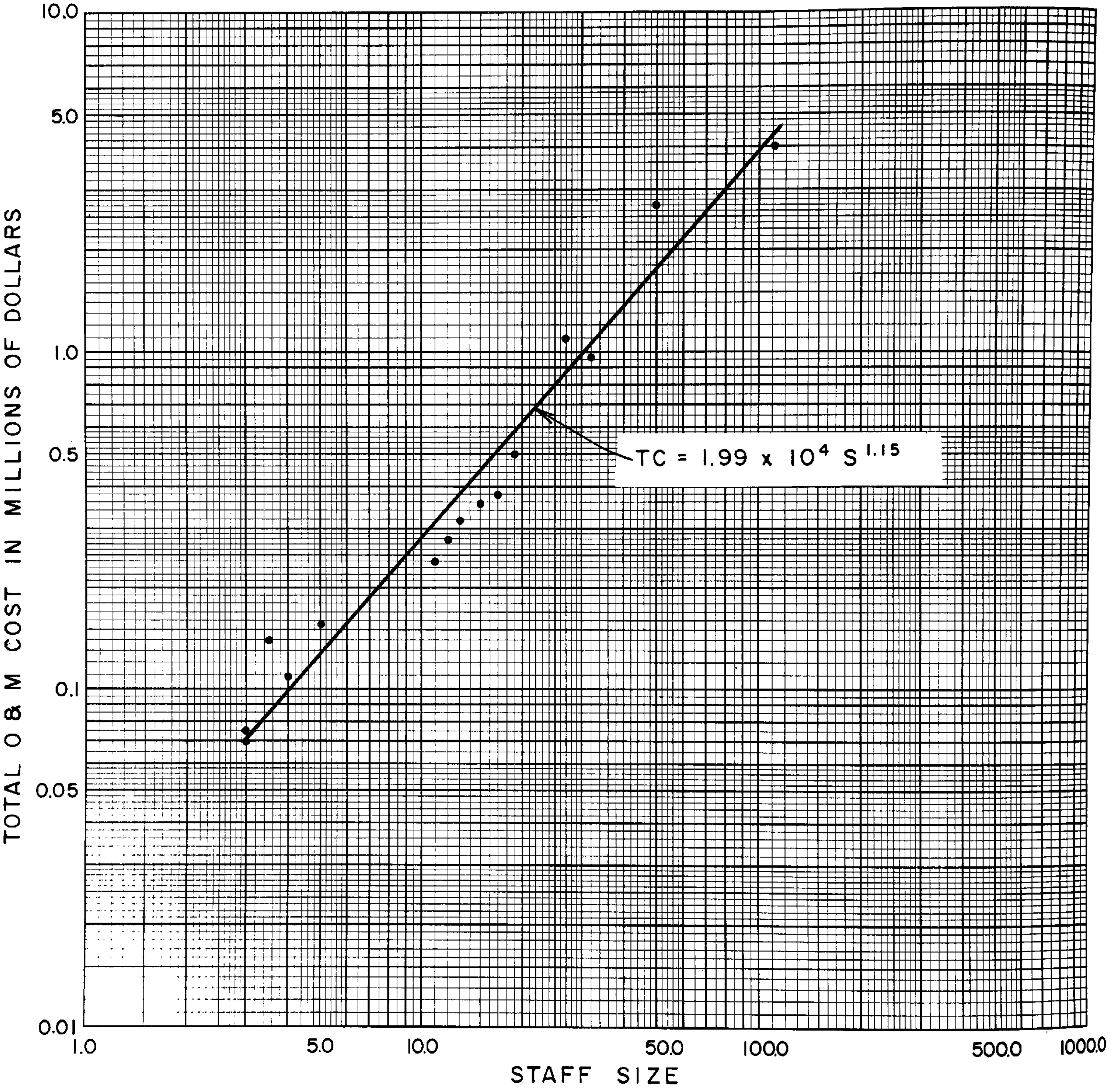
TOTAL O & M COST VS. STAFF SIZE
SECONDARY TREATMENT-ACTIVATED SLUDGE
EPA REGION I

FIGURE E. 3-15



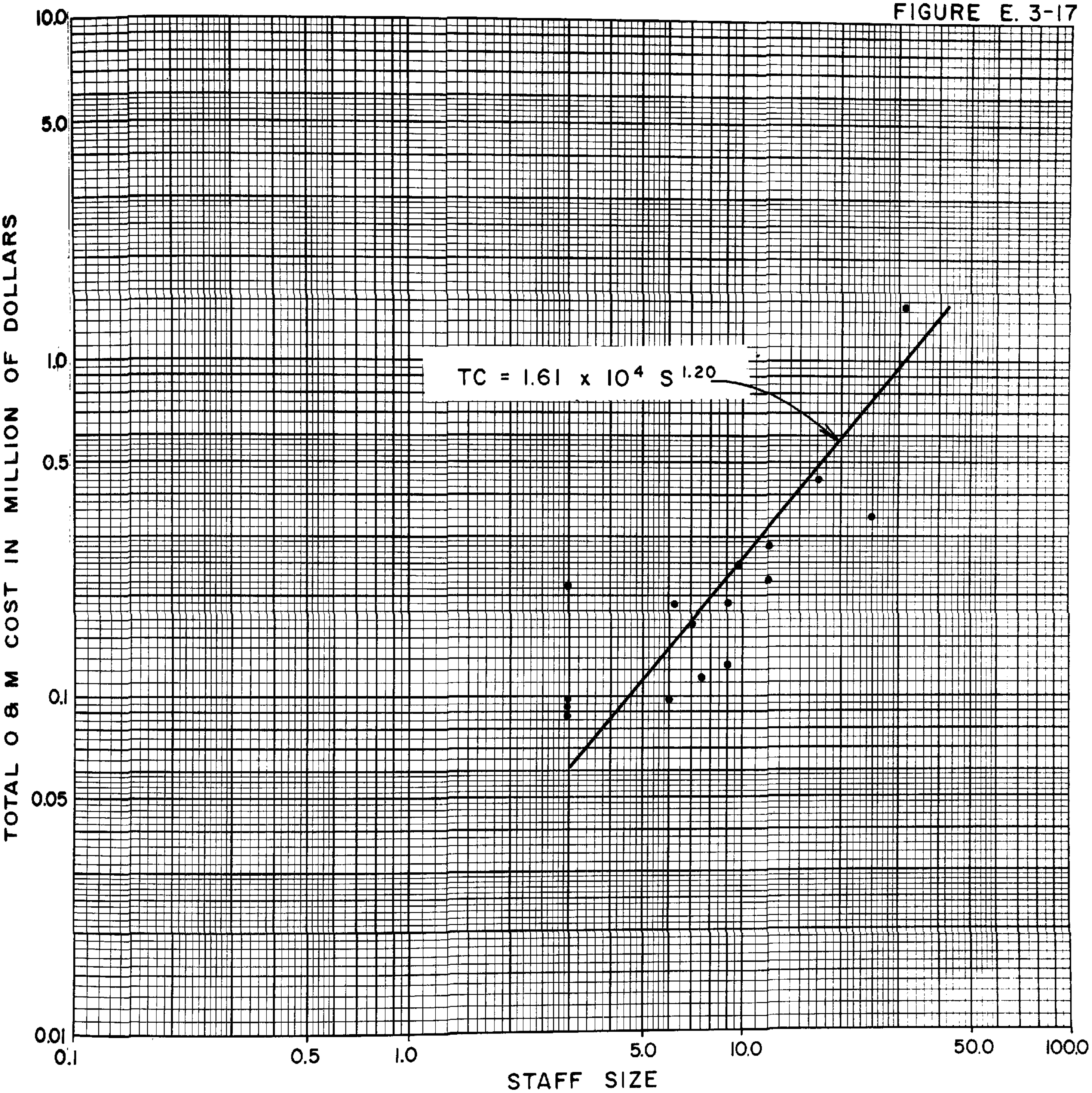
TOTAL O & M COST VS. STAFF SIZE
SECONDARY TREATMENT-ACTIVATED SLUDGE
EPA REGION II

FIGURE E. 3-16



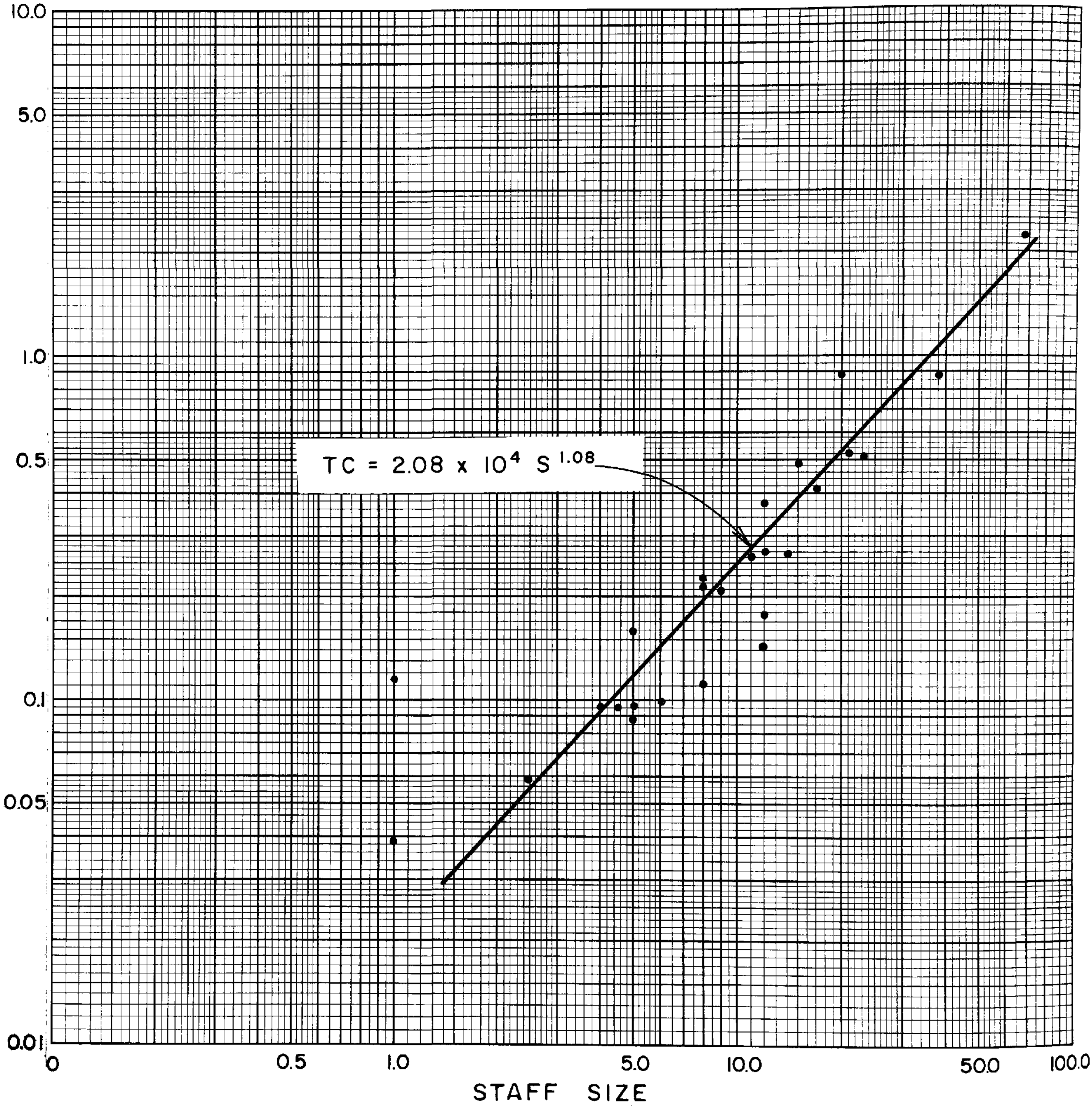
TOTAL O & M COST VS. STAFF SIZE
SECONDARY TREATMENT-ACTIVATED SLUDGE
EPA REGION III

FIGURE E. 3-17



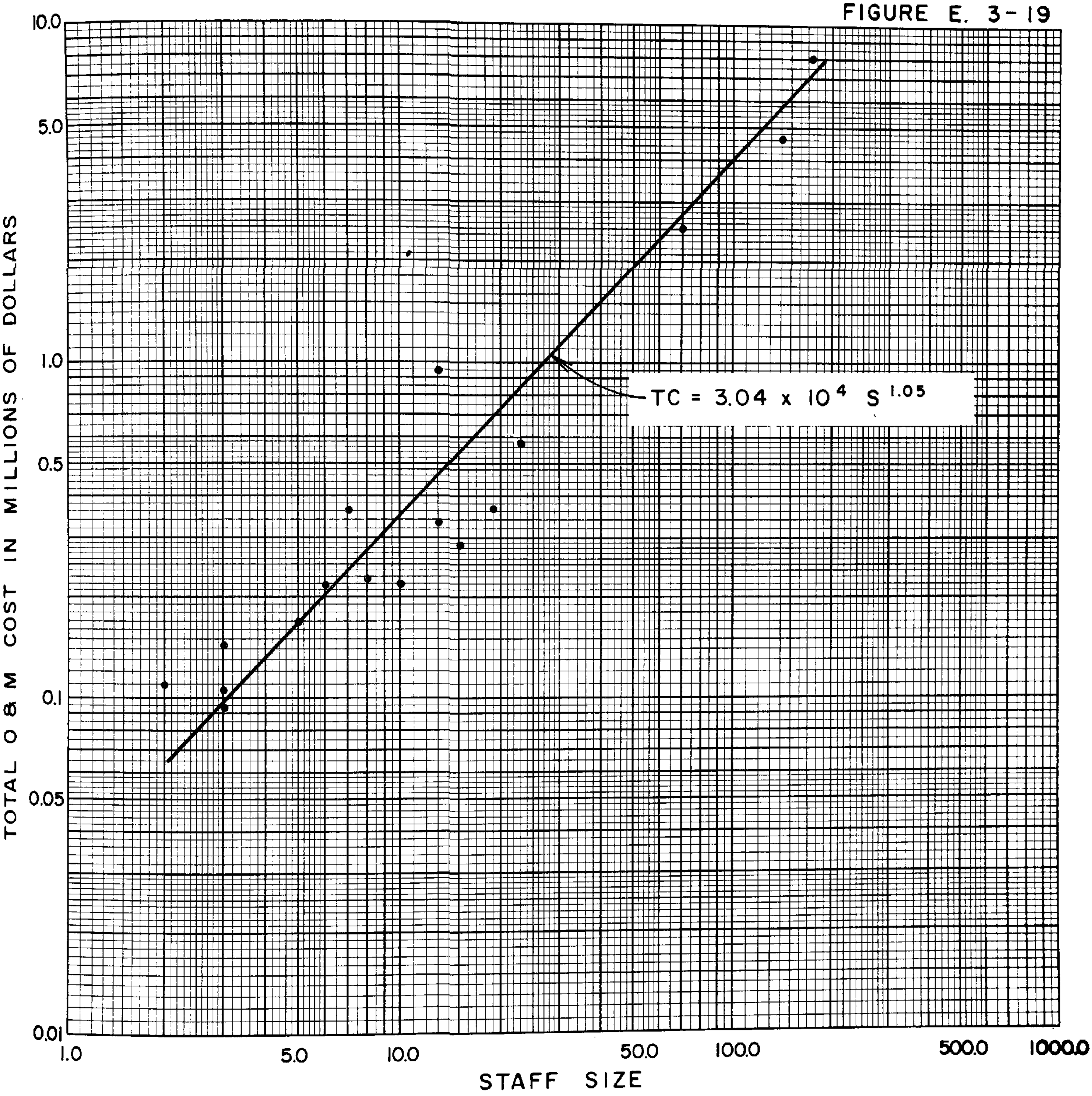
TOTAL O & M COST VS. STAFF SIZE
SECONDARY TREATMENT-ACTIVATED SLUDGE
EPA REGION IV

FIGURE E. 3-18



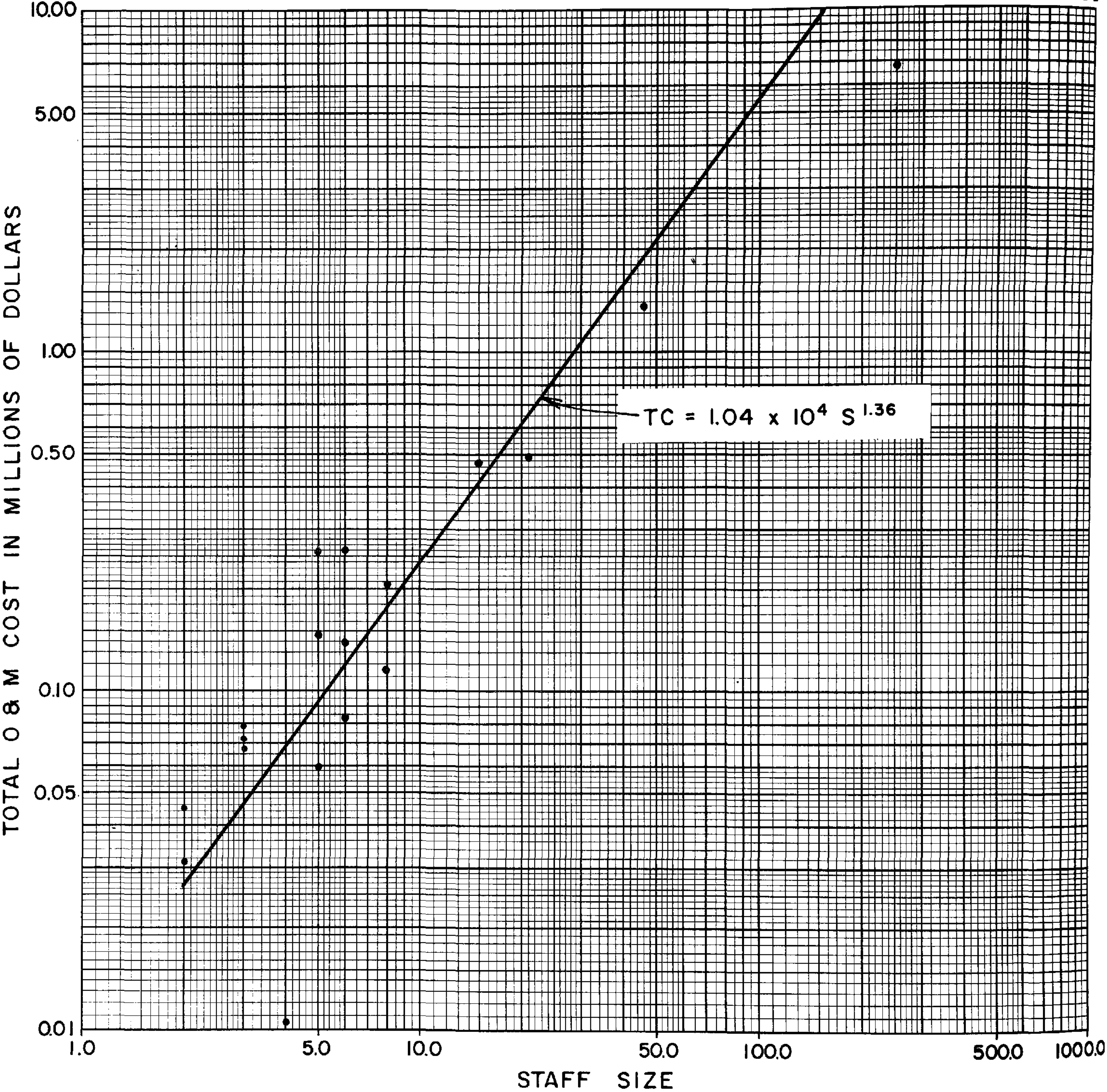
TOTAL O & M COST VS. STAFF SIZE
SECONDARY TREATMENT-ACTIVATED SLUDGE
EPA REGION V

FIGURE E. 3-19



TOTAL O & M COST VS. STAFF SIZE
SECONDARY TREATMENT-ACTIVATED SLUDGE
EPA REGION VI

FIGURE E. 3-20

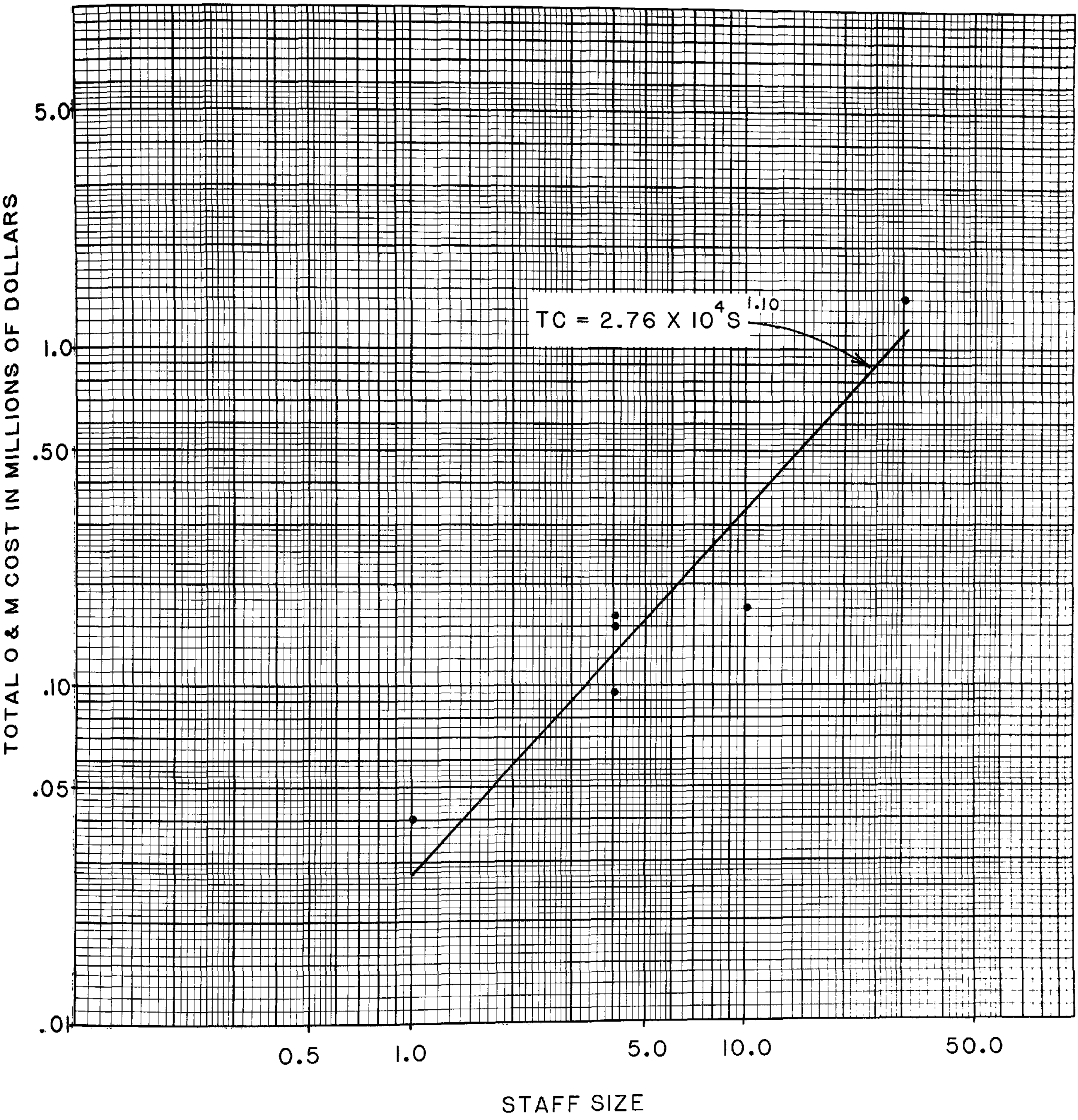


TOTAL O&M COST VS. STAFF SIZE

SECONDARY TREATMENT – ACTIVATED SLUDGE

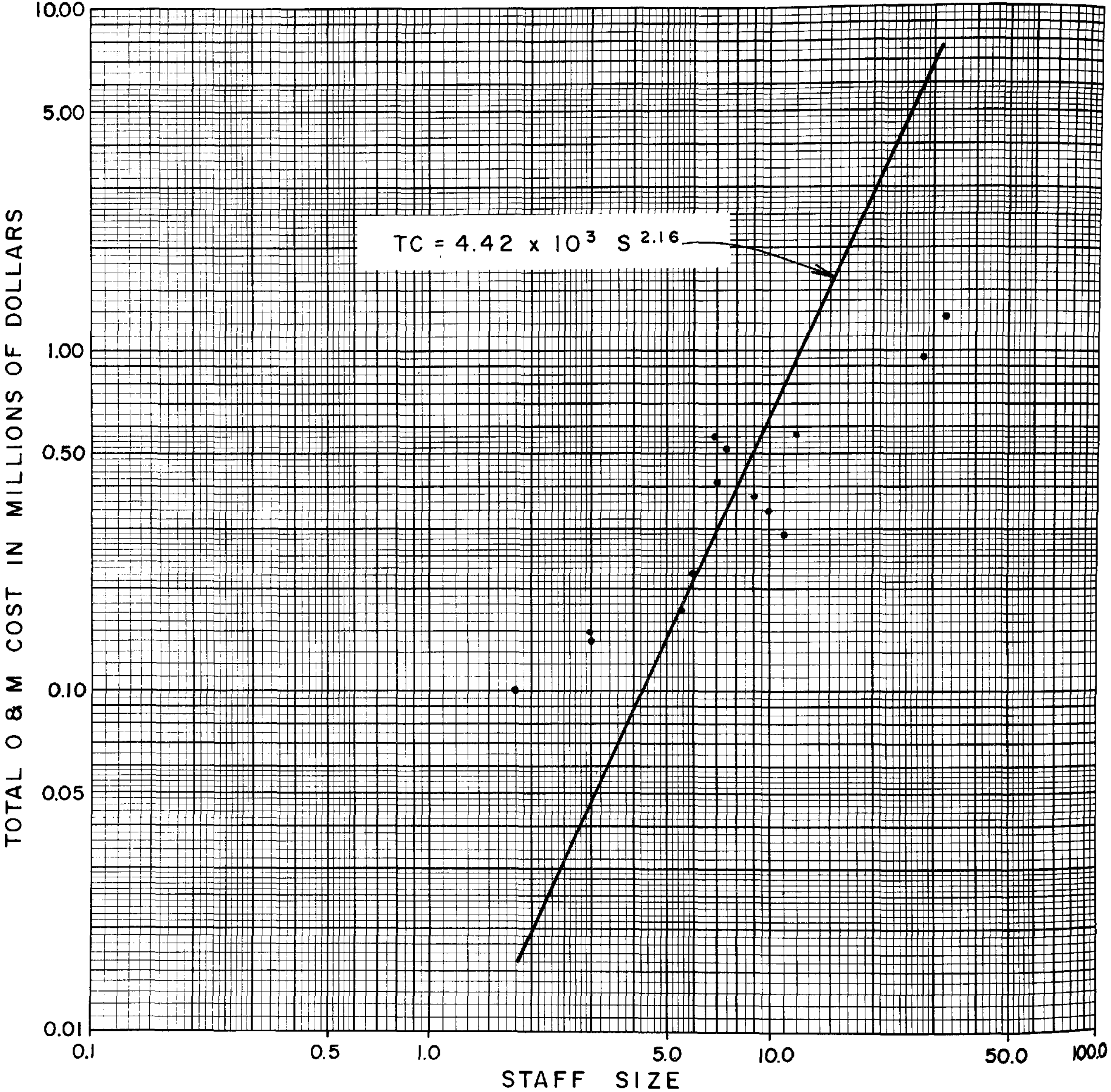
EPA REGION VIII

FIGURE E. 3-21



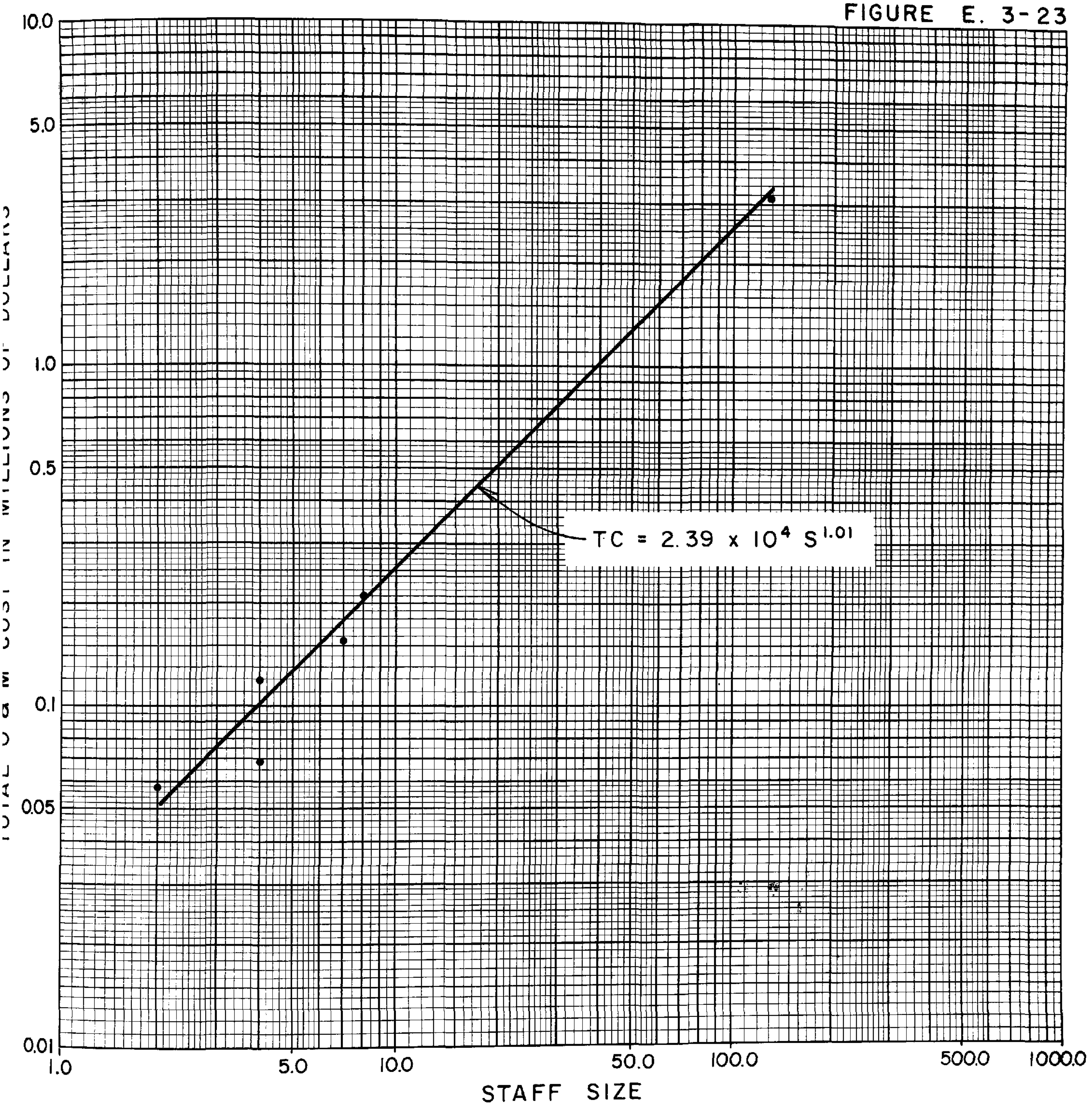
TOTAL O & M COST VS. STAFF SIZE
SECONDARY TREATMENT-ACTIVATED SLUDGE
EPA REGION IX

FIGURE E. 3-22



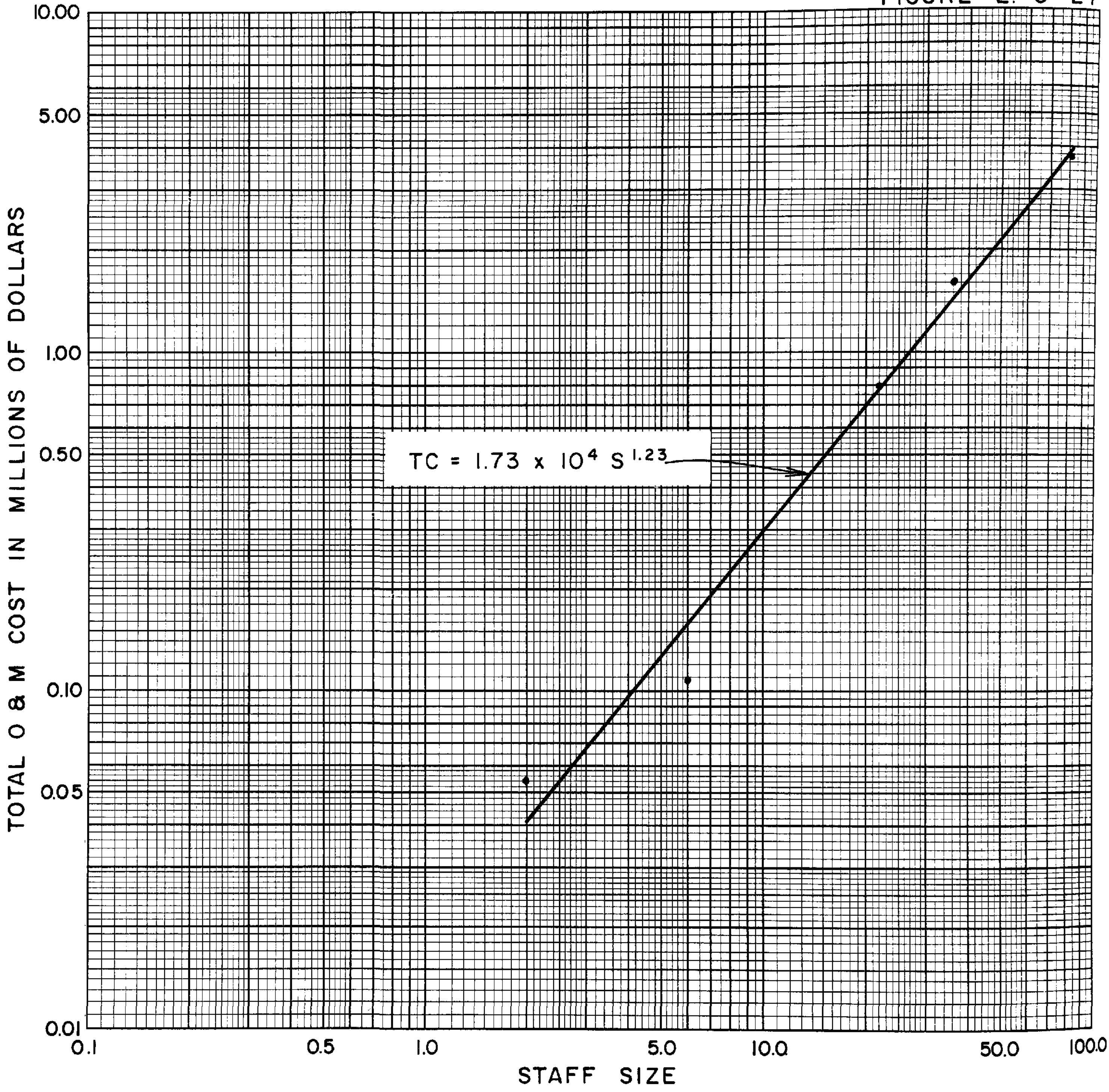
TOTAL O & M COST VS. STAFF SIZE
SECONDARY TREATMENT-ACTIVATED SLUDGE
EPA REGION X

FIGURE E. 3-23



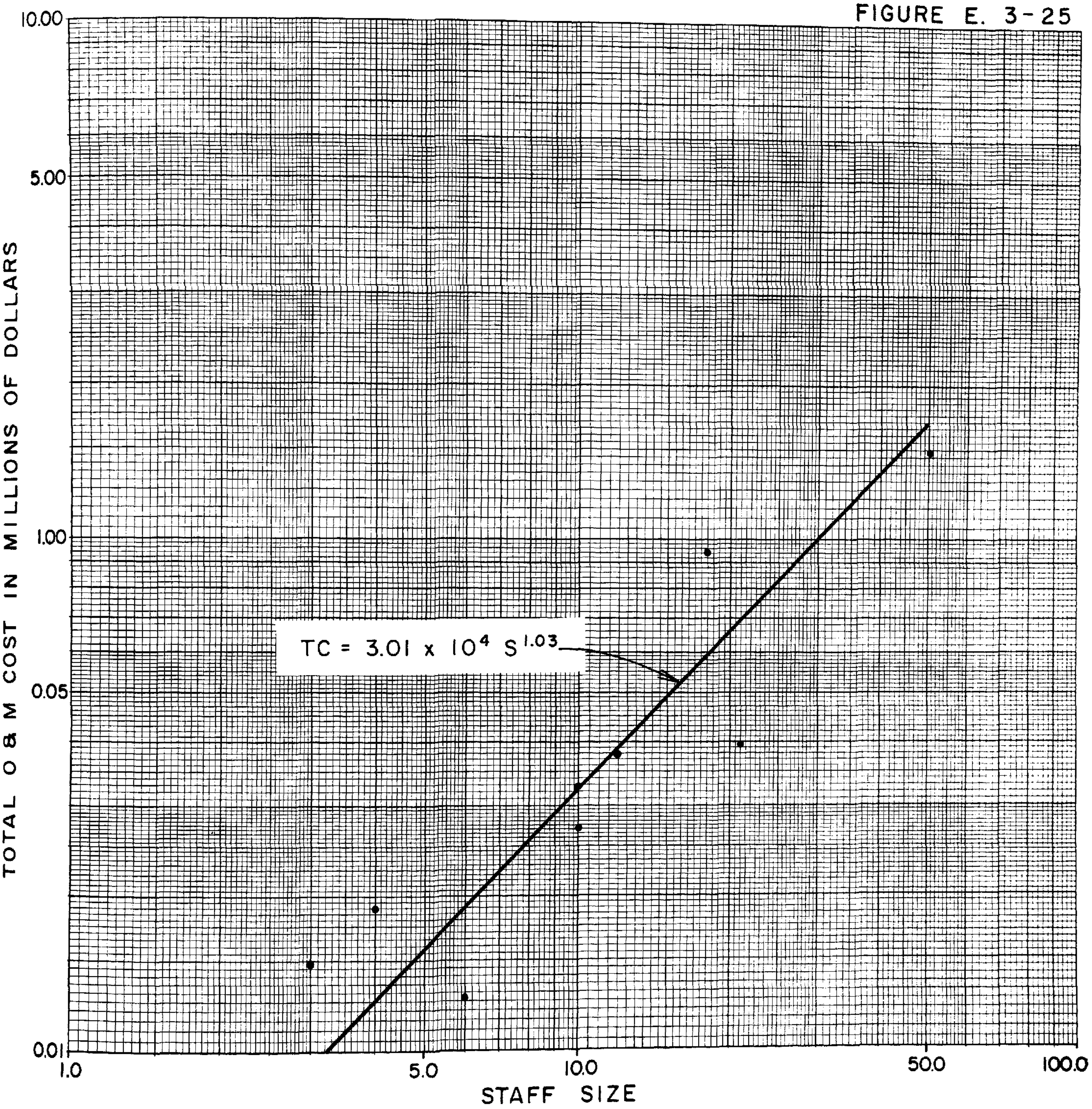
TOTAL O & M COST VS. STAFF SIZE
ADVANCED TREATMENT
EPA REGION II

FIGURE E. 3-24



TOTAL O & M COST VS. STAFF SIZE ADVANCED TREATMENT EPA REGION V

FIGURE E. 3-25



TOTAL O & M COST VS. STAFF SIZE
ADVANCED TREATMENT
EPA REGION IX

FIGURE E. 3-26

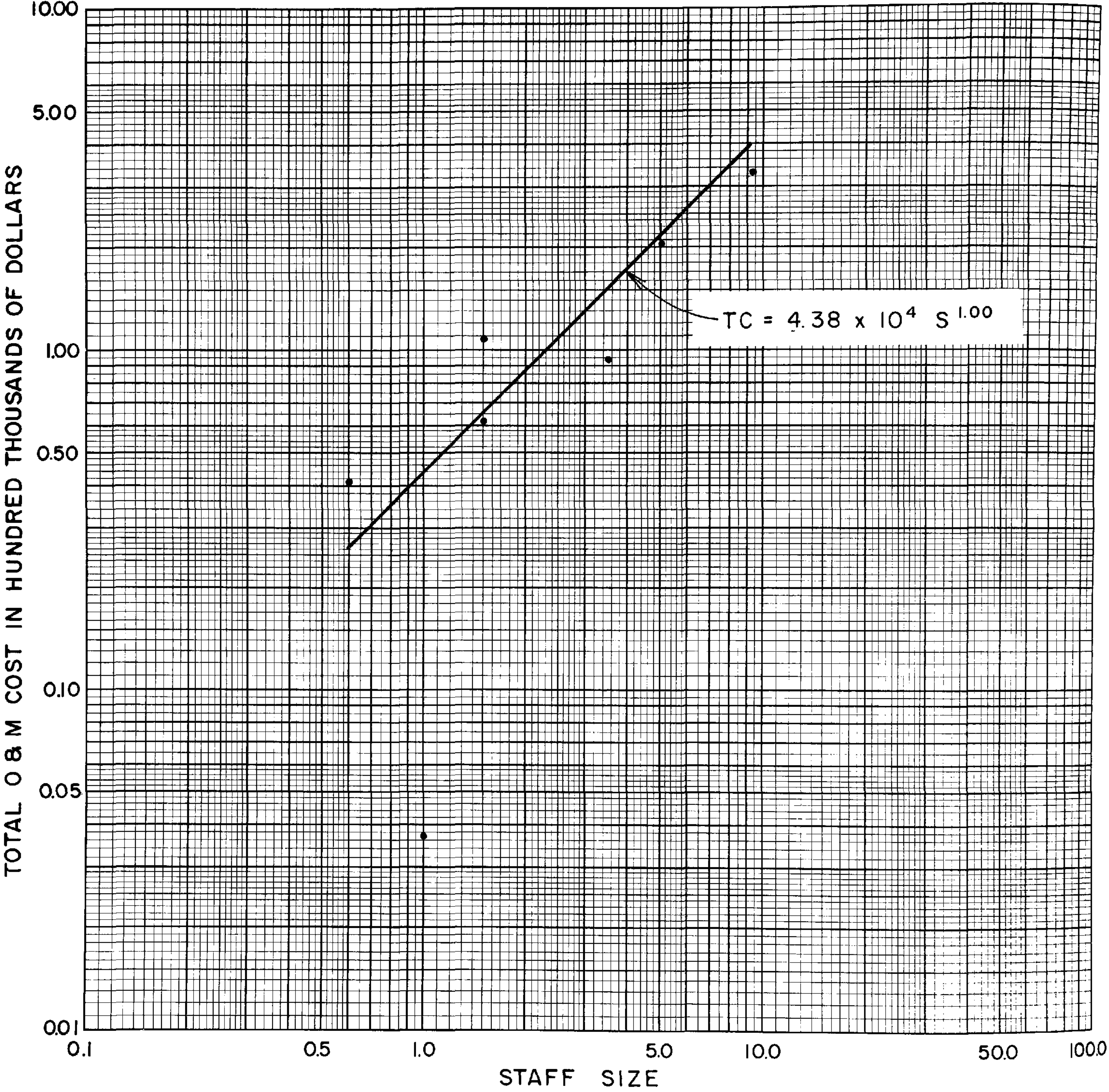


TABLE E.4

APPARENT NON-SIGNIFICANT O&M RELATIONSHIPS

- Staff Size vs Actual Flow, Nationally
  - a) Oxidation Ditch
  - b) Aerated Lagoon
- Influent BOD Strength vs Percent Industrial Flow of Actual Flow
- Influent SS Strength vs Percent Industrial Flow of Actual Flow
- Component Total O&M Costs vs Actual Flow, Level of Treatment
- Average Cost Per Employee vs Actual Flow, Level of Treatment
  - a) Nationally for 3 Size Groups
  - b) Regionally for 3 Size Groups
- Average Cost Per MG Treated vs Actual Flow, Level of Treatment
- Component Process Costs vs Actual Flow, Level of Treatment
  - a) Nationally for 3 Size Groups
  - b) Regionally for 3 Size Groups
- Percent BOD Removal vs Percent Design Flow Capacity
- Percent SS Removal vs Percent Design Flow Capacity
- Average Cost Per MG Treated vs Percent BOD Removal, Level of Treatment
- Average Cost Per MG Treated vs Percent SS Removal, Level of Treatment
- Average Cost Per Pound BOD Removed vs Percent BOD Removed, Level of Treatment
- Average Cost Per Pound SS Removed vs Percent SS Removed, Level of Treatment
- Influent BOD Strength vs Per Capita Flow (Where Industrial Flow = 0)
- Influent SS Strength vs Per Capita Flow (Where Industrial Flow = 0)

APPENDIX F

SEWER SYSTEMS

F.1 Gravity Sewer and Force Main Systems Surveyed Indicating Operating Authority, Service Population, and Total Length

F.2 Lift (Pump) Stations Surveyed Indicating Total Capacity (mgd) and Horsepower (hp)

EPA SURVEY

TABLE F.1

O&M SAMPLED SEWERS

TOTAL LENGTH OF GRAVITY SEWERS AND FORCE MAINS

ID NO	FACILITY NAME	CITY	STATE	OPERATING AUTHORITY	SERVICE POPULATION	TOTAL LENGTH OF GRAVITY SEWERS (MI)	TOTAL LENGTH OF FORCE MAINS (MI)
151	AUGUSTA SAN.DIST SS	AUGUSTA	MAINE	AUGUSTA SAN.DIST	20000	64.00	9.00
152	BANGOR S.S.	BANGOR	MAINE	BANGOR,CITY OF	30000	121.00	1.79
154	ORONO SS	ORONO	MAINE	ORONO, TOWN OF	10000		
157	BRUNSWICK SS	BRUNSWICK	MAINE	BRUNSWICK SD	13000	35.00	
158	FALMOUTH SS	FALMOUTH	MAINE	FALMOUTH, TOWN OF	6500	19.00	
160	SANFORD SS	SANFORD	MAINE	SANFORD SD	11000	58.00	
161	KITTERY SS	KITTERY	MAINE	KITTERY, TOWN OF	7500	10.00	
165	SKOWHEGAN SS	SKOWHEGAN	MAINE	SKOWHEGAN, CITY OF	7000	15.00	
216	ROCHESTER S.S.	ROCHESTER	NEW YORK	MONROE CO PURE WATERS DIV	350000	700.00	
217	ORANGETOWN SEW SYS	ORANGEBURG	NEW YORK	ORANGETOWN DPW	70000	300.00	
218	ROCKLAND COUNTY STP	ORANGEBURG	NEW YORK	ROCKLAND CO SD #1,BD OF C	145000	69.00	11.00
220	RAMAPO SEW SYS	SUFFERN	NEW YORK	RAMAPO,TOWN OF,DPW	30000	176.00	
221	STONY POINT SEW SYS	STONY POINT	NEW YORK	STONY POINT TN OF	9000	35.00	
222	ARLINGTON SEW SYS	POUGHKEEPSIE	NEW YORK	POUGHKEEPSIE T.ARLINGTON	23000	100.00	
223	SEWER SYSTEM	SUFFERN	NEW YORK	SUFFERN,VILLAGE OF	11000	27.00	
224	MONTICELLO SEW SYS	MONTICELLO	NEW YORK	MONTICELLO,VILLAGE OF	7500	25.00	
226	PLATTSBURGH SEW SYS	PLATTSBURGH	NEW YORK	PLATTSBURGH,CITY OF	25000	47.00	
227	TUPPER LAKE SEW SYS	TUPPER LAKE	NEW YORK	TUPPER LAKE, VILLAGE OF	5000	45.00	
228	SARANAC LAKE SEW SY	SARANAC LAKE	NEW YORK	SARANAC LAKE VILLAGE OF	10000	34.00	
229	CANTON SEW SYS	CANTON	NEW YORK	CANTON,VILLAGE OF	10000	16.00	
230	OGDENSBURG SEW SYS	OGDENSBURG	NEW YORK	OGDENSBURG,CITY OF	14000	62.00	
231	LOWVILLE SEW.SYS	LOWVILLE	NEW YORK	LOWVILLE VILLAGE OF	3800	48.00	
232	OWEGO # 2 S.S.	APALACHIN	NEW YORK	OWEGO,TN	7500	31.00	1.50
233	SIDNEY S.S.	SIDNEY	NEW YORK	SIDNEY,VILLAGE OF	4970	19.00	
234	CHEMUNG CO SD #1 SS	ELMIRA	NEW YORK	CHEMUNG,CO OF	16090	92.00	.29
235	CAYUGA HGTS S.S.	CAYUGA HGTS	NEW YORK	CAYUGA HGTS,VILLAGE OF	7200	35.00	
237	MANLIUS S.S.	MANLIUS	NEW YORK	MANLIUS,VILLAGE OF	4500	18.00	
238	ONEIDA CO. SS	UTICA	NEW YORK	ONEIDA CO.DPW	125000	30.00	4.00
239	ILLION SS	ILLION	NEW YORK	ILLION,VILLAGE OF	7000	17.00	
241	JAMESTOWN S.S.	JAMESTOWN	NEW YORK	JAMESTOWN CITY OF DPW	40000	135.00	1.00
242	OLEAN S.S.	OLEAN	NEW YORK	OLEAN CITY OF	20000	70.00	
243	WARSAW S.S.	WARSAW	NEW YORK	WARSAW,VILLAGE OF	4000	16.00	
244	BATAVIA S.S.	BATAVIA	NEW YORK	BATAVIA,CITY OF	19500	52.00	
245	AMHERST S.S.	AMHERST	NEW YORK	AMHERST,TOWN OF	60000	270.00	
246	ALFRED S.S.	ALFRED	NEW YORK	ALFRED,VILLAGE OF	8500	2.50	
247	BATH S.S.	BATH	NEW YORK	BATH,VILLAGE OF	6530	24.00	
248	PENN YAN S.S	PENN YAN	NEW YORK	PENN YAN,VILLAGE OF	5200	17.50	
249	SPENCERPORT S.S.	SPENCERPORT	NEW YORK	SPENCERPORT,VILLAGE OF	5000	15.00	
250	WEBSTER S.S.	WEBSTER	NEW YORK	WEBSTER,VILLAGE OF	7000	20.00	
251	OYSTER BAY S.S.	OYSTER BAY	NEW YORK	OYSTER BAY,TOWN OF	7500	20.50	
252	BETHLEHEM S.S.	DELMAR	NEW YORK	BETHLEHEM,TOWN OF	18000	82.00	11.00
253	SEWAGE DIS.DIST NO2	E.ROCKAWAY	NEW YORK	NASSAU CO.DPW	558400	1553.00	2.50
254	PORT JERVIS S.S.	PORT JERVIS	NEW YORK	PORT JERVIS,CITY OF	8800	38.00	.50
304	LITITZ STP	LITITZ	PENNSYLVANIA	LITITZ BOROUGH	7600	27.00	
305	SPRINGETTSBURY TWP	SPRINGETTSBURY	PENNSYLVANIA	SPRINGETTSBURY TWP SEW.	48000	72.00	.29
306	LEMOYNE BORO JT. AD	LEMOYNE	PENNSYLVANIA	LEMOYNE BORO MUN. AUTH.	16500	16.00	3.00
307	MECHANICSBURG STP	MECHANICSBURG	PENNSYLVANIA	MECHANICSBURG MUN. AUTH.	9500	45.00	3.00
308	CHAMBERSBURG WWTP	CHAMBERSBURG	PENNSYLVANIA	CHAMBERSBURG BORO MUN. AU	17000	53.69	.86

TABLE F.1 CONTINUED

O&M SAMPLED SEWERS

TOTAL LENGTH OF GRAVITY SEWERS AND FORCE MAINS

ID NO	FACILITY NAME	CITY	STATE	OPERATING AUTHORITY	SERVICE POPULATION	TOTAL LENGTH OF GRAVITY SEWERS (MI)	TOTAL LENGTH OF FORCE MAINS (MI)
309	HARRISBURG STP	HARRISBURG	PENNSYLVANIA	HARRISBURG SEW. AUTH.	130000		
310	UPPER SAUCON TWP WW	CENTER VALLEY	PENNSYLVANIA	UPPER SAUCON VAL. MUN. AU	9000	27.00	1.39
313	BETHLEHEM WWTP	BETHLEHEM	PENNSYLVANIA	BETHLEHEM, CITY OF	100000		
314	HATFIELD TWP AWT	HATFIELD	PENNSYLVANIA	HATFIELD TWP. MUN. AUTH.	10000	55.00	1.00
318	GREATER HAZLETON JS	HAZLETON	PENNSYLVANIA	GREATER HAZLETON JSA	42000	5.00	5.00
321	SUNBURY WWTP	SUNBURY	PENNSYLVANIA	SUNBURY, CITY OF MUN. AUT	13250	23.00	1.00
366	FREDERICKSBURG SS	FREDERICKSBURG	VIRGINIA	FREDERICKSBURG, CITY OF	28000		35.00
368	PINNER'S POINT SS	PORTSMOUTH	VIRGINIA	PORTSMOUTH, CITY OF	92393		
370	CHARLOTTESVILLE S.S	CHARLOTTESVILLE	VIRGINIA	CHARLOTTESVILLE, CITY OF	50000	168.00	1.00
371	LEXINGTON SS	LEXINGTON	VIRGINIA	LEXINGTON, CITY OF	7600	26.00	.29
372	BEDFORD SS	BEDFORD	VIRGINIA	BEDFORD, CITY OF	6374		
400	BOCA RATON SEWERS	BOCA RATON	FLORIDA	BOCA RATON CITY OF	35000	201.00	73.00
401	VIRGINIA KEYS COLL	MIAMI	FLORIDA	MIAMI-DADE W&S	400000	570.00	250.00
402	GOULDS COLL.	GOULDS	FLORIDA	MIAMI-DADE W&S	20000		
403	HOMESTEAD SEWERS	HOMESTEAD	FLORIDA	HOMESTEAD CITY OF	10000	18.00	2.00
404	N.MIAMI PLT 1 SEWER	NORTH MIAMI	FLORIDA	NORTH MIAMI CITY OF	50000	89.00	
405	FT.PIERCE CITY OF	FT.PIERCE	FLORIDA	FT.PIERCE CITY OF	33000	121.00	16.00
407	KISSIMMEE 192 STP	KISSIMMEE	FLORIDA	KISSIMMEE CITY OF	2000	60.00	
408	STUART SEWERS	STUART	FLORIDA	STUART CITY OF	8800		20.00
409	GRANT ST STP	MELBOURNE	FLORIDA	MELBOURNE CITY OF	21225	74.00	1.00
410	COCOA SS	COCOA	FLORIDA	COCOA	15025	48.00	23.00
413	HOLLY HILL SS	HOLLY HILL	FLORIDA	HOLLY HILL CITY OF	10000	50.00	3.00
414	SOUTH STP SS	TITUSVILLE	FLORIDA	TITUSVILLE CITY OF	10000	34.00	113.00
415	OCALA STP #1 SS	OCALA	FLORIDA	OCALA CITY OF	13500	197.00	25.00
416	JACKSONVILLE BEACH	JACKSON.BEACH	FLORIDA	JACKSONVILLE BEACH CITY	17700	500.00	10.00
418	ST.AUGUSTINE SS	ST.AUGUSTINE	FLORIDA	ST.AUGUSTINE CITY OF	21200	56.00	12.00
420	LAKELAND SS (BARTOW	BARTOW	FLORIDA	LAKELAND CITY OF	23000	68.00	
421	LAKELAND SS	LAKELAND	FLORIDA	LAKELAND CITY OF	63000	220.00	
422	TARPON SPRINGS SS	TARPON SPRINGS	FLORIDA	TARPON SPRINGS CITY OF	15000	44.00	
424	SARASOTA SS	SARASOTA	FLORIDA	SARASOTA CITY OF	54000	200.00	48.00
425	ST.PETERSBURG SS	ST. PETERBURG	FLORIDA	ST. PETERSBURG CITY OF	236140		
426	PINELLAS PARK SS	PINELLAS PARK	FLORIDA	PINELLAS PARK CITY OF		120.00	
430	PENSACOLA SS	PENSACOLA	FLORIDA	PENSACOLA CITY OF	25000		
431	TALLAHASSEE SS	TALLAHASSEE	FLORIDA	TALLAHASSEE CITY OF	85000	389.00	
432	DANIA SS	DANIA	FLORIDA	DANIA CITY OF	6000	18.00	10.00
433	CORAL GABLES SS	CORAL GABLES	FLORIDA	CORAL GABLES CITY OF	25000	100.00	15.00
464	ATHENS S.S.	ATHENS	GEORGIA	ATHENS, CITY OF	42000	222.00	
469	BRUNSWICK SS	BRUNSWICK	GEORGIA	BRUNSWICK, CITY OF	35000	90.00	10.00
474	THOMASVILLE WPCP	THOMASVILLE	GEORGIA	THOMASVILLE, CITY OF	19095	110.00	
436	HATTIESBURG SS	HATTIESBURG	MISSISSIPPI	HATTIESBURG CITY OF	45000	72.00	1.00
441	GREENVILLE SS	GREENVILLE	MISSISSIPPI	GREENVILLE CITY OF	55000		
446	PICAYNE SS	PICAYUNE	MISSISSIPPI	PICAYNE CITY OF	12000		
505	MARIETTA SS	MARIETTA	OHIO	MARIETTA, CITY OF	19200	100.00	
506	STEUBENVILLE SS	STEUBENVILLE	OHIO	STEUBENVILLE, CITY OF	32000	120.00	
507	ALLIANCE SS	ALLIANCE	OHIO	ALLIANCE, CITY OF	26500	112.00	
511	RAVENNA SS	RAVENNA	OHIO	RAVENNA, CITY OF	12000	70.00	
512	BARBERTON SS	BARBERTON	OHIO	BARBERTON, CITY OF	35300	100.00	
517	SOLON SS	SOLON	OHIO	SOLON, CITY OF	15500	44.00	

TABLE F.1 CONTINUED

O&M SAMPLED SEWERS

TOTAL LENGTH OF GRAVITY SEWERS AND FORCE MAINS

ID NO	FACILITY NAME	CITY	STATE	OPERATING AUTHORITY	SERVICE POPULATION	TOTAL LENGTH OF GRAVITY SEWERS (MI)	TOTAL LENGTH OF FORCE MAINS (MI)
518	BEDFORD SS	BEDFORD	OHIO	BEDFORD, CITY OF	16500	75.00	
520	AVON LAKE SS	AVON LAKE	OHIO	AVON LAKE, CITY OF	12000	63.00	
522	NORWALK SS	NORWALK	OHIO	NORWALK, CITY OF	13500		
523	TOLEDO SS	TOLEDO	OHIO	TOLEDO, CITY OF	445000	2800.00	
525	DEFIANCE SS	DEFIANCE	OHIO	DEFIANCE, CITY OF	17800	80.00	
526	VAN WERT SS	VAN WERT	OHIO	VAN WERT, CITY OF	11320	90.00	
527	FINDLAY SS	FINDLAY	OHIO	FINDLAY, CITY	36000		
534	COLUMBUS SEWERAGE	COLUMBUS	OHIO	COLUMBUS, CITY OF	865000		
537	XENIA SEWERS	XENIA	OHIO	XENIA, CITY OF	28500	87.00	
540	MIAMISBURG SEWERS	MIAMISBURG	OHIO	MIAMISBURG, CITY OF	18200	51.00	1.00
541	NEWARK SEWERS	NEWARK	OHIO	NEWARK, CITY OF	43000	160.00	
542	SIDNEY SEWERAGE SYS	SIDNEY	OHIO	SIDNEY,CITY OF	17000	66.00	
547	DAYTON SEWERS	DAYTON	OHIO	CITY OF DAYTON	317000		
552	GRAFTON SEWERS	GRAFTON	WISCONSIN	GRAFTON W & S COMMISSION	8434	31.00	
553	WAUKESHA SEWERS	WAUKESHA	WISCONSIN	WAUKESHA, CITY OF	49500	147.00	
554	JANESVILLE SS	JANESVILLE	WISCONSIN	JANESVILLE WPC UTIL.	50000	203.00	
556	RICHLAND CENTER SEW	RICHLAND CENTER	WISCONSIN	RICHLAND CENTER, CITY OF	5100	35.00	1.00
557	WATERTOWN SEWERS	WATERTOWN	WISCONSIN	WATERTOWN, CITY OF	16000	71.00	
558	REEDSBURG SEW. SYS.	REEDSBURG	WISCONSIN	REEDSBURG, CITY OF	4800	23.00	
559	SHEBOYGAN SS	SHEBOYGAN	WISCONSIN	SHEBOYGAN, CITY OF	49000	143.00	
560	APPLETON SS	APPLETON	WISCONSIN	APPLETON, CITY OF	57000	190.00	
561	WISCONSIN DELLS SS	WISCONSIN DELLS	WISCONSIN	WISCONSIN DELLS, CITY OF	3000	18.00	2.00
562	WISCONSIN RAPIDS SS	WISCONSIN RAPID	WISCONSIN	WISCONSIN RAPIDS, CITY OF	35000	91.00	
563	STURGEON BAY SS	STURGEON BAY	WISCONSIN	STURGEON BAY UTILITIES	7000		
564	ROTHSCHILD SS	ROTHSCHILD	WISCONSIN	ROTHSCHILD, VIL. OF	5000	16.00	
565	MERRILL SS	MERRILL	WISCONSIN	MERRILL, CITY OF	9500	65.00	
566	LACROSSE SS	LACROSSE	WISCONSIN	LACROSSE, CITY OF	65000	160.00	
567	SUPERIOR SS	SUPERIOR	WISCONSIN	SUPERIOR, CITY OF	32000	123.00	
568	EAU CLAIRE SS	EAU CLAIRE	WISCONSIN	EAU CLAIRE, CITY OF	47000	201.00	
569	TOMAH SS	TOMAH	WISCONSIN	TOMAH, CITY OF	5700	30.00	
570	MADISON INTERCEPTOR	MADISON	WISCONSIN	MADISON METRO. SEW. DIST.	240000	102.00	
571	MADISON COLL. SYS.	MADISON	WISCONSIN	MADISON, CITY OF	170000	531.00	
572	MIDDLETON COLL. SYS	MIDDLETON	WISCONSIN	MIDDLETON, CITY OF	8200	36.00	
601	IRVING COLLECTION S	IRVING	TEXAS	IRVING CITY OF	115244	415.00	
602	EVLESS W&S SYSTEM	EVLESS	TEXAS	EVLESS DPW	27000	55.00	
603	SEWAGE COLLECTORS	COPPELL	TEXAS	COPPELL CITY OF	825	8.00	
654	WW COLLECTION SYS	LEWISVILLE	TEXAS	LEWISVILLE DPW	23000	31.00	5.00
683	BROWNSVILLE COLL S	BROWNSVILLE	TEXAS	BROWNSVILLE CITY OF	48135	200.00	
698	SEWAGE COLLECTION	GALVESTON	TEXAS	GALVESTON DEPT OF UTILITY	60000	136.00	
704	MEXICO COLL.	MEXICO	MISSOURI	MEXICO CITY OF	13000	100.00	
705	COLUMBIA COLLECTORS	COLUMBIA	MISSOURI	COLUMBIA CITY OF	59850	218.00	
802	LONGMONT COLL. SYS.	LONGMONT	COLORADO	LONGMONT CITY OF	37000	57.00	
803	BRIGHTON COLL. SYS.	BRIGHTON	COLORADO	BRIGHTON CITY OF	16000	35.00	
804	S. LAKEWOOD COLL.	DENVER	COLORADO	S. LAKEWOOD SAN. DIST.	17000	29.00	
806	N. TABLE MTN. SS	DENVER	COLORADO	N. TABLE MTN. W & SAN DIS	4500	18.00	
807	WESTMINSTER COLL.	WESTMINSTER	COLORADO	WESTMINSTER, CITY OF	32000	140.00	
808	BOULDER COLLECTION	BOULDER	COLORADO	BOULDER CITY OF	57904	237.00	
810	WINDSOR COLLECTION	WINDSOR	COLORADO	WINDSOR CITY OF	5000	23.00	

TABLE F.1 CONTINUED

O&M SAMPLED SEWERS

TOTAL LENGTH OF GRAVITY SEWERS AND FORCE MAINS

ID NO	FACILITY NAME	CITY	STATE	OPERATING AUTHORITY	SERVICE POPULATION	TOTAL LENGTH OF GRAVITY SEWERS (MI)	TOTAL LENGTH OF FORCE MAINS (MI)
814	ESTES PARK COLLECTI	ESTES PARK	COLORADO	ESTES PARK SAN. DIST.	2500	13.39	
815	VAIL COLL.	VAIL	COLORADO	VAIL W. & SAN. DIST.	2500	26.00	
817	COLORADO SPRINGS SS	COLORADO SPRING	COLORADO	COLORADO SPRINGS, CITY OF	150000	650.00	
935	CAMARILLO SEWER SYS	CAMARILLO	CALIFORNIA	CAMARILLO SAN. DIST.	27000	160.00	
937	SANTA PAULA SEWER S	SANTA PAULA	CALIFORNIA	SANTA PAULA, CITY OF	18600	47.50	
945	VENTURA SEWER SYST	VENTURA	CALIFORNIA	VENTURA, CITY OF	69700	550.00	
946	HILL CANYON TRIBUTA	THOUSAND OAKS	CALIFORNIA	THOUSAND OAKS, CITY OF	69500	308.00	
947	OXNARD SEWER SYSTEM	OXNARD	CALIFORNIA	VENTURA REGIONAL CO. S.D.	93000		
021	TUKWILA COLL SYS	TUKWILA	WASHINGTON	TUKWILA CITY OF	3000		
022	BOTHELL COLL SYS	BOTHELL	WASHINGTON	BOTHELL DPW	5120	28.00	
024	BELLEVUE COLL SYS	BELLEVUE	WASHINGTON	BELLEVUE SEW DIST	18228	272.00	

TABLE F.2

O&M SAMPLED SEWERS
PUMP STATIONS

ID NO	FACILITY NAME	CITY	STATE	OPERATING AUTHORITY	TOTAL CAPACITY (MGD)	TOTAL HORSEPOWER
151	AUGUSTA SAN.DIST SS	AUGUSTA	MAINE	AUGUSTA SAN.DIST	28.00	1530
152	BANGOR S.S.	BANGOR	MAINE	BANGOR,CITY OF	35.00	
154	ORONO SS	ORONO	MAINE	ORONO, TOWN OF		
157	BRUNSWICK SS	BRUNSWICK	MAINE	BRUNSWICK SD		
158	FALMOUTH SS	FALMOUTH	MAINE	FALMOUTH, TOWN OF		
160	SANFORD SS	SANFORD	MAINE	SANFORD SD		
161	KITTERY SS	KITTERY	MAINE	KITTERY, TOWN OF		206
165	SKOWHEGAN SS	SKOWHEGAN	MAINE	SKOWHEGAN, CITY OF		
216	ROCHESTER S.S.	ROCHESTER	NEW YORK	MONROE CO PURE WATERS DIV	27.00	360
217	ORANGETOWN SEW SYS	ORANGEBURG	NEW YORK	ORANGETOWN DPW	25.00	
218	ROCKLAND COUNTY STP	ORANGEBURG	NEW YORK	ROCKLAND CO SD #1,BD OF C	64.00	2800
220	RAMAPO SEW SYS	SUFFERN	NEW YORK	RAMAPO,TOWN OF,DPW	1.30	148
221	STONY POINT SEW SYS	STONY POINT	NEW YORK	STONY POINT TN OF	1.00	25
222	ARLINGTON SEW SYS	POUGHKEEPSIE	NEW YORK	POUGHKEEPSIE T.ARLINGTON	11.00	500
223	SEWER SYSTEM	SUFFERN	NEW YORK	SUFFERN,VILLAGE OF	2.20	200
224	MONTICELLO SEW SYS	MONTICELLO	NEW YORK	MONTICELLO,VILLAGE OF	5.00	275
226	PLATTSBURGH SEW SYS	PLATTSBURGH	NEW YORK	PLATTSBURGH,CITY OF	9.90	300
228	SARANAC LAKE SEW SY	SARANAC LAKE	NEW YORK	SARANAC LAKE VILLAGE OF	12.00	90
229	CANTON SEW SYS	CANTON	NEW YORK	CANTON,VILLAGE OF	1.20	40
230	OGDENSBURG SEW SYS	OGDENSBURG	NEW YORK	OGDENSBURG,CITY OF	10.00	90
231	LOWVILLE SEW.SYS	LOWVILLE	NEW YORK	LOWVILLE VILLAGE OF	1.00	6
232	OWEGO # 2 S.S.	APALACHIN	NEW YORK	OWEGO,TN	10.00	240
234	CHEMUNG CO SD #1 SS	ELMIRA	NEW YORK	CHEMUNG,CO OF	2.20	42
238	ONEIDA CO. SS	UTICA	NEW YORK	ONEIDA CO.DPW	65.00	825
241	JAMESTOWN S.S.	JAMESTOWN	NEW YORK	JAMESTOWN CITY OF DPW	43.00	325
242	OLEAN S.S.	OLEAN	NEW YORK	OLEAN CITY OF	43.00	334
244	BATAVIA S.S.	BATAVIA	NEW YORK	BATAVIA,CITY OF	12.00	250
245	AMHERST S.S.	AMHERST	NEW YORK	AMHERST,TOWN OF	25.00	420
247	BATH S.S.	BATH	NEW YORK	BATH,VILLAGE OF	.10	3
248	PENN YAN S.S	PENN YAN	NEW YORK	PENN YAN,VILLAGE OF	.50	20
249	SPENCERPORT S.S.	SPENCERPORT	NEW YORK	SPENCERPORT,VILLAGE OF	.07	5
251	OYSTER BAY S.S.	OYSTER BAY	NEW YORK	OYSTER BAY,TOWN OF	1.60	40
252	BETHLEHEM S.S.	DELMAR	NEW YORK	BETHLEHEM,TOWN OF	23.60	840
253	SEWAGE DIS.DIST NO2	E.ROCKAWAY	NEW YORK	NASSAU CO.DPW	47.00	490
254	PORT JERVIS S.S.	PORT JERVIS	NEW YORK	PORT JERVIS,CITY OF	2.30	60
305	SPRINGETTSBURY TWP	SPRINGETTSBURY	PENNSYLVANIA	SPRINGETTSBURY TWP SEW.	7.40	240
306	LEMOYNE BORO JT. AD	LEMOYNE	PENNSYLVANIA	LEMOYNE BORO MUN. AUTH.	4.30	2
307	MECHANICSBURG STP	MECHANICSBURG	PENNSYLVANIA	MECHANICSBURG MUN. AUTH.	2.60	44
308	CHAMBERSBURG WWTP	CHAMBERSBURG	PENNSYLVANIA	CHAMBERSBURG BORO MUN. AU	.86	20
309	HARRISBURG STP	HARRISBURG	PENNSYLVANIA	HARRISBURG SEW. AUTH.	69.00	1038
310	UPPER SAUCON TWP WW	CENTER VALLEY	PENNSYLVANIA	UPPER SAUCON VAL. MUN. AU	1.00	60
314	HATFIELD TWP AWT	HATFIELD	PENNSYLVANIA	HATFIELD TWP. MUN. AUTH.		
318	GREATER HAZLETON JS	HAZLETON	PENNSYLVANIA	GREATER HAZLETON JSA		850
321	SUNBURY WWTP	SUNBURY	PENNSYLVANIA	SUNBURY, CITY OF MUN. AUT	4.80	65
368	PINNER'S POINT SS	PORTSMOUTH	VIRGINIA	PORTSMOUTH, CITY OF	199.00	1525
370	CHARLOTTESVILLE S.S	CHARLOTTESVILLE	VIRGINIA	CHARLOTTESVILLE, CITY OF	.50	60
371	LEXINGTON SS	LEXINGTON	VIRGINIA	LEXINGTON, CITY OF	.50	15
372	BEDFORD SS	BEDFORD	VIRGINIA	BEDFORD, CITY OF	6.40	350

TABLE F.2 CONTINUED

O&M SAMPLED SEWERS
PUMP STATIONS

ID NO	FACILITY NAME	CITY	STATE	OPERATING AUTHORITY	TOTAL CAPACITY (MGD)	TOTAL HORSEPOWER
400	BOCA RATON SEWERS	BOCA RATON	FLORIDA	BOCA RATON CITY OF	54.40	1285
401	VIRGINIA KEYS COLL	MIAMI	FLORIDA	MIAMI-DADE W&S	51.60	9750
402	GOULDS COLL.	GOULDS	FLORIDA	MIAMI-DADE W&S	22.00	241
403	HOMESTEAD SEWERS	HOMESTEAD	FLORIDA	HOMESTEAD CITY OF	1.80	225
404	N.MIAMI PLT 1 SEWER	NORTH MIAMI	FLORIDA	NORTH MIAMI CITY OF		840
405	FT.PIERCE CITY OF	FT.PIERCE	FLORIDA	FT.PIERCE CITY OF	67.00	3120
407	KISSIMMEE 192 STP	KISSIMMEE	FLORIDA	KISSIMMEE CITY OF	6.00	140
408	STUART SEWERS	STUART	FLORIDA	STUART CITY OF	5.00	168
409	GRANT ST STP	MELBOURNE	FLORIDA	MELBOURNE CITY OF	7.50	100
410	COCOA SS	COCOA	FLORIDA	COCOA	23.00	522
413	HOLLY HILL SS	HOLLY HILL	FLORIDA	HOLLY HILL CITY OF		230
414	SOUTH STP SS	TITUSVILLE	FLORIDA	TITUSVILLE CITY OF	54.00	
415	OCALA STP #1 SS	OCALA	FLORIDA	OCALA CITY OF		2700
416	JACKSONVILLE BEACH	JACKSON.BEACH	FLORIDA	JACKSONVILLE BEACH CITY	7.00	1110
418	ST.AUGUSTINE SS	ST.AUGUSTINE	FLORIDA	ST.AUGUSTINE CITY OF	28.00	684
420	LAKELAND SS (BARTOW	BARTOW	FLORIDA	LAKELAND CITY OF	6.50	101
421	LAKELAND SS	LAKELAND	FLORIDA	LAKELAND CITY OF		
422	TARPON SPRINGS SS	TARPON SPRINGS	FLORIDA	TARPON SPRINGS CITY OF	7.00	178
424	SARASOTA SS	SARASOTA	FLORIDA	SARASOTA CITY OF	15.00	600
425	ST.PETERSBURG SS	ST. PETERBURG	FLORIDA	ST. PETERSBURG CITY OF	57.00	2127
426	PINELLAS PARK SS	PINELLAS PARK	FLORIDA	PINELLAS PARK CITY OF	12.50	4200
431	TALLAHASSEE SS	TALLAHASSEE	FLORIDA	TALLAHASSEE CITY OF	128.00	3440
432	DANIA SS	DANIA	FLORIDA	DANIA CITY OF	9.00	200
433	CORAL GABLES SS	CORAL GABLES	FLORIDA	CORAL GABLES CITY OF	103.00	800
469	BRUNSWICK SS	BRUNSWICK	GEORGIA	BRUNSWICK, CITY OF		1125
474	THOMASVILLE WPCP	THOMASVILLE	GEORGIA	THOMASVILLE, CITY OF	4.30	81
436	HATTIESBURG SS	HATTIESBURG	MISSISSIPPI	HATTIESBURG CITY OF		
505	MARIETTA SS	MARIETTA	OHIO	MARIETTA, CITY OF		
506	STEUBENVILLE SS	STEUBENVILLE	OHIO	STEUBENVILLE, CITY OF		
507	ALLIANCE SS	ALLIANCE	OHIO	ALLIANCE, CITY OF	4.00	
511	RAVENNA SS	RAVENNA	OHIO	RAVENNA, CITY OF		
512	BARBERTON SS	BARBERTON	OHIO	BARBERTON, CITY OF		
517	SOLON SS	SOLON	OHIO	SOLON, CITY OF		
518	BEDFORD SS	BEDFORD	OHIO	BEDFORD, CITY OF		
522	NORWALK SS	NORWALK	OHIO	NORWALK, CITY OF		97
523	TOLEDO SS	TOLEDO	OHIO	TOLEDO, CITY OF		
525	DEFIANCE SS	DEFIANCE	OHIO	DEFIANCE, CITY OF	6.00	
526	VAN WERT SS	VAN WERT	OHIO	VAN WERT, CITY OF		
527	FINDLAY SS	FINDLAY	OHIO	FINDLAY, CITY		
540	MIAMISBURG SEWERS	MIAMISBURG	OHIO	MIAMISBURG, CITY OF	1.80	107
542	SIDNEY SEWERAGE SYS	SIDNEY	OHIO	SIDNEY,CITY OF	5.90	
552	GRAFTON SEWERS	GRAFTON	WISCONSIN	GRAFTON W & S COMMISSION	4.50	104
553	WAUKESHA SEWERS	WAUKESHA	WISCONSIN	WAUKESHA, CITY OF	27.00	744
556	RICHLAND CENTER SEW	RICHLAND CENTER	WISCONSIN	RICHLAND CENTER, CITY OF	4.00	33
557	WATERTOWN SEWERS	WATERTOWN	WISCONSIN	WATERTOWN, CITY OF	4.00	
558	REEDSBURG SEW. SYS.	REEDSBURG	WISCONSIN	REEDSBURG, CITY OF		
559	SHEBOYGAN SS	SHEBOYGAN	WISCONSIN	SHEBOYGAN, CITY OF		
560	APPLETON SS	APPLETON	WISCONSIN	APPLETON, CITY OF	26.00	

TABLE F.2 CONTINUED

O&M SAMPLED SEWERS
PUMP STATIONS

ID NO	FACILITY NAME	CITY	STATE	OPERATING AUTHORITY	TOTAL CAPACITY (MGD)	TOTAL HORSEPOWER
561	WISCONSIN DELLS SS	WISCONSIN DELLS	WISCONSIN	WISCONSIN DELLS, CITY OF	6.00	
562	WISCONSIN RAPIDS SS	WISCONSIN RAPID	WISCONSIN	WISCONSIN RAPIDS, CITY OF	36.00	
564	ROTHSCHILD SS	ROTHSCHILD	WISCONSIN	ROTHSCHILD, VIL. OF		
565	MERRILL SS	MERRILL	WISCONSIN	MERRILL, CITY OF		12
566	LACROSSE SS	LACROSSE	WISCONSIN	LACROSSE, CITY OF		
567	SUPERIOR SS	SUPERIOR	WISCONSIN	SUPERIOR, CITY OF		
568	EAU CLAIRE SS	EAU CLAIRE	WISCONSIN	EAU CLAIRE, CITY OF	10.00	140
569	TOMAH SS	TOMAH	WISCONSIN	TOMAH, CITY OF	2.00	30
570	MADISON INTERCEPTOR	MADISON	WISCONSIN	MADISON METRO. SEW. DIST.		
571	MADISON COLL. SYS.	MADISON	WISCONSIN	MADISON, CITY OF		
601	IRVING COLLECTION S	IRVING	TEXAS	IRVING CITY OF	5.00	600
602	EVLESS W&S SYSTEM	EVLESS	TEXAS	EVLESS DPW	3.00	60
603	SEWAGE COLLECTORS	COPPELL	TEXAS	COPPELL CITY OF		22
654	WW COLLECTION SYS	LEWISVILLE	TEXAS	LEWISVILLE DPW	6.00	
683	BROWNSVILLE COLL S	BROWNSVILLE	TEXAS	BROWNSVILLE CITY OF		
698	SEWAGE COLLECTION	GALVESTON	TEXAS	GALVESTON DEPT OF UTILITY	21.00	
704	MEXICO COLL.	MEXICO	MISSOURI	MEXICO CITY OF	1.40	40
705	COLUMBIA COLLECTORS	COLUMBIA	MISSOURI	COLUMBIA CITY OF	2.30	
803	BRIGHTON COLL. SYS.	BRIGHTON	COLORADO	BRIGHTON CITY OF	1.80	20
806	N. TABLE MTN. SS	DENVER	COLORADO	N. TABLE MTN. W & SAN DIS		
807	WESTMINSTER COLL.	WESTMINSTER	COLORADO	WESTMINSTER, CITY OF	7.10	255
808	BOULDER COLLECTION	BOULDER	COLORADO	BOULDER CITY OF		
814	ESTES PARK COLLECTI	ESTES PARK	COLORADO	ESTES PARK SAN. DIST.		
817	COLORADO SPRINGS SS	COLORADO SPRING	COLORADO	COLORADO SPRINGS, CITY OF		
935	CAMARILLO SEWER SYS	CAMARILLO	CALIFORNIA	CAMARILLO SAN. DIST.	21.00	355
945	VENTURA SEWER SYST	VENTURA	CALIFORNIA	VENTURA, CITY OF	21.00	660
946	HILL CANYON TRIBUTA	THOUSAND OAKS	CALIFORNIA	THOUSAND OAKS, CITY OF	1.80	140
947	OXNARD SEWER SYSTEM	OXNARD	CALIFORNIA	VENTURA REGIONAL CO. S.D.		
021	TUKWILA COLL SYS	TUKWILA	WASHINGTON	TUKWILA CITY OF		160
022	BOTHELL COLL SYS	BOTHELL	WASHINGTON	BOTHELL DPW		72
024	BELLEVUE COLL SYS	BELLEVUE	WASHINGTON	BELLEVUE SEW DIST		720

APPENDIX G

SEWER SYSTEM GRAPHICAL RELATIONSHIPS
POTENTIALLY SIGNIFICANT O&M RELATIONSHIPS

EPA SURVEY

TABLE G.1

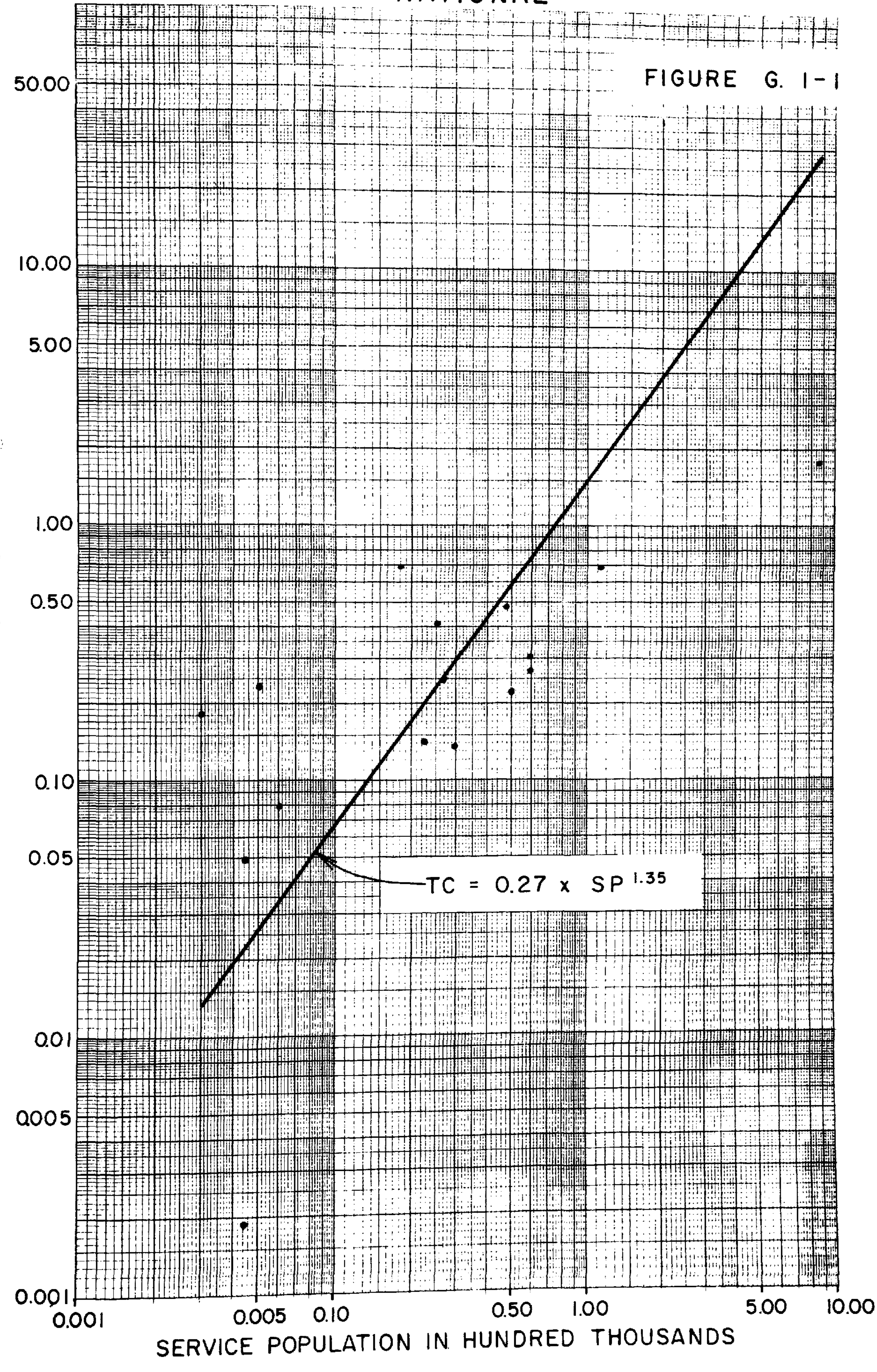
POTENTIALLY SIGNIFICANT O&M RELATIONSHIPS
SEWERS SYSTEMS: TOTAL COST VS SERVICE POPULATION

Title	Equation	Sample Size (n)	Correlation Coefficient (r)	F-Test Value
Separate Sewer System, National	$TC = 0.27 \times SP^{1.35}$	17	0.74	17.71
WWTP + Separate Sewer System, National	$TC = 0.09 \times SP^{1.39}$	92	0.80	160.45
WWTP + Mixed Sewer System, National	$TC = 0.012 \times SP^{1.55}$	30	0.89	108.07
Separate Sewer System, Region VI	$TC = 26.69 \times SP^{0.87}$	6	0.98	113.40
WWTP + Separate Sewer System, Region II	$TC = 0.22 \times SP^{1.30}$	21	0.92	105.07
WWTP + Separate Sewer System, Region III	$TC = 0.14 \times SP^{1.31}$	11	0.85	23.59
WWTP + Separate Sewer System, Region IV	$TC = 4.16 \times SP^{1.07}$	26	0.78	37.86
WWTP + Separate Sewer System, Region V	$TC = 0.10 \times SP^{1.35}$	19	0.71	17.15
WWTP + Separate Sewer System, Region VIII	$TC = 10.44 \times SP^{0.92}$	8	0.95	54.49
WWTP + Mixed Sewer System, Region II	$TC = 0.025 \times SP^{1.52}$	9	0.93	48.15
WWTP + Mixed Sewer System, Region V	$TC = 1.20 \times 10^{-3} \times SP^{1.76}$	16	0.84	32.72

Where TC equals total OM&R cost in dollars and
SP equals the number of people served by the sewer system.

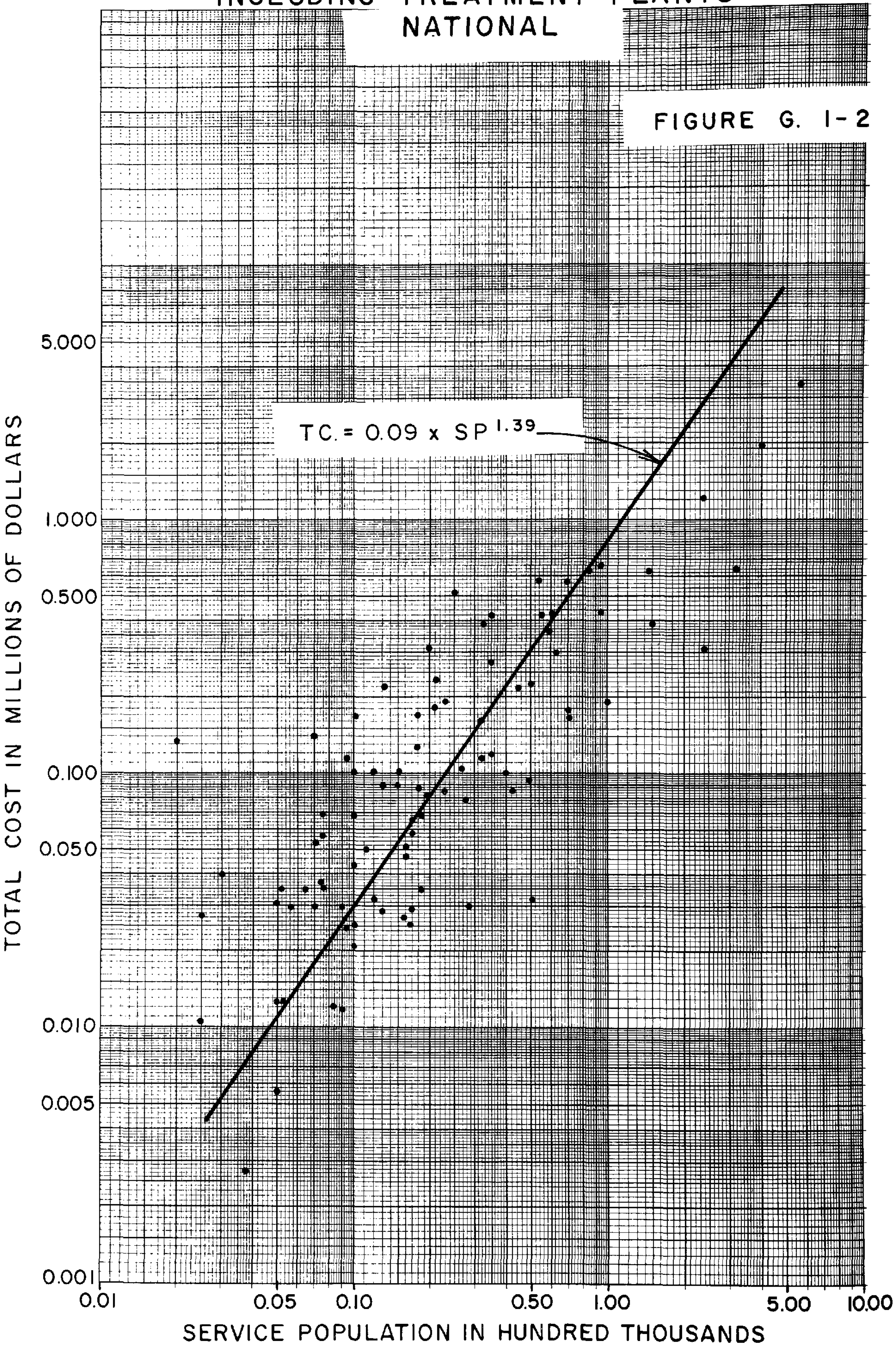
TOTAL COST VS. SERVICE POPULATION
SEPARATE SEWER SYSTEMS
NATIONAL

FIGURE G. 1-1



TOTAL COST VS. SERVICE POPULATION SEPARATE SEWER SYSTEMS INCLUDING TREATMENT PLANTS NATIONAL

FIGURE G. 1-2



TOTAL COST VS. SERVICE POPULATION
MIXED SEWER SYSTEMS
INCLUDING TREATMENT PLANTS
NATIONAL

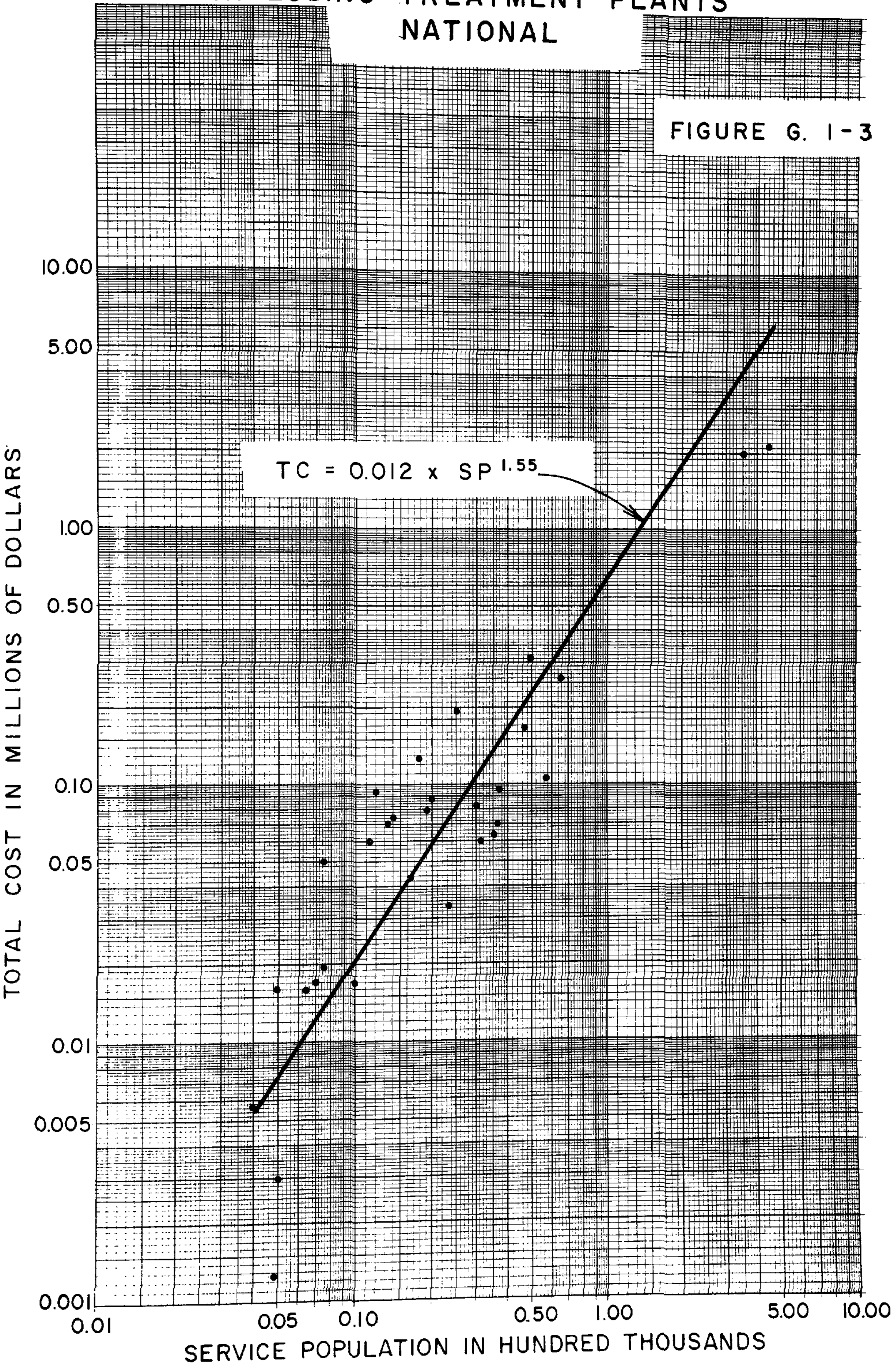


FIGURE G. 1-3

TOTAL COST VS. SERVICE POPULATION
SEPARATE SEWER SYSTEMS
EPA REGION VI

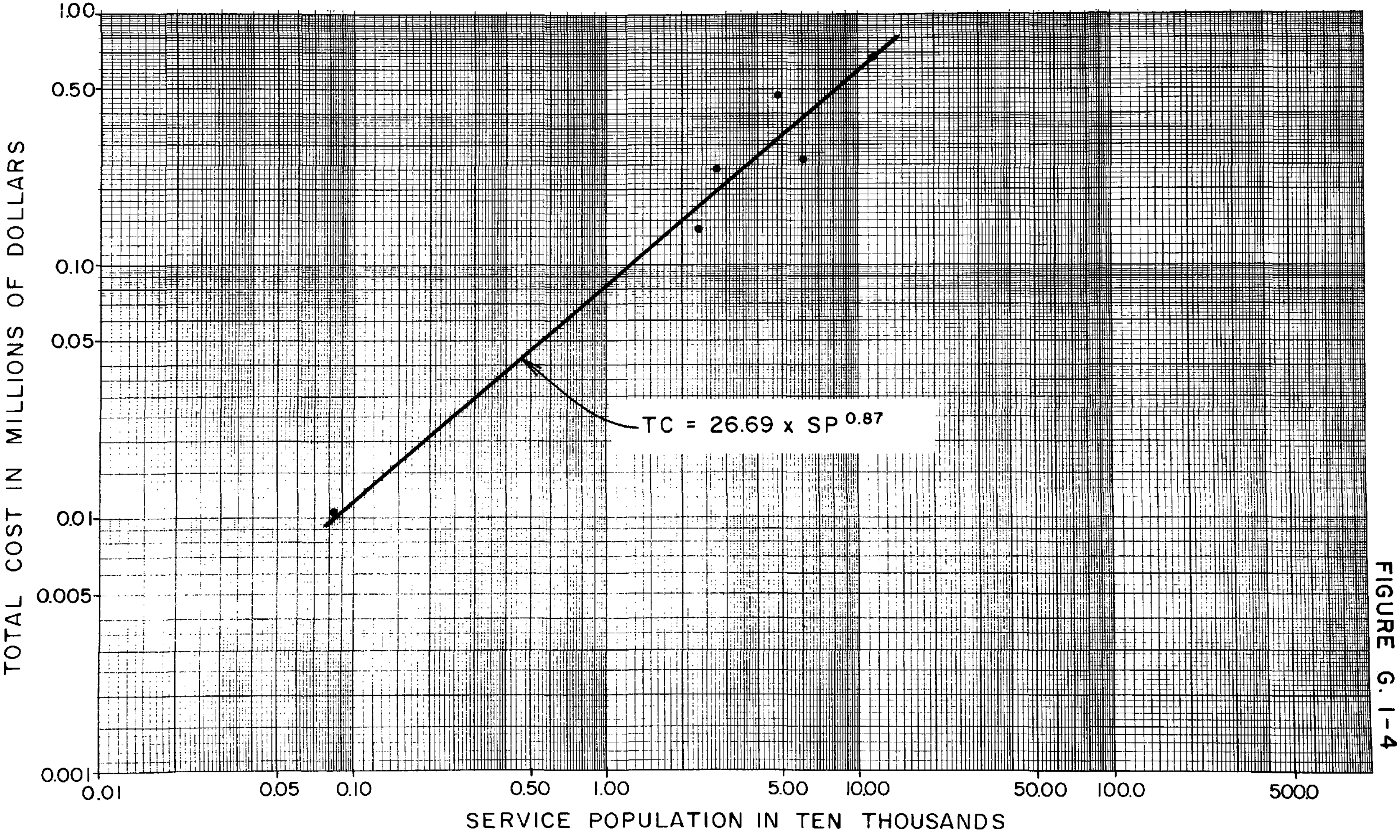
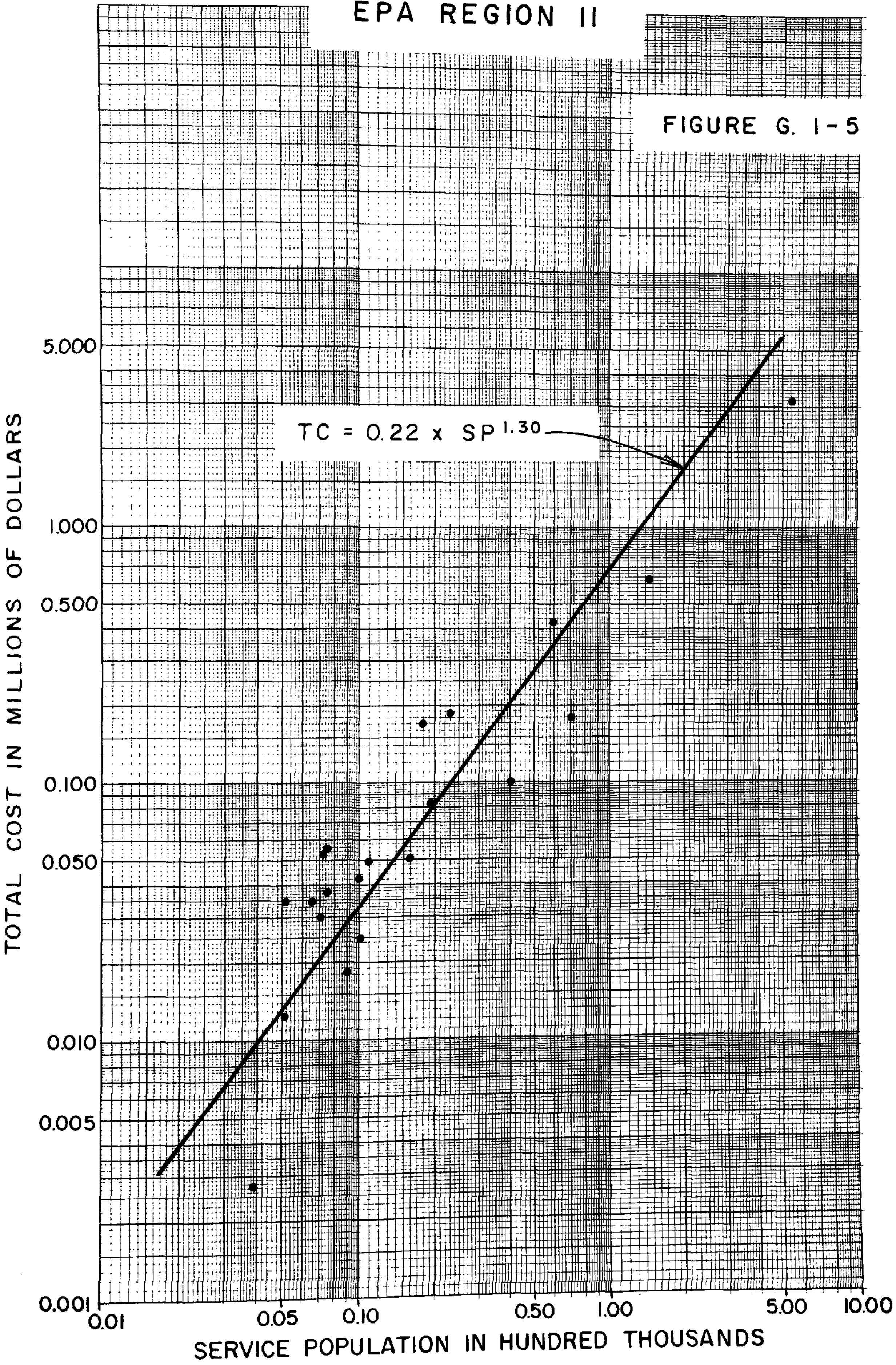


FIGURE G. 1-4

TOTAL COST VS. SERVICE POPULATION SEPARATE SEWER SYSTEMS INCLUDING TREATMENT PLANTS EPA REGION II

FIGURE G. 1-5



TOTAL COST VS. SERVICE POPULATION
SEPARATE SEWER SYSTEMS
INCLUDING TREATMENT PLANTS
EPA REGION III

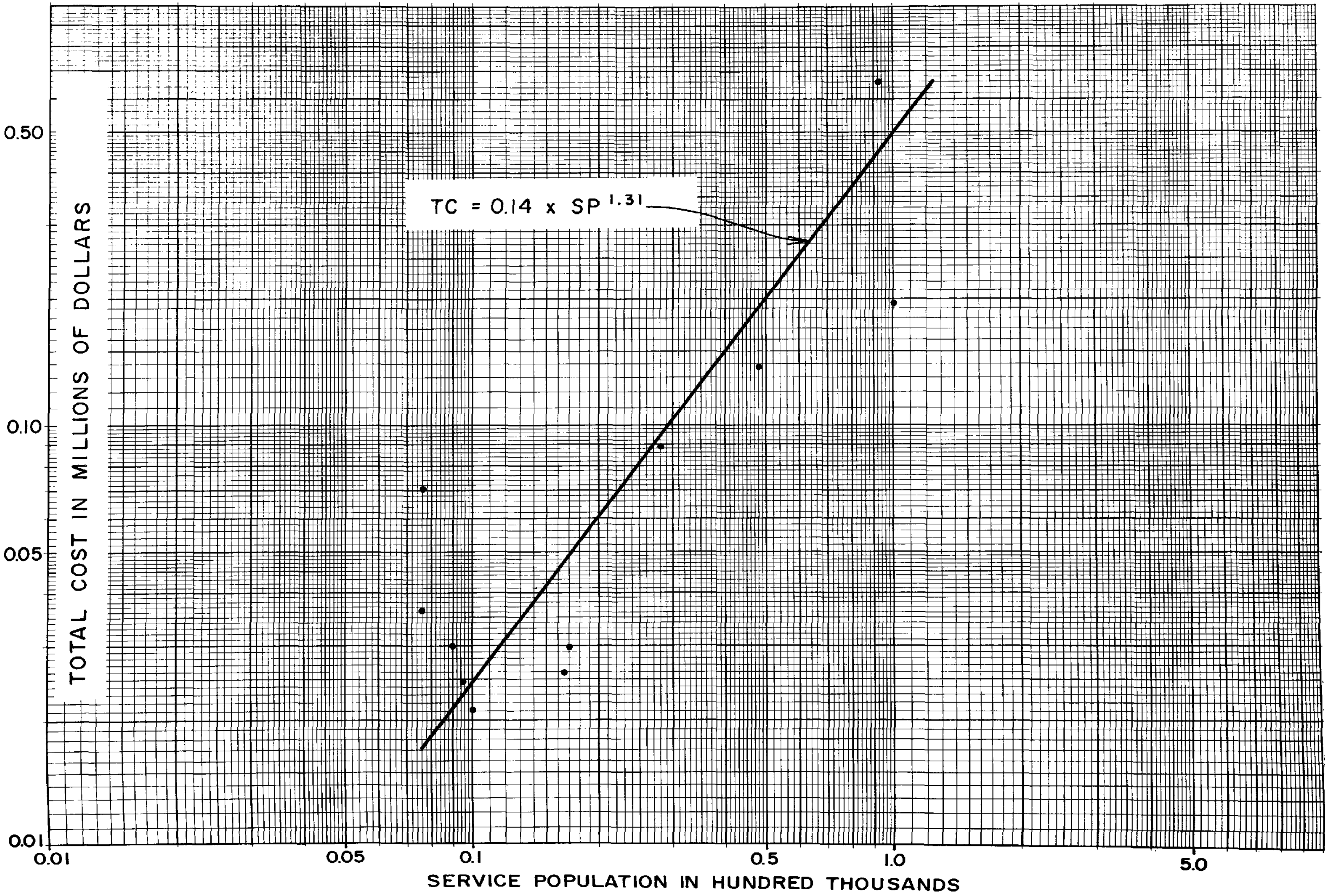
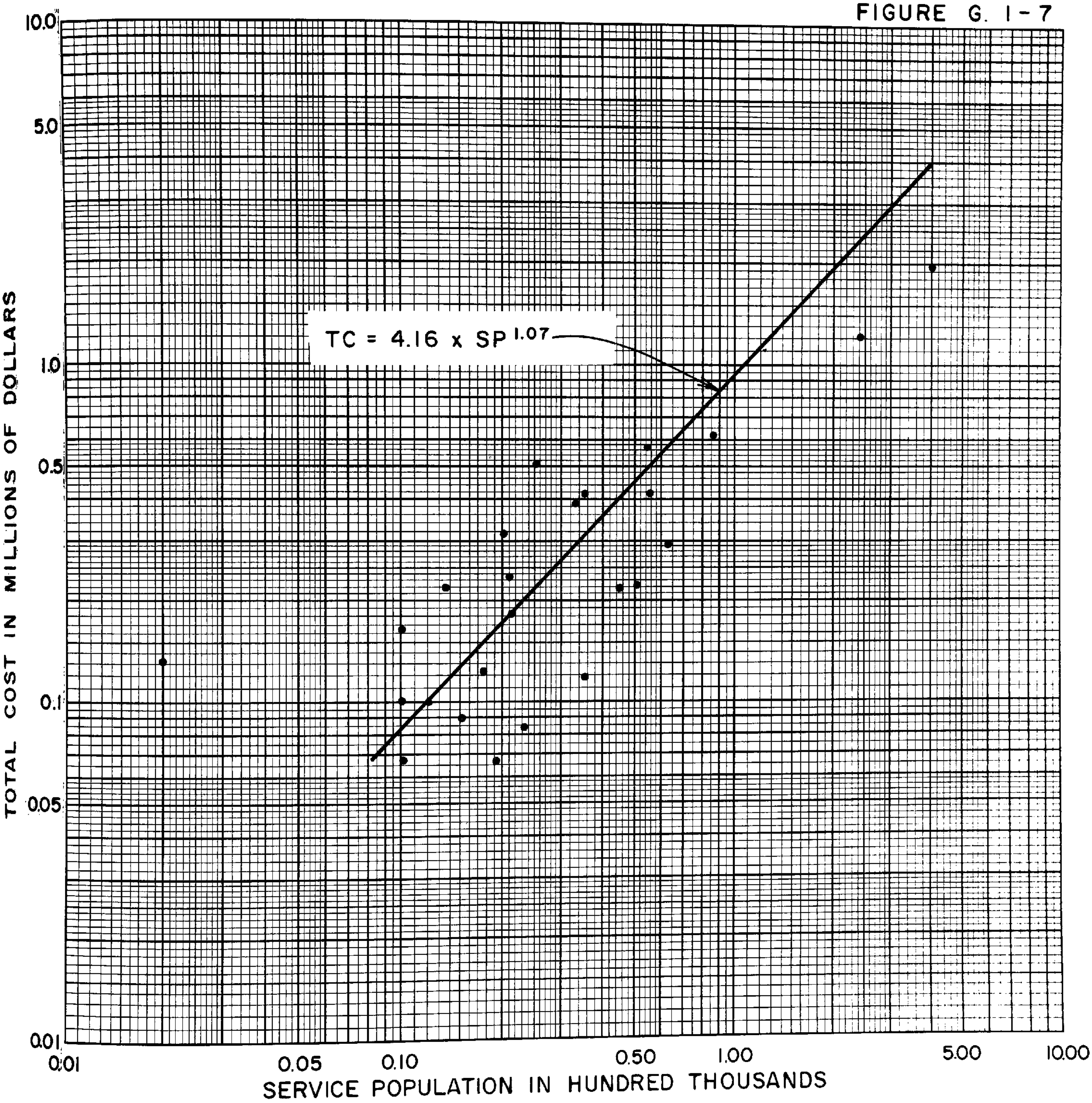


FIGURE G. 1-6

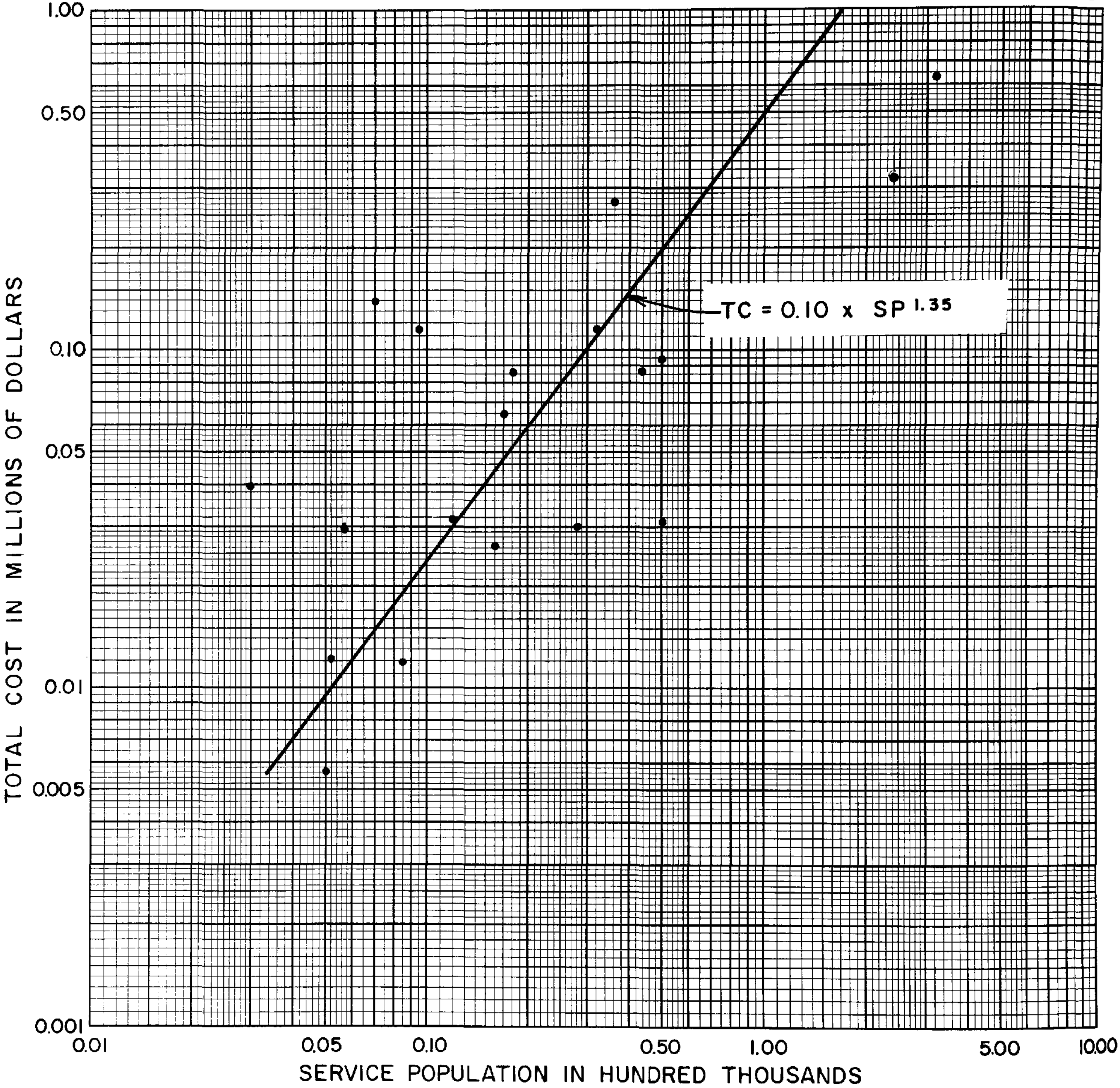
TOTAL COST VS. SERVICE POPULATION
SEPARATE SEWER SYSTEMS
INCLUDING TREATMENT PLANTS
EPA REGION IV

FIGURE G. 1-7



TOTAL COST VS. SERVICE POPULATION
SEPARATE SEWER SYSTEMS
INCLUDING TREATMENT PLANTS
EPA REGION V

FIGURE G. 1-8



TOTAL COST VS. SERVICE POPULATION
SEPARATE SEWER SYSTEMS
INCLUDING TREATMENT PLANTS
EPA REGION VIII

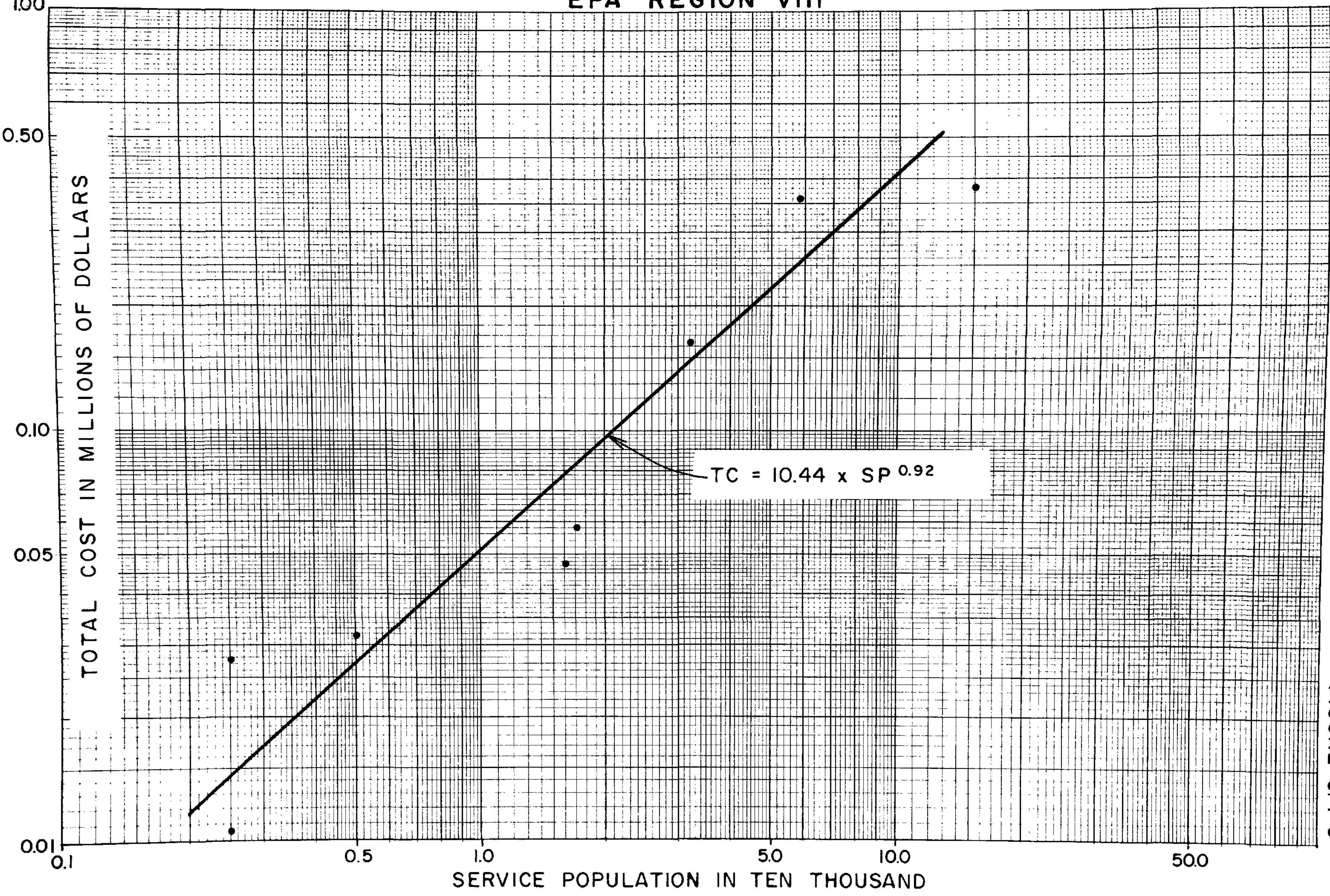


FIGURE G. 1-9

TOTAL COST VS. SERVICE POPULATION
MIXED SEWER SYSTEMS
INCLUDING TREATMENT PLANTS
EPA REGION II

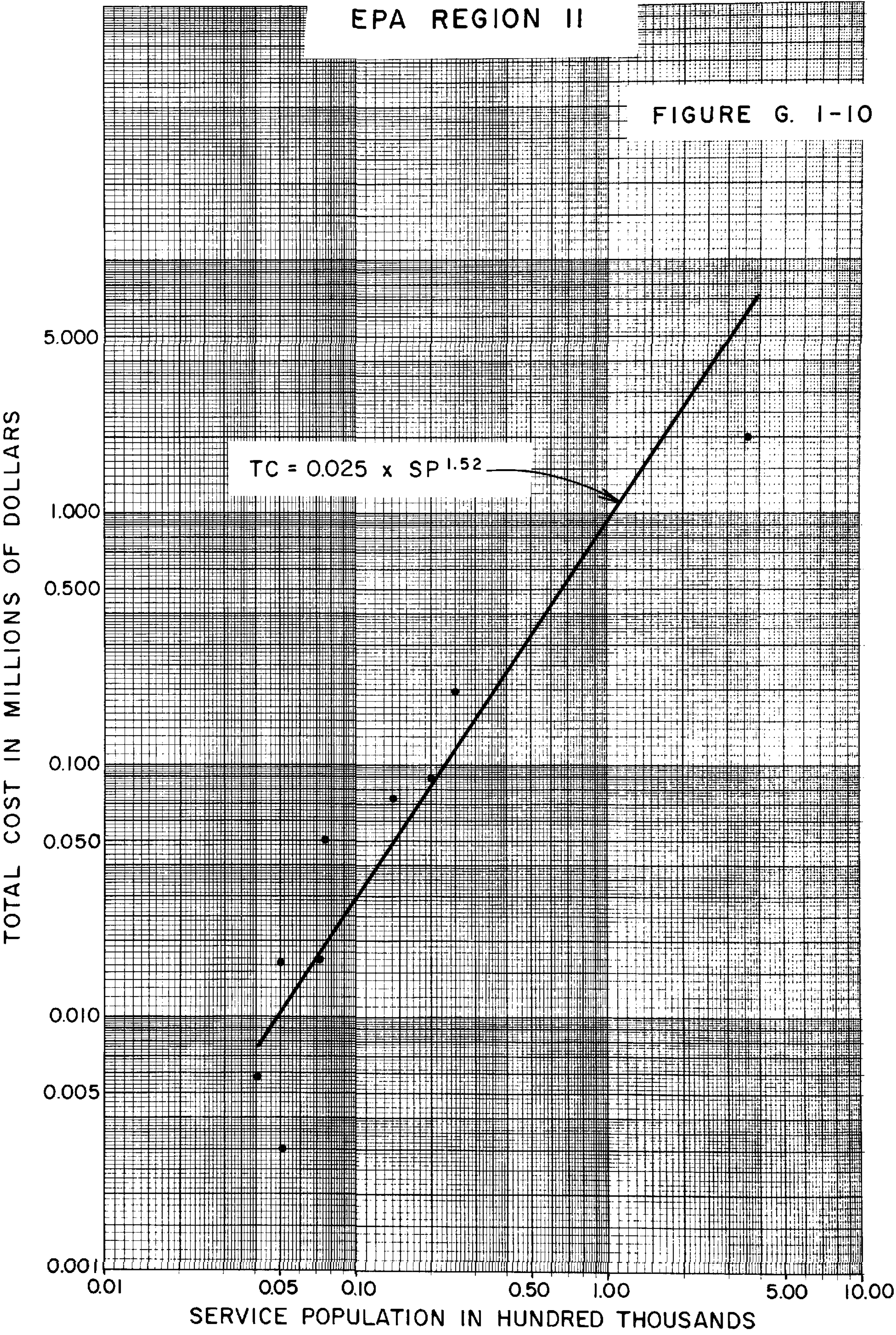


FIGURE G. 1-10

TOTAL COST VS. SERVICE POPULATION
MIXED SEWER SYSTEMS
INCLUDING TREATMENT PLANTS
EPA REGION V

FIGURE G. 1-11

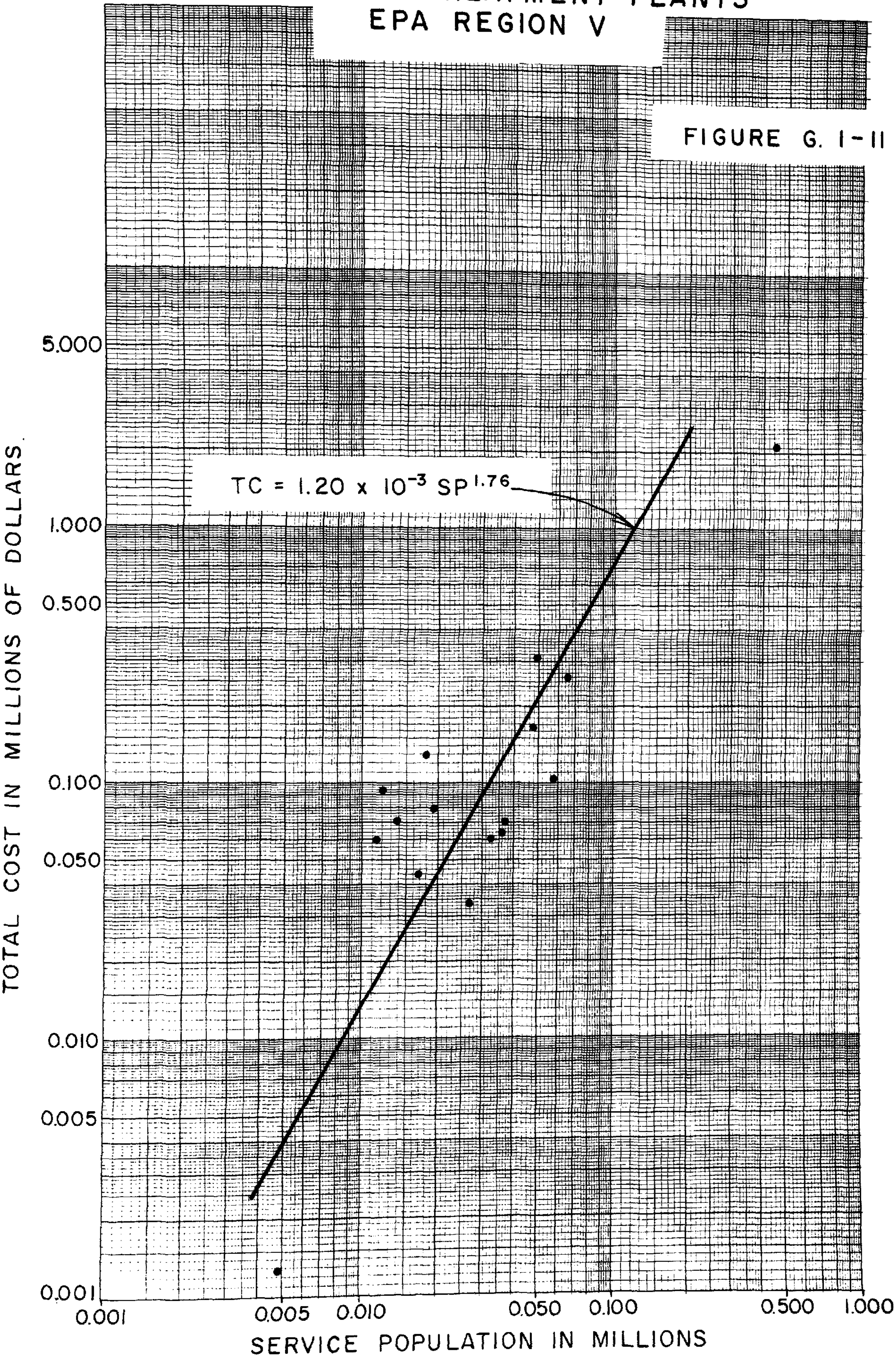


TABLE G.2

POTENTIALLY SIGNIFICANT O&M RELATIONSHIPS
SEWER SYSTEMS: TOTAL COST VS TOTAL LENGTH OF GRAVITY SEWERS

Title	Equation	Sample Size (n)	Correlation Coefficient (r)	F-Test Value
Total Cost vs Total Length of Gravity Sewers, National	$TC = 56.35 \times L^{1.72}$	132	0.75	172.26
Total Cost of Gravity Sewers, Region II	$TC = 31.14 \times L^{1.90}$	34	0.78	50.86
Total Cost of Gravity Sewers, Region V	$TC = 14.71 L^{1.89}$	34	0.75	42.22
Total Cost of Gravity Sewers, Region VI	$TC = 1.44 \times 10^3 \times L^{1.12}$	6	0.94	29.14
Total Cost of Gravity Sewers, Region VIII	$TC = 1.46 \times 10^3 \times L^{0.97}$	10	0.94	57.16

Where TC equals total OM&R cost in dollars and
L equals the total length of the gravity sewer system.

TOTAL COST VS. TOTAL LENGTH OF GRAVITY SEWERS
NATIONAL

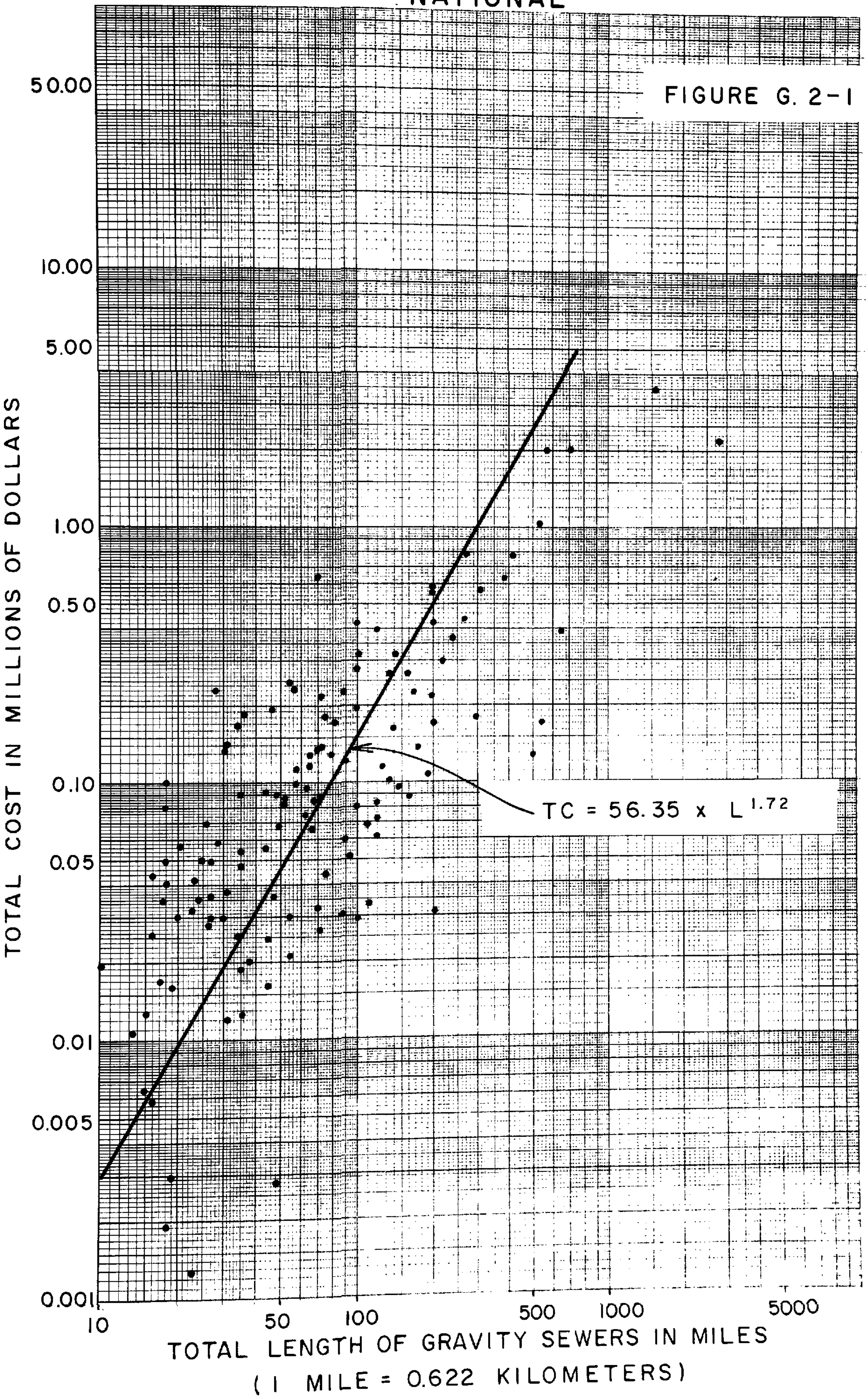
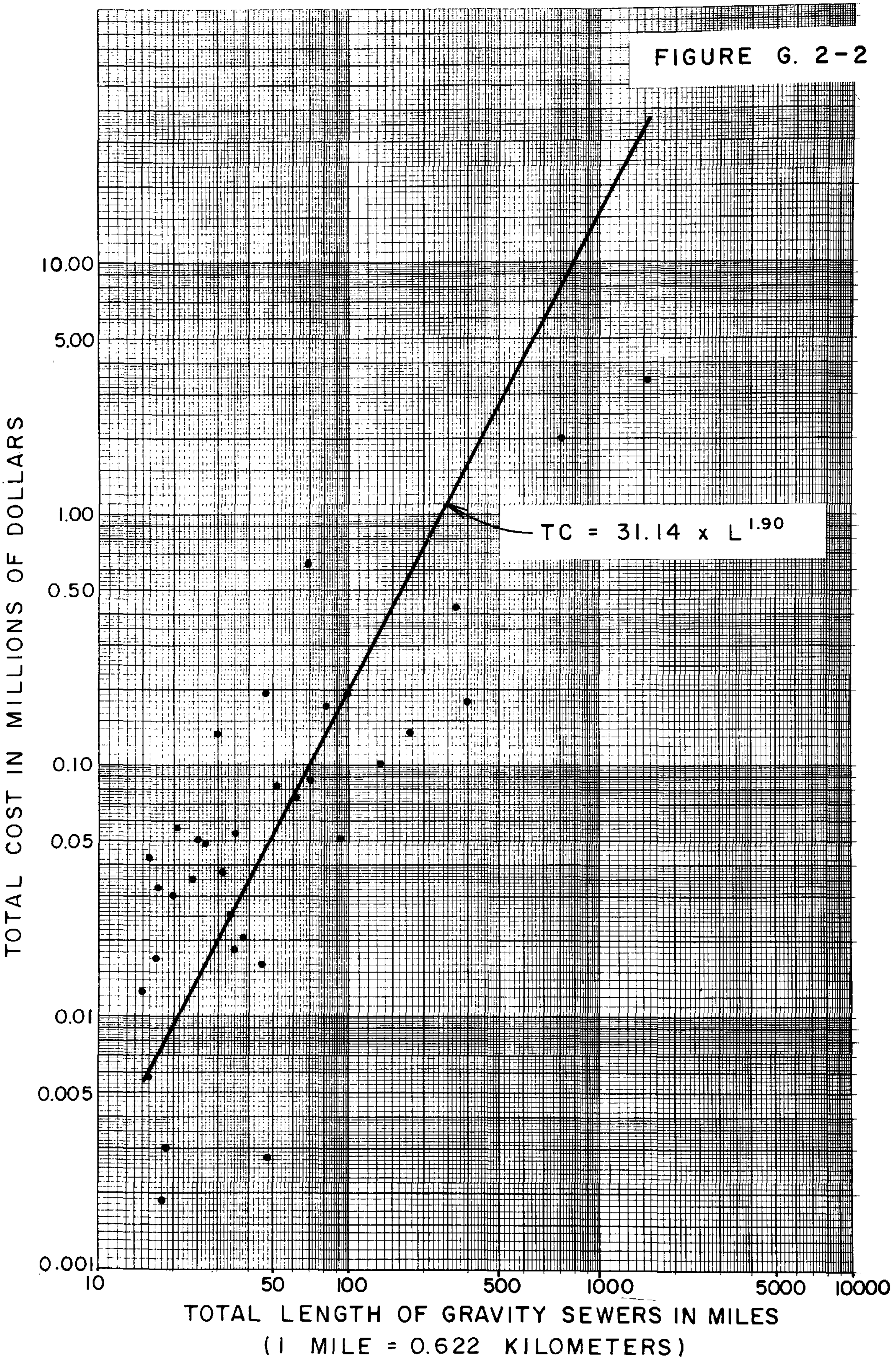


FIGURE G. 2-1

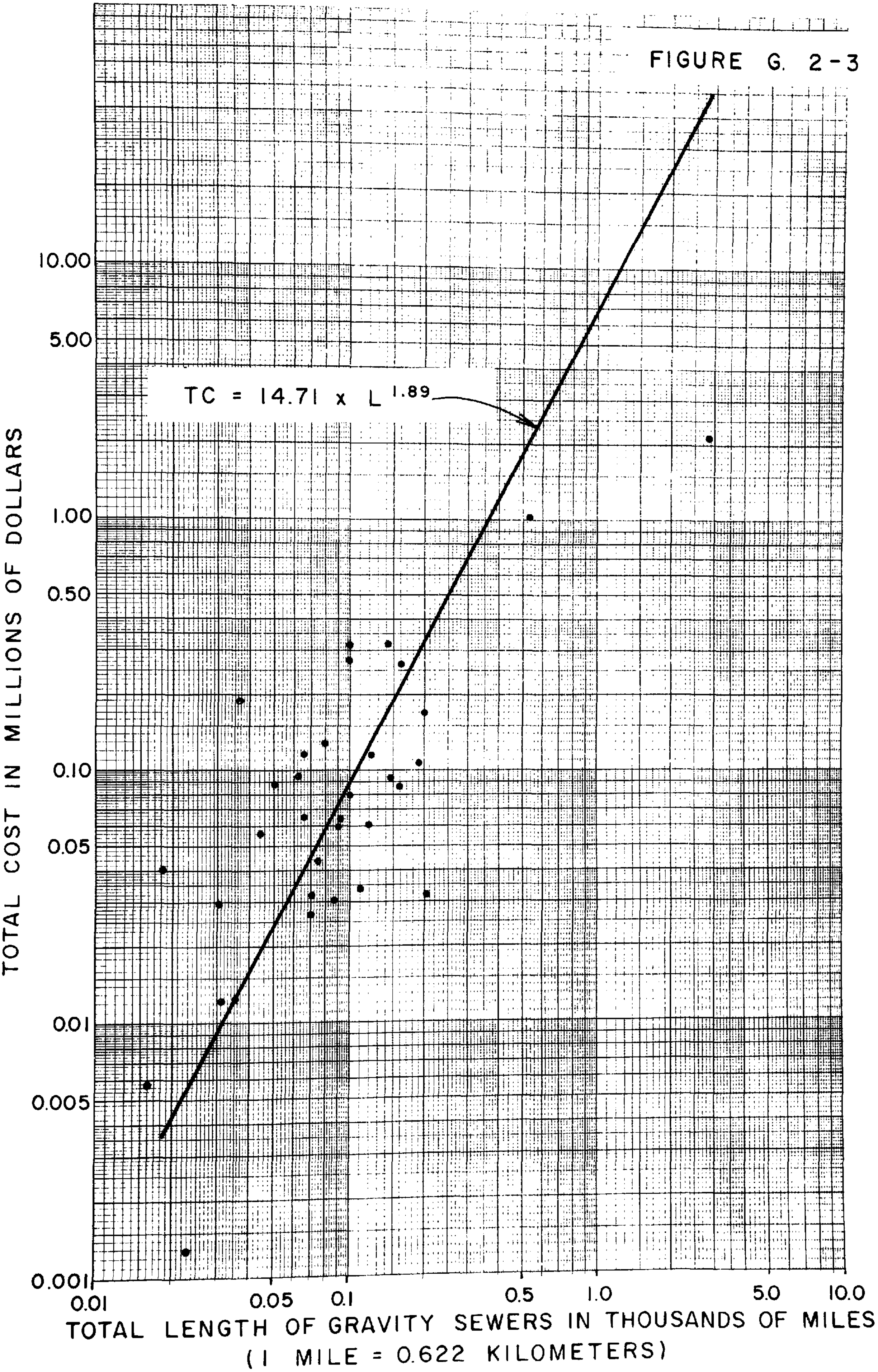
TOTAL COST VS. TOTAL LENGTH OF GRAVITY SEWERS EPA REGION II

FIGURE G. 2-2



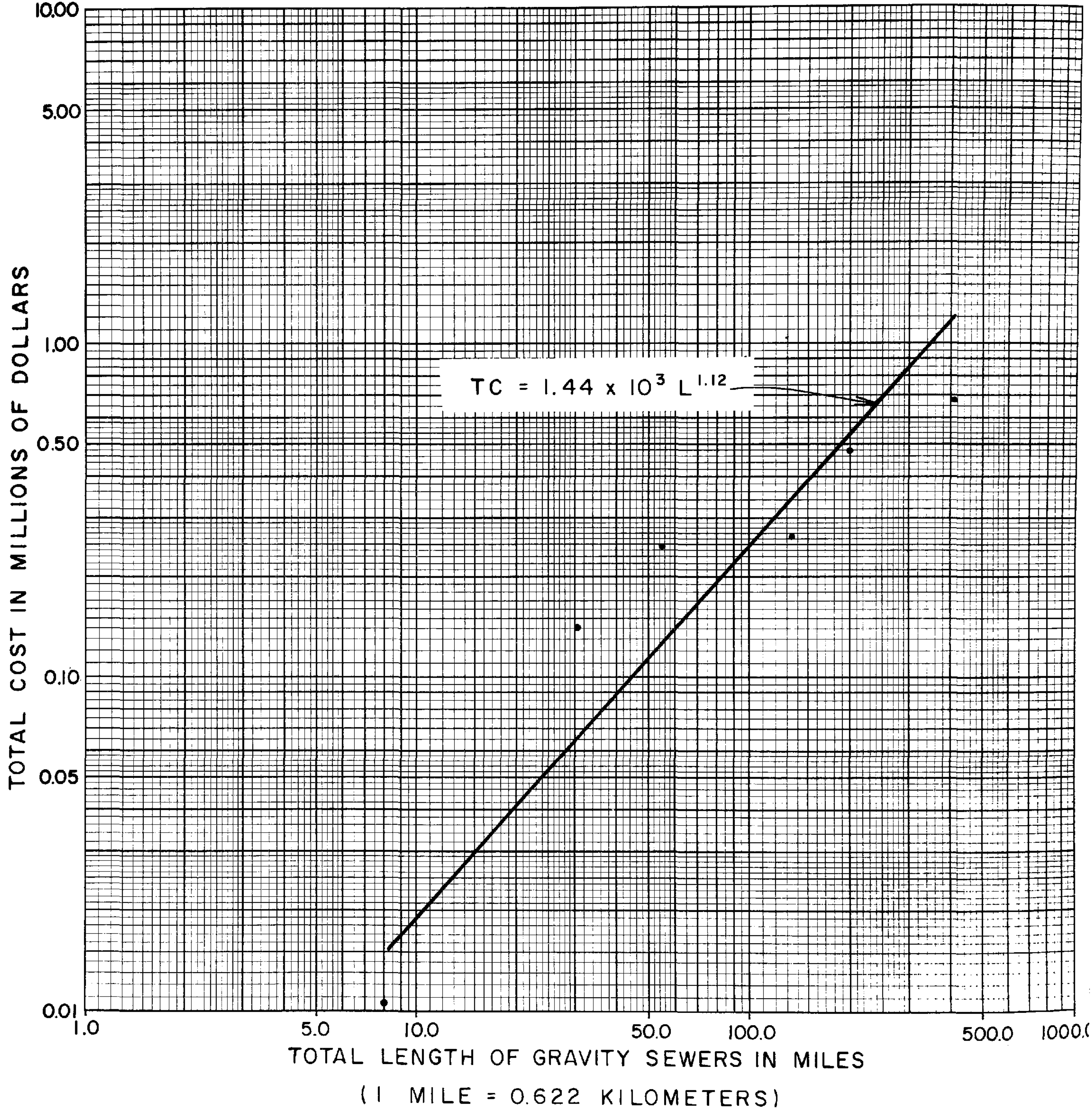
TOTAL COST VS. TOTAL LENGTH OF GRAVITY SEWERS
EPA REGION V

FIGURE G. 2-3



TOTAL COST VS. TOTAL LENGTH OF GRAVITY SEWERS EPA REGION VI

FIGURE G. 2-4



TOTAL COST VS. LENGTH OF GRAVITY SEWERS
EPA REGION VIII

FIGURE G. 2-5

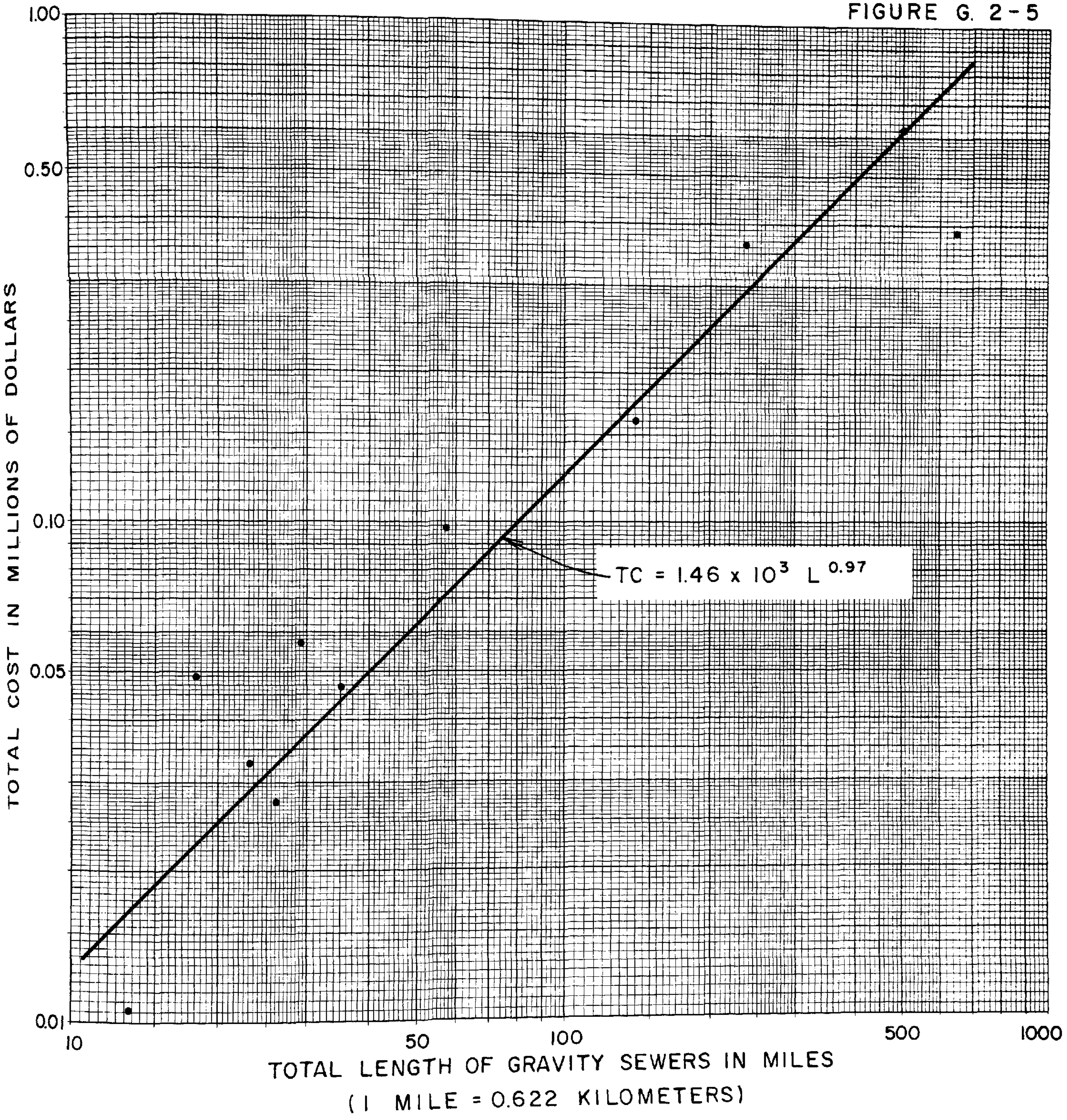


TABLE G.3

POTENTIALLY SIGNIFICANT O&M RELATIONSHIPS
SEWER SYSTEM: TOTAL COST VS STAFF SIZE

Title	Equation	Sample Size (n)	Correlation Coefficient (r)	F-Test Value
Total Cost vs Staff Size - All Systems, National	$TC = 1.65 \times 10^4 S^{1.14}$	97	0.91	436.82
Total Cost of Staff, Region I	$TC = 1.45 \times 10^4 S^{1.20}$	6	0.99	149.10
Total Cost of Staff, Region II	$TC = 1.65 \times 10^4 S^{1.12}$	28	0.92	151.14
Total Cost of Staff, Region III	$TC = 2.19 \times 10^4 S^{1.07}$	5	0.96	35.39
Total Cost of Staff, Region IV	$TC = 1.84 \times 10^4 S^{1.05}$	23	0.84	50.55
Total Cost of Staff, Region V	$TC = 8.58 \times 10^3 S^{1.34}$	13	0.91	51.70
Total Cost of Staff, Region VIII	$TC = 2.46 \times 10^4 S^{.91}$	9	0.91	31.85

Where TC equals total OM&R cost in dollars and
S equals the size of the staff to maintain the sewer system.

TOTAL O & M COST VS. STAFF SIZE
NATIONAL

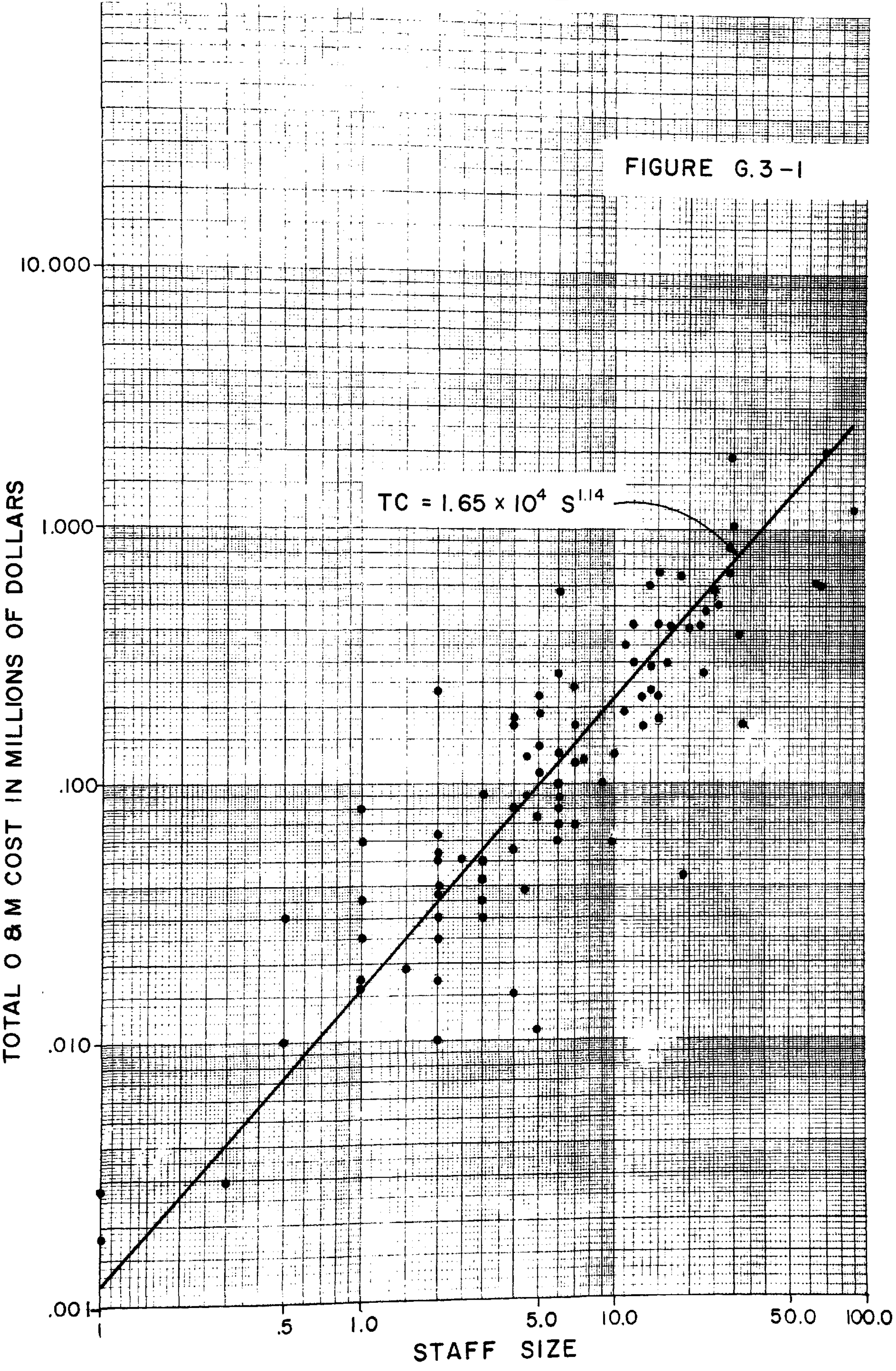
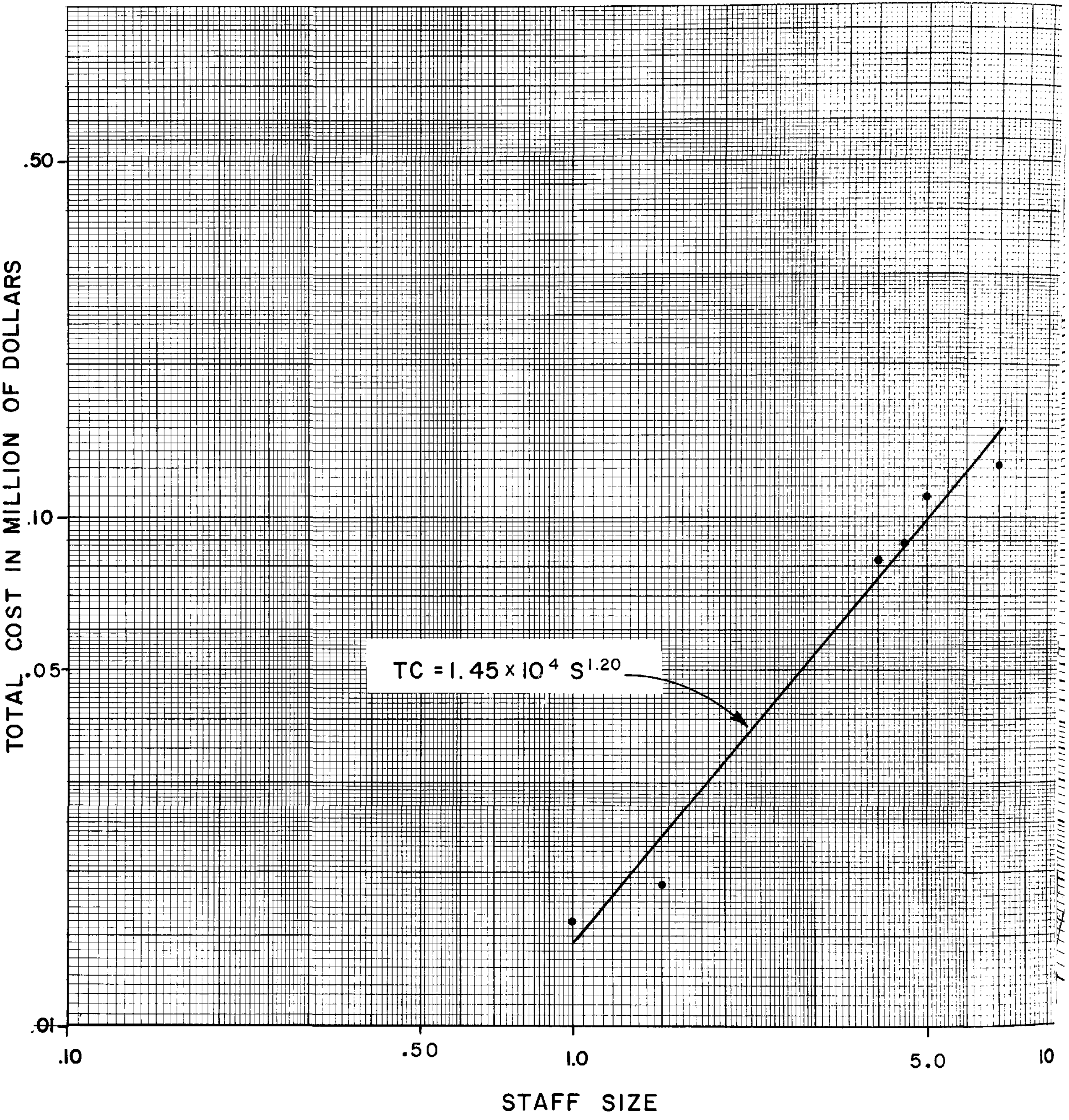


FIGURE G.3-1

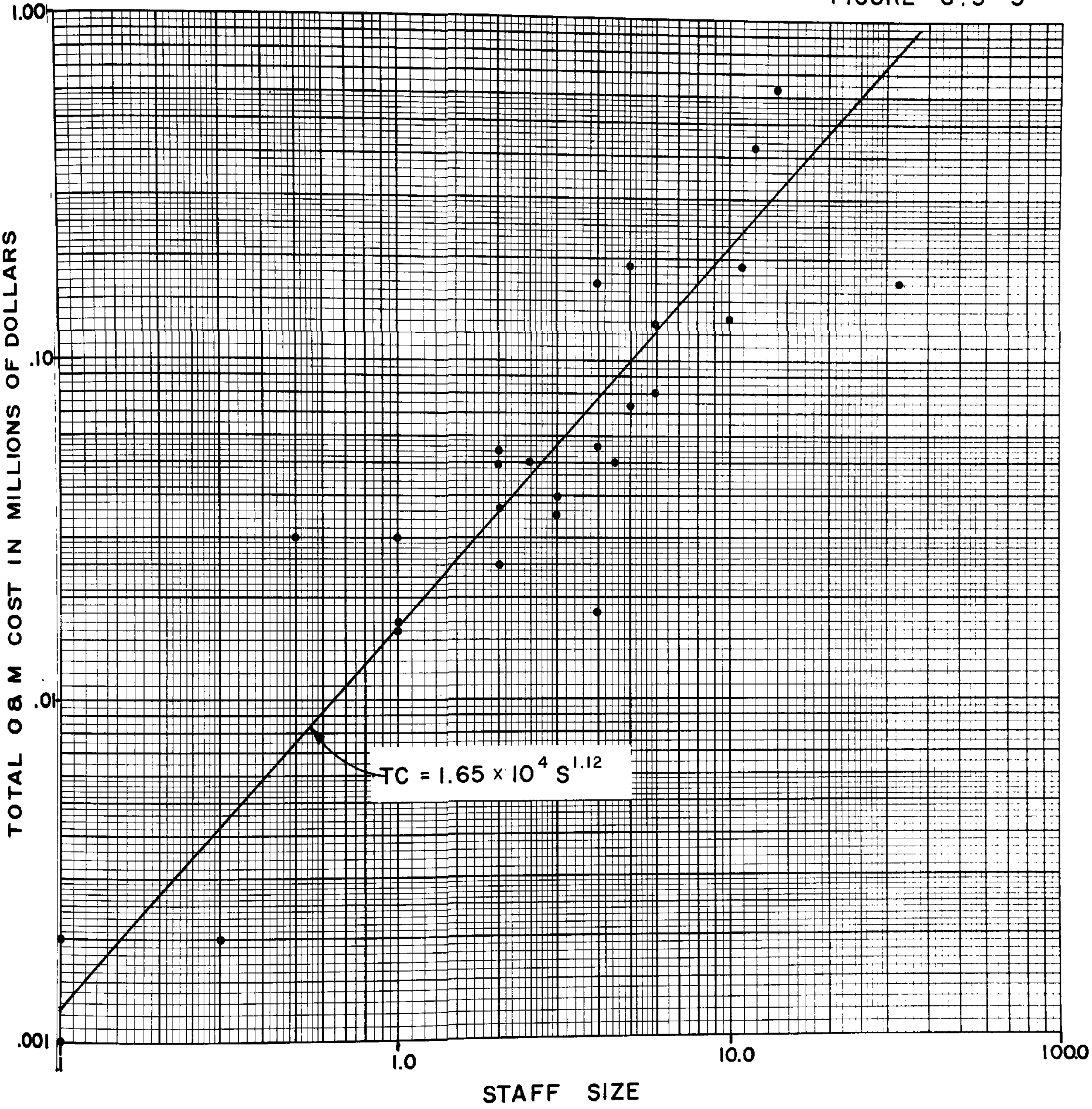
FIGURE G.3-2

TOTAL O&M COST VS. STAFF SIZE
EPA REGION I



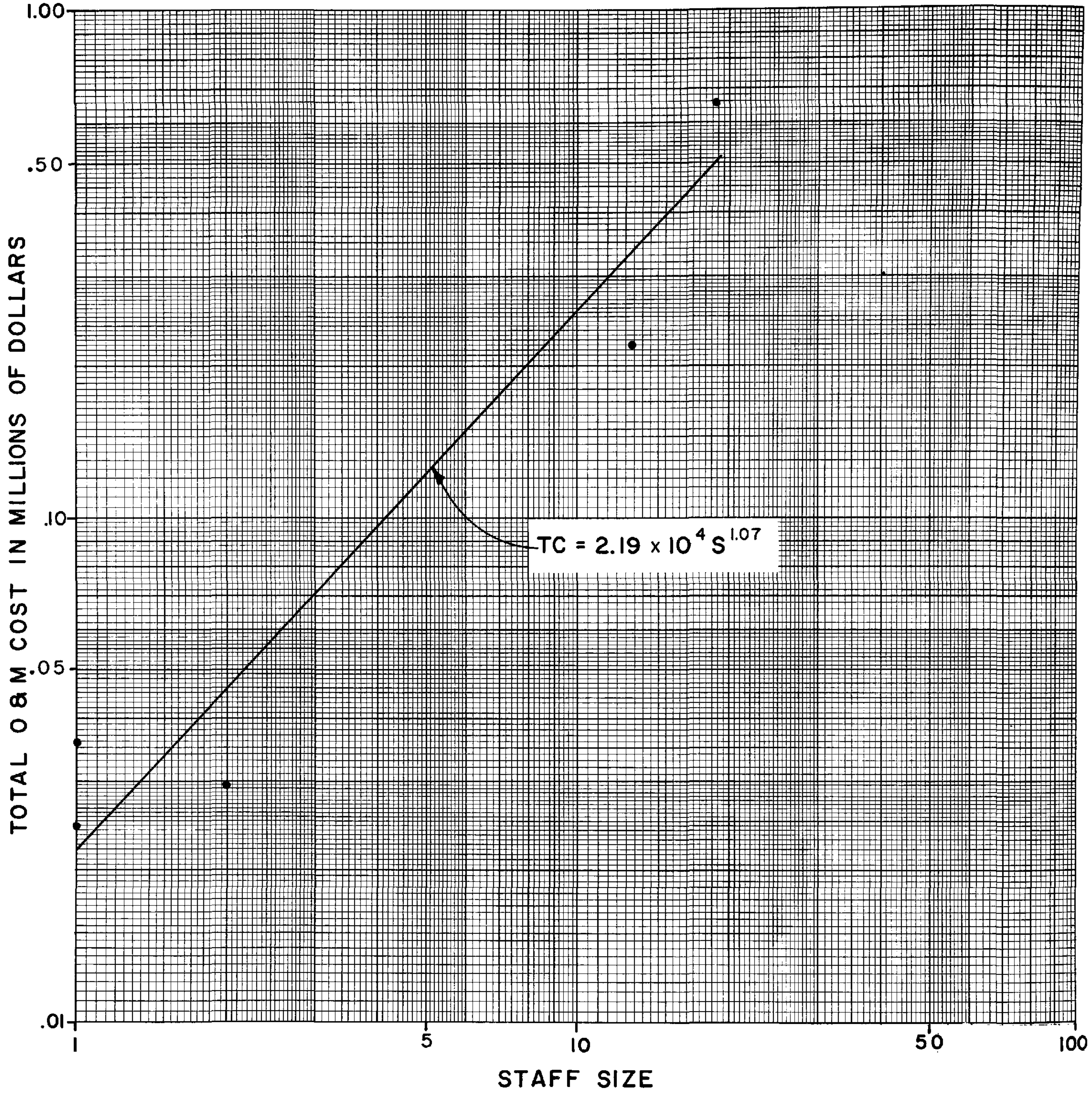
TOTAL O & M COST VS. STAFF SIZE
EPA REGION II

FIGURE G.3-3



TOTAL O & M COST VS. STAFF SIZE
EPA REGION III

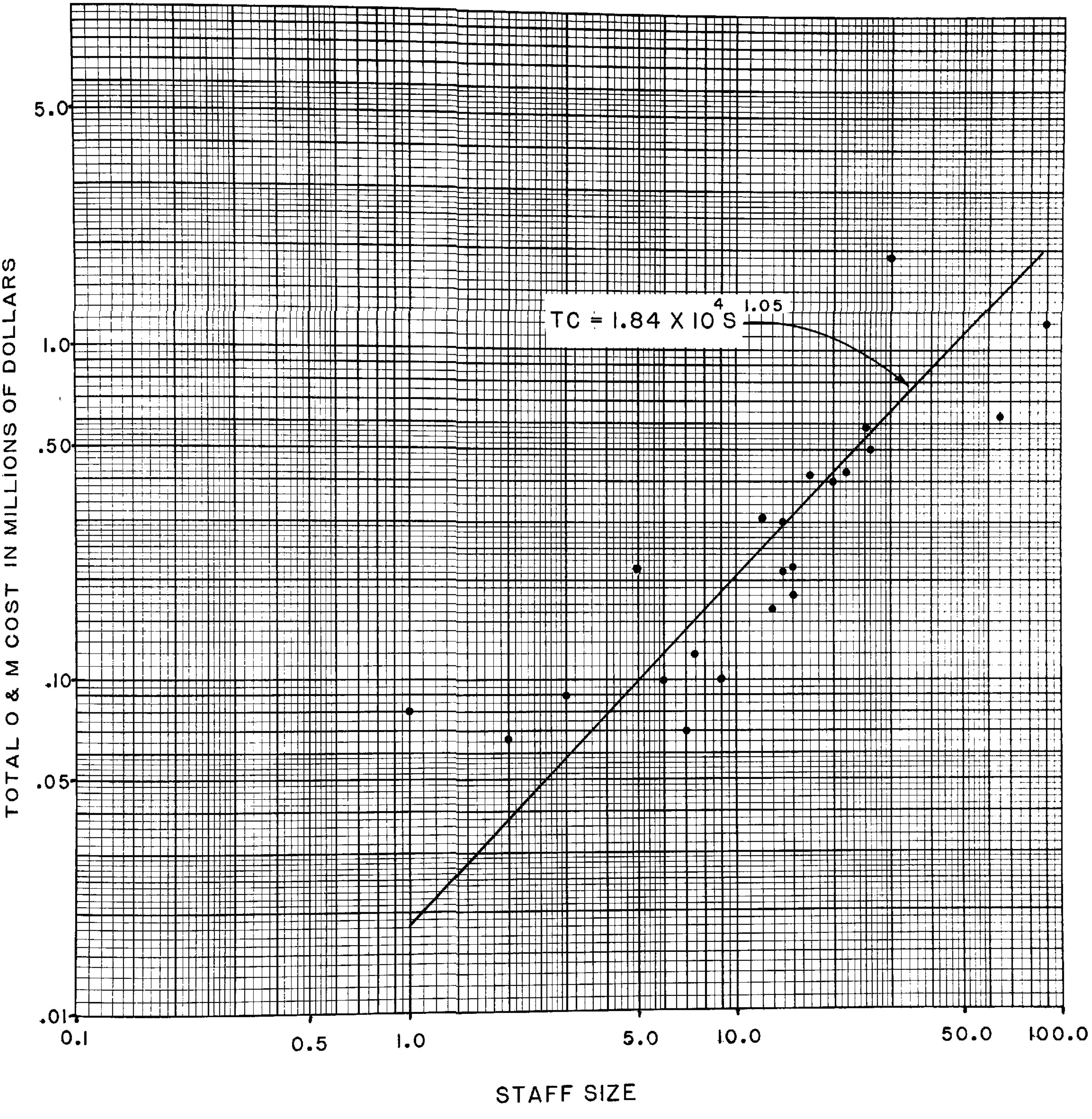
FIGURE G. 3-4



TOTAL O&M COST VS. STAFF SIZE

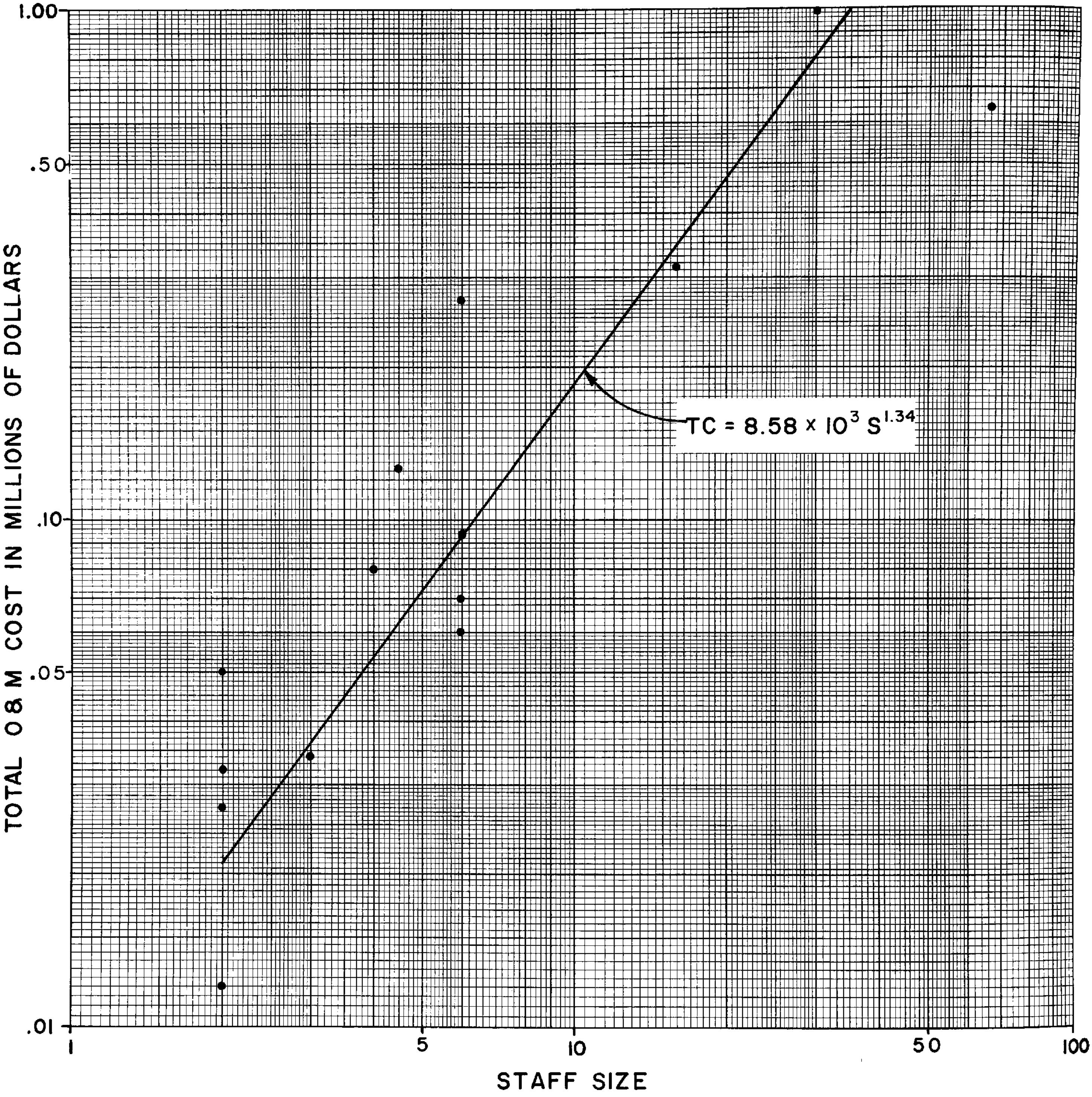
EPA REGION IV

FIGURE G. 3-5



TOTAL O&M COST VS. STAFF SIZE
EPA REGION V

FIGURE G.3-6



TOTAL O & M COST VS. STAFF SIZE
EPA REGION VIII

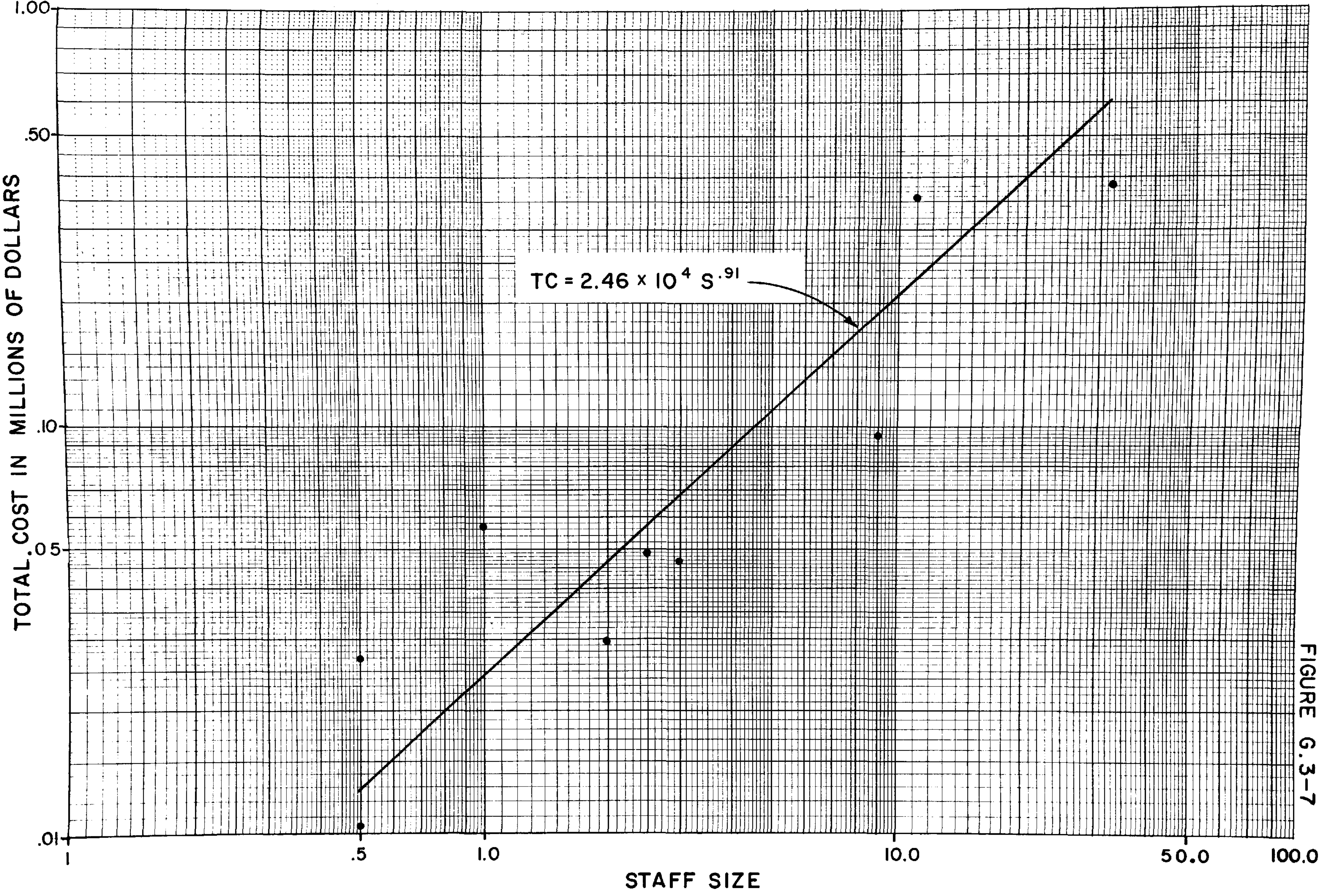


FIGURE G.3-7

TABLE G.4

POTENTIALLY SIGNIFICANT O&M RELATIONSHIPS
SEWER SYSTEMS: STAFF SIZE VS SERVICE POPULATION

Title	Equation	Sample Size (n)	Correlation Coefficent (r)	F-Test Value
All Sewer Systems National	$S = 2.74 \times 10^{-6} SP^{1.44}$	143	0.81	260.13

Where S equals the size of the staff to maintain the sewer system and SP equals the number of people served by the sewer system.

STAFF SIZE VS. SERVICE POPULATION NATIONAL

FIGURE G.4-1

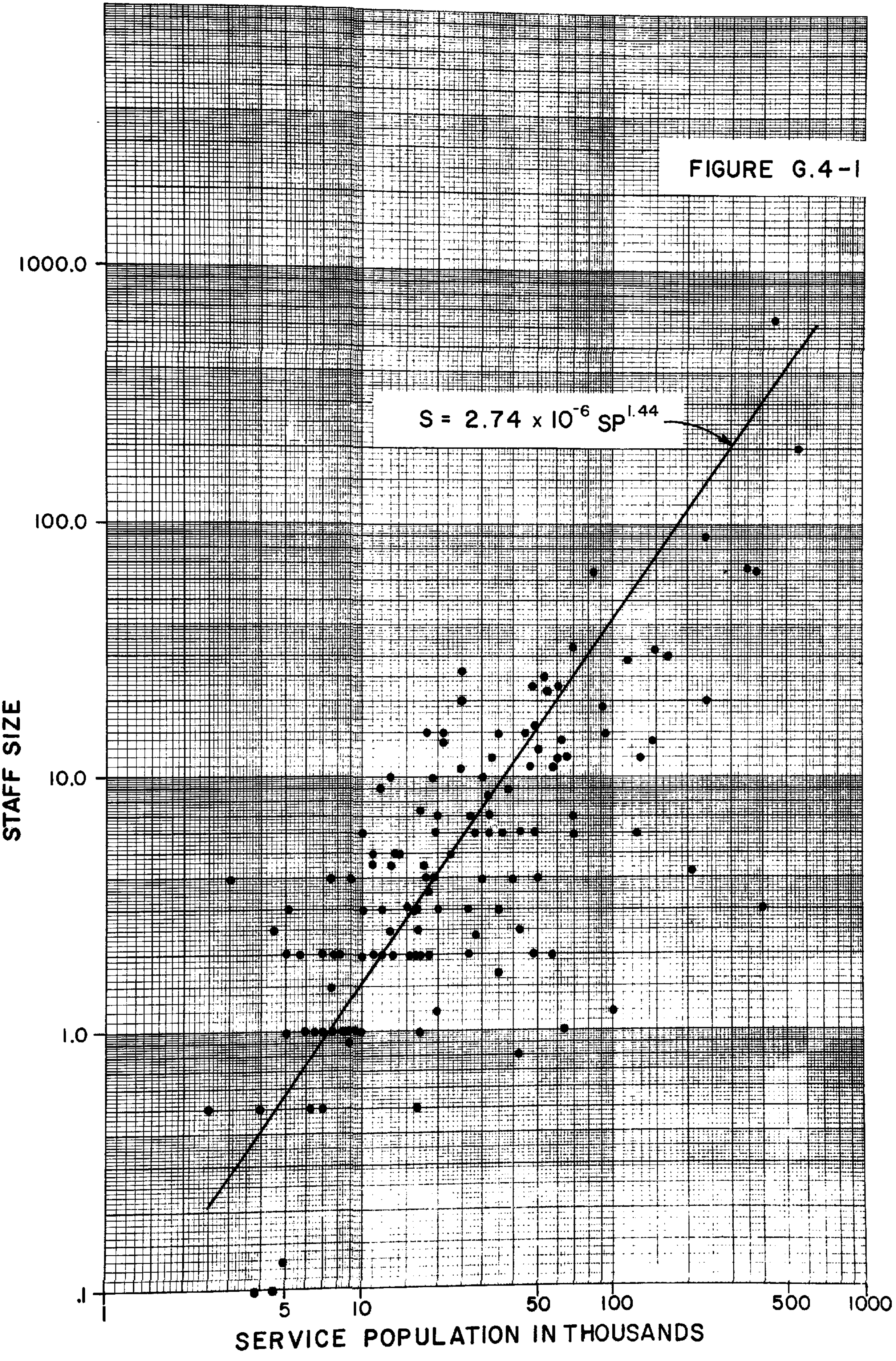


TABLE G.5

POTENTIALLY SIGNIFICANT O&M RELATIONSHIPS
SEWER SYSTEMS: STAFF SIZE VS LENGTH OF GRAVITY SEWERS

Title	Equation	Sample Size (n)	Correlation Coefficient (r)	F-Test Value
Staff Size vs Length of Gravity Sewers - All Systems, National	$S = 2.81 \times 10^{-3} L^{1.72}$	127	0.68	111.92

Where S equals the size of the staff to maintain the sewer system and L equals the total length of the gravity sewer system.

STAFF SIZE VS. TOTAL LENGTH OF GRAVITY SEWERS

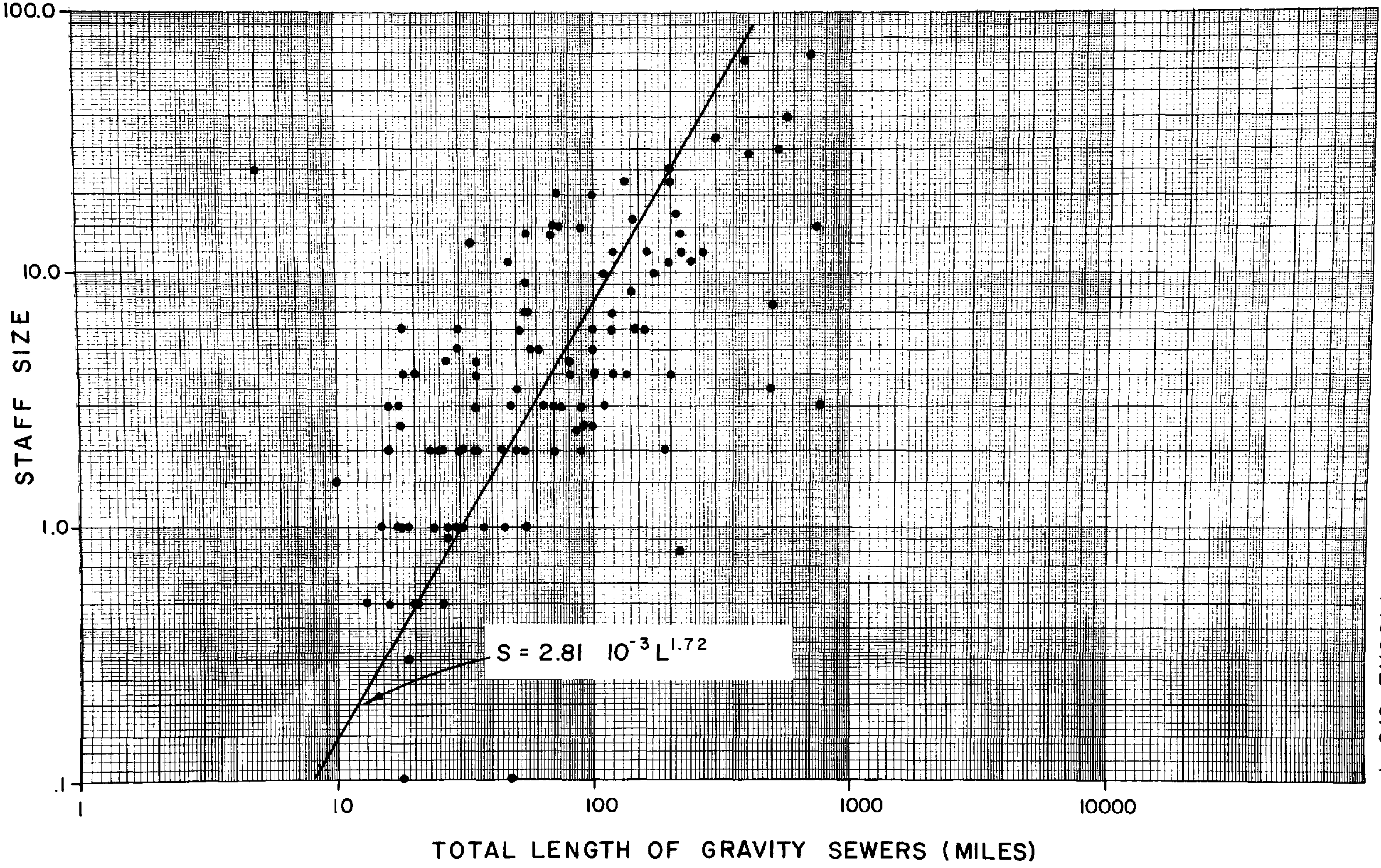


FIGURE G.5-1

TABLE G.6

POTENTIALLY SIGNIFICANT O&M RELATIONSHIPS
SEWER SYSTEMS: OPERATING COST VS STAFF SIZE

Title	Equation	Sample Size (n)	Correlation Coefficient (r)	F-Test Value
All Sewer Systems National	$OC = 1.39 \times 10^4 S^{1.16}$	114	0.88	385.48

Where OC equals operating cost of the sewer system and
S equals the size of the staff to maintain the sewer system.

OPERATING COST VS. STAFF SIZE
NATIONAL

FIGURE G. 6-1

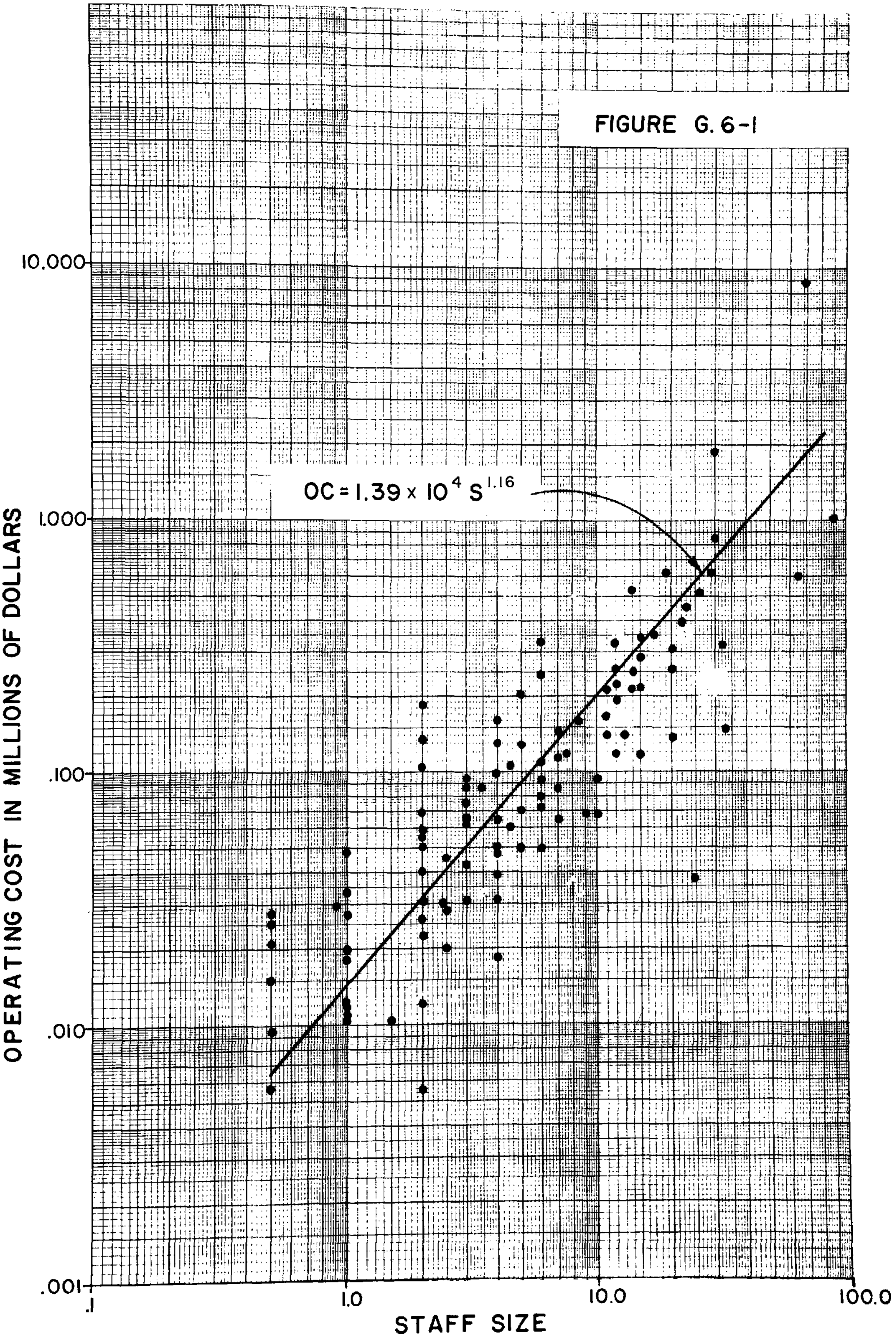


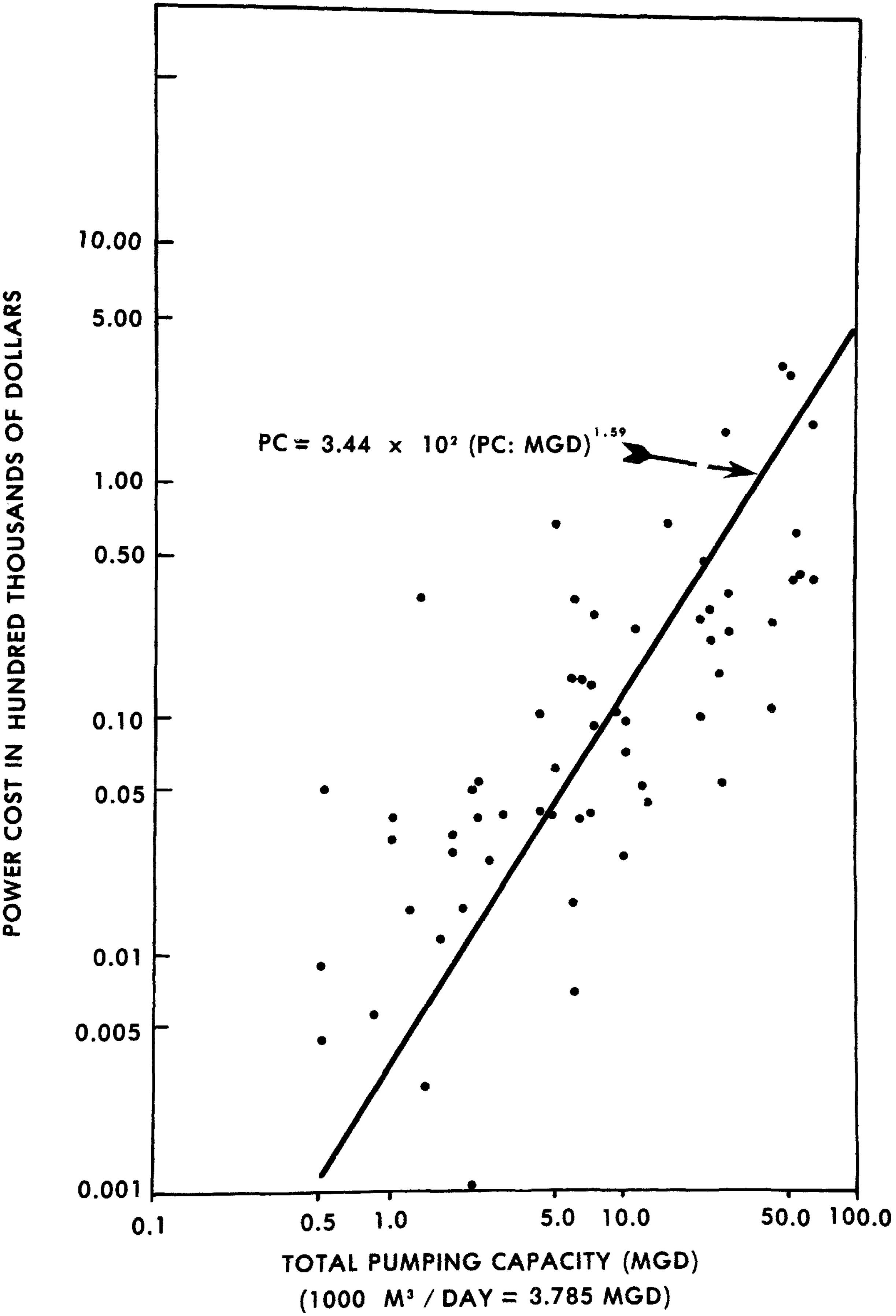
TABLE G.7

POTENTIALLY SIGNIFICANT O&M RELATIONSHIPS
POWER COSTS VS PUMPING CAPACITY

Title	Equation	Sample Size (n)	Correlation Coefficient (r)	F-Test Value
Power Costs vs Total Pumping Capacity (mgd), National	$PC = 3.44 \times 10^2 (PC{:}mgd)^{1.59}$	63	0.72	65.34
Power Costs vs Total Horsepower of Pump Stations, National	$PC = 4.35 \times HP^{1.44}$	63	0.73	69.37
Power Costs vs Total Pumping Capacity, Region II	$PC = 2.75 \times 10^2 (PC{:}mgd)^{1.73}$	21	0.72	20.36
Power Costs vs Total Pumping Capacity, Region III	$PC = 1.24 \times 10^3 (PC{:}mgd)^{0.90}$	10	0.83	17.32

Where PC equals power costs,
PC:mgd equals total pumping capacity in million gallons per day, and
HP equals horsepower of pump stations.

POWER COST VS. TOTAL PUMPING CAPACITY
SEWER SYSTEMS NATIONAL



POWER COST VS TOTAL HORSEPOWER OF PUMP STATIONS NATIONAL

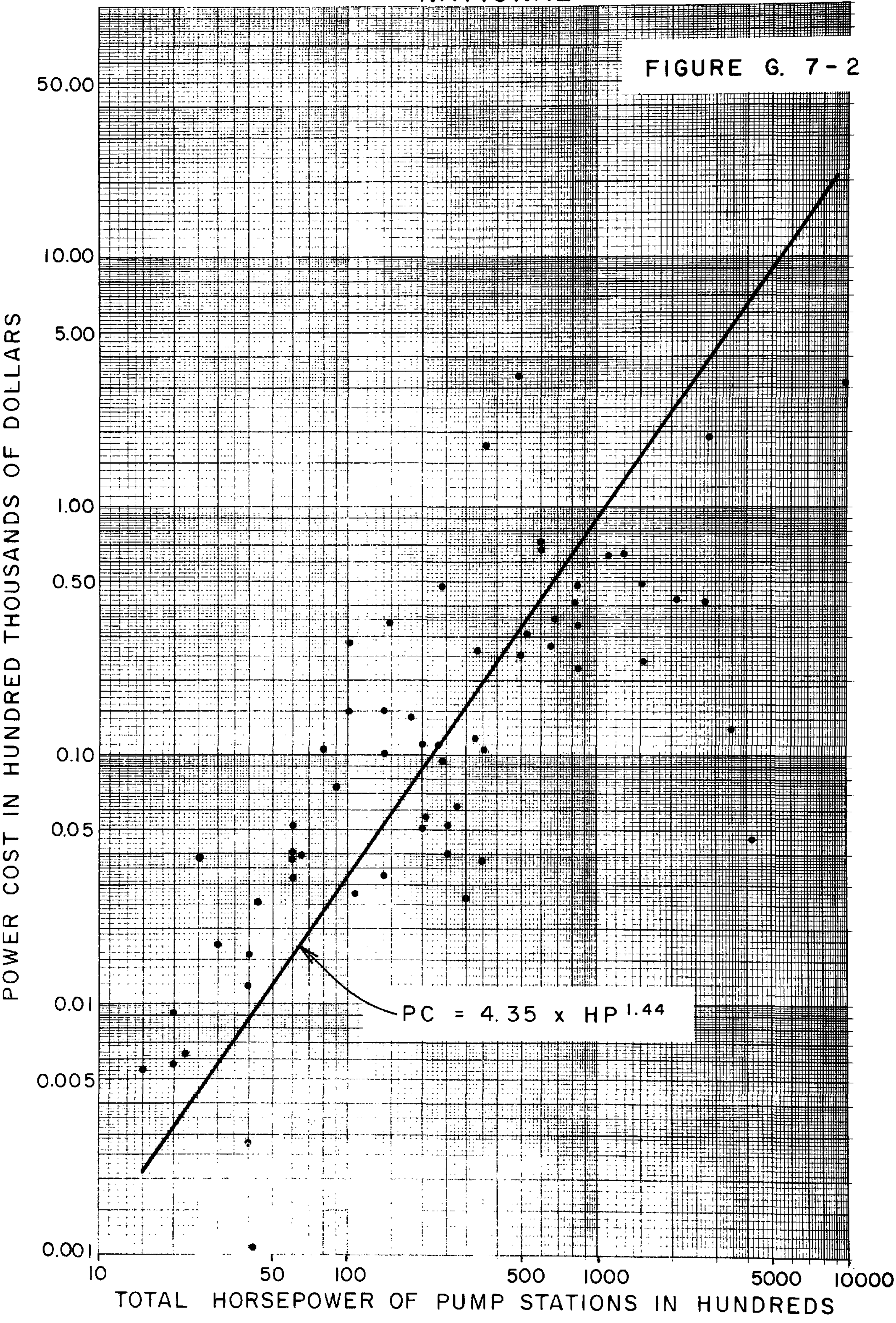
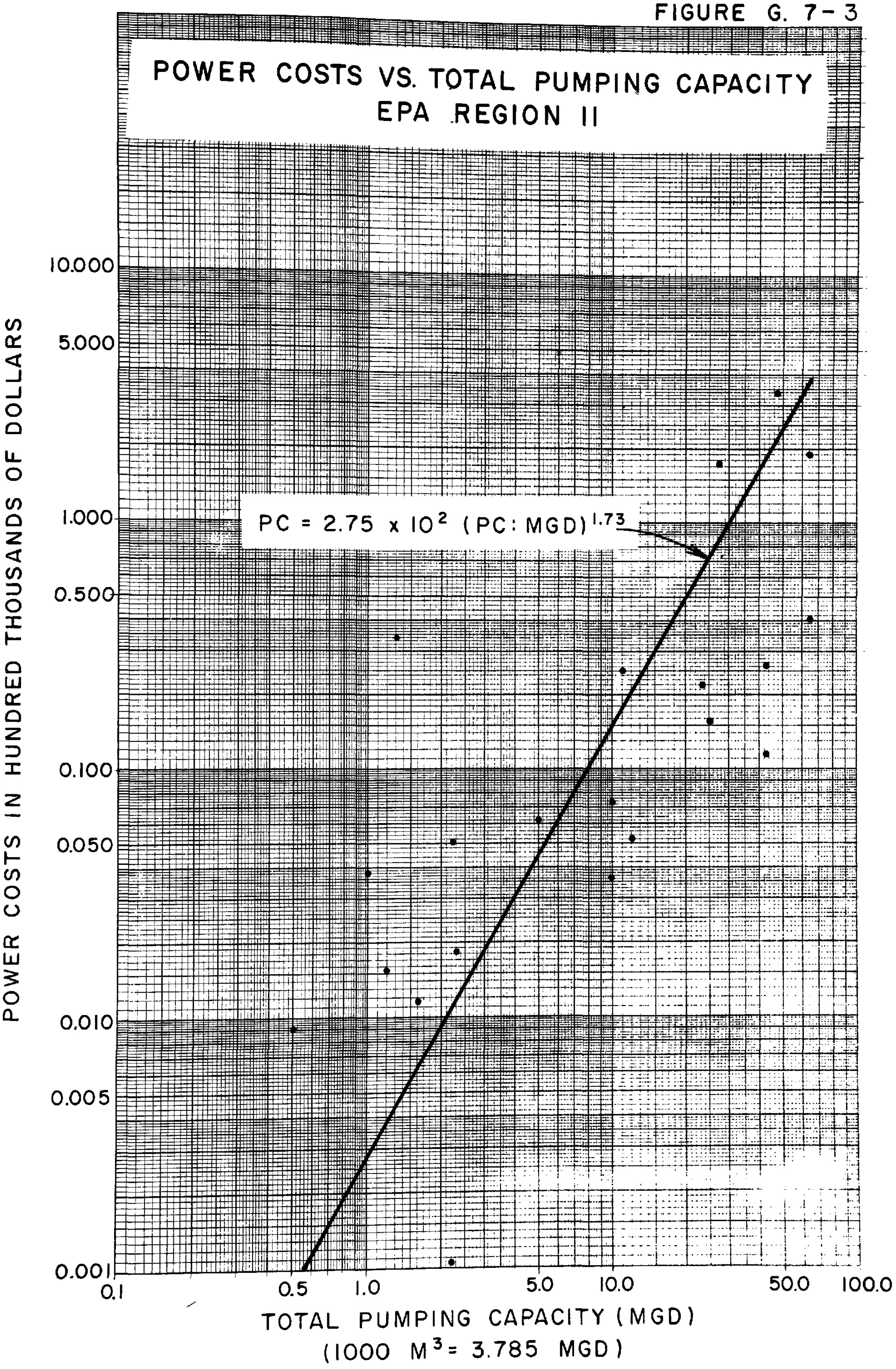


FIGURE G. 7-3


POWER COSTS VS. TOTAL PUMPING CAPACITY
EPA REGION II
PC = 2.75 x 10^2 (PC: MGD)^1.73
POWER COSTS IN HUNDRED THOUSANDS OF DOLLARS
10.000
5.000
1.000
0.500
0.100
0.050
0.010
0.005
0.001
0.1
0.5
1.0
5.0
10.0
50.0
100.0
TOTAL PUMPING CAPACITY (MGD)
(1000 M^3 = 3.785 MGD)

POWER COST VS. TOTAL PUMPING CAPACITY
EPA REGION III

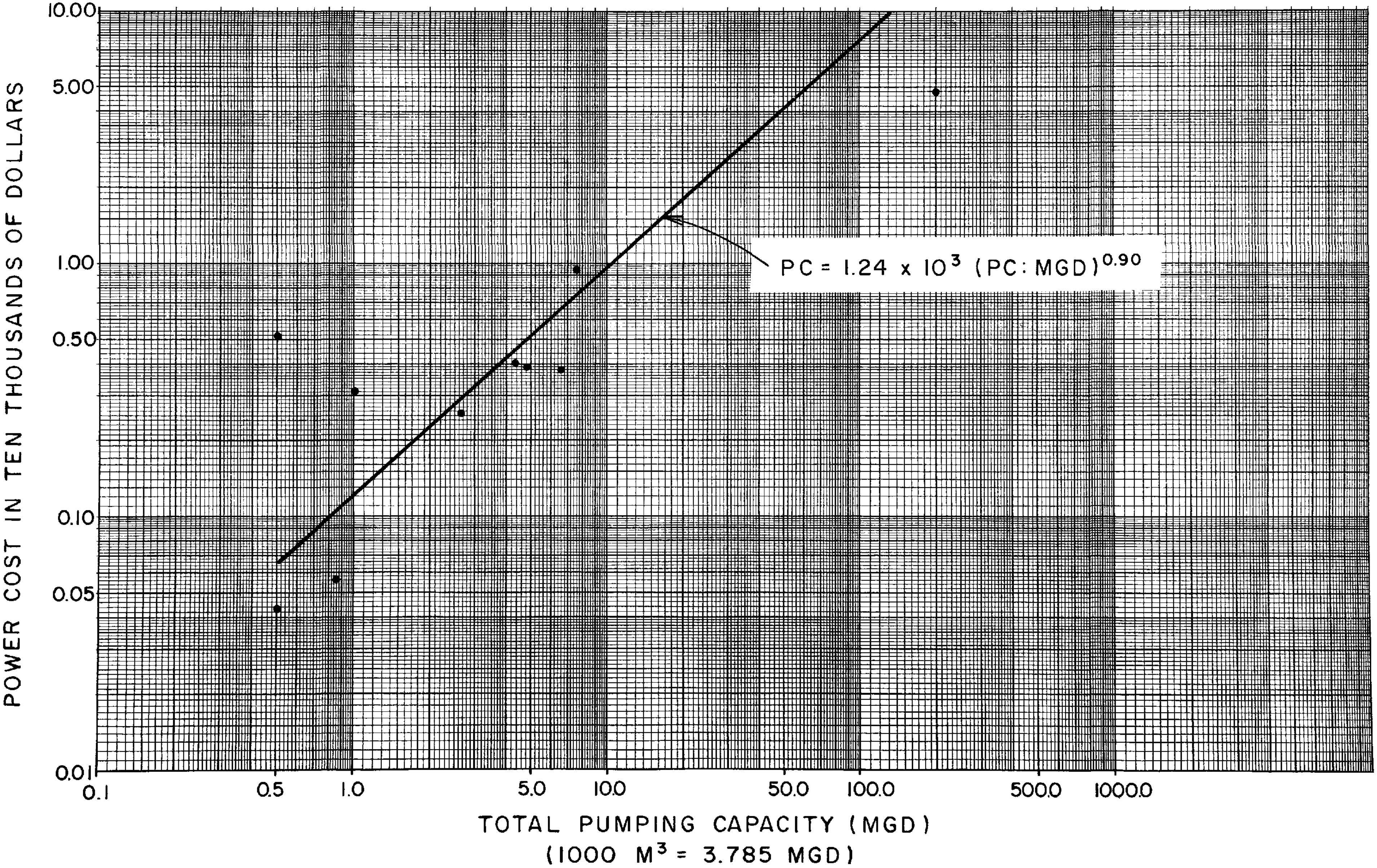


FIGURE G. 7-4

CONVERSION EQUIVALENTS TO METRIC UNITS

1000 cubic meters per day = mgd x 3.785

1000 kilograms (metric ton) = tons x 0.907

kilograms = pounds x 0.454

kilometers = miles x 1.609

kilowatts = horsepower x 0.7457

REFERENCES

Culp, Gordon, 1977, Environmental pollution control alternatives: Municipal Wastewater, U.S. EPA Technology Transfer (EPA-625/5-76-012).

U.S. Environmental Protection Agency, February 1977, Cost estimates for construction of publicly-owned wastewater treatment facilities: Summaries of Technical Data (Categories I-IV), MCD-48B, 430/9-76-011.