77-21,387

MAYNE, Tony, 1938-
A SYSTEMS APPROACH TO MANPOWER PLANNING FOR THE WATER TREATMENT INDUSTRY.

The University of Oklahoma, Ph.D., 1977
Engineering, civil

Xerox University Microfilms, Ann Arbor, Michigan 48106

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

A SYSTEMS APPROACH TO MANPOWER PLANNING FOR THE WATER TREATMENT INDUSTRY

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

TONY MAYNE

Norman, Oklahoma

1976

A SYSTEMS APPROACH TO MANPOWER PLANNING

FOR THE WATER TREATMENT INDUSTRY

APPROVED BY

DISSERTATION COMMITTEE

ACKNOWLEDGMENTS

I would like to express my deepest gratitude to Professor George W. Reid for program direction and guidance.

I am also grateful to Jim Dawson and The Oklahoma Foundation for Research and Development Utilization, Inc., as he made this work possible through employment during the data collection phase of this project.

I would like to thank my typist Trish Abolins for having so skillfully typed this dissertation from the disorganization of my work.

Any omissions or errors are those of the author.

ABSTRACT

A SYSTEMS APPROACH TO MANPOWER PLANNING

FOR THE WATER TREATMENT INDUSTRY

by Tony Mayne

Major Professor: George W. Reid

This study was concerned with the development of a predictive model for the use of developing staffing guidelines for the water treatment industry. This methodology yielded models for preparation of staffing guidelines for a continuum of system sizes and source types.

The water treatment industry has been furnishing high quality public drinking water for decades with only a few incidences of public health problems. Some problems have occurred and can be overcome in part by placing qualified utility employees in appropriate numbers in the utilities. A complete job description for the operator classification of worker is developed by distillation from the list of duties performed by a nationwide sample of this worker category. Further, recommendations on total staffing and operator staffing are mathematically based on a statistical analysis of data from 56 utilities surveyed.

The surveyed utilities were chosen from a variety of system source types, sizes, and geographical locations. Source type and the number of source connections are the primary determinants for required staffing with production volume and community population less accurate but useful size indicators.

Finally, the recommendation is made that the federal government should not undertake a major educational program for the operator classification of worker. An analysis of the duties performed indicates that site specific, on-the-job training is all that is required for small and intermediate sited utilities. Large utilities experience a large degree of job specialization only slightly utility related.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF GRAPHS

A SYSTEMS APPROACH TO MANPOWER PLANNING FOR THE WATER TREATMENT INDUSTRY

CHAPTER I

INTRODUCTION

The purpose of this dissertation is to identify, quantify, and evaluate the manpower requirements of the water treatment industry.

A systems approach was devised as a means of developing the predictive technology for staffing within this industry. The methodology involves no hypothetical guesswork nor is it burdened with detailed work measurement type analysis.

On the contrary, the rational approach of investigating a successful, operational system in motion is developed to yield a model for staffing information. This model is then used to predict manpower requirements through disaggregation for system sub-sets and the accuracy is then checked.

Data for these evaluations were collected from actual on-site visits to 56 water utilities deemed representative of the industry as a whole.

After the data were collected, an analysis was begun to determine what the significant characteristics of the industry were and what the relationship between these parameters and actual staffing was. Once these determinants were identified and analyzed, staffing guides could be prepared for a continuum of water utility system types, sizes, and locations. (See page 23.)

To more specifically detail the purposes of the study, the original "identify, quantify, and evaluate" were broken-down into the following statements of objectives:

1. Identify and quantify specific job titles within the industry.
2. Identify and quantify specific task characteristics for the above job titles.
3. Determine common parameters used to quantify characteristics of the industry. What are the indicators of size or scale?
4. Correlate the indicators to task and job titles.
5. Determine the significant factors affecting employment estimates and the degree of effect induced in the predicted totals.
6. Develop a model utilizing the appropriate technical coefficients for use in predicting aggregate or specific job title employment for a continuous set of system sizes.

In order to meet the above objectives the following methodologies were employed: 1) Review of the literature pertinent to manpower planning for related wastewater programs; 2) on-site interviews to determine both physical and employment data; 3) an examination and assessment of data from 56 utility surveys; 4) follow-up projections of the operator classification for several system sites; 5) detailed statistical analysis of system employment determinants, comparing actual and projected employment for the 56 utilities; 6) projected total employment by categories for an example utility.

Chapter I	Introduction.
Chapter II	Details the establishment of need for the research and gives the definition of manpower planning through a discussion of the pertinent literature.
Chapter III	Discusses the methodology of data collection and discusses its relationship to classical work measurement procedures.
Chapter IV	Explains the data management techniques and statistical methods used to evaluate the data and to derive appropriate technical coefficients.
Chapter V	Gives special attention to the operator classification detailing requirements and identifying problems.
Chapter VI	Details the development of staffing guides for a variety of specific determinants, using total employees and operators as the dependent variables.
Chapter VII	Summarizes the applicability of the staffing guides and draws some conclusions from the study.

CHAPTER II

PROBLEM IDENTIFICATION

During the late 1960's the country began to realize that significant interest, funds, and legislation would be required to make serious inroads into alleviating problems attributable to a generally deteriorating water quality. Shortcomings of earlier water quality legislation became apparent through continually increasing water quality problems and renewed interest resulted in Public Law 92-500, the Federal Water Pollution Control Act Amendments of 1972. It was obvious that manpower planning and education should be investigated as tools to up-grade water quality.

The Environmental Protection Agency requested and funded several studies aimed at assessing manpower needs within the general water sector. The primary thrust originally was in evaluating the wastewater industry with follow-on work dealing with the water treatment industry. These two sectors were judged to be primary determinants of what is publically visible water quality.

The need for a study of this type was identified by a report in 1970 entitled Community Water Supply Study, Analysis of National Survey Finding [1]. This study was performed by the Bureau of Water Hygiene of the Public Health Service. Its purpose was to "investigate public water supply systems in the United States."

Among the findings, four were of specific importance in prompting an overall study of the manpower requirements of this industry. These four findings [2] were:

1. 41% of the systems surveyed delivered water that violated the 1962 U.S. Public Health Service Drinking Water Standards.
2. 61% of the plant operators had not received any water treatment training at a short school or higher level.
3. Many of the operators are only part time employees with very low salaries and, furthermore, of the full time operators only 29% made $7500 per year or more in 1969.
4. Smaller systems have greater problems with quality control and retention of qualified operators.

With these problem areas identified, a "blue-ribbon" committee (Appendix III) composed of the water utility leaders was established to make recommendations on specific sites to be surveyed. Five parameters: system size; ownership type; source type; treatment required; and location region, were used as a basis for selection of the 56 utilities.

There are an estimated 40,000 water systems nation-wide. A representative sample of these was to be surveyed by in-depth personal interviews of system employees on site. The advisory committee, suggested by the study team and made up of leaders from the industry and involved segments of Federal and State agencies, had the responsibility for picking the representative sample. It was deemed necessary that the sample be designed to incorporate as wide a diversity in characteristics as possible. The committee initially proposed a list of 127 sites based on variety among the parameters listed below. These site choices were also based on some familiarity with the systems. The unusual facilities were shied away from as being unrepresentative of the industry. Because of the composition of the advisory committee and their inherent familiarity with specific facilities across the nation, significant interaction between the committee and the survey team took place to pare the list to a level compatible with the funding limitations.

The actual site locations then did indeed reflect diversity and a fair working knowledge of the utilities specified. The sample was chosen based on variety within the following parameters:

1. System Ownership
    a. Public
    b. Private
2. System Size
    a. Large (greater than 100,000 population)
    b. Medium (between 1000 and 100,000 population)
    c. Small (less than 1000 population)
3. Treatment
    a. Full (coagulation, sedimentation, filtration, disinfection)
    b. Partial (aeration, filtration, disinfection)
    c. Disinfection only
    d. None

4. Geographical Location
    a. Northeast
    b. Southeast
    c. Northwest
    d. Southwest
5. Source Type
    a. Well
    b. Surface
    c. Combination

Data deemed important in the survey are of two types: qualitative and quantitative. Qualitative data includes the segmentation of job titles relevant to a set of specific tasks, and tasks for various operational and maintenance duties typical within the industry. Quantification is more extensive. Specified segments and duties within the industry may be described by the qualification of jobs and the full-time equivalents, man-hours, or number of employees (quantification). Further, an analysis of actual time spent in major segments of the day-to-day operating industry is made. The only source of both types of data is the actual survey.

Further, the committee felt that making recommendations based on actual tasks performed would be a more valid approach to training and planning than developing training programs and fitting the job descriptions to already graduated students. This idea will be discussed further in Chapter III, Methodology, as the two ideas are inseparable.

Much has been seen in various public media recently about potential difficulties with public drinking water supplies (New Orleans, 1975, for example). While some of the public concern is probably not justified, no one can doubt that some problems within this industry do exist. The public furor is concerned with how dangerous certain municipal water supplies are. The Office of Water Hygiene study referenced above contained only vague allusions to reported incidents of water-borne disease outbreaks and one is forced to conclude that these do indeed constitute a potential, and not imminent, threat to the health of water consumers from public supplies. The point is well-taken though, that the study did reveal significant potential for problems. As will be demonstrated in Chapter V, the inappropriate assignment of tasks to certain work classifications does indeed seem to lead to difficulties.

At this point it is appropriate to give a definition of manpower planning, distilled from Bauman et al [3]. Manpower planning is the determination of an organization's manpower needs in terms of numbers, skills, and capabilities and matching these needs to present employees; the determination of further needs in terms of numbers, skills, and capabilities; and the determination of training requirements to meet the needs. This definition guided the overall thrust of the project and answers were developed based on the component parts of the definition.

Numerous manpower studies for the wastewater industry have been under taken for various subcomponents (treatment, collection) for a variety of sizes of facilities. These studies are relatively straightforward in using a sampling of the industry as a basis for determining needs. Further, sample sizes are generally in the range of 50 to 150 sites visited. Sample sizes in this range are very useful in determining the bulk parameters of various system configurations but may not be sufficient for analysis where a large number of system determinants are to be examined.

The wastewater studies were more ideally suited to small sample sizes because of the fact that wastewater characteristics are fairly uniform nation-wide and the processes used to treat the wastewater are few in number. Further, most wastewater comes from a source made up primarily of domestic, or domestic "like" sewage.

On the other hand, public water supplies come from any of three primary sources. Ground water, surface water, and a combination of ground and surface make up the vast majority of domestic water sources. The quality of water used prior to treatment varies from excellent to very poor in an almost continuous range of degrees. The quality of the raw product is the single most important determinant in analyzing the process used in treatment.

There is a general tendency in water systems to tend toward surface sources with increasing size. This, in turn, has a large impact on the processes involved as surface sources generally involve the conventional processes of coagulation, sedimentation, filtration and purification. In contrast, well sources usually involve only the purification process intervening between production and distribution.

An additional factor of variability is that domestic sewage has a fairly constant set of per capita parameters. Therefore the unit processes used in treatment may vary little given a specific system size. In contrast as the water quality varies in a set of similar-sized municipal water supply systems, processes may be added or deleted based on the constituents involved in the determination of quality.

This discussion serves to point out that water supply has a greater degree of variability over the same set of size variances than the corresponding wastewater segment. This factor is evident throughout the study and serves to temper the degree of confidence in specific answers. Given that there is greater variability, an attempt is made herein to show what the variables are and how to allow for them. Or to say another way, increasing the number of variables in a given sample size decreases the limits of confidence unless the variables are analyzed and their effect mitigated. It was deemed necessary in this study to examine these factors and generate technical coefficients relative to them.

As identified earlier in this chapter, smaller systems have been suggested to have greater problems in manpower retention and quality control. The 1974 AWWA Wage and Salary Survey [4] sheds considerable light on one of the primary problem areas, that of wages. The correlation of poor wages in small communities with low manpower retention and poorly-qualified operators is obvious, but the relationship is explored further by looking at a matrix of task statements versus system size. The AWWA Wage and Salary Survey indicates that wages increase with increasing system size, but an analysis of the task statement matrix shows that job requirements are relatively independent of system size for higher order job functions. As was also identified by Bauman et al, [5] many of the smaller systems are comprised primarily of part-time employees, and their ability to properly discharge their duties at the water utility is further challenged by the addition of duties in other segments of the public works realm. Therefore, the triple problem exists of poor training, poor pay, and too many duty areas - all compunding the problems in smaller communities.

One factor taken for granted all-too-often is that the finished water must be of uniform high quality because the general criterion is whether or not it is safe for public consumption. Water quality may vary significantly and still be acceptable (more or less) and safe for human consumption, but the end product will be argued about in terms of potability. However, no argument takes place if the water causes the consumer to become ill. The purpose of this study then is to recommend staffing which will insure the safety of the finished product within the realm of public acceptability.

An area also given considerable study prior to initiation of the actual survey is that of work measurement. It was originally thought, based on the Olympus Research [6] and Namour Studies [7], that more classical work measurement techniques would be used in determining what people actually did in their jobs. Considerable effort in the initial phases of the study went into familarization with what could be obtained and accomplished with actual work measurements. As will be discussed in the next chapter, the value of detailed measurement in an industry performing as does the water utility industry simply is not worth the effort and expense required to obtain it. This is, of course, one of the major limitations of work measurement in that the time required for the measurements must be justified by the information gained. In the case of this study, the information was obtainable in sufficient detail from other sources. These sources include actual job descriptions and principal task observations where job descriptions do not exist.

REFERENCES

[1] U. S. Department of Health, Education, and Welfare, Bureau of Water Hygiene. Community Water Supply Study - Analysis of National Survey Findings. July, 1970, pp. i-viii.

[2] U. S. Department of Health, Education, and Welfare, Bureau of Water Hygiene. Community Water Supply Study - Analysis of National Survey Findings. July, 1970, pp. i-vii.

[3] Baumann, E. Robert, Keith L. McRoberts, and C. E. Smith. Estimating Staffing and Cost Factors for Small Wastewater Treatment Plants Less than 1 MGD, Part I. Staffing Guidelines for Conventional Municipal Wastewater Treatment Plants Less than 1 MGD. Ames: Department of Industrial Engineering and Engineering Research Institute, Iowa State University, June, 1973; for Manpower Development Staff, Office of Water Program Operations, U. S. Environmental Protection Agency, Washington, D.C., pp. I-12 and I-121.

[4] Oklahoma Foundation for Research and Development Utilization, Inc. Manpower Planning for the Water Treatment Industry. Final Report, Oklahoma City, 1974.

[5] Baumann, E. Robert, Keith L. McRoberts, and C. E. Smith. Estimating Staffing and Cost Factors for Small Wastewater Treatment Plants Less than 1 MGD, Part I. Staffing Guidelines for Conventional Municipal Wastewater Treatment Plants Less than 1 MGD. Ames: Department of Industrial Engineering and Engineering Research Institute, Iowa State University, June, 1973; for Manpower Development Staff, Office of Water Program Operations, U. S. Environmental Protection Agency, Washington, D.C., p. I-7.

[6] Olympus Research Corporation. Manpower Planning for Wastewater Treatment Plants. For Division of Manpower Development and Training, Bureau of Adult, Vocational, and Technical Education, U. S. Office of Education, pp. 96-108.

[7] Namour, Elie. Manpower Requirements for Wastewater Collection Systems in Cities of 150,000 to 500,000 in Population. Greensboro: Center for Manpower Research and Training, North Carolina A & T State University, March, 1974; for the Manpower Development Staff, Office of Water Program Operations, U. S. Environmental Protection Agency, Washington, D.C., pp. 24-31.

CHAPTER III

DATA COLLECTION METHODOLOGY

Very early in this study, after studying much available literature on classical work measurements, it was decided that an approach of looking at a sample of the industry, as structured and performing, would yield the most acceptable information. Needs then could be synthesized from job descriptions, skills, and experience. Two sets of forms were used: the first to determine the physical characteristics of the specific utility such as number of consumers, length of the distribution system, area of region served, number and type of pumps, amount and type of storage, source type, etc. (Appendix I.a); the second to determine employment information (Appendix I.b). This form was subdivided, personnel-wise, into five water utility operations segments: raw water transmission, treatment, storage, distribution, and administration. In other words, the survey forms quantified or cataloged the various measures indicated by the advisory committee to be important. After the initial forms were designed, the survey team took them to the field for an analysis of their adequacy. A discussion of the results of the field use with the advisory committee resulted in a rearrangement of the format of the form but did not alter the information to be gathered. The revised forms were then used to resurvey the initial sample and for the rest of the study.

The data gathered were obtained by extensive interviews within the utilities and from an on site analysis of job descriptions where they existed. The idea was to learn what employees actually did in each job and what education, training, and experience they had. The times spent by each employee were entered on the forms as a percent of a full time equivalent. A full time equivalent represents one man employed full time and working solely within the water utility. People working less than full time were entered as a fraction of a full time equivalent based on how much time they spent exclusively in the water utility. Many communities have an integrated public works system and for this type extensive measurements and interviews were done to properly allocate the employees to the water utility only.

After the data were collected, an analysis was begun to determine what the significant characteristics of the industry were. Initially employees were put into three broad categories: operations, administration, and support. The general purpose and thrust of the project was to determine the personnel in the operations-type jobs and this category was then subdivided into the five previously identified general segments of operation: raw water transmission, treatment, storage, distribution, and administration. A list of jobs performed or tasks was generated with the total time used in each task and entered for each employee title. Additionally, the study team performed the analysis of the data from the 1974 American Water Works Association Wage and Salary Survey. This was suggested to be an important parameter to be used in determining the effectiveness of training and certification program recommendations especially for the "operator" classification.

Of all the job titles observed, that of "operator" has the greatest diversity in requirements and meaning. If the increasing demands on this classification of worker are to be met by education and certification programs, a standard job definition is required.

The quality and type of data obtained from the employment survey lends itself to analysis of job title-related groupings of tasks. Since all the utilities surveyed yielded information on time spent in tasks performed, a compilation of tasks performed by the "operator" classification could be undertaken. A complete listing in matrix form of tasks performed by the "operator" classification in each of the surveyed municipalities was prepared with the entries in the matrix representing the percent of total time spent at each task (Table V-1). The job numbers correspond to actual task statements from Table V-2. Those duties requiring significant amounts of time in the majority of the utilities are lumped together and used as the "standard" job description. This "standard" job description is generated for the operator classification and consists of a job definition based on specific tasks performed and the average amount of time spent in each task.

From the tasks performed and the physical parameters (size), staffing charts may be prepared for a broad range of system sizes. For the operator classification, three physical parameters were deemed significant determinants of the size characteristic: daily production (MGD), taps served, and community population. A staffing chart was prepared indicating the corresponding values of the size determinants and the staffing required. A further generality is that staffing is usually based on the largest of these three size determinants.

A comparison of the staffing charts with actual staffing data for the operator classification indicates there is some deviation from the expected staffing for several utilities. An analysis of the characteristics of all the utilities surveyed yielded 14 parameters which cause the variability. They include, among others:

1. System age - both treatment plant and distribution system
2. Degree of automation - once again for the treatment plant and the distribution system
3. Management capability
4. Community factor - which is a bulk parameter indicating a composite of several civic characteristics

The staffing guides are based on the U. S. average and therefore assumed an average bias towards all of these parameters. Deviation in the staffing patterns of the individual utilities reflect the bias of one or more of these parameters.

One of the tacit assumptions made at the onset was that staffing guides, training program recommendations, and task statements do not have to involve the level of detail inherent in work measurements. Further, the advantages of a somewhat detached overview of the utilities had many more advantages in terms of objectivity than detailed on the job task measurement. The reason for this is that work measurement is geared, in concept and in practice, to streamline or eliminate unnecessary motions, or to perform specific task movements with optimal results from minimum effort. The detail implied by these techniques is not warranted by the information proposed by the study.

With few exceptions, much of the staff required by and observed in the utilities is contingency based. Or, the staffing level reflects what is necessary on the peak day. During other periods of the year, the staff functions in a more or less auxiliary capacity performing more routine, "make-work" tasks. This, of course, is more characteristic of the operations personnel than other work areas in the utilities. The support functions operate on this basis to a lesser extent. Management functions are the least variable on a seasonal basis as the decision-making and administrative duties go on year around. During the peak months of demand and during the characteristic odor and taste months of spring and fall, the support and management duties related to customer service and complaint functions get more attention.

The job descriptions and task statements are meant to serve as an annual definition with the understanding that certain tasks are seasonally oriented but may be averaged over the year.

Interviews and data surveys have been completed for 56 water utilities and were conducted in a variety of ways as appropriate to gain the necessary information. Of the surveyed systems, thirteen were visited where interviews were held with at least seventy-five percent of the total employees. Persons interviewed also include those employees whose duties were divided between water services and functions performed for other municipal services. Fifteen utilities were visited where interviews were held with personnel from both the administrative and operations segments of the system. The remaining systems were visited and interviews were conducted with the administrative head, Director of Personnel and/or Assistant Superintendent. In this manner it has been possible to look, not only at those persons directly engaged water production and system maintenance, but also at those persons providing supportive services and those whose time and responsibilities are divided between water, sewerage, and/or other municipal services. The arrangement of employees into an organization providing many public works services and where the employees perform work on other than water-related services was quite prevalent throughout the water utility sample. Virtually all medium and small water utilities were integrated with other services, and many large utilities also assign part of their employees into diversified activities. Specifically, seventy-six percent of the utilities surveyed and for which the data have been compiled are integrated with other public or municipal services.

CHAPTER IV

STATISTICAL APPROACH

As data collection progressed and analysis was undertaken, it became apparent from data plots that indeed there seemed to be a relationship between numbers of employees engaged in various duties and several measures of system size. As part of the project design, a wide range of system sizes and the alleged determinants were encompassed within the sample to be surveyed.

The first data plots investigated were for total employees versus system size determinants. All these plots visually appeared linear when plotted log-log (pp. 41-45, 60-65). It was therefore reasonable to assume that the equations were of a power function nature of a form $Y = aX^b$ (pp. 114-123). To obtain the specific equation for any given plot involves data analysis to yield estimates for a and b, the technical coefficients in the above equation. This was done by the standard, least squares, best fit, fit of the data for an equation form identified as a power function.

After the equations were developed, the data were analyzed for correlation to the equation. The determinant with the highest correlation coefficient between employees and size was that of the number of taps served, r = 0.9946 . Other very significant determinants included:

1) community population, r = 0.9739;

2) daily production volume, r = 0.9596 .

Another size determinant with a lesser degree of correlation is the length of the distribution lines, r = 0.8091.

A large list of the potential determinants was generated but the very high degree of correlation between the number of employees and the four primary determinants rendered an analysis of characteristics from that list unnecessary. The list (Table IV-1) follows for information only, based on the understanding that the impact of each variable is small and is, as yet, undetermined.

A variable which does seem to be very significant but which was not analyzed as to effect due to a lack of sufficient data is the impact on staffing from private ownership of the utility. Only an estimate of this impact may be derived from the data and suggests that private utilities employ approximately 55% as many employees as public utilities would, given the same size determinants.

The text of this paper contains plots of employees versus system size and for all cases, best fit lines derived from the data. It is hoped that these plots will be the stimulus for a more detailed and continuing investigation of this very important industry.

As will be addressed in Chapter VI, Staffing Guides, a series

TABLE IV-1

RANK OF IMPORTANCE OF POSSIBLE VARIABLES

VARIABLES		TOTAL EMPLOYEES	TREATMENT EMPLOYEES
1. Population Served)			
2. TAPS)	(Scale)	1	1
3. MGD Produced)			
4. System Age			
(a) Treatment Plant		7	6
(b) Distribution System		6	8
5. Ownership		3	3
(a) Public (b) Private			
6. Length of Dist. Sys.)	(Crowding)	8	9
7. Population Density)		9	10
8. Degree of Automation of Plant		12	7
(a) None (Manual Back Wash Manual Valves Etc.) (b) Partial (Typically Local Pneumatic @ Plant) (c) Full (Full Central Supvr. Control System)			
9. Degree of Automation of Dist. System		11	11
(a) None (Manual Valving & Pumping Control) (b) Full (Central Supvr. Control Sys.)			
10. Community Factor		5	5
(a) Enlightened (b) Average (c) Maximization of Employment			
11. Management Capability		4	4
(a) Cost (b) Service (c) Employment			
12. Geographical Region		10	12
13. Source		2	2

of equivalent parameters were developed for the size determinants based on the larger of the three primary determinants for each individual system. Using this technique,a slightly higher correlation coefficient was obtained when compared to any single measure of system size.

Since the number of taps was the most highly correlated independent variable, the other measures of size were derived with their relationship based on the number of taps.

For a variety of size and source parameters, equations were developed using the least-square, best-fit method for generating the regression equation. Since, as previously identified, the equations are power functions, the procedure developed uses the logarithms of the parameters involved. In all cases system sizes are considered the independent variable and employees then are the dependent variable.

The methodology follows:

$$a_0 = \frac{(\Sigma Y)(\Sigma X^2) - (\Sigma X)(\Sigma XY)}{N(\Sigma X^2) - (\Sigma X)^2}$$

where: X is the log of the independent variable

Y is the log of the dependent variable

N is the number of data entries.

$$a_1 = \frac{N(\Sigma XY) - (\Sigma X)(\Sigma Y)}{N(\Sigma X^2) - (\Sigma X)^2}$$

$\therefore Y = 10^{a_0} X^{a_1}$ describes the regression equation.

The data were then analyzed to see how well the regression equation predicted the results by generating a correlation coefficient as a measure of quality of fit of the data.

The form of the correlation coefficient is:

$$r = \sqrt{\frac{\Sigma(Y_{est} - \bar{Y})^2}{\Sigma(Y_{act} - \bar{Y})^2}}$$

where: Y_{est} = log dependent variable as predicted by regression equation

Y_{act} = log dependent variable as measured in the study

$\bar{Y}$ = average log of the dependent variable as measured in the study.

A summary of the statistical analyses follows for the parameters analyzed. This summary is provided to acquaint the reader with the actual parameters analyzed and the general form and accuracy measure of the predictive equations.

Since all the equations are of the form $Y = 10^a X^{a_1}$, or $Y = a_3 X^{a_1}$ where $a_3 = 10^{a_1}$, a summary table cataloging the coefficients in addition to the measures of accuracy (r^2, r) is presented for convenience. The detailed calculations for each variable are presented in Appendix IV.

TABLE IV-2

STATISTICAL SUMMARY BY VARIABLES

Title	a_3	a_1	r^2	r
Total Employees vs. Taps - All Sources	$8.2462X10^{-3}$	0.8977	0.9892	0.9946
Total Employees vs. Population - All Sources	$6.3910X10^{-3}$	0.8198	0.9486	0.9739
Total Employees vs. MGD - All Sources	$8.3491X10^{-3}$	0.7847	0.9209	0.9596
Total Employees vs. Taps - Surface Sources	$7.8860X10^{-3}$	0.9159	0.9539	0.9767
Total Employees vs. Taps - Well Sources	$9.3000X10^{-3}$	0.8551	0.9389	0.9689
Total Employees vs. Taps, Combination Systems	$4.3043X10^{-3}$	0.7262	0.9906	0.9953
Operators vs. Taps - All Sources	$1.0202X10^{-1}$	0.4059	0.6467	0.8042
Operators vs. Taps - Surface Sources	$4.9320X10^{-2}$	0.4927	0.6277	0.7923
Operators vs. Taps - Well Sources	$2.7351X10^{-1}$	0.2536	0.5586	0.7474
Operators vs. Taps - Combination Systems	$1.6185X10^{-1}$	0.3870	0.7588	0.8711

CHAPTER V

THE OPERATOR CLASSIFICATION

As was mentioned in Chapter III, the "operator" classification is an area of great concern. This concern is due, in part, to the realization that this job title encompasses the lowest level of effective decision-making in many utilities which has a direct effect on finished water quality.

There is great variation in duties performed by this class of worker. The operator in most utilities is a curious conglomeration of menial physical labor and moderate level management decision-making. The job is not unlike the job of the foreman in more industrially-structured situations. However, unlike the foreman, the operator has both greater management responsibility and more physical labor requirements.

From all of the job descriptions obtained and from on-site analysis, a list of applicable task statements was compiled (Table V-2). The total list included some 42 task statements ranging from very physically composed to pure decision-making. The list was put into matrix form using the community as the second plot parameter. This matrix is Table V-1 and contains the percentage of time spent in each task. Those tasks requiring a small precentage of time in the various communities were deleted and a new list compiled, Table V-3. This list represents a complete job description based on the composite work performed by the "operator" classification worker.

A further feature of Table V-2, the matrix, which can be garnered visually is that if the tasks are ordered from most mental to most physical, a specific concomitant phenomenon is apparent. For the larger communities, the operator has more decision-making "mental" type duties and fewer of the menial, physical work duties. This is presumably one of the reasons that from the AWWA Wage and Salary Survey - 1974, the larger communities pay higher wages. Operator wages are seen to be directly proportional to community size.

An interesting additional observation is that while the larger communities operator duties require fewer physical chores, the inverse is not true. The corresponding drop in mental or decision-making duties for smaller communities does not take place to the same extent. So there exists the problem that frequently the "operator" is the system decision-maker in the smaller communities in spite of the fact that he is poorly paid and, as been identified earlier, poorly trained. There is now established a cause and effect relationship between some of the undesirable features of smaller public supply systems. These features include decision-making requirements, poor pay, a wide variety of duties, and occasionally, improper direction or support. It is presumed that someone in a community has the necessary capability and

and training to make informed public health decisions and frequently the only available person is the "operator."

TABLE V-1

PERCENTAGE OF TOTAL TIME SPENT PER TREATMENT TASK

TASK NO.

Town #	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
1	17			2	6			11	3	2		11	1	3						8			6	3				12	4				6	6								
2	1			3	1	1		5	19			10	4	4						28	6		7					10	1	1			4	1								
3				6	6	3		6	2	7		6	5	1	3	2	2			17	5	2	6	2	3	2		8	2	2			3	2								
4	13			4	5							4	8	8	1	1				12	3		8					17			3	8	3									4
5	22			1	2			3	1	1		5	9	2		2	7			3	2		3					16	4		1	1	3	1	2	2			1	3		4
6	9	5		3	1			3	2	1		5	1	2		2				16	3		5	1	2			16	1		1	1	5	3	1					8		3
7	3			5	2	1		2	4	2		5	4	4	4				4	4	4							5	2	2	4	8	10	4						6		6
8	8				10							10																13					10	15								
9	5	4		3	1			5	4	2		10	7	2			8			15			2					8	3		2	2	3	2	3							5
10	14				5			5	5			9	5			9				9	9								5	5	9	9	5									
11	2	13		6	2	2		1	1	1		1	6	1	2		4			2	6	1	2	1	2	1		6	2	2	4	4	4	4	3	2	1	1	1	5		3
12	7	2		1	2			1	2	2			10	1		2				3	3		1	1	2			2	2		4	3	4	5	4	5	4	3	1	6	3	4
13	3	1			1	1		4	3			2	4	1	2		9			6	9	2	3	1	2			5	2	1	1	2	2	2	6	1	1	1	2	9		3
14	13			3	3			3	5				3		3					13	7							7	2	2	8	8	8									5
15	6	6		1	3	4		7	1	1		15	10	1						10	4		4		2			5	1				1	1						6		13
16		4	4	4	4	4		4	4	2		7	5	3		1												18	8	12	3	1	13	3								
17	8	7		3	2	2		13		1		12	13	3		1				7	7							5	3				3	3	1					7		1
18	20					10															30	5						10	5					10								
19	14	6		7	3	1	1	4		1		7		3	1					2	6	1						9	1				5	5	4	4				3		9
20	12	5		2	3	3		3		3	3	5	7	2						10	7							5		2	7		1	1	3	2	2		2			
21		2		2	1			2	2			22	3		1					7	12	2	2	2	2			2	1		3	4	6	6	4	4						3
22		5	5			5		10		5			5		10					10	10		5	5	5					3			3	5						5		
23		3			3	3				3			5	3			3			3	7	3						3		3	7		3	5	7	8				5		5
24		8		1	4			5	1	1		4	6	1			1			6	8	1	1		1			6	1	1	8		4	3	5	5	3	3	1	4		4
25		25						5				10									10	5									10	30	10									5
26	4	7		1	3	3		1	2	7		6	7	1		1	2			4	5	1	2		2			7		1	5	3	3	1		3	3	3		4		2
27	3	3		2	3	3		2		3		2	3	1	2		3			3	7	2	3	3	3			7			8	2	2	2	3	3	3	3		3		3
28		10			10					10			10							20								5			5				10		10	5		5		
29				3		5				13			8		5		5			3	13	4	3		10					8					8	8						3
30		5			3			8				5	5	3						10	8	3						5	2		8		3	3	3	3	3	3		5		2
31		17																		7	7	3							17	17			20		3	3	3					
32		4		2	2								10		4		8				8	4						2	2		2	4			6	6	2	2		8		4
33	5	3		2	1	1		5		5		8	4			2	5			8	3		3	2				8		1	3				5	5	4			3		5
34	9	7		7	7	3		1		3			1	1		1	1			3	6	2	2		3			5	5	2	5	5	5	5	5	5				1		1
35		1																		1	1														1	4	1	2				
36		10						10					10							10	10							10					5	5	2	3				10		
37		10		5				10					10							20			15					10							5					5		5
38		10		2																			5										10			5	3					5
# OF ENTRIES	22	27		25	29			28		74		24	31	22						32	31	16						31	23		23		31	26	23							25
AVG TIME %	9.2	6.8		3.1	3.4			5.0		3.4		7.6	5.9	2.3						8.8	7.3							8.0	3.3		4.8		5.4	4.0	4.1							4.2

TABLE V-2

TREATMENT OPERATION TASK STATEMENTS — ALL SYSTEMS

TASK NO.	STATEMENT
1	Organizes and supervises working activities of treatment plant personnel in accordance with approved policies and procedures. Establishes job schedules, shift schedules, and oversees workers engaged in daily operations and maintenance of water treatment plant pumps and motors, instrumentation, chemical feeders, mechanical mixing devices, laboratory analyses, filter beds, and general maintenance functions. Provides technical assistance and expert advice to personnel involved in daily plant functions. Develops quality standards for plant operations, recommends changes in methods and procedures, investigates equipment failures, diagnoses faulty operations. Advises as to the proper procedures for maintaining quality and quantity of water at proper pressures, plant maintenance, personnel training and safety, cost control, advance planning, and assists in implementation of municipal or water system policies.
2	Unloads and stores sacks or tanks of chemical additives which are used as coagulants, disinfectants, or quality adjusting agents. May operate cranes, fork lifts, or other unloading equipment.
3	Mixes chemicals to provide the proper dosage to assure finished water of high quality. Loads or places sacks of chemical additives into chemical feeding machine.
4	Controls, observes and sets automatic dial settings to insure that the proper mixture and dosage of chemical additives is maintained during the treatment process.
5	Periodically observes and checks automatic chemical feed system for failures and maladjustments.
6	Performs minor preventative maintenance on automatic chemical feed system. Periodically cleans outside and inside of chemical feeders, loosens and removes chemical particles which have built up over a period of time.

TASK NO.	STATEMENT
7	Performs major corrective maintenance on chemical feeding components as necessary. Inspects and repairs electrical circuitry, switches, and other components regulating flow of chemicals and additives into mixing channels or basins. Utilizes standard electrical system diagnostic equipment such as induction, regulators, volt-ohmmeters, oscillisscope, etc.
8	Regularly observes flocculators, mixing, and settling basins to insure proper operation of components.
9	Periodically checks and tests for short circuiting by making standard dye tests.
10	Regularly (annually or semi-annually) empties settling basin and performs maintenance on side-walls, mixing shafts and propellers, applies anti-corrosion compounds to walls and mechanical parts. Applies lime-copper sulfate slurry to walls of basin to reduce algal growth. Performs preventive maintenance by regularly assisting in washing basin, cleaning flocculator paddles and shafts, and regularly checking and maintaining oil level on flocculator drive motor.
11	Performs or assists in performing minor corrective maintenance on settling basin and mechanical components. Work includes painting walls, replacing or repairing bearings, correcting malfunctions in drive motor, replacing drive shafts, fusing or welding broken paddles, etc.
12	Periodically observes filtration components checking for presence of mudballs and other foreign material prohibiting efficient operation. Probes filter media periodically to determine extent of media movement. Observes sightwell for turbidity detection.
13	Determines from headloss indicator chart or guage if backwashing is needed. During backwashing continues to observe headloss indicator until headloss is less than prescribed limits. Determines from headloss indicator chart if backwashing is needed. Initiates reverse flow of water through filter, continues to observe headloss indicator chart until headloss is less than prescribed limits.
14	Schedules filtering and backwashing to insure water quality is maintained and service area demands are met.

TASK NO.	STATEMENT
15	Manually adjusts flow as needed to maintain the proper rate of water flow through the filter.
16	Observes and checks monitoring lights, devices and telemetering components that oversee automatic filtering operations to insure proper filtration and backwashing.
17	Performs regular preventive maintenance on filter beds by periodically checking media leakage detector, cleaning sand out of depository, running periodic checks for mudball accumulation, and checking for bed shrinkage and clogged areas during filtration.
18	Performs minor corrective maintenance by rebuilding media as necessary, occasional surface washing of filter media and performing corrective maintenance on valves, electrical circuitry, telemetering devices and other components of water filters.
19	Empties filter beds and performs anti-rust and corrosion maintenance on side walls, water channels, and other appurtenances. May assist in removing media, replacing media, regrading media, correcting for side wall pull-away and bed shrinkage which may occur during filtration.
20	Periodically checks and listens to pumps and motors to insure proper operation.
21	Periodically releases excessive gland pressure and checks packing, shafts and sleeves. Repacks bearings as necessary.
22	Lubricates induction or synchronous motors. Insures proper motor ventilation is maintained to prevent overheating; checks voltage and frequency regularly to maintain proper alignment between motor and pump. Listens for and corrects abnormal noises caused by foreign matter in pump, air in pump, and worn or coated impellers. May perform major maintenance by replacing worn parts, rebuilding motors and pumps, overhauling motors, repairs and fabricates a variety of metal parts and equipment as needed. Installs new pumps and motors as necessary.
23	Regularly checks compressors, airlines, pneumatic valves and other components to insure sustained adequacy of liquid and gas transfers among physical components of water treatment plant.

TASK NO.	STATEMENT
24	Periodically bleeds airlines to insure and maintain proper operational efficiency.
25	Performs preventative maintenance on compressor by lubricating moving parts and replacing worn parts. May repair or assist in repairing compressors tanks, and valves by replacing worn parts, welding or fusing worn metal parts, lubricating moving parts, and painting external structure.
26	Regularly checks airline for leaks and pressure losses. Replaces airline as needed.
27	Installs or assists in installing new compressors, and tanks as needed.
28	Inspects and observes instruments and guages, records readings and controls equipment regulating flow of raw and treated water into and out of treatment plant settling basins, filters, and storage tanks.
29	Tests and calibrates electronic and pneumatic measuring recording, telemetering and control instruments, control panels, equipment, and systems such as flow; pressure, level, and temperature indicators, recorders and transmitters, pneumatic valve controllers, chemical feed controls, boiler flame scanners, PH meters, turbidimeters, spectrophotometers, digital and analog transmitters and receivers.
30	Adjusts, performs preventive and corrective maintenance on a variety of electrical instruments. Replaces chart and ink. Reads technical blueprints and schematic diagrams and uses variety of equipment such as; oscilliscopes, volt-ohmmeters, regulators, ohmmeters, meggars, multimeters, synchronoscopes, calibration charts, and galvonometers, to repair circuitry and components of a variety of electrical equipment ranging from instrument control panels and telemetering circuitry to chemical analyzing equipment. Lubricates moving parts, replaces worn and defective parts and maintains circuits.
31	Takes sample of raw and treated water. Determines PH level, amount of hardness, alkalinity, turbidity, amount of chlorine residual, fluorine residual. May also perform dissolved oxygen, carbon dioxide, iron, manganese and silica tests depending upon local conditions. May utilize jar tests or operate an atomic absorption unit. Uses a variety of testing equipment such as colorimeter, atomic absorption spectrophotometer, turbidimeter, burrettes, test tubes, beakers, gas burners, and incubators. Records and maintains log of test results.

TASK NO.	STATEMENT
32	Collects sample of raw and treated water to test for presence of coliform organisms. Performs presumptive and confirmed tests for coliform organisms. Uses autoclaves, incubators, test tubes, beakers, gas burners, etc. in performance of tests. Records and maintains log of test results.
33	Determines amount of water to be treated, stored, and distributed in order to meet the demands of service area; determination made after considering such external factors as rainfall, average temperature, average and monthly increase in industrial, commercial, and residential customers. Records and keeps log of determinations.
34	Determines proper chemical dosage for prescribed amounts of finished water to insure proper water quality is maintained. Records and keeps log of chemicals used and their cost in treating raw water.
35	Picks up trash, sweeps floors, dusts, cleans working areas, washes treatment plant windows.
36	Picks up trash in vicinity of treatment plant. Maintains external appearance by trimming hedges, sweeping walks and watering and fertilizing flower beds.
37	Mows grass and performs other outside maintenance work as needed.
38	Hauls grass and other trash to dump or landfill.
39	Paints building and appurtenances as needed.
40	Assists in cleaning sludge basin. Performs maintenance of side walls, mixing shafts, and propellers, applies anti-corrosion compounds to walls and mechanical parts. Assists in loading sludge into trucks for disposal.
41	Performs other work in and around treatment plant of an unskilled or semi-skilled nature as directed.

TASK NO.	STATEMENT
42	Keeps clerical information pertaining to hours on job, shifts and work schedules, personnel records, daily water production, amount of water treated and pumped, accumulated rainfall, chemical and bacterial tests initiated and completed, pounds of chemicals used, costs to produce given quantities of finished water, average hours of filter runs, record of preventative and corrective maintenance performed, and costs of replacement parts and tools.

TABLE V-3

TREATMENT OPERATION TASK STATEMENTS — TRUNCATED

% OF TOTAL TIME SPENT	TASK NO.	STATEMENT
9.2	1	Organizes and supervises working activities of treatment plant personnel in accordance with approved policies and procedures. Establishes job schedules, shift schedules, and oversees workers engaged in daily operations and maintenance of water treatment plant pumps and motors, instrumentation, chemical feeders, mechanical mixing devices, laboratory analyses, filter beds, and general maintenance functions. Provides technical assistance and expert advice to personnel involved in daily plant functions. Develops quality standards for plant operations, recommends changes in methods and procedures, investigates equipment failures, diagnoses faulty operations. Advises as to the proper procedures for maintaining quality and quantity of water at proper pressures, plant maintenance, personnel training and safety, cost control, advance planning, and assists in implementation of municipal or water system policies.
6.8	2	Unloads and stores sacks or tanks of chemical additives which are used as coagulants, disinfectants, or quality adjusting agents. May operate cranes, fork lifts, or other unloading equipment.
3.1	4	Controls, observes and sets automatic dial settings to insure that the proper mixture and dosage of chemical additives is maintained during the treatment process.
3.4	5	Periodically observes and checks automatic chemical feed system for failures and maladjustments.
5.0	8	Regularly observes flocculators, mixing, and settling basins to insure proper operation of components.

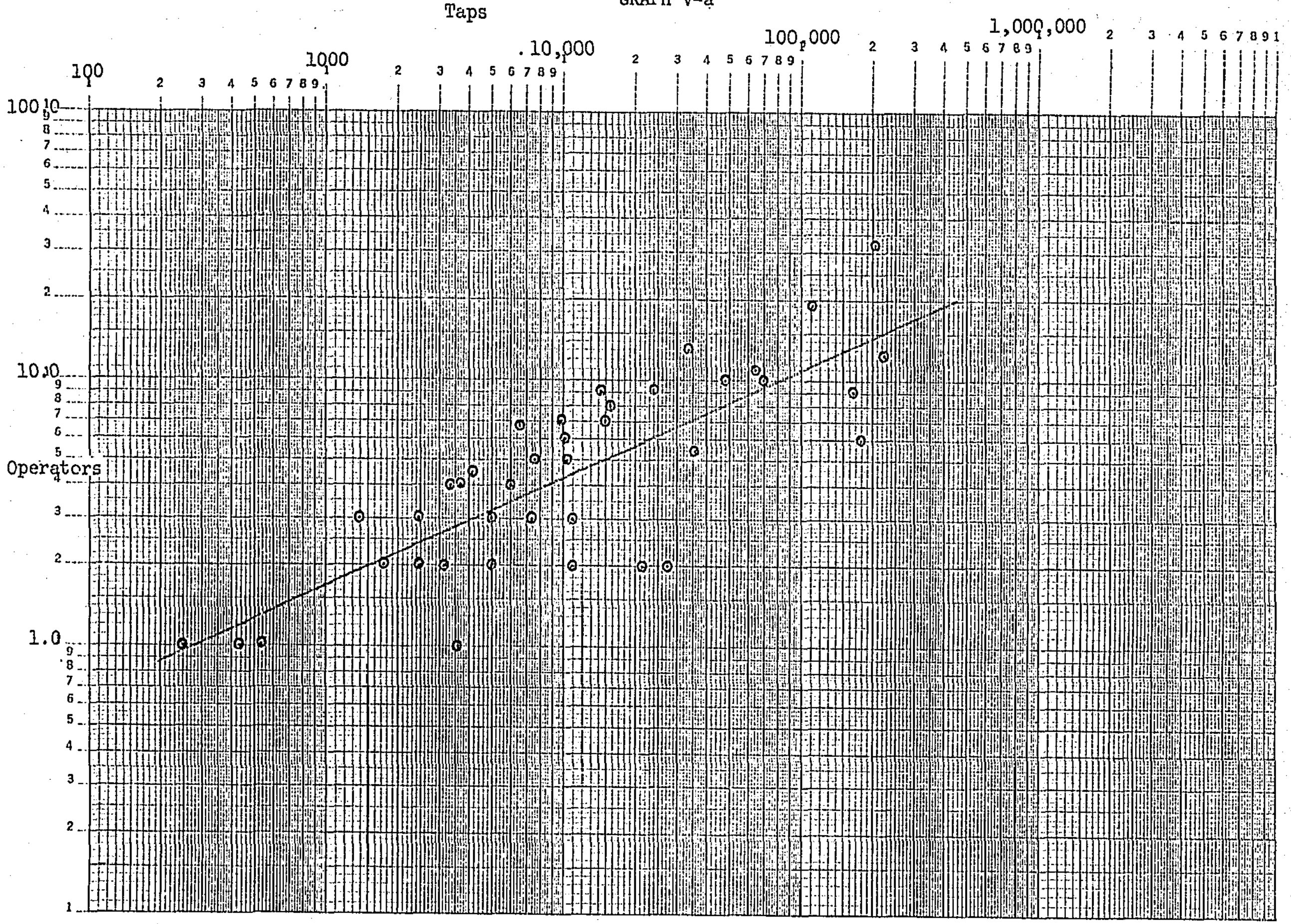
% OF TOTAL TIME SPENT	TASK NO.	STATEMENT
3.4	10	Regularly (annually or semi-annually) empties settling basin and performs maintenance on side-walls, mixing shafts and propellers, applies anti-corrosion compounds to walls and mechanical parts. Applies lime-copper sulfate slurry to walls of basin to reduce algal growth. Performs preventive maintenance by regularly assisting in washing basin, cleaning flocculator paddles and shafts, and regularly checking and maintaining oil level on flocculator drive motor.
7.6	12	Periodically observes filtration components checking for presence of mudballs and other foreign material prohibiting efficient operation. Proves filter media periodically to determine extent of media movement. Observes sightwell for turbidity detection.
5.9	13	Determines from headloss indicator chart or guage if backwashing is needed. During backwashing continues to observe headloss indicator until headloss is less than prescribed limits. Determines from headloss indicator chart if backwashing is needed. Initiates reverse flow of water through filter, continues to observe headloss indicator chart until headloss is less than prescribed limits.
2.3	14	Schedules filtering and backwashing to insure water quality is maintained and service area demands are met.
8.8	20	Periodically checks and listens to pumps and motors to insure proper operation.
7.3	21	Periodically releases excessive gland pressure and checks packing, shafts and sleeves. Repacks bearings as necessary.
8.0	28	Inspects and observes instruments and guages. Records readings and controls equipment regulating flow of raw and treated water into and out of treatment plant settling basins, filters, and storage tanks.

% OF TOTAL TIME SPENT	TASK NO.	STATEMENT
3.3	29	Tests and calibrates electronic and pneumatic measuring recording, telemetering and control instruments, control panels, equipment, and systems such as flow; pressure, level, and temperature indicators, recorders and transmitters, pneumatic valve controllers, chemical feed controls, boiler flame scanners, PH meters, turbidimeters, spectrophotometers, digital and analog transmitters and receivers.
4.8	31	Takes sample of raw and treated water. Determines PH level, amount of hardness, alkalinity, turbidity, amount of chlorine residual, flourine residual. May also perform dissolved oxygen, carbon dioxide, iron, manganese and silica tests depending upon local conditions. May utilize jar tests or operate an atomic absorption unit. Uses a variety of testing equipment such as colorimeter, atomic absorption spectrophotometer, turbidimeter, burrettes, test tubes, beakers, gas burners, and incubators. Records and maintains log of test results.
5.4	33	Determines amount of water to be treated, stored, and distributed in order to meet the demands of service area; determination made after considering such external factors as rainfall, average temperature, average and monthly increase in industrial, commercial, and residential customers. Records and keeps log of determinations.
4.0	34	Determines proper chemical dosage for prescribed amounts of finished water to insure proper water quality is maintained. Records and keeps log of chemicals used and their cost in treating raw water.
4.1	35	Picks up trash, sweeps floors, dusts, cleans working areas, washes treatment plant windows.
4.2	42	Keeps clerical information pertaining to hours on job, shifts and work schedules, personnel records, daily water production, amount of water treated and pumped, accumulated rainfall, chemical and bacterial tests initiated and completed, pounds of chemicals used, costs to produce given quantities of finished water, average hours of filter runs, record of preventative and corrective maintenance performed, and costs of replacement parts and tools.

Graph V-a follows and is a plot of system size (taps served) versus number of operators for all sources. The computed correlation coefficient $r = 0.8042$ based on a straight line equation $Y = 1.0202 \times 10^{-1} X^{0.4059}$ (equation X.IV-g). As the relatively small correlation coefficient indicates, there is a significant amount of deviation from the best-fit line. One of the identifiable problems is that for the smaller systems, the minimum number of operators is 1.0 as identified earlier because there is a slight shift in duties within the general classification.

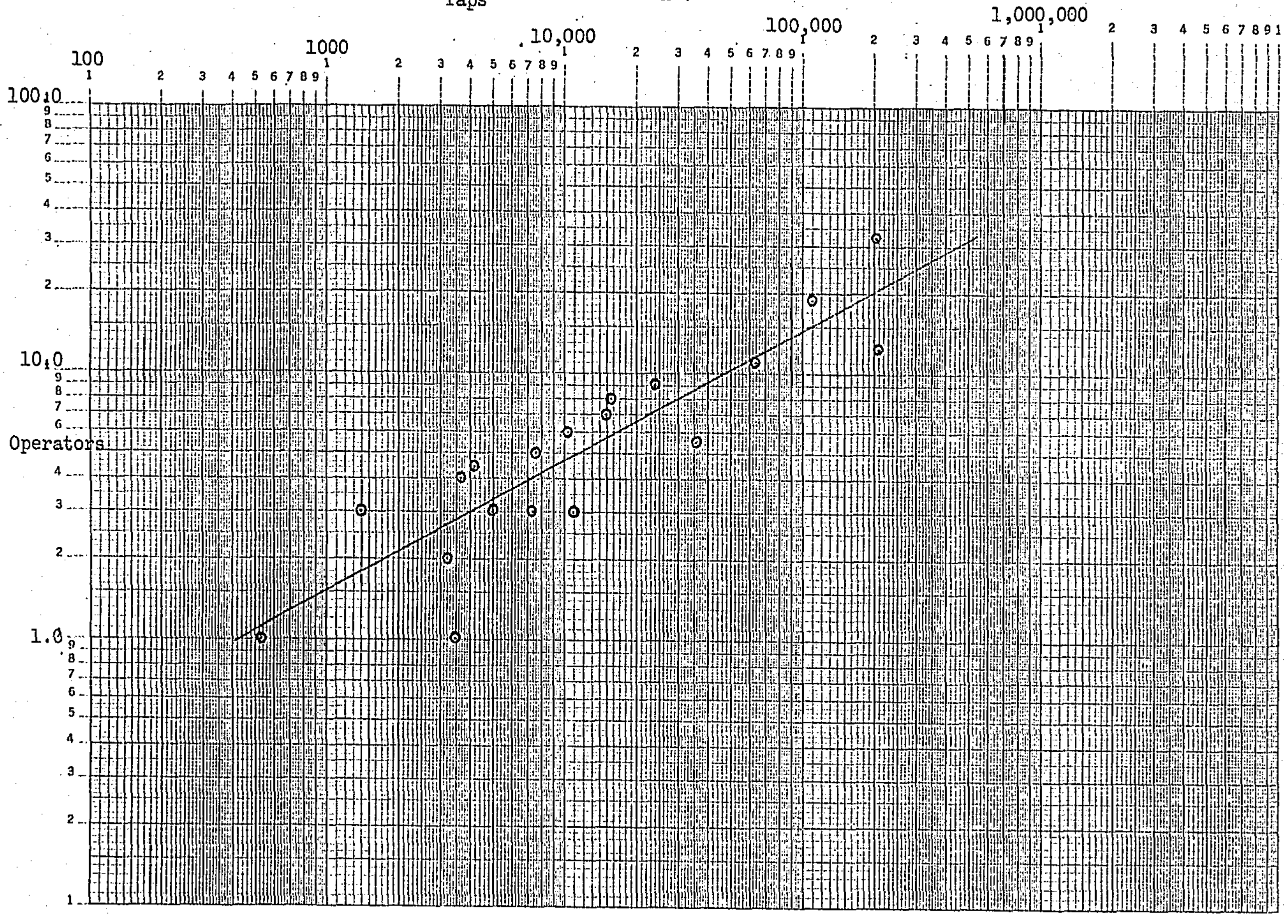
Graphs of operators for a variety of source types are also presented which are plots of equations IV-h, IV-i, and IV-j, Appendix IV.

GRAPH V-a



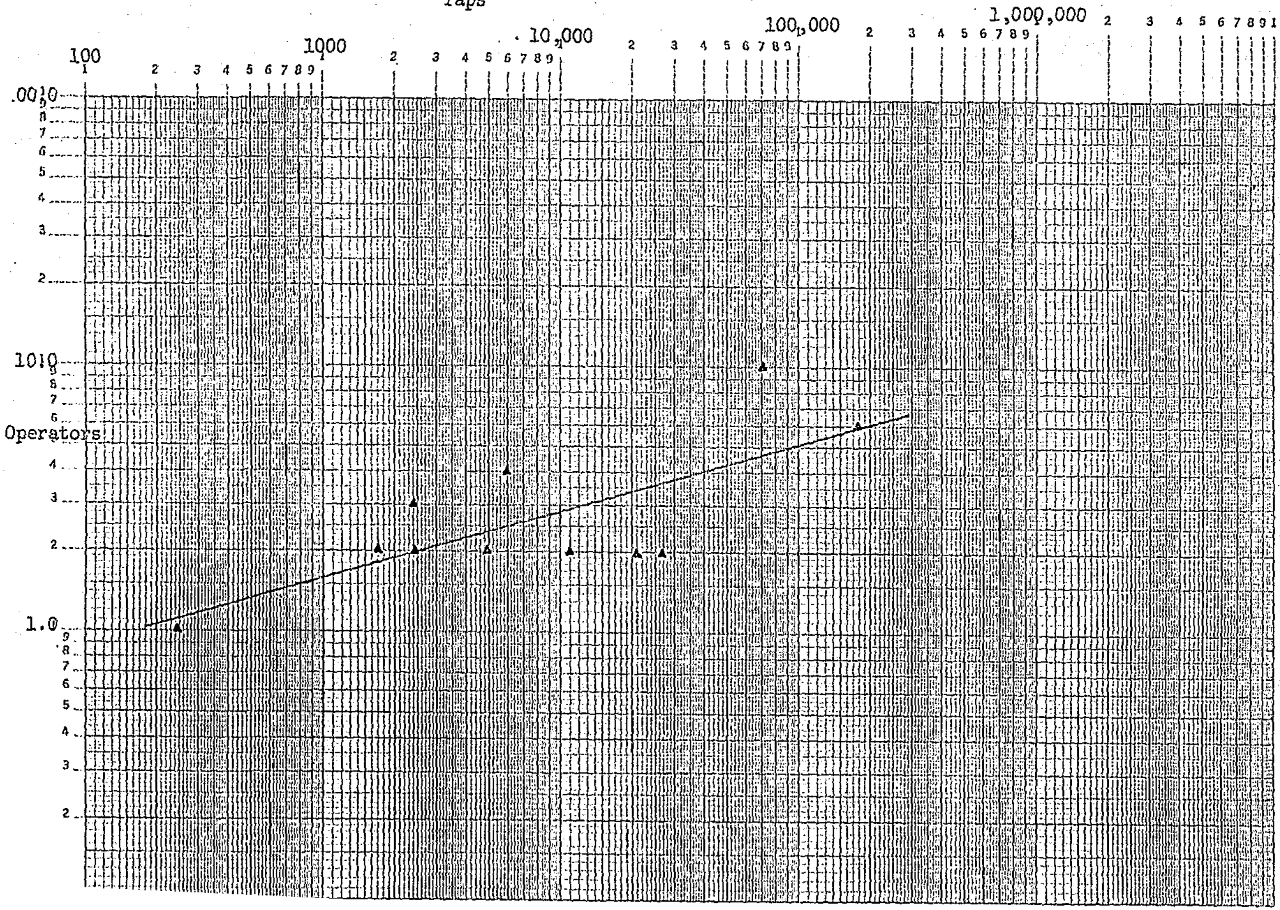
Operators vs. Taps - All Sources

GRAPH V-b



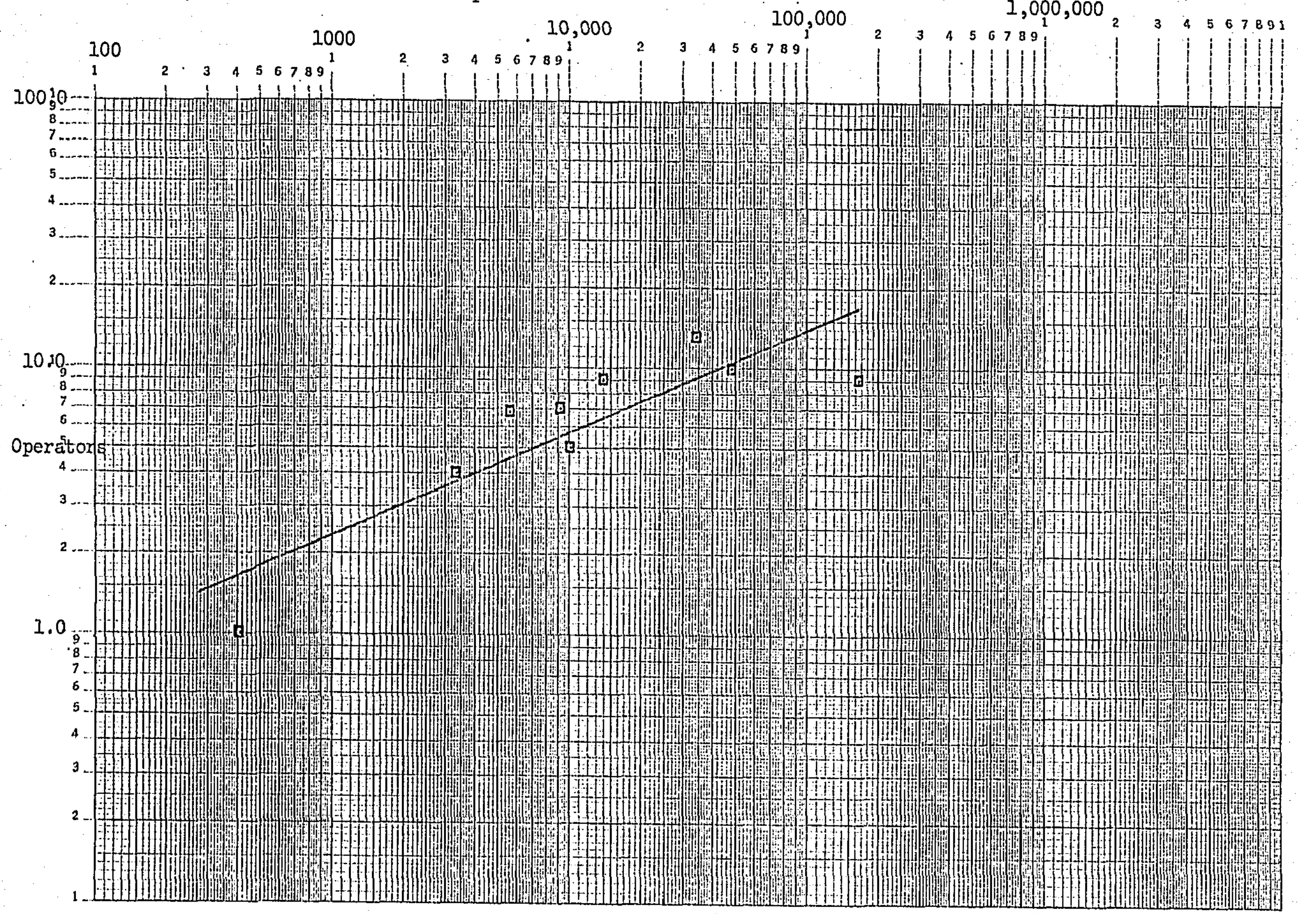
K+E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A. 46 7522

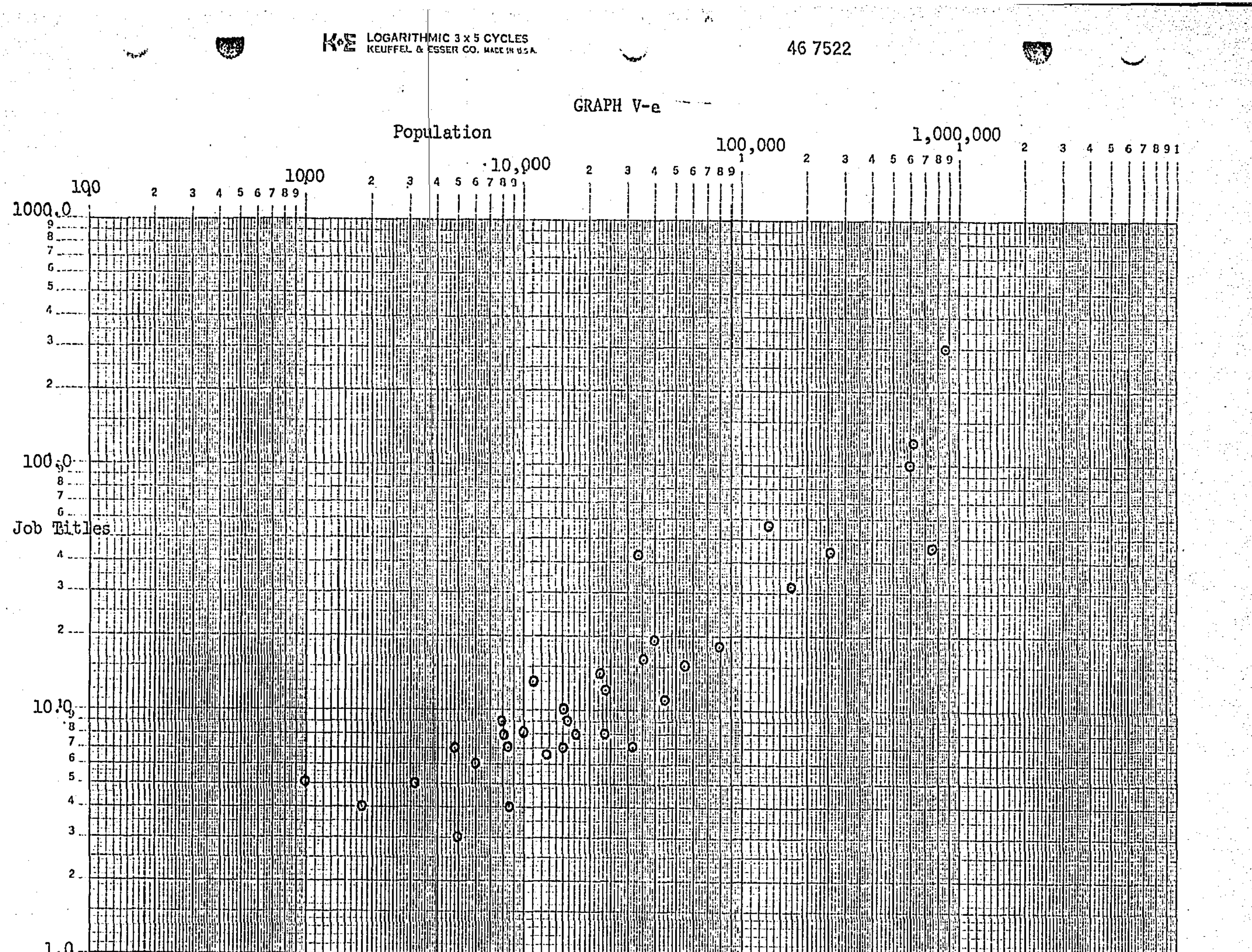
GRAPH V-c



K+E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 7522

GRAPH V-d





K+E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 7522
GRAPH V-e
Population
100
1000
10,000
100,000
1,000,000
1000.0
100.0
Job Titles
10.0
1.0

As was previously discussed in Chapter IV there are some fairly obvious deviations from the expected data plots for the operator related curves V-a, V-b, V-c, V-d.

A specific example is for curve V-c where 2.0 operators are observed in the data to cover a range of well system size from 1,700 taps to 27,000 taps. The same phenomenon occurs to a lesser extent for 3.0 operators for surface systems.

In these cases the major cause for deviation from expected staffing is directly a function of the tasks required in the operator job description. It is easily understood from looking at the range of task statements (Table V-2) that job description including few task statements require fewer personnel to perform them than job descriptions containing many tasks.

A further observation from Graph V-a is that as system size gets very large, there is a wide range of observer operator staffing in the data. The tendency in water utility systems toward increasing sophistication in system operation begins to lead to a host of personnel classifications of a very specialized system related, job titles. These include among others: systems technicians, electronics technicians, systems engineers. Part of the evidence for this is Graph V-e which plots and demonstrates very adequately the general tendency of large systems to diversify and specialize job titles and their associated tasks.

These worker classifications do indeed take over many of the control functions previously under the charge of the operator. Many large utilities are very conventional in design and operation, while the newer larger systems tend to be highly automated. However, there is little tendency evidenced in the data to indicate any significant reduction in personnel as a result of automation. As more and more systems become highly automated, the potential staffing reductions may be further analyzed.

To demonstrate the point made about staffing for operators, examine the bottom four entries in Table V-1. The range of percentage of total time spent in operator functions is from 11% to 95% and therefore if the systems were of equivalent size it would be expected that one system could require several times as many operators to get an equivalent amount of work done.

CHAPTER VI

COMPOSITE STAFFING GUIDES

As was indicated in Chapter IV, correlation coefficients for both composite and single-category workers were developed. These correlation coefficients are based on least-square, best-fit lines of exponential form. These equations may be used to generate staffing guides for a continuum of system sizes by "plugging-in" the appropriate system parameters and proceeding to solve the equations for actual manpower requirements.

The validity of the process has already been established through correlation coefficient development. These coefficients are expressions of the approximation of the best-fit line to the actual data gathered in the field survey portion of the study. Prediction equations were developed for several system size parameters and then equations were generated relating the ranked group of size determinants. The corresponding values of the other size determinants are then listed in the staffing guides as an auxiliary indicator of system size. The auxiliaries are presented and related to each other because the largest of the system size determinants is the indicator used for determining the staffing required for a specific situation. The prediction equations are developed for the auxiliary determinants based on their relationship to employees versus taps, using employees as the dependent variable. First, auxiliary relationships are developed algebraically by solving the simultaneous equations for a given number of employees and taps.

$$Y_1 = 8.2462 \times 10^{-2} X_1^{0.8977} \tag{6-1}$$

where X_1 is the number of taps served and Y_1 is the number of total employees and where X_2 is the population:

$$Y_1 = 6.391 \times 10^{-2} X_2^{0.8198} \tag{6-2}$$

Equating the two gives:

$$8.2462 \times 10^{-2} X_1^{0.8977} = 6.391 \times 10^{-2} X_2^{0.8198} \tag{6-3}$$

$$X_2^{0.8198} = 1.2903 X_1^{0.8977} \tag{6-4}$$

and simplifying,

$$X_2 = (1.2903 X_1^{0.8977})^{1.2198} \tag{6-5}$$

$$X_2 = 1.3647 X_1^{1.0950} . \tag{6-6}$$

And relating taps and production volume

$$Y_1 = 8.2462 \times 10^{-2} X_1^{0.8977} \tag{6-1}$$

where X_1 , as before, is the number of taps served, and

$$Y_1 = 8.3491X_3^{0.7847} \tag{6-7}$$

where X_3 is the production volume in MGD. As before, equating the two gives

$$8.2462 \times 10^{-2}X_1^{0.8977} = 8.3491X_3^{0.7847} \tag{6-8}$$

$$X_3^{0.7847} = 9.8768 \times 10^{-4}X_1^{0.8977} \tag{6-9}$$

$$X_3 = (9.8768 \times 10^{-4}X_1^{0.8977})^{1.2744} \tag{6-10}$$

$$X_3 = 1.4789 \times 10^{-4}X_1^{1.1440} . \tag{6-11}$$

Equations (6-6) and (6-11) were used to derive the equivalent sizes of system determinants, as listed in Chart VI-1.

TABLE VI-1

Staffing Chart - System Size vs. Total Employees, All Sources

Size			Employees		
Taps	Population	MGD	Calculated	Staff	Employees per Tap
100	211	0.029	0.515	0.50	0.0050
200	452	0.063	0.959	1.00	0.0050
300	704	0.101	1.380	1.50	0.0050
500	1231	0.181	2.183	2.25	0.0045
700	1780	0.266	2.953	3.00	0.0043
1000	2630	0.400	4.068	4.00	0.0040
2000	5619	0.884	7.579	7.50	0.0038
3000	8760	1.405	10.906	11.00	0.0037
5000	15325	2.521	17.251	17.25	0.0035
7000	22152	3.705	23.334	23.50	0.0034
10000	32737	5.571	32.141	32.25	0.0032
20000	69930	12.312	59.880	60.00	0.0030
30000	109015	19.578	86.172	86.25	0.0029
50000	190726	35.120	136.307	136.50	0.0027
70000	275689	51.610	184.373	184.50	0.0026
100000	470415	77.614	253.953	254.00	0.0025
200000	870292	171.521	473.139	473.00	0.0024
300000	1356704	272.750	680.872	681.00	0.0023
500000	2373610	489.283	1077.008	1077.00	0.0021

TABLE VI-2

Staffing Chart - Population vs. Total Employees, All Sources

Size	Employees	
Population	Calculated	Staff
100	0.278	0.25
200	0.492	0.50
300	0.686	0.75
500	1.043	1.00
700	1.374	1.50
1000	1.841	1.75
2000	3.249	3.25
3000	4.530	4.50
5000	6.886	7.00
7000	9.074	9.00
10000	12.155	12.25
20000	21.456	21.50
30000	29.917	30.00
50000	45.476	45.50
70000	59.921	60.00
100000	80.273	80.00
200000	141.695	141.50
300000	197.566	197.50
500000	300.320	300.50
700000	395.713	396.00
1000000	530.113	530.00
2000000	935.736	936.00
3000000	1304.706	1305.00

TABLE VI-3

Staffing Chart - MGD vs. Total Employees, All Sources

Size	Employees	
MGD	Calculated	Staff
0.025	0.462	0.50
0.050	0.796	0.75
0.075	1.094	1.00
0.100	1.371	1.50
0.250	2.813	2.75
0.500	4.846	5.00
0.750	6.662	6.75
1.000	8.349	8.50
2.500	17.136	17.25
5.000	29.520	29.50
7.500	40.579	40.50
10.000	50.856	51.00
25.000	104.377	104.50
50.000	179.813	180.00
75.000	247.173	247.00
100.000	309.770	310.00
250.000	635.775	636.00
500.000	1095.271	1095.50
750.000	1505.568	1505.50

Since the worker classification of the "operator" was deemed to be of special significance, a best-fit equation was developed for the data. Because of the fact that the highest correlation coefficient for total employees was derived using taps as the size indicator, this same parameter was used to develop the equation predicting the required number of operators for various system sizes and source types.

The equation derived was:

$$Y_2 = 0.102015X_1^{0.40595} \quad . \tag{6.12}$$

Y_2 is the number of operators and X_1 , as before, is the number of taps served. The correlation coefficient of $r = 0.804$ indicates a lesser degree in the accuracy of the predictive equation. However, this accuracy is reasonable given the fact that in smaller systems, the only employee may, in fact, be the operator. Thus staffing guides for the operator classification indicates the larger of the operator classification or total employees if the total employees is 1.0 or less. In fact, there was a pronounced tendency toward having 1.0 operators for a wide range of system sizes where the calculated number is less than 1.0 (see Graph V-a).

TABLE VI-4

Operators - All Sources

Size	Operators	
Taps	Calculated	Staff
100	0.662	0.50
200	0.877	0.75
300	1.033	1.00
500	1.271	1.25
700	1.458	1.50
1000	1.685	1.75
2000	2.232	2.25
3000	2.631	2.50
5000	3.238	3.25
7000	3.712	3.75
10000	4.290	4.25
20000	5.684	5.75
30000	6.700	6.75
50000	8.245	8.25
70000	9.452	9.50
100000	10.924	11.00
200000	14.474	14.50
300000	17.064	17.00
500000	20.996	21.00

TABLE VI-5

Operators - Surface Systems

Size	Operators	
Taps	Calculated	Staff
100	0.4769	0.50
200	0.6710	0.75
300	0.8194	0.75
500	1.0539	1.00
700	1.2439	1.25
1000	1.4829	1.50
2000	2.0866	2.00
3000	2.5480	2.50
5000	3.2772	3.25
7000	3.8681	3.75
10000	4.6113	4.50
20000	6.4884	6.50
30000	7.9232	8.00
50000	10.1907	10.25
70000	12.0282	12.00
100000	14.3391	14.50
200000	20.1763	20.25
300000	24.6377	24.50
500000	31.6888	31.75

TABLE VI-6

Operators - Well Sources

Size	Operators	
Taps	Calculated	Staff
100	0.8794	1.00
200	1.0484	1.00
300	1.1619	1.00
500	1.3226	1.25
700	1.4404	1.50
1000	1.5768	1.50
2000	1.8798	1.75
3000	2.0834	2.00
5000	2.3716	2.25
7000	2.5828	2.50
10000	2.8273	2.75
20000	3.3707	3.25
30000	3.7357	3.75
50000	4.2524	4.25
70000	4.6312	4.50
100000	5.0696	5.00
200000	6.0439	6.00
300000	6.6985	6.75
500000	7.6249	7.75

TABLE VI-7

Operators - Combination Sources

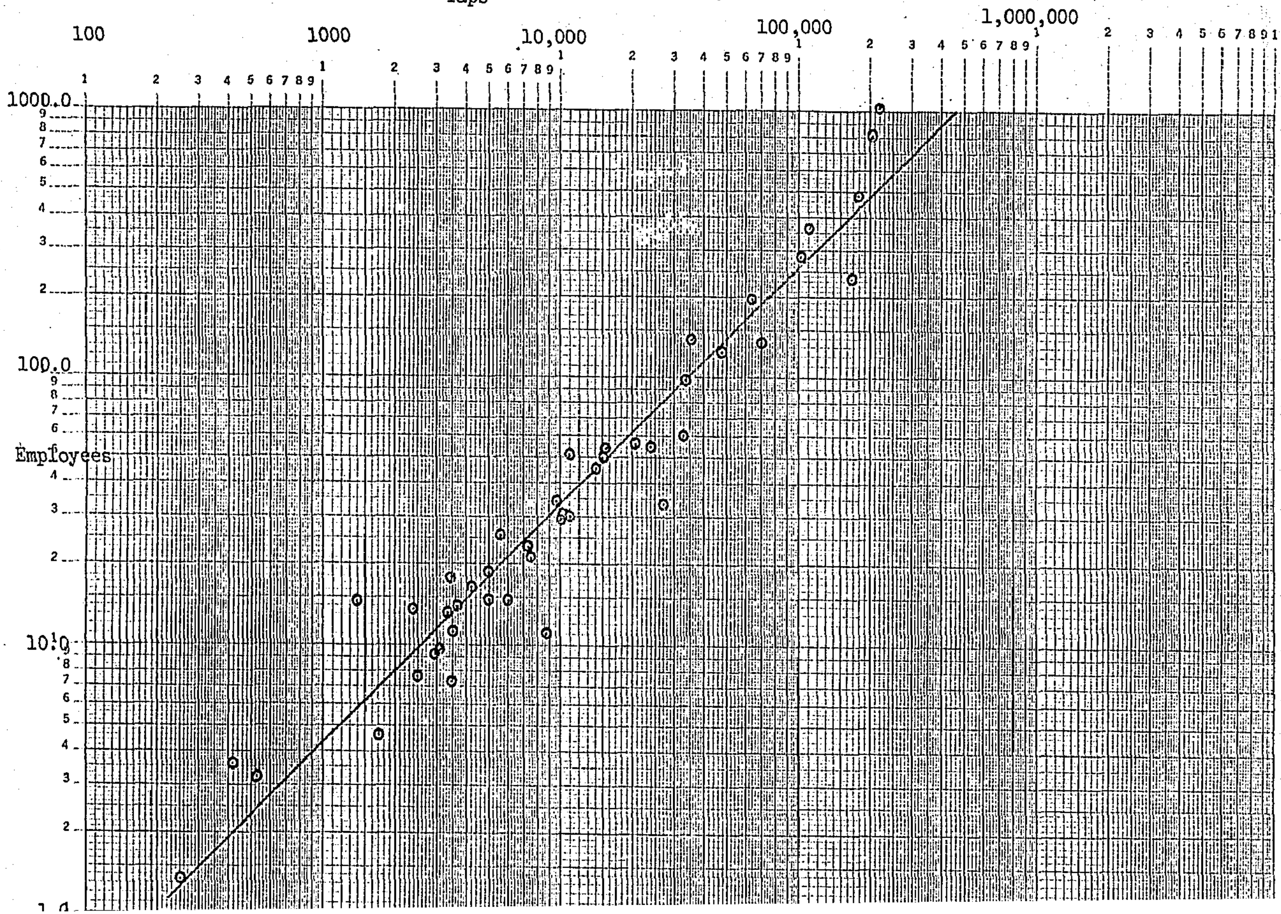
Size	Operators	
Taps	Calculated	Staff
100	0.9619	1.00
200	1.2578	1.25
300	1.4715	1.50
500	1.7931	1.75
700	2.0425	2.00
1000	2.3448	2.25
2000	3.0663	3.00
3000	3.5872	3.50
5000	4.3713	4.50
7000	4.9793	5.00
10000	5.7163	5.75
20000	7.4750	7.50
30000	8.7450	8.75
50000	10.6565	10.75
70000	12.1385	12.25
100000	13.9352	14.00
200000	18.2226	18.25
300000	21.3186	21.25
500000	25.9785	26.00

It should be pointed out that since the size parameters are incremental and not continuous, the staffing guides should be used only for rough estimates of staffing requirements.

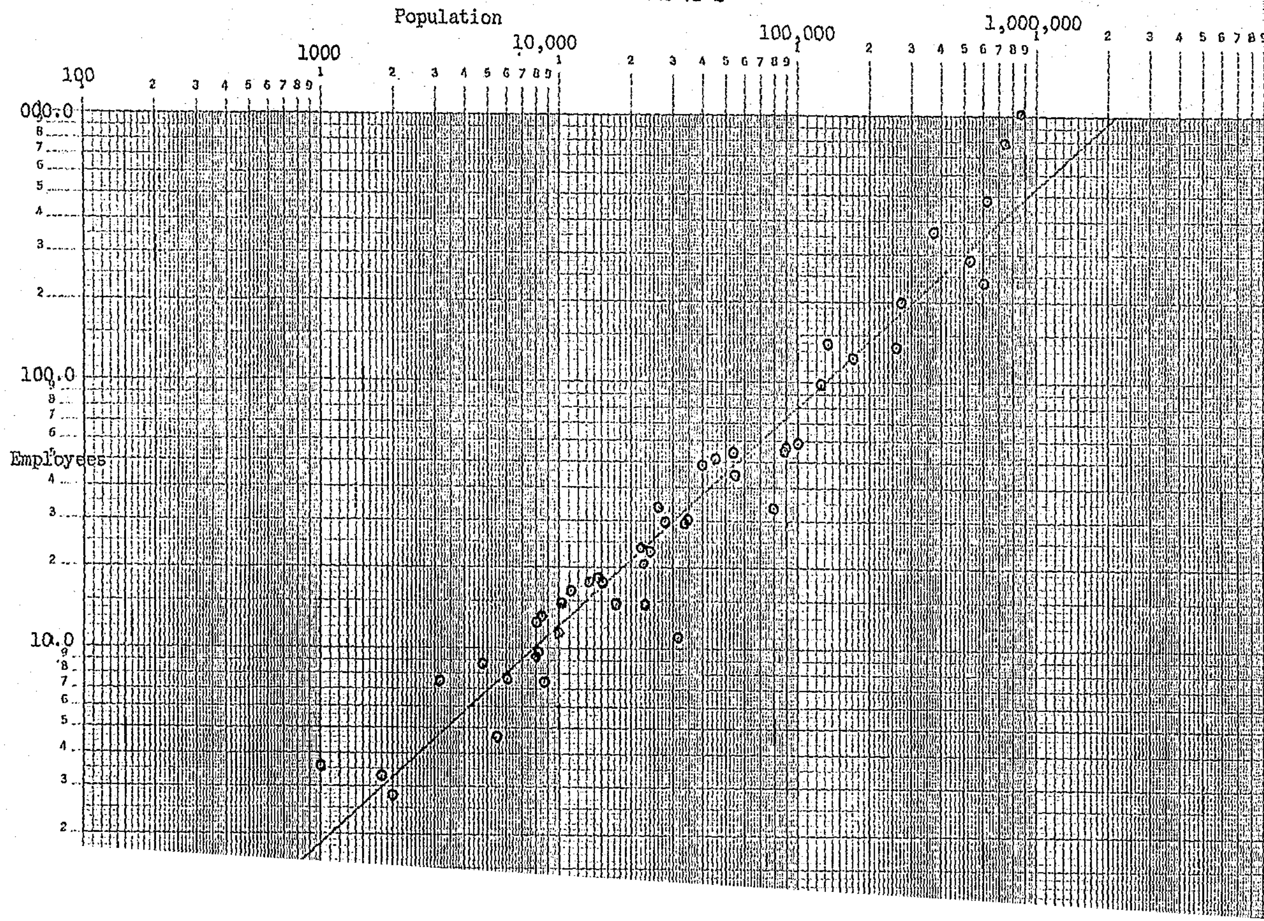
Graphs have been plotted for a variety of system sources and size determinants. These graphs served as the basic data resource to determining the general equation form. Additionally, the graphs represent the most easily accessed predictive mechanism for a continuum of system sizes. They represent a visual presentation of equations IV-a, IV-b, IV-c, IV-d, and IV-f, Appendix IV.

A detailed example problem using the equations and graphs developed for this project follows on page 76 and demonstrates how easily used the methodology is.

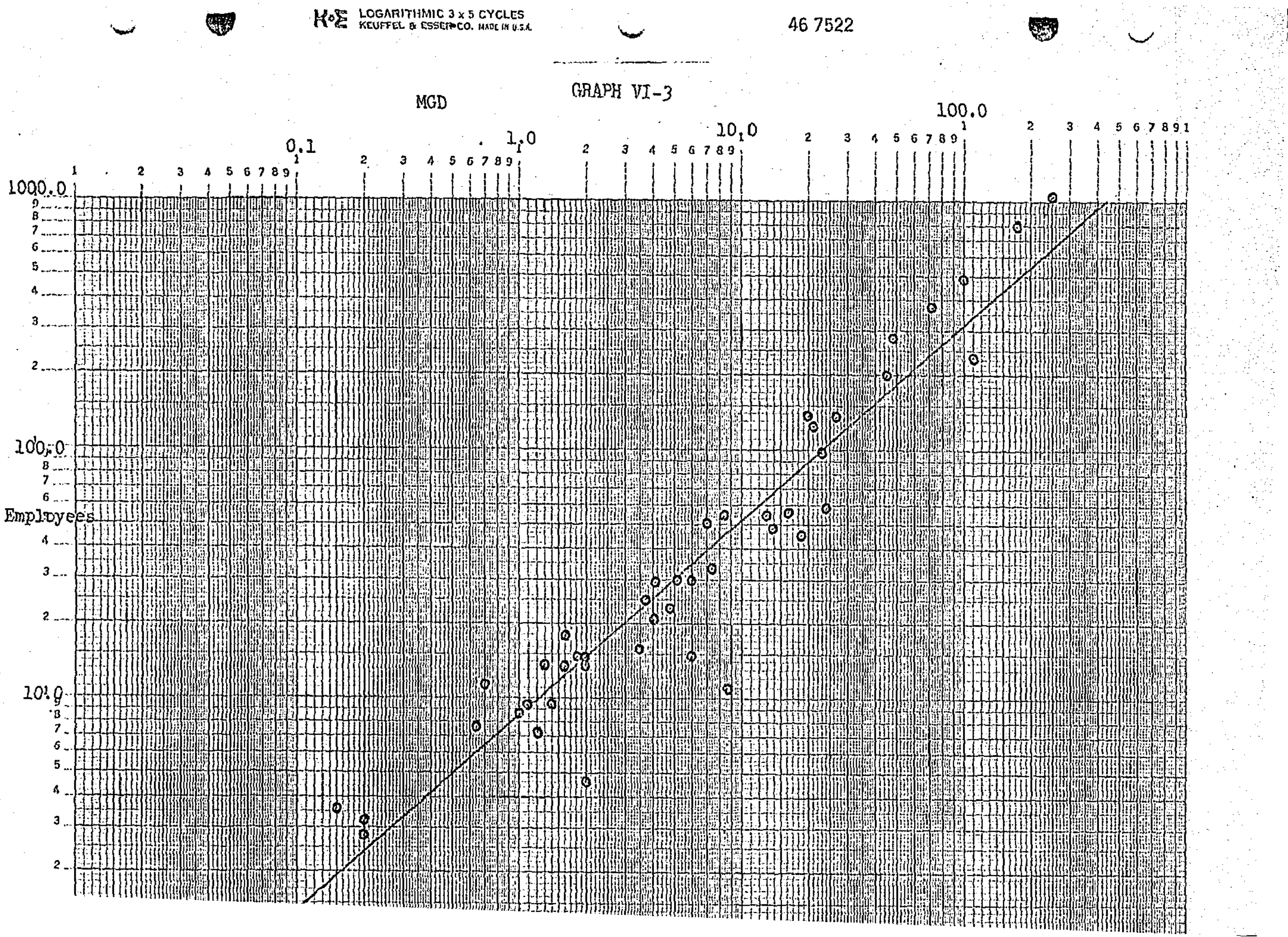
GRAPH VI-1


Taps
100
1000
10,000
100,000
1,000,000
Employees
1000.0
100.0
10.0
1.0

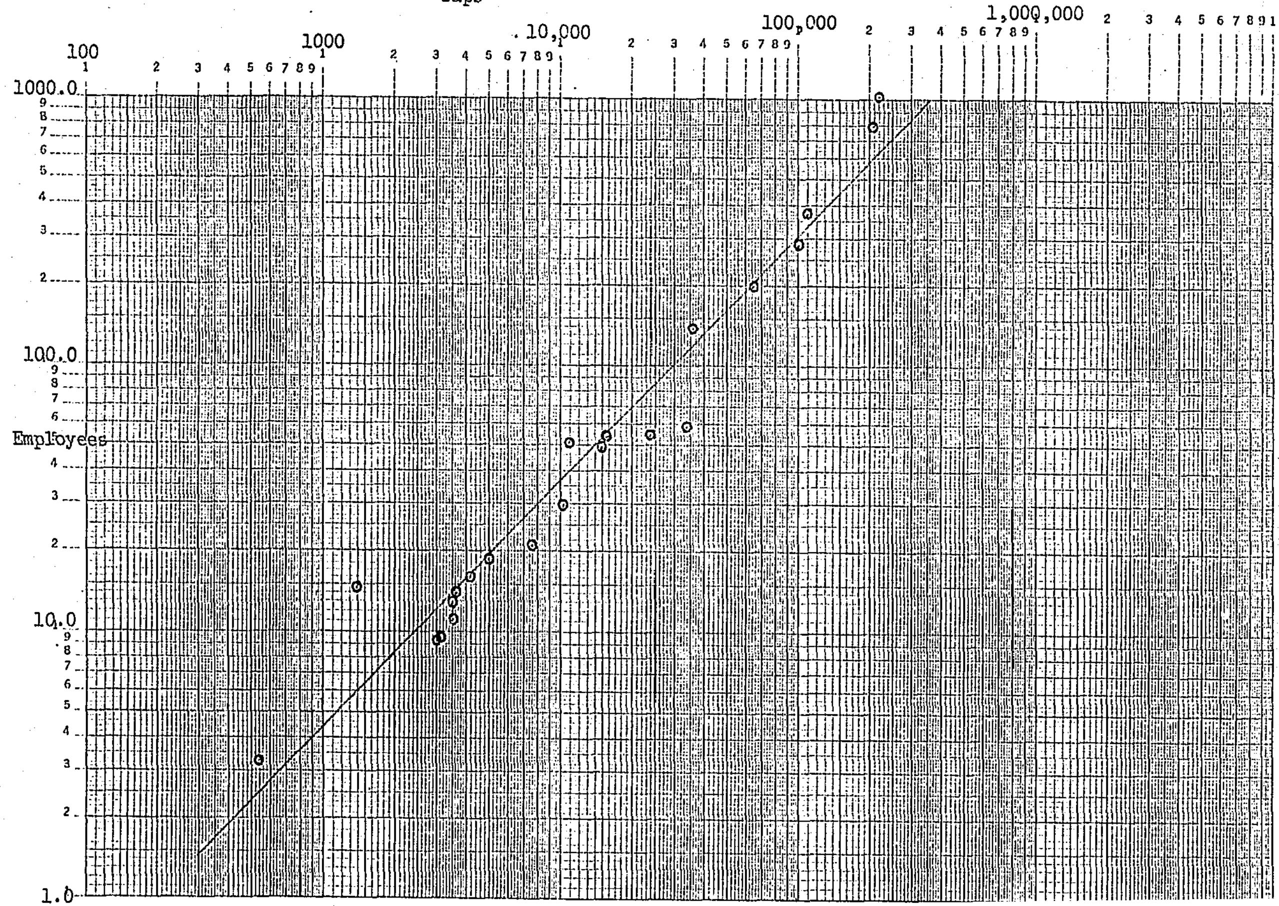
GRAPH VI-2


Population
100
1000
10,000
100,000
1,000,000
Employees
1000.0
100.0
10.0

GRAPH VI-3

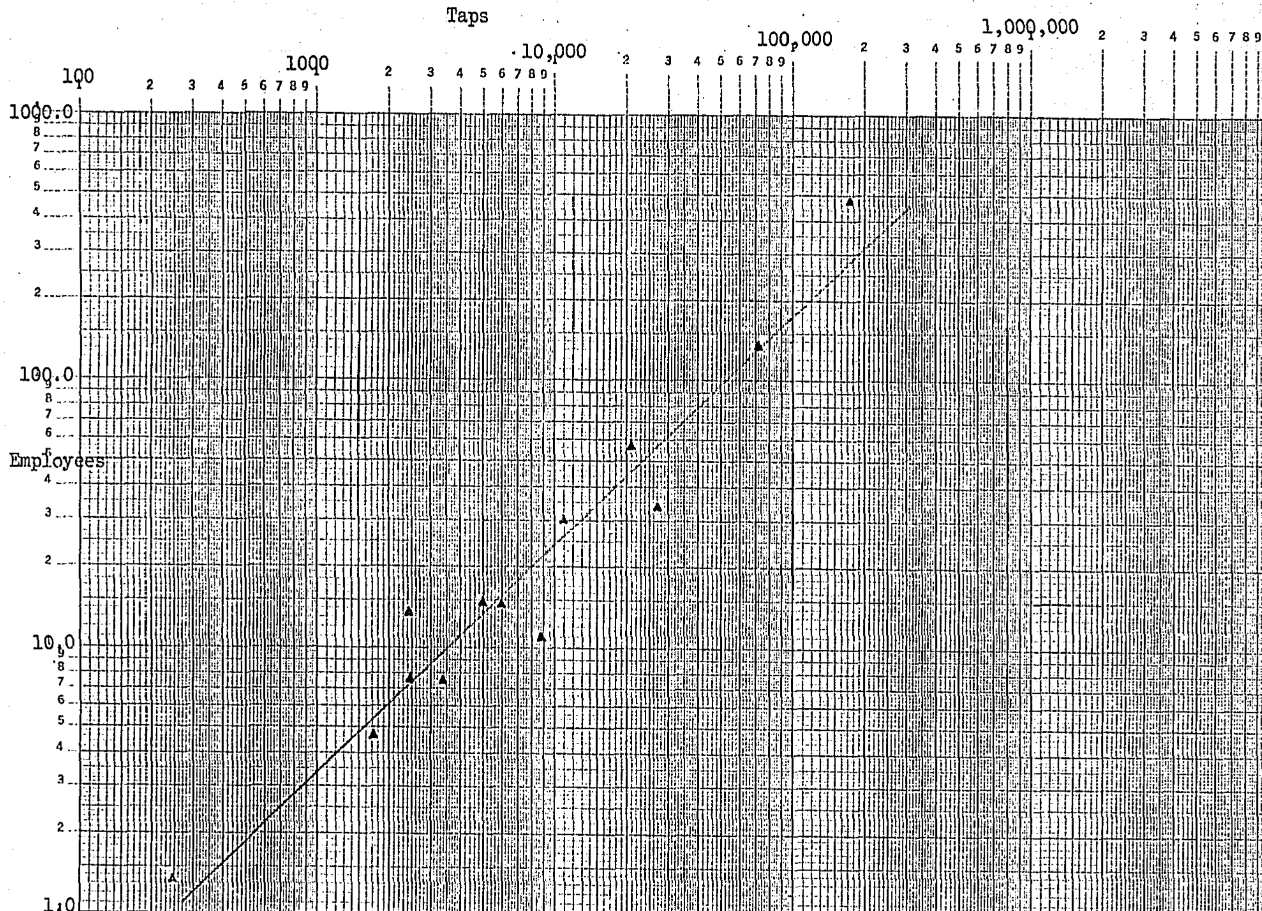

K&E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 7522
MGD
0.1
1.0
10.0
100.0
1000.0
100.0
10.0
Employees

GRAPH VI-4

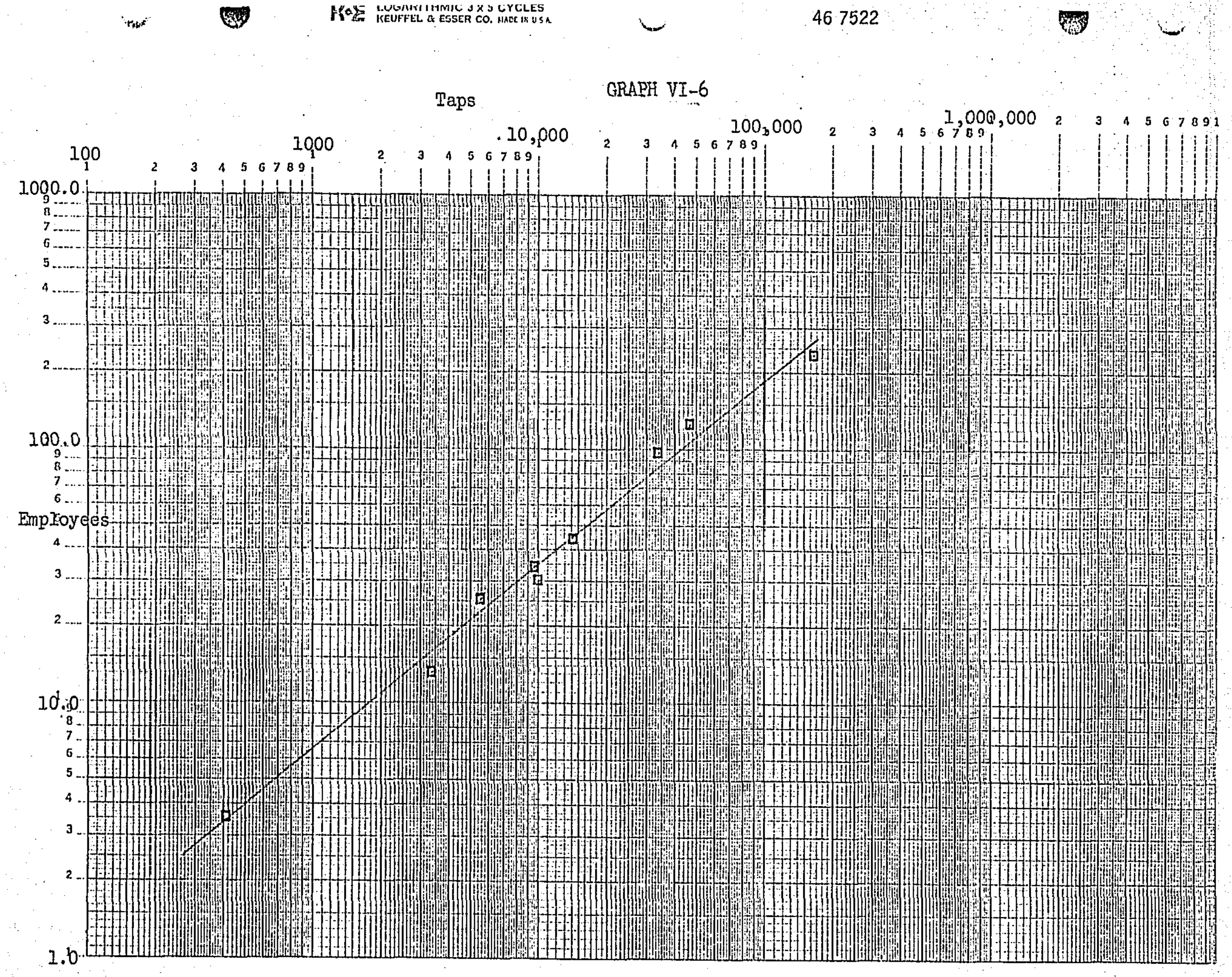

Taps
100
1000
10,000
100,000
1,000,000
Employees
1000.0
100.0
10.0
1.0

K&E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 7522

GRAPH VI-5



GRAPH VI-6



Total Employees vs. Taps - Combination Sources

Example Problem.

Given: A community of 85,000 with 23,000 taps, producing 14.4 MGD. The utility is public in ownership and utilizes a surface source for raw water.

Required: What is total staffing and how many operators are required for the system?

Methodology:

1. Using equation 6.6, relating taps and population, 85,000 is entered as X_2 and the equation is solved for X_1 as 23,902, then entered into equation 6-11 relating taps and MGD. The answer is 15.0 MGD which is larger than 14.4 so population is the largest of the three measures of size. A normalized number of taps then is used which is 23,902 as calculated from 6.6.

2. a. Using equation A.III-d) and relating taps to employees for surface sources, Y_2 is solved to be 80.7355.

   b. Using graph A.III-d and reading directly, approximately 81.0 employees are indicated. This method is less elegant and slightly less precise than solving equation A.IV-d) but yields closely approximate answers directly from the graph. The graph is a direct plot of solutions to equation A.IV-d).

3. a. Solving equation A.III-h) for operators gives 7.08.

   b. From graph A.III-8, operators for surface sources, the required number of 7.0 can be read directly.

Some comments are in order to address the problem of obviously deviant data points as are identifiable from a visual inspection of the graphs.

Data, even highly correlated data, has some deviation from a best-fit equation but the reasons for points simply not fitting the curves should be identified. The sources for errors are of two types. One is that physical size measures are inaccurately known. In water utility systems the potential for errors seems largest in older systems where historical records may not be precise. In other cases the presence in the community of highly water consumptive industry may create significant difficulty in determining a realistic assessment of system size. Per capita consumption varies significantly throughout the nation between climate and social characteristics. In very highly urbanized sections of the eastern part of the country, the population per tap served is higher than in less densely populated areas.

An analysis of the data plots suggests that several data entries are probably in error and in other cases there is a specific cause to significant data mislocation. Two examples are apparent from Graph III-3. The entry of 11.0 employees and 8.7 MGD corresponds to the community of Merced, California. This town is in the San Joaquin Valley and as is characteristic of more arid communities has a high per capita annual consumption figure which accounts for the fact that the MGD produced is almost twice what most other communities would expect to produce. The feature of this community which causes further difficulty pertains to the staffing level. The utility at the time of this survey was in the process of passing from private ownership to municipally owned. The private utility in the time after sale but before municipal take-over had allowed the staff (and service) to decline through attrition almost to the point of being inadequate to the task of providing a service to the community.

An example of basic size data error concerns the point corresponding to 4.6 employees and 2.0 MGD. It is estimated that Purcell, Oklahoma, probably accurately produces approximately 0.75 MGD. This determination is based on the fact that not only does the rank order for the rest of the size determinants break down for MGD but a solution to equation (6-11) relating taps to MGD indicates that an average figure of 0.75 MGD is more reasonable. No known water consumptive industries exist.

An additional example of data error corresponds to 14.6 employees and 1400 taps on Graph III-4. A look at the data summary tables and the graph indicates that probably an error exists. Solving equation (6-4) for taps indicates that for a population of 10,346 for the community of Somerset, Kentucky, the expected number of taps is approximately 3490.

In all cases the above eliminates an obvious (visually and rank order) data error.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Summary

This dissertation has analyzed the composite employment patterns of the water treatment industry. From the statement of an identified nation-wide problem, a methodology for investigating staffing characteristic of this industry was developed in Chapter III. The purpose of the methodology is to derive the coefficients to be used in a predictive methodology to allow for staffing guidelines to be prepared.

As data were collected, it became obvious that there was a connection between staffing quantities and various measures of system size. These measures of size were evaluated as to accuracy in Chapter IV, and taps were thereafter used as the best indicator of size.

Due to an identified set of needs for the operator classification, Chapter V is devoted to an in-depth evaluation of the tasks characteristic of that class of worker. Further, an operator-task matrix was prepared yielding information on a reasonable, fact-based job description; approximate percentage of time spent in each task; and a tie of the matrix entries to one of the identified problems characteristic of the industry.

Using the methodology developed for Chapter IV, a series of staffing guides are prepared for total employees versus system size measures. Staffing guides are also prepared for the special operator classification versus source type using taps as the measure of size. These staffing guides can serve as estimates for staffing by the utilities or may be aggregated for state or national manpower estimates.

Conclusions

There are several conclusions that can be drawn from this dissertation. Most are related to the very high correlation between system size and the number of total employees or between system size and the number of operators. The conclusion is that predictable quantities of employees can be accurately derived using the methodology herein. A detailed example is in Chapter VI.

This dissertation makes a national job description for the operator classification, based on actual observation of tasks performed within approximately fifty utilities. Further, educational programs may now be developed for the operator classification based on actual tasks performed. Development of curriculum to meet established needs differs somewhat from an accepted past practice of educators preparing curricula then fitting the job title with trained people regardless of needs. Cooperation between educators and the employing utilities is mandated by the fact that one-to-one correspondence between the two is necessary for entry level position efficiency.

One underlying idea of the study was to develop the justification for significant, federally funded education programs for select job titles, specifically "operators." Given the validity of the job description developed for the survey of actual tasks performed, it seems very difficult to imagine a cost effective program to provide skills to potential workers who either have the basic skills already or don't need additional skills to perform the work indicated. Although this conclusion was outside the scope of this study, it is inevitable from even a coursory examination of the task statements developed from actual job analysis and job descriptions. This conclusion is very much contrary to the conclusions drawn from the earlier wastewater studies and extensive educational requirements for operations personnel. This difference certainly helped to highlight the validity of the systems approach of analyzing requirements based on equipment related tasks.

It should be pointed out that the task statements developed for this industry as currently operating is appropriate only for the currently in-place technology. If there are treatment technology changes in the future, then an evaluation of those changes in associated duties should be made.

It can be seen from the various charts and graphs that similar sized systems with similar sources have similar quantities of people performing similar tasks regardless of other system characteristics. Because of the very high correlation of total employees to source type and size, other factors such as geographical location, age, etc. are relatively unimportant to estimating requisite staffing. Two factors, system ownership and automation may have some very significant impact and should provide direction for future studies.

Growth factors (positive or negative) may be used to investigate future utility staff requirements. These are easily derived accurately from the staffing charts or grossly from the graphs which continuously plot system size measures.

For the operator classification some variation in staffing was noted and can be directly attributed to the fact that there was observed a diverse set of job descriptions for this category. If the job description includes many tasks not actually related to the job title, then increases in the number of personnel required for a specific job title will occur.

Although in Chapter II a set of problems was identified in the drinking water industry related to potential qualification discrepencies, an examination of the task statement for the operator classification does not indicate a significant relationship between the observed public health problem and a lack of appropriate training.

Finally, and most importantly, a methodology has been developed which makes it possible to make recommendations for staffing based on observation of actual characteristics for a wide range of system sizes. The extrapolation of this methodology to other utility types is obvious and should provide considerable insight into their similar characteristics of operation and structure.

BIBLIOGRAPHY

Books

1. Astrand, Per-Olof. Textbook of Work Physiology. New York: McGraw-Hill Book Company, 1970.

2. Niebel, Benjamin W. Motion and Time Study. Homewood, Illinois: Richard D. Irwin, Inc., 1972.

3. Olympus Research Corporation. Manpower Planning for Wastewater Treatment Plants. For Division of Manpower Development and Training, Bureau of Adult, Vocational, and Technical Education, U.S. Office of Education.

Publications

1. Baumann, E. Robert, Keith L. McRoberts, and C. E. Smith. Estimating Staffing and Cost Factors for Small Wastewater Treatment Plants Less than 1 MGD, Part I. Staffing Guidelines for Conventional Municipal Wastewater Treatment Plants Less than 1 MGD. Ames: Department of Industrial Engineering and Engineering Research Institute, Iowa State University, June 1973; for Manpower Development Staff, Office of Water Program Operations, U. S. Environmental Protection Agency, Washington D.C.

2. Lamp, George E., Jr., E. Robert Baumann, Keith L. McRoberts, and C. E. Smith. Estimating Staffing and Cost Factors for Small Wastewater Treatment Plants Less than 1 MGD, Part II. Estimating Costs of Package Wastewater Treatment Plants. Ames: Department of Industrial Engineering and Engineering Research Institute, Iowa State University, June 1973; for Manpower Development Staff, Office of Water Program Operations, U. S. Environmental Protection Agency, Washington D.C.

3. Namour, Elie. Manpower Requirements for Wastewater Collection Systems in Cities of 150,000 to 500,000 in Population. Greensboro: Center for Manpower Research and Training, North Carolina A & T State University, March 1974; for the Manpower Development Staff, Office of Water Program Operations, U. S. Environmental Protection Agency, Washington D.C.

4. U. S. Department of Health, Education, and Welfare, Bureau of Water Hygiene. Community Water Supply Study - Analysis of National Survey Findings. July 1970.

5. U. S. Environmental Protection Agency, Office of Water Programs. Estimating Staffing for Municipal Wastewater Treatment Facilities. March 1973; Contract # 68-01-0328.

6. U. S. Environmental Agency, Public Service Careers Section. Guidelines to Career Development for Waste Water Plant Personnel. September 1973.

Dissertations and Unpublished Reports

1. Moser, Collette Helen. "An evaluation of area skill surveys as a basis for manpower policies." University of Wisconsin, DLMA #91-53-67-16-1, April 1971.

2. American Water Works Association, Salary Survey, October 1974, published as Development of Manpower Planning Criteria for Water Supply Systems. Final Report Appendix C and D, Oklahoma Foundation for Research and Development Utilization, Inc., Oklahoma City, October 1974.

3. Oklahoma Foundation for Research and Development Utilization, Inc. Development of Manpower Planning for Water Supply Systems. Final Report # OK(R)3801, Oklahoma City, October 1974.

APPENDIX I

SURVEY FORMS

a) Physical Parameters

WATER SYSTEM PHYSICAL PARAMETER INVENTORY

Date

Location Parameters

1. Region ______________________
2. State ______________________
3. County ______________________
4. City ______________________
5. System Ownership ______________________
6. System Operated By ______________________

Dimension Parameters

7. Population, 1970 Census ______________________
8. Population, 1975 Estimates ______________________
9. Population Served ______________________
10. Total Number of Hookups ______________________
11. Total Design Capacity ______________________
12. Average Daily Use ______________________
13. Total Number of Employees, Full Time Equivalent

    ____

Source

14. Type of Source ______

    SU - Surface
    GR - Ground
    BT - Both

15. Primary Source ______

    (LA - Lake; ST - Stream; SP - Spring; DW - Deep Wells; SW - Shallow Wells; PO - Purchased)

16. Secondary Source ______
17. If Surface, name of lake ______________________
18. If Surface, acre/feet capacity ______________________

If Wells:

19. Number of Active Wells ____________

20. Number of Pumps ____________

21. Capacity of Pumps ____________ G/D

Distribution System

22. Number of Pumps, Distribution System ____________

23. Total Capacity of Distribution System Pumps ____________

24. Length of Distribution Lines, Miles ____________

Treatment Plant

25. Treatment Plant 0 - No; 1 - Yes ______

26. Aeration ____________

27. Mixing ____________

28. Coagulation - Flocculation ____________

29. Sedimentation ____________

30. Disinfection ____________

31. Taste & Odor ____________

32. Filtration ____________

33. Softening ____________

34. Corrosion Control ____________

35. Iron-Manganese ____________

36. Desalination ____________

37. Ammoniation ____________

38. Degree of Automation 0 - None; 1 - Mixed; 2 - Highly ______

39. Partial Treatment 0 - No; 1 - Yes ______

40. Double Treatment 0 - No; 1 - Yes ______

Raw Water Transmission

41. Length of Transmission Line, Miles ________________

42. Air Hammer Prevention 0 - No; 1 - Yes ______

43. Number of Pumps, Raw Water Transmission ________________

44. Size of Transmission Lines ________________

45. Total Raw Water Storage Capacity ________________

b) Employment Information

City	
State	
Form No.	Page No. A.1
Form Administration	
Date	Interviewer

JOB, POSITION OR OTHER SOURCE		Outside Sources	Other City Dept.	Total All Inside Positions								
Budgeted Number of Jobs												
Actual Number of Incumbents												
Job Number												
Estimation Basis												
Occupation Code												
Staffing Code												
Management												
Direct Supervision												
Indirect Supervision												
Planning & Budget												
Cost Estimation												
Contractor Selection												
Site Selection												
Land Acquisition												
Inspection												
Purchasing												
Design Functions												
Construction Coord.												
City Dept. Coordination												
Personnel												
Administration												
Training												
Personnel Selection												

City	
State	
Form No.	Page No. A.2
Form Administration	
Date	Interviewer

JOB, POSITION, OR OTHER SOURCE		Outside Sources	Other City Dept.	Total All Inside Positions								
Budgeted Number of Jobs												
Actual Number of Incumbents												
Job Number												
Estimation Basis												
Occupation Code												
Staffing Code												
Purchasing												
Administration												
Warehousing												
Inventory Record												
Purchasing												
Public Relations												
Complaints												
Meeting Public												
Commercial												
Finance												
Bonds Administration												
Auditing												
Accounting												
Comptroller												

City	
State	
Form No.	Page No. A.3
Form Administration	
Date	Interviewer

JOB, POSITION OR OTHER JOBS		Outside Sources	Other City Dept.	Total All Inside Positions									
Budgeted Number of Jobs													
Actual Number of Incumbents													
Job Number													
Estimation Basis													
Occupation Code													
Staffing Code													
Marketing													
Customer Service													
Public Promotion													
Developer Service													
Industrial Service													
Metering													
Meter Reading													
Meter Calibration													
Meter Maintenance													
Billing													
Engineering													
Plant													
Distribution													
Construction													
Customer Services													

City	
State	
Form No.	Page No. TP.1
Form Treatment Plant	
Date	Interviewer

JOB, POSITION OR OTHER SOURCE		Outside Sources	Other City Dept.	Total All Inside Positions								
Budgeted Number of Jobs												
Actual Number of Incumbents												
Job Number												
Estimation Basis												
Occupation Code												
Staffing Code												
Supervision & Administration												
Direct Supervision of Others												
Technical Assistance												
Chemical Additions												
Unload, Store & Handle												
Physical Mixing												
Control Adjustment												
Visual Check												
Minor P. M.												
Major P. M.												
Other												
Settling Basin-Visual Check												
Settling Test												
Minor P. M.												
Minor C. M.												
Other												
Filters - Visual Check												
Backwashing												
Scheduling Filt. & B.W.												
Flow Adjustment - Manual												
Flow Adjustment - Augo.												

City	
State	
Form No.	Page No. TP 2
Form Treatment Plant	
Date	Interviewer

JOB, POSITION OR OTHER SOURCE		Outside Sources	Other City Dept.	Total All Inside Positions								
Budgeted Number of Jobs												
Actual Number of Incumbents												
Job Number												
Estimation Basis												
Occupation Code												
Staffing Code												
Filters (Cont.)												
Minor P. M.												
Minor C. M.												
Major Maint.												
Other												
Motor - Visual Check												
Minor P. M. & C. M.												
Major Repair												
Other												
Pumps - Visual Check												
Minor P. M. & C. M.												
Repacking												
Other												
Compressor, Airline, Tanks, Val.												
Visual Check												
Bleeding												
Minor P. M. & C. M.												
Replace Lines												
Major Maint.												

City	
State	
Form No.	Page No. TP.3
Form Treatment Plant	
Date	Interviewer

JOB, POSITON OR OTHER SOURCE		Outside Sources	Other City Dept.	Total All Inside Positions								
Budgeted Number of Jobs												
Actual Number of Incumbents												
Job Number												
Estimation Basis												
Occupation Code												
Staffing Code												
Gauges & Instruments												
Visual Check												
Other Testing												
Chart & Ink Replacement												
Minor Mtc.												
Major Mtc.												
Laboratory Testing												
Chemical												
Bacterial												
Unit Process Control												
G/D for System Balance												
Chemical Dose Levels												
Building & Grounds												
Custodial Inside												
Custodial Outside												
Mowing												
Hauling												
Clean Sludge Basin												
Painting												
Other												

City	
State	
Form No.	Page No. TP.4
Form Treatment Plant	
Date	Interviewer

JOB, POSITION OR OTHER SOURCE		Outside Sources	Other City Dept.	Total All Inside Positions								
Budgeted Number of Jobs												
Actual Number of Incumbents												
Job Number												
Estimation Basis												
Occupation Code												
Staffing Code												
Clerical & Secretarial												
Employee Upgrade												

City	
State	
Form No.	Page No. T.1
Form Raw Water Transmission	
Date	Interviewer

JOB, POSITION OR OTHER SOURCE	Outside Sources	Other City Dept.	Total All Inside Positions								
Budgeted Number of Jobs											
Actual Number of Incumbents											
Job Number											
Estimation Basis											
Occupation Code											
Staffing Code											
Supervision & Administration											
Direct Supervision of Others											
Technical Assistance											
Intake Screen											
Inspection											
Minor P. M.											
Sludge Removal											
Pumps & Valves Visual Check											
Minor P. M.											
Minor C. M.											
Major Mtc.											
Instrumentation-Visual Check											
P. M.											
Calibration											
Lines Inspection											
P. M.											
Emergency Repair											

City	
State	
Form No.	Page No. T.2
Form Raw Water Transmission	
Date	Interviewer

JOB, POSITION OR OTHER SOURCE		Outside Sources	Other City Dept.	Total All Inside Positions								
Budgeted Number of Jobs												
Actual Number of Incumbents												
Job Number												
Estimation Basis												
Occupation Code												
Staffing Code												
Air Hammer Prevention												
P. M.												
Employee Upgrade												

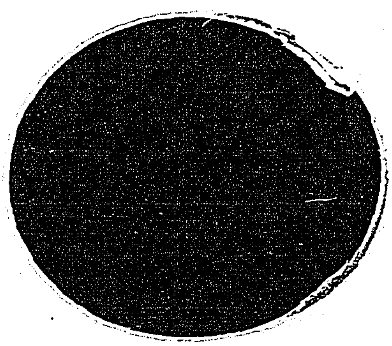
City	
State	
Form No.	Page No. S.1
Form Storage	
Date	Interviewer

JOB, POSITION OR OTHER SOURCE		Outside Sources	Other City Dept.	Total All Inside Positions								
Budgeted Number of Jobs												
Actual Number of Incumbents												
Job Number												
Estimation Basis												
Occupation Code												
Staffing Code												
Supervision & Administration												
Direct Supervision of Others												
Technical Assistance												
Storage Facility Inspection												
Applied Treatment												
Chemical Add.												
Sampling												
Pumps & Valves Visual Check												
Minor P. M.												
Minor C. M.												
Repair												
Unit & Ground Work												
Mowing												
Painting												
Mech. Mtc.												
Employee Upgrade												

City	
State	
Form No.	Page No. D.1
Form Distribution	
Date	Interviewer

JOB, POSITION OR OTHER SOURCE	Outside Sources	Other City Dept.	Total All Inside Positions								
Budgeted Number of Jobs											
Actual Number of Incumbents											
Job Number											
Estimation Basis											
Occupation Code											
Staffing Code											
Supervision & Administration											
Direct Supervision of Others											
Technical Assistance											
Pumps & Valves											
Visual Check											
Minor P. M.											
Minor C. M.											
Major Mtc.											
Lines											
Inspection											
P. M.											
Installation											
Customer Hookup											
Emergency Repair											
Meter Installation											
Calibration											
Internal Auto. Mtc.											
Internal Equip. Mtc.											
Employee Upgrade											

c) Survey Example



WATER SYSTEM PHYSICAL PARAMETER INVENTORY

Date

Location Parameters

1. Region SW
2. State CA
3. County SANTA CLARA
4. City SAN JOSE
5. System Ownership INV
6. System Operated By INV

Dimension Parameters

7. Population, 1970 Census 524,000
8. Population, 1975 Estimates ______
9. Population Served 600,000
10. Total Number of Hookups 167,000
11. Total Design Capacity 220 MGD
12. Average Daily Use 110, ~~000~~ MGD
13. Total Number of Employees, Full Time Equivalent 242

Source

14. Type of Source BT

SU - Surface
GR - Ground
BT - Both

15. Primary Source LA, ST, DW, PO
(LA - Lake; ST - Stream; SP - Spring; DW - Deep Wells; SW - Shallow Wells; PO - Purchased)
16. Secondary Source PO
17. If Surface, name of lake Several Reservoirs
18. If Surface, acre/feet capacity 28 x 10^6 GPD Yield

If Wells:

19. Number of Active Wells 150
20. Number of Pumps 150
21. Capacity of Pumps 23 x 10^6 G/D

Distribution System

22. Number of Pumps, Distribution System 162
23. Total Capacity of Distribution System Pumps 220 MGD
24. Length of Distribution Lines, Miles 1900

Treatment Plant

25. Treatment Plant 0 - No; 1 - Yes 1
26. Aeration 0
27. Mixing 1
28. Coagulation - Flocculation 1
29. Sedimentation 1
30. Disinfection 1
31. Taste & Odor 1
32. Filtration 1
33. Softening 0
34. Corrosion Control 0
35. Iron-Manganese 0
36. Desalination 0
37. Ammoniation 0

38. Degree of Automation 0 - None; 1 - Mixed; 2 - Highly 2
39. Partial Treatment 0 - No; 1 - Yes 0
40. Double Treatment 0 - No; 1 - Yes 0

Raw Water Transmission

41. Length of Transmission Line, Miles 4

42. Air Hammer Prevention 0 - No; 1 - Yes 0

43. Number of Pumps, Raw Water Transmission 0

44. Size of Transmission Lines 30 INCH

45. Total Raw Water Storage Capacity 0

(148.75)

148.75

City	San Jose
State	CA
Form No.	
Page No.	A.1
Form	Administration
Date	
Interviewer	

Job, Position or Other Source	Outside Sources	Other City Dept.	Total All Inside Positions	[illegible]	[illegible]	Engineering Services	General Services	Water Res. Div.	[illegible]	Construction Inspection	[illegible]
Budgeted Number of Jobs				42	2	25	47	13	25	5	2
Actual Number of Incumbents				42	2	25	47	13	25	5	2
Job Number				1	2	3	4	5	6	7	8
Estimation Basis											
Occupation Code											
Staffing Code											
Management											
Direct Supervision		(22.50)		17.50		.25	4.75				
Indirect Supervision		(13.00)		10.5		.75	1.75				
Planning & Budget		(4.25)		2.00		1.00	1.25				
Cost Estimation		(4.50)		.75		2.50	1.25				
Contractor Selection											
Site Selection											
Land Acquisition											
Inspection		(7.50)							3.50	4.00	
Purchasing		(2.25)		.50			1.75				
Design Functions		(1.50)				1.50					
Construction Coord.		(4.[illegible])		.50		2.50				1.00	
City Dept. Coordination											
Personnel											
Administration		(3.00)		1.50			1.50				
Training											
Personnel Selection		(2.75)		1.50			1.25				

CITY	San Jose
STATE	
FORM NO.	PAGE NO. A.2
FORM	Administration
DATE	INTERVIEWER

JOB, POSITION OR OTHER SOURCE	OUTSIDE SOURCES	OTHER CITY DEPT.	TOTAL ALL EXISTING POSITIONS	Executive [illegible]	Computer [illegible]	Engineering Services	Clerical Service	Meter Reading	Water Service [illegible]	Construction [illegible]	Storekeeper
BUDGETED NUMBER OF JOBS				42	2	25	47	13	25	5	2
ACTUAL NUMBER OF INCUMBENTS				42	2	25	47	13	25	5	2
JOB NUMBER				1	2	3	4	5	6	7	8
ESTIMATION BASIS											
OCCUPATION CODE											
STAFFING CODE											
Purchasing											
Administration		(1.50)		1.00							.50
Warehousing		(.75)									.75
Inventory Record		(2.00)					1.25				.75
Purchasing		(.75)					.75				
Public Relations											
Complaints		(6.25)					.75		5.50		
Meeting Public		(.75)		.25					.50		
Commercial											
Finance											
Bonds Administration											
Auditing		(2.00)		1.00			1.00				
Accounting		(2.75)		1.00			1.75				
Comptroller		(2.00)		1.00			1.00				

CITY	San Jose
STATE	
FORM NO.	PAGE NO. A.3
FORM	Administration
DATE	INTERVIEWER

JOB, POSITION OR OTHER SOURCE	OUTSIDE SOURCES	OTHER CITY DEPT.	TOTAL ALL SPECIFIC POSITIONS	[illegible] and Admin. Services	Consultant Operations	Engineering Services	Clerical Services	Meter Readers	Water Servicemen	Construction Inspector	Stockkeeper
BUDGETED NUMBER OF JOBS				42	2	25	47	13	25	5	
ACTUAL NUMBER OF INCUMBENTS				42	2	25	47	13	25	5	
JOB NUMBER				1	2	3	4	5	6	7	8
ESTIMATION BASIS											
OCCUPATION CODE											
STAFFING CODE											
Marketing											
Customer Service		(13.00)		.50			4.50		8.00		
Public Promotion		(2.75)		.50			2.25				
Developer Service		(1.25)		.50			.75				
Industrial Service		(1.00)		.50			.50				
Metering											
Meter Reading		(13.00)						13.00			
Meter Calibration		(2.50)							2.50		
Meter Maintenance		(2.50)							2.50		
Billing		(13.50)					13.50				
Engineering											
Plant		(3.50)		.50	.50	2.50					
Distribution		(4.75)		.50	1.50	2.75					
Construction		(.50)				.50					
Customer Services		(.50)				.50					

CITY San Jose	
STATE CA.	
FORM NO.	PAGE NO. T.1
FORM Raw Water Transmission	
DATE	INTERVIEWER

4.50

(41.50

Job, Position or Other Source	Outside Sources	Other City Dept.	Total All Inside Positions	[illegible]	[illegible]	[illegible]					
Budgeted Number of Jobs				14	38	25					
Actual Number of Incumbents				14	39	25					
Job Number				9	15	3					
Estimation Basis											
Occupation Code											
Staffing Code											
Supervision & Administration											
Direct Supervision of Others		(.70)		.70							
Technical Assistance		(.70)		.20		.50					
Intake Screen											
Inspection		(1.25)			1.25						
Minor P. M.											
Sludge Removal											
Pumps & Valves Visual Check											
Minor P. M.											
Minor C. M.											
Major Mtc.											
Instrumentation - Visual Check											
P. M.											
Calibration											
Lines Inspection		(1.60)		.10	1.50						
P. M.		(.25)			.25						
Emergency Repair											

CITY	
STATE	
FORM NO.	PAGE NO. T.2
FORM Raw Water Transmission	
DATE	INTERVIEWER

JOB, POSITION OR OTHER SOURCE		OUTSIDE SOURCES	OTHER CITY DEPT.	TOTAL ALL INSIDE POSITIONS								
BUDGETED NUMBER OF JOBS												
ACTUAL NUMBER OF INCUMBENTS												
JOB NUMBER												
ESTIMATION BASIS												
OCCUPATION CODE												
STAFFING CODE												
Air Hammer Prevention												
P. M.												
Employee Upgrade												

CITY	
STATE	
FORM NO.	PAGE NO. TP 3
FORM Treatment Plant	
DATE	INTERVIEWER

JOB, POSITION OR OTHER SOURCE	OUTSIDE SOURCES	OTHER CITY DEPT.	TOTAL ALL BASIC POSITIONS	Executive Service	Clerical Service	[illegible] Supervision	Treatment Plant Operator	Pump Operator	[illegible]	Laborer	
BUDGETED NUMBER OF JOBS				25	47	14	2	5	7	38	
ACTUAL NUMBER OF INCUMBENTS				25	47	14	2	5	7	33	
JOB NUMBER				3	4	9	11	12	13	15	
ESTIMATION BASIS											
OCCUPATION CODE											
STAFFING CODE											
Gauges & Instruments											
Visual Check		(1.10)							1.10		
Other Testing											
Chart & Ink Replacement		(.35)							.35		
Minor Mtc.											
Major Mtc.											
Laboratory Testing	Contract										
Chemical	out.										
Bacterial											
Unit Process Control											
G/D for System Balance		(.50)							.50		
Chemical Dose Levels		(.50)							.50		
Building & Grounds		(.75)				.75					
Custodial Inside		(1.25)								1.25	
Custodial Outside		(1.50)								1.50	
Mowing		(.75)								.75	
Hauling		(.25)								.25	
Clean Sludge Basin		(1.00)								1.00	
Painting		(.25)								.25	
Other											

CITY San Jose	
STATE	
FORM NO.	PAGE NO. TP.1
FORM Treatment Plant	
DATE	INTERVIEWER

JOB, POSITION OR OTHER SOURCE	OUTSIDE SOURCES	OTHER CITY DEPT.	TOTAL ALL CLASSES POSITIONS	Senior [illegible] Sanitary [illegible]	[illegible]	[illegible] Engineer	Treatment Plant Operator	[illegible] Operator	Production Operator	Labor	
BUDGETED NUMBER OF JOBS				25	47	14	2	5	7	38	
ACTUAL NUMBER OF INCUMBENTS				25	47	14	2	5	7	38	
JOB NUMBER				2	4	9	11	12	13	15	
ESTIMATION BASIS											
OCCUPATION CODE											
STAFFING CODE											
Supervision & Administration											
Direct Supervision of Others		(2.50)				1.00			1.00		
Technical Assistance		(3.25)		2.75					.50		
Chemical Additions											
Unload, Store & Handle		(2.50)								2.50	
Physical Mixing											
Control Adjustment		(.20)							.20		
Visual Check		(.50)							.50		
Minor P. M.											
Major P. M.											
Other											
Settling Basin-Visual Check		(1.00)					.50		.50		
Settling Test		(.25)							.25		
Minor P. M.		(.15)							.15		
Minor C. M.											
Other											
Filters - Visual Check		(1.00)					.50		.50		
Backwashing		(.10)							.10		
Scheduling Filt. & B.W.		(.25)							.25		
Flow Adjustment - Manual											
Flow Adjustment - Auto.											

CITY	
STATE	
FORM NO.	PAGE NO. TP.2
FORM Treatment Plant	
DATE	INTERVIEWER

Job, Position or Other Source	Outside Sources	Other City Dept.	Total All Positions	[illegible]	[illegible]	[illegible]	Treatment Plant Operator	Pump Operator	Production Operator	Helper	
Budgeted Number of Jobs				25	47	14	2	5	7	38	
Actual Number of Incumbents				25	47	14	2	5	7	38	
Job Number				3	4	9	11	12	13	15	
Estimation Basis											
Occupation Code											
Staffing Code											
Filters (Cont.)											
Minor P. M.											
Minor C. M.											
Major Maint.											
Other											
Motor - Visual Check		(1.00)					.50	.50			
Minor P.M. & C.M.		(.25)						.25			
Major Repair		(.25)						.25			
Other											
Pumps - Visual Check		(1.00)					.25	.75			
Minor P.M. & C.M.		(.25)						.25			
Repacking		(.50)						.50			
Other		(.25)						.25			
Compressor, Airline, Tanks, Val.		(.45)					.25		.20		
Visual Check		(.10)							.10		
Bleeding		(.30)							.30		
Minor P.M. & C.M.											
Replace Lines											
Major Maint.											

CITY	
STATE	
FORM NO.	PAGE NO. TP.4
FORM Treatment Plant	
DATE	INTERVIEWER

JOB, POSITION OR OTHER SOURCE	OUTSIDE SOURCES	OTHER CITY DEPT.	TOTAL ALL INSIDE POSITIONS	[illegible]	[illegible]	Plant Supervisor	Treatment Plant Operator	Pump Operator	Maintenance Operator	Laborer	
BUDGETED NUMBER OF JOBS				25	47	14	2	5	7	38	
ACTUAL NUMBER OF INCUMBENTS				25	47	14	2	5	7	38	
JOB NUMBER				3	4	9	11	12	13	15	
ESTIMATION BASIS											
OCCUPATION CODE											
STAFFING CODE											
Clerical & Secretarial		(2.50)			2.50						
Employee Upgrade											

75

CITY	
STATE	
FORM NO.	PAGE NO. S.1
FORM Storage	
DATE	INTERVIEWER

JOB, POSITION OR OTHER SOURCE	OUTSIDE SOURCES	OTHER CITY DEPT.	TOTAL ALL INSIDE POSITIONS	[illegible]	[illegible]	[illegible] Operator	[illegible]				
BUDGETED NUMBER OF JOBS				25	14	5	38				
ACTUAL NUMBER OF INCREMENTS				25	14	5	38				
JOB NUMBER				3	9	12	15				
ESTIMATION BASIS											
OCCUPATION CODE											
STAFFING CODE											
Supervision & Administration											
Direct Supervision of Others		(.75)			.75						
Technical Assistance		(.75)		.50	.25						
Storage Facility Inspection		(.50)			.50						
Applied Treatment											
Chemical Add.											
Sampling											
Pumps & Valves Visual Check		(.75)				.75					
Minor P. M.		(.25)				.25					
Minor C. M.		(1.00)				.25	.75				
Repair											
Unit & Ground Work											
Mowing		(1.50)					1.50				
Painting		(2.00)					2.00				
Mech. Mtc.		(2.25)					2.25				
Employee Upgrade											

CITY San Jose	
STATE CA	
FORM NO.	PAGE NO. D.1
FORM Distribution	
DATE	INTERVIEWER

(45.75)
48.75

Job, Position or Other Source	Outside Sources	Other City Dept.	Total All Existing Positions	Engineering ...	Group Serviceman	Water Service Dispatcher	Utility Mtc. Mechanic	Pump Operator	Service Crew	Laborer	Clerical Services
Budgeted Number of Jobs				25	14	25	7	5	4	38	47
Actual Number of Incumbents				25	14	25	7	5	4	38	47
Job Number				3	9	6	10	12	14	15	4
Estimation Basis											
Occupation Code											
Staffing Code											
Supervision & Administration											
Direct Supervision of Others		(4.50)			4.50						
Technical Assistance		(.75)		.50	.25						
Pumps & Valves											
Visual Check		(.75)						.75			
Minor P. M.		(.15)						.15			
Minor C. M.		(.05)						.05			
Major Mtc.		(.05)						.05			
Lines											
Inspection		(2.00)			2.00						
P. M.		(7.50)								7.50	
Installation		(10.50)			1.00				4.00	5.50	
Customer Hookup		(7.50)			1.00	2.50				4.00	
Emergency Repair		(3.00)			1.00					2.00	
Meter Installation											
Calibration		(4.00)					2.00			2.00	
Internal Auto. Mtc.		(3.00)					3.00				
Internal Equip. Mtc.		(2.00)					2.00				
Service Dispatching		(3.00)									(3.00)
Employee Upgrade											

APPENDIX II

DATA SUMMARY

	Town	Source	Total Employees	Operators	Taps	Length Distribution Lines	MGD	Population
1	Dallas	La	1027.90	12.5	221794	3500.0	250.00	878000
2	Denver	La	797.50	32.0	206892	1750.0	175.00	766000
3	Memphis	Dw	481.20	6.0	180000	2000.0	100.00	623530
4	San Jose	Bt	235.00	9.0	167000	1900.0	110.00	600000
5	Annandale	St	285.00	--	101695	1200.0	48.82	530000
6	Omaha	St	367.70	19.0	111151	1425.0	73.00	380000
7	Richmond	St	199.00	11.0	65000	1012.5	45.00	275000
8	Lynnbrook	Dw	135.00	10.0	70287	695.0	26.36	260100
9	Montgomery	Bt	123.00	10.0	48000	690.0	21.00	170000
10	Concord	St	138.50	5.5	36000	509.0	20.00	135000
11	Roanoke	Bt	96.60	13.0	34000	505.0	23.00	125000
12	Arlington	St	59.10	--	33000	420.0	24.40	100000
13	Salem	Sw	56.40	2.0	21248	342.0	16.50	90000
14	Lawton	La	54.85	9.0	24000	300.0	13.00	87960
15	Vancouver	Dw	33.75	2.0	27671	340.0	--	80000
16	Norman	Bt	45.50	9.0	14100	--	18.60	55000
17	Danville	St	53.80	8.0	15838	232.0	8.50	53000
18	Bowling Green	St	51.10	3.0	11000	51.1	7.00	45000
19	Rome	St	49.00	7.0	15000	--	14.00	40000
20	Murfreesboro	Bt	30.30	5.0	10322	--	5.10	35427
21	Orangeburg	St	29.60	6.0	10249	--	4.10	34745
22	Merced	Sw	11.00	--	8998	122.0	8.66	31500

	Town	Source	Total Employees	Operators	Taps	Length Distribution Lines	MGD	Population
23	Olympia	Sp	30.00	2.0	11000	--	6.00	28000
24	Ponca City	Bt	34.30	7.0	9695	150.0	7.50	26525
25	Hendersonville	St	23.00	3.0	7400	85.0	4.80	24000
26	Edmond	Dw	14.50	4.0	6020	125.0	6.00	23200
27	Martinsville	La	21.10	5.0	7654	--	4.00	22500
28	Altus	Bt	25.30	6.8	5695	120.0	3.70	22403
29	Americus	Sw	14.70	7.0	5000	--	1.84	17500
30	Glassen	St	18.70	3.0	5000	50.0	--	16000
31	Campbellsville	La	13.95	4.0	3711	100.0	2.00	15250
32	Manassas	La	17.90	--	3500	--	1.60	13500
33	Newman	La	16.20	4.5	4175	--	3.50	11205
34	Somerset	La	14.60	3.0	1400	80.0	1.90	10346
35	Hada/Coyall	St	11.15	1.0	3554	--	.70	10000
36	Conway	Dw	7.30	--	3438	--	1.20	8750
37	Clinton	Bt	13.20	4.0	3360	--	1.60	8663
38	Franklin	St	9.50	2.0	3188	--	1.40	8200
39	Weatherford	Dw	13.50	3.0	2479	85.0	1.30	8050
40	Cynthiana	St	9.30	--	3000	35.0	1.10	8000
41	Rogersville	Sp	7.60	2.0	2485	6.5	0.65	6100
42	Purcell	Sw	4.62	2.0	1725	--	2.00	5425
43	Hobart	La	8.65	2.5	--	26.0	1.00	4867
44	Cordell	Dw	7.41	1.0	--	--	--	3182

	Town	Source	Total Employees	Operators	Taps	Length Distribution Lines	MGD	Population
45	Buchanan	La	2.80	1.6	--	--	0.2000	2000
46	Walton	La	3.25	1.0	530	20.0	0.2006	1800
47	Watkinsville	Bt	3.60	1.0	416	15.0	0.1500	1000
48	Bronwood	Dw	1.35	1.0	250	--	0.1050	500

APPENDIX III

PROJECT ADVISORY COMMITTEE

PROJECT ADVISORY COMMITTEE

Mr. Samuel S. Baxter
Consulting Engineer
Former President, AWWA and
Director of Philadelphia
Water Department
Philadelphia, Pennsylvania

Mr. James P. Dawson
Executive Vice-President
Oklahoma Foundation for Research
and Development Utilization, Inc.
Oklahoma City, Oklahoma

Dr. Richard N. DeVries
Associate Professor of Civil
Engineering
Oklahoma State University
Stillwater, Oklahoma

Mr. Morton S. Ettlestein
Chief, Manpower Development
Environmental Protection Agency
Washington, D.C.

Mr. Henry J. Graeser, Jr.
Superintendent of Water Works
City of Dallas
Dallas, Texas

Dr. Edgar A. Jeffrey
Water Supply Division
Environmental Protection Agency
Washington, D.C.

Mr. Leo Louis
President
Gary-Hobart Water Company
Former President, AWWA
Gary, Indiana

Mr. John (Jack) McCarthy
Office of Education
Division of Manpower Development
and Training
Washington, D.C.

Mr. Walter Peters
Director of Education
American Water Works
Association
Denver, Colorado

Dr. George W. Reid
Professor of Civil Engineering
and Environmental Science
The University of Oklahoma
Norman, Oklahoma

Dr. Meredith Thompson
Commissioner
Division of Sanitary
Engineering
New York State Health
Department
Albany, New York

Alternates

Mr. D. D. Heffelfinger
Chief Engineer and Secretary
Mahoning Valley Sanitary
District
Youngstown, Ohio

Mr. Kenneth J. Miller
Assistant to Manager,
Environmental and Quality
Control
Denver Water Department
Denver, Colorado

APPENDIX IV

STATISTICAL SUMMARY

IV - a) Total Employees vs. Taps, All Sources

$$N = 45$$

$$\Sigma X = 180.7907$$

$$\Sigma X^2 = 748.4620$$

$$\Sigma Y = 68.5303$$

$$\Sigma XY = 295.1851$$

$$\Sigma(Y_{est} - \bar{Y})^2 = 17.8264$$

$$\Sigma(Y_{act} - \bar{Y})^2 = 18.0209$$

$$r^2 = 0.9892$$

$$r = 0.9946$$

$$Y_1 = 8.2462 \times 10^{-3} X_1^{0.8977}$$

IV - b) Total Employees vs. Population, All Sources

$$N = 48$$

$$\Sigma X = 214.8384$$

$$\Sigma X^2 = 989.5672$$

$$\Sigma Y = 70.7866$$

$$\Sigma XY = 339.7751$$

$$\Sigma(Y_{est} - \bar{Y})^2 = 18.8137$$

$$\Sigma(Y_{act} - \bar{Y})^2 = 19.8341$$

$$r^2 = 0.9486$$

$$r = 0.9739$$

$$Y_1 = 6.3910 \times 10^{-3} X_2^{0.8198}$$

IV - c) Total Employees vs. MGD, All Sources

$$N = 45$$

$$\Sigma X = 32.6761$$

$$\Sigma X^2 = 52.7670$$

$$\Sigma Y = 67.1149$$

$$\Sigma XY = 71.5222$$

$$\Sigma(Y_{est} - \bar{Y})^2 = 17.8775$$

$$\Sigma(Y_{act} - \bar{Y})^2 = 19.4136$$

$$r^2 = 0.9209$$

$$r = 0.9596$$

$$Y_1 = 8.3491X_3^{0.7847}$$

IV - d) Total Employees vs. Taps, Surface Sources

$$N = 23$$

$$\Sigma X = 93.9987$$

$$\Sigma X^2 = 394.8337$$

$$\Sigma Y = 37.7214$$

$$\Sigma XY = 163.9367$$

$$\Sigma(Y_{est} - \bar{Y})^2 = 8.9514$$

$$\Sigma(Y_{act} - \bar{Y})^2 = 9.3844$$

$$r^2 = 0.9539$$

$$r = 0.9767$$

$$Y_1 = 7.8860 \times 10^{-3} X_1^{0.9159}$$

IV - e) Total Employees vs. Taps, Well Sources

$$N = 13$$

$$\Sigma X = 50.3062$$

$$\Sigma X^2 = 201.2849$$

$$\Sigma Y = 16.6087$$

$$\Sigma XY = 69.9272$$

$$\Sigma(Y_{est} - \bar{Y})^2 = 4.8369$$

$$\Sigma(Y_{act} - \bar{Y})^2 = 5.1518$$

$$r^2 = 0.9389$$

$$r = 0.9689$$

$$Y_1 = 9.3000 \times 10^{-3} X_1^{0.8551}$$

IV - f) Total Employees vs. Taps, Combination Systems

$$N = 9$$

$$\Sigma X = 36.4858$$

$$\Sigma X^2 = 152.3416$$

$$\Sigma Y = 14.2007$$

$$\Sigma XY = 60.7856$$

$$\Sigma(Y_{est} - \bar{Y})^2 = 2.3357$$

$$\Sigma(Y_{act} - \bar{Y})^2 = 2.3579$$

$$r^2 = 0.9906$$

$$r = 0.9953$$

$$Y_1 = 4.3043 \times 10^{-2} X_1^{0.7262}$$

IV - g) Operators vs. Taps, All Sources

$$N = 39$$

$$\Sigma X = 156.7533$$

$$\Sigma X^2 = 650.1790$$

$$\Sigma Y = 24.9714$$

$$\Sigma XY = 108.5429$$

$$\Sigma(Y_{est} - \bar{Y})^2 = 3.3186$$

$$\Sigma(Y_{act} - \bar{Y})^2 = 5.1319$$

$$r^2 = 0.6467$$

$$r = 0.8042$$

$$Y_2 = 1.0202 \times 10^{-1} X_1^{0.4059}$$

IV - h) Operators vs. Taps, Surface Sources

$$N = 19$$

$$\Sigma X = 77.4130$$

$$\Sigma X^2 = 324.3048$$

$$\Sigma Y = 13.3070$$

$$\Sigma XY = 58.6003$$

$$\Sigma(Y_{est} - \bar{Y})^2 = 2.1772$$

$$\Sigma(Y_{act} - \bar{Y})^2 = 3.4684$$

$$r^2 = 0.6277$$

$$r = 0.7923$$

$$Y_2 = 4.9320 \times 10^{-2} X_1^{0.4927}$$

IV - i) Operators vs. Taps, Well Sources

$$N = 11$$

$$\Sigma X = 42.8158$$

$$\Sigma X^2 = 173.1445$$

$$\Sigma Y = 4.6634$$

$$\Sigma XY = 19.7974$$

$$\Sigma(Y_{est} - \bar{Y})^2 = 0.4258$$

$$\Sigma(Y_{act} - \bar{Y})^2 = 0.7622$$

$$r^2 = 0.5586$$

$$r = 0.7474$$

$$Y_2 = 2.7351 \times 10^{-1} X_1^{0.2536}$$

IV - j) Operators vs. Taps, Combination Systems

$$N = 9$$

$$\Sigma X = 36.4858$$

$$\Sigma X^2 = 152.3416$$

$$\Sigma Y = 30.0958$$

$$\Sigma XY = 7.0010$$

$$\Sigma(Y_{est} - \bar{Y})^2 = 0.6633$$

$$\Sigma(Y_{act} - \bar{Y})^2 = 0.8742$$

$$r^2 = 0.7588$$

$$r = 0.8711$$

$$Y_2 = 1.6185 \times 10^{-1} X_1^{0.3870}$$