COMPUTER SIMULATION OF TRICKLING FILTER PLANT OPERATION

by

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ABSTRACT

The extensive review of the literature on the trickling filter process revealed that four basic approaches had been adopted in the performance evaluation of this particular wastewater treatment process, namely the graphical, first order reaction, statistical, and mechanistic approaches. Of these four techniques, the statistical regression approach proposed by Galler and Gotaas in 1964 has received much attention within the last years, and treatment plant performance evaluation using such concepts is obviously justified.

The high rate trickling filter plant of Alexandria, Virginia, U.S.A., consisting of primary settlers, followed by a parallel arrangement of three trickling filter units, and secondary settlers was adopted for computer performance simulation. Seven years of field data, constituting a total of eighty-four monthly average observations formed the basis for the performance evaluation of this high rate trickling filter plant.

Linear and non linear regression algorithms were evaluated so as to best describe both the physical and biological performance of the treatment facility. The multiple linear regression technique was finally adopted because the response of the intrinsically linear models was as representative as that obtained through non linear regression techniques. Simulation of all major treatment units within the treatment plant was performed, evaluating both BOD and suspended solids removal efficiencies.

Two subsystem arrangements were examined: a first subsystem was analysed taking into consideration the trickling filter and final settling tank as a single treatment unit, while a second subsystem arrangement was examined by considering the trickling filter and final settling tank as two distinct treatment units.

A total of eight mathematical expressions resulted from the present investigation. High multiple correlation coefficients (R) were achieved, ranging from 0.9184 to 0.9779, thus giving an indication of the goodness of fit of the field data.

The arrangement in series of the mathematical expressions developed, subjected to a convergence criterion in the recirculation of the trickling filter effluent, essentially describes the performance of the wastewater treatment plant. A computer program written in Fortran IV, and referred to as CSTF, performs the required mathematical manipulations for computer performance evaluation.

A sensitivity analysis of the sewage characteristics of the wastewater treatment plant as a whole, and of the treatment units individually is also presented. The simulation program is supplied with an input matrix describing maximum, minimum, and average expected values for primary influent BOD, suspended solids, flow, recirculation, and sewage temperature. Changes in the performance of the treatment plant while subjected to input parameter variations are also reported and analysed. In addition, the input matrix also takes into consideration weather flow variations, such as dry and wet weather flow conditions. Of the input conditions examined, variations in the suspended solids concentration and in the weather flow conditions, affected most significantly the BOD and suspended solids concentration of the plant effluent.

A sludge production sensitivity analysis was also performed. The analysis indicated that secondary sludge production accounted for 10 to 15% of the total sludge to be disposed, while primary sludge made up the remaining 85 to 90%. Variations in the suspended solids concentrations, in the rates of flow and in the weather flow conditions, produced the greatest variations in the total sludge production of the treatment plant.

The performance of the Alexandria sewage treatment plant was also compared with other mathematical models. The mathematical formulations of Eckenfelder and Galler and Gotaas were however observed to disagree in some instances with predicted plant performance, but could still be considered as the most representative models from the ones analysed.

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A_p	specific surface area of filter media in ft^2/ft^3
a	coefficient equal to 0.079 in the model of Schulze
a_0	temperature conversion model coefficient equal to 41.96217
a_1	temperature conversion model coefficient equal to 0.18005
a_2	temperature conversion model coefficient equal to 0.26993
α	probability of making a Type I error while testing statistical hypothesis
ASA	Alexandria Sanitation Authority
b	$= 1.035^{(T_c-20)}$
b_i's	approximations of the true value of B_i's for i=0, $..n^*$
b_o^*	coefficient equal to ln B_o
B_i's	general coefficients for 1=0, $....n^*$
β	probability of making a Type II error in the testing of statistical hypotheses
BMD	computer package developed at the University of California at Los Angeles
BOD	Biochemical Oxygen Demand
c	parameter defined by the series $1 + (1-f) + (1-f)^2 +...$
c^*	coefficient in Eckenfelder's model equal to 2.5
C_{D-X}	unitless parameter function of the coefficient of biosorption
C_{O2}	oxygen concentration
d	coefficient equal to 0.67 in the model of Schulze
D	depth of filter media in feet
D_L	oxygen diffusivity through the film thickness

ΔL_r	removable BOD actually removed, in pounds per unit area
E_1	fractional efficiency of BOD removal for the first stage trickling filter system
E_2	fraction efficiency of BOD removal for the second stage trickling filter system
e_i	residual
e_i^*	transformation of the residual equal to ln e_i
f	coefficient of biosorption
F	factor reflecting increased BOD removal due to recirculation $F = (1+r_1)/(1+r_1/10)^2$
h	aerobic film thickness in centimeters
HR	hydraulic rate of flow for the ASA sewage treatment plant models in MGAD
k	Thériault's proportionality constant
K	Velz's rate of removal constant (base e)
K'	Velz's rate of removal constant (base 10)
K^*	Roesler and Smith rate constant equal to 0.69
K_E	Eckenfelder's modified rate constant
K_H	Howland's rate constant
K_r	unit oxygen utilization rate
K_{20}	experimentally established rate constant
L	organic BOD concentration
L'	removable BOD applied in pounds per day per unit area
L^*	total removable fraction of BOD in mg/l
L_D^*	removable BOD remaining at depth D of the filter media in mg/l
L_e	BOD of the filter system effluent in mg/l

L_{el}	BOD of the effluent from the trickling filter system in pounds per acre per day
L_o	BOD applied to the filter in mg/l
L_{ol}	BOD applied to the filter in pounds per acre per day
L_{pe}	BOD leaving the primary tank in pounds per day
L_{po}	BOD applied to the primary tank in pounds per day
L_{se}	BOD load leaving the secondary settling tank in pounds per day per 1000 cubic foot
L_{so}	BOD load entering the secondary settling tank in pounds per day
L_{te}	BOD load leaving the trickling filter unit in pounds per day per 1000 cubic foot
L_{to}	BOD load applied to the trickling filter unit in pounds per day per 1000 cubic foot
L_{sel}	BOD load leaving the secondary settling tank in pounds per day
m	coefficient in Eckenfelder's model equal to 0.33
m'	coefficient in the model of Roesler and Smith equal to 1.0
m_1	value appearing to reflect the kinetic properties of the waste entering a first stage trickling filter system
m_2	value appearing to reflect the kinetic properties of the waste entering the second stage of a trickling filter system
n	coefficient in Eckenfelder's model equal to 0.5
n'	coefficient in the model of Roesler and Smith equal to 0.67
n^*	number of observations used in the regression analysis
n_1	value equal to $m_1/(m_1-1)$
n_2	value equal to $m_2/(m_2-1)$

OR1	primary settling tank overflow rate in GPD/ft^2
OR2	secondary settling tank overflow rate in GPD/ft^2
p	number of parameters within a model
ϕ	sum of squares of the deviations
Q	hydraulic rate of flow in MGAD
r_1	ratio of recirculated flow to influent flow
r_2	second stage recirculation ratio
R	multiple correlation coefficient
R_*	ratio of the flow through the filter to the flow entering the treatment plant
R^2	coefficient of determination
R of R	Range of Residuals
s	standard error of the estimate
$s_{\bar{D}}$	standard error of the mean difference
$\tilde{s}_{\bar{D}}$	standard deviation of the mean difference
S	saturation capacity of a unit volume in pounds per unit volume
s^2	residual mean square
σ^2	standard deviation
SS_{po}	suspended solids load applied to the primary settling tank in pounds per day
SS_{pe}	suspended solids load leaving the primary settling tank in pounds per day
SS_{se}	suspended solids load leaving the secondary settling tank in pounds per day per thousand cubic foot
SS_{sel}	suspended solids load leaving the secondary settling tank in pounds per day
SS_{so}	suspended solids load applied to the secondary settling tank in pounds per day
SS_{te}	suspended solids load leaving the trickling filter unit in pounds per day per thousand cubic foot

SS_{to}	suspended solids load applied to the trickling filter unit in pounds per day per thousand cubic foot
t	time parameter
t_H	time of travel within the filter media in minutes
't'	t Test Parameter
T_c	sewage temperature in degree Centigrade
T_f	sewage temperature in degree Fahrenheit
T_{ai}	observed average monthly air temperature for month i
$Ta(i-1)$	observed average monthly air temperature for month i-1
T_{si}	predicted average monthly sewage temperature for month i
UND	Unit Normal Deviate
V	volume of filter media in acre-foot
W	BOD loading of settled raw sewage in pounds per day (exclusive of recirculation)
W'	BOD loading in pounds per day applied to a second stage trickling filter system
X	number of saturated unit depths
X_i	independent variable
Y_i	true value of the dependent variable
$\hat{Y}_i$	predicted value of the dependent variable

CHAPTER 1

INTRODUCTION

1.1 Historical Background of the Trickling Filter Process

Trickling filters, also referred to as biological filters and percolating filters, evolved from a nineteenth century England practice of treating domestic sewage. The process is different however from present practices; it consisted in passing settled sewage onto areas of land, using the soil as a media for biological activity (1).

Modifications to the above process led the Lawrence Experiment Station of the Massachussetts State Board of Health in 1888 to the concept of treating settled sewage by using a bed of porous media such as gravel, broken rock, clinker or slag. This form of treatment was soon very popular with municipal officials (1,2).

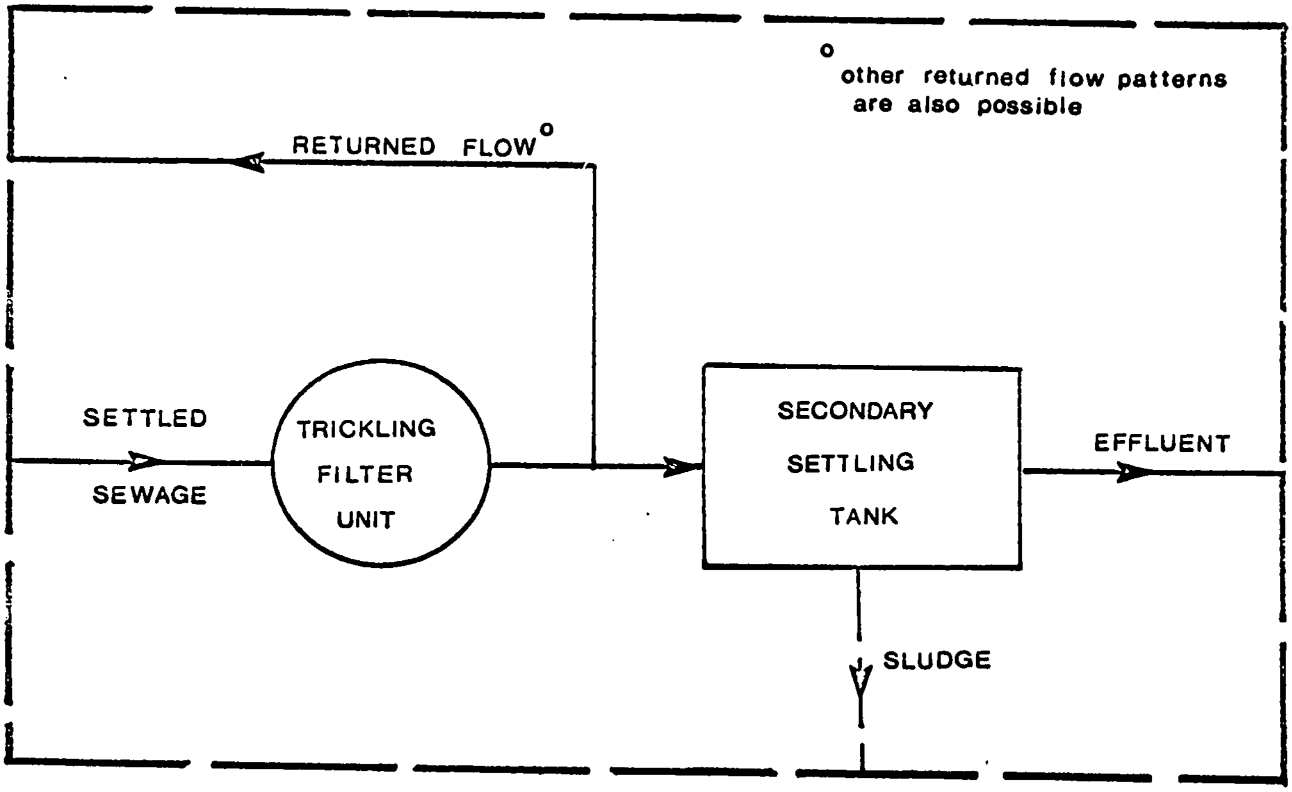
Although trickling filters, as they are known today originated in the United States, English engineers are reported to have developed many of the technical features of the process, such as: i) wastewater distribution by spray, and ii) the use of false bottom floors to support the media, thereby eliminating clogging of the filter floor (2).

In 1903, this form of treatment was used for the first time in the United States to treat sewage on a municipal level. Even if today the treatment of domestic sewage using trickling filter systems is less popular than the activated sludge process, the process itself still receives much attention from all levels, mainly because of some of the following advantages: i) ease of operation, ii) resistance to shock loads, iii) rapid recovery when disturbed, iv) ideal process for treating wastewaters that present a sludge bulking problem, and v) the introduction of plastic filter media, allowing the application of higher hydraulic and organic loads. Obviously the system does also present serious disadvantages, namely: i) high capital investments, ii) large land requirements, iii) odors and iv) filter fly breeding (Psychoda) (2).

1.2 The Trickling Filter Process - Physical and Biological

The trickling filter process usually consists of a trickling filter unit followed by a secondary settling tank, as illustrated schematically in Figure 1.1. The filter unit itself, usually circular but sometimes rectangular, consists of a bed of stone, slag, gravel, coke, or plastic media, varying in depth from three to ten feet (3). The stone or rock media accounts presently for over 75% of the municipal trickling filter installations in the United

FIGURE 1.1 TRICKLING FILTER SYSTEM



States (4). The grading of the stone media ranges commonly from one and a half to four inches. The available filter media (stone, plastic) provide a ratio of surface area per unit volume, ranging from fifteen to thirty square feet per cubic foot, with a void ratio close to 50% for the stone media, and 95% for the plastic media (1).

Trickling filters with plastic media are increasing in popularity because they tend to offer more flexibility, namely deeper bed depths, larger surface area per unit volume, and less chance of clogging due to increased aeration and void space. However, the effluent is generally of lower quality making it a roughing filter as opposed to a polishing filter (5).

The rate of flow onto a filter, commonly referred to as the hydraulic loading, and the amount of organic matter applied, defined as the organic loading,are commonly used for the classification of either standard or high rate trickling filter installations. Table 1.1 adopted from the Water Pollution Control Federation, Manual of Practice No. 8 (6) illustrates the basic differences between these two popular types of trickling filter systems.

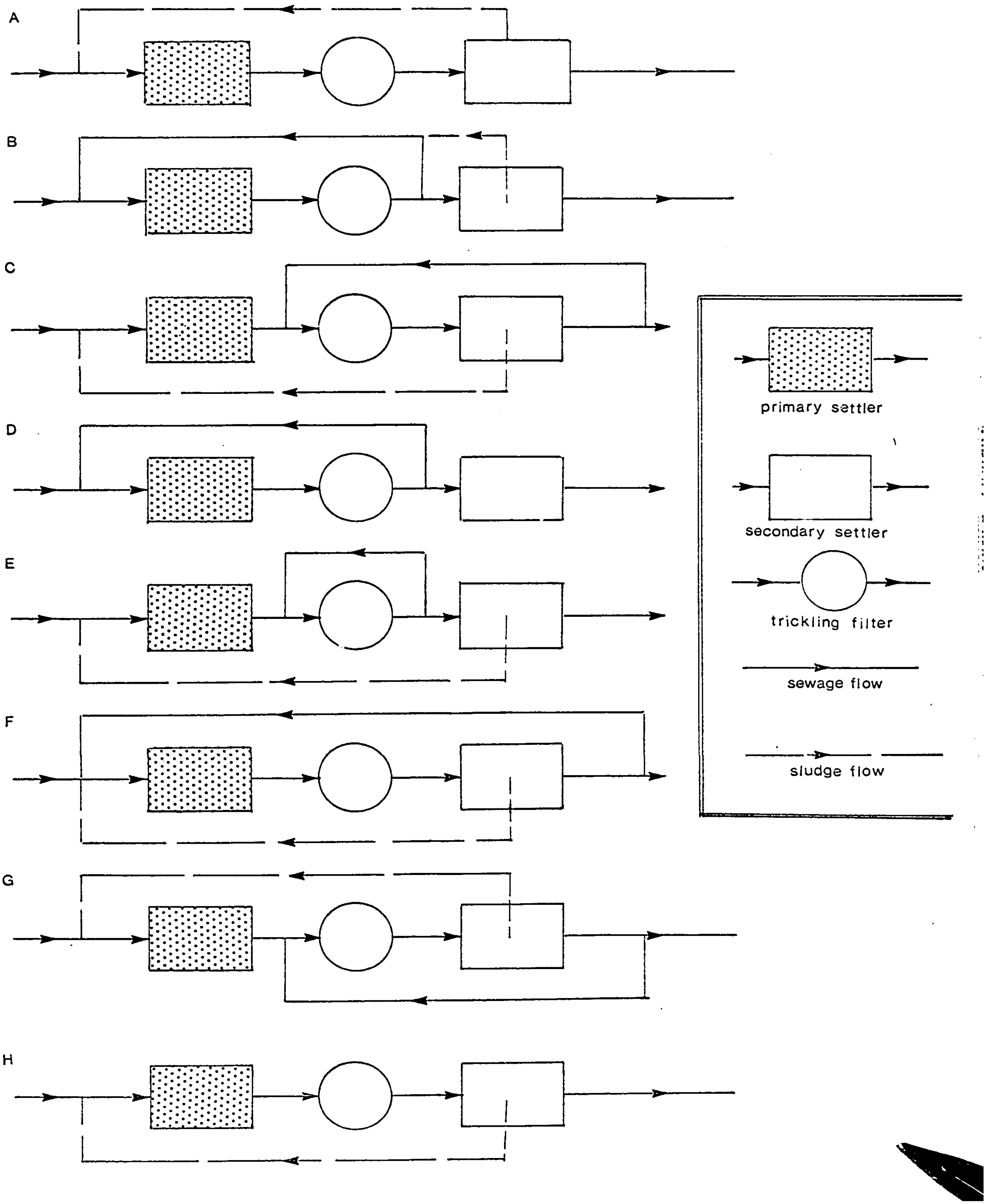
Figure 1.2 illustrates diagrammatically the most popular physical arrangements for single stage trickling filter systems. This illustrates both the flexibility of the process along with the inability of engineers to isolate the most effective installation. Similar flow pattern

TABLE 1.1

Trickling Filter Classification

Type of trickling Filter installation	Hydraulic Load	Organic Load
Standard Rate	1.1 to 4.4 MGAD or 25 to 100 GPD/ft^2	5 to 25 #/D/1000 ft^3 220 to 1100 #/D/acre ft
High Rate	8.7 to 44.0 MGAD 200 to 1000 GPD/ft^2	25 to 300 #/D/1000 ft^3 1100 to 13000 #/D/acre ft

FIGURE 1.2 SINGLE STAGE TRICKLING FILTER FLOW PATTERNS

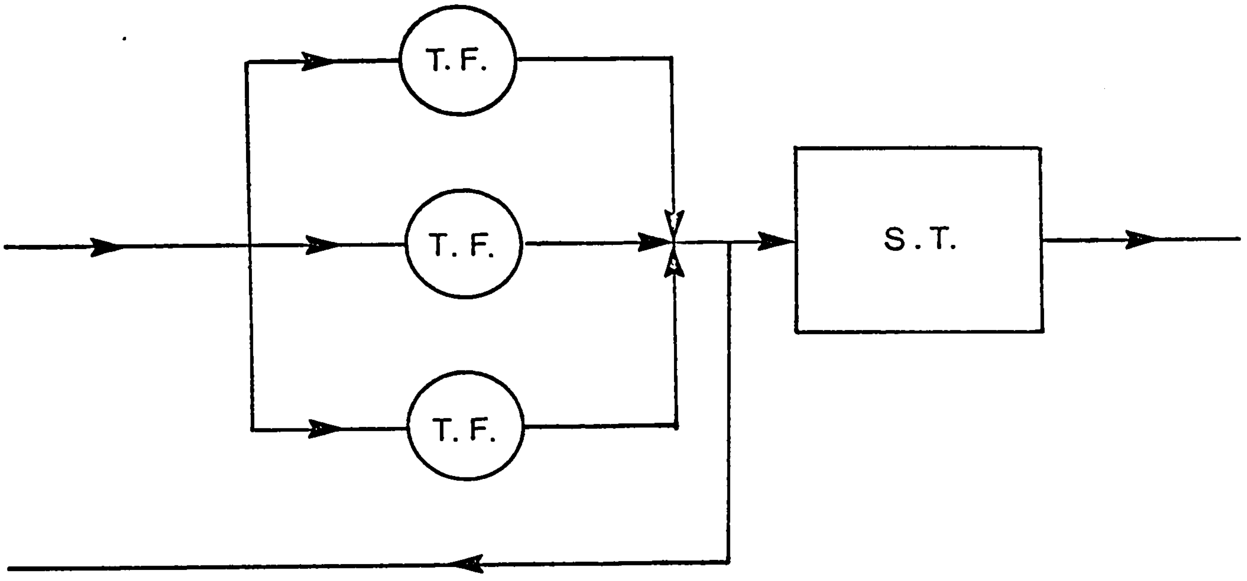


variations also apply to the two-stage biofiltration installations.

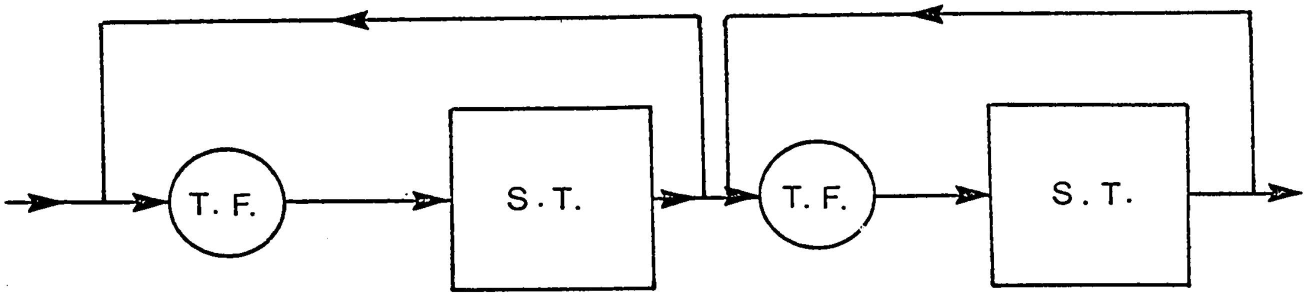
Two or more trickling filter units in parallel, followed by a secondary settler, are termed 'parallel single stage installations,' while two trickling filter systems in series are termed 'double or two-state trickling filter installations.' Typical arrangements are presented in Figure 1.3. Figure 1.4, illustrates a cutaway view of a stone media trickling filter unit, thus defining the physical components of the treatment unit.

The principles involved in the removal of organic matter through biological filtration are similar to those of the activated sludge. Both the trickling filter and the activated sludge systems depend on the bio-chemical oxidation of complex organic matter from the settled sewage (6). Thus in a trickling filter treatment unit, the settled sewage from the primary settling tank, is sprayed through the air onto the surface of the filter media after which it trickles or percolates through the voids undergoing biological oxidation while in contact with the aerobic portion of the slime or film layer attached to the filter media. Figure 1.5 illustrates the biological oxidation mechanism of the waste by the slime layer. The slime layer, depending on its thickness, usually consists of aerobic and anaerobic sublayers. The microorganisms in the aerobic sublayer use

FIGURE 1.3 PARALLEL AND TWO-STAGE TRICKLING FILTER INSTALLATIONS



a) Parallel trickling filter system



b) Two-stage trickling filter system

FIGURE 1.4 SECTION OF A TRICKLING FILTER UNIT

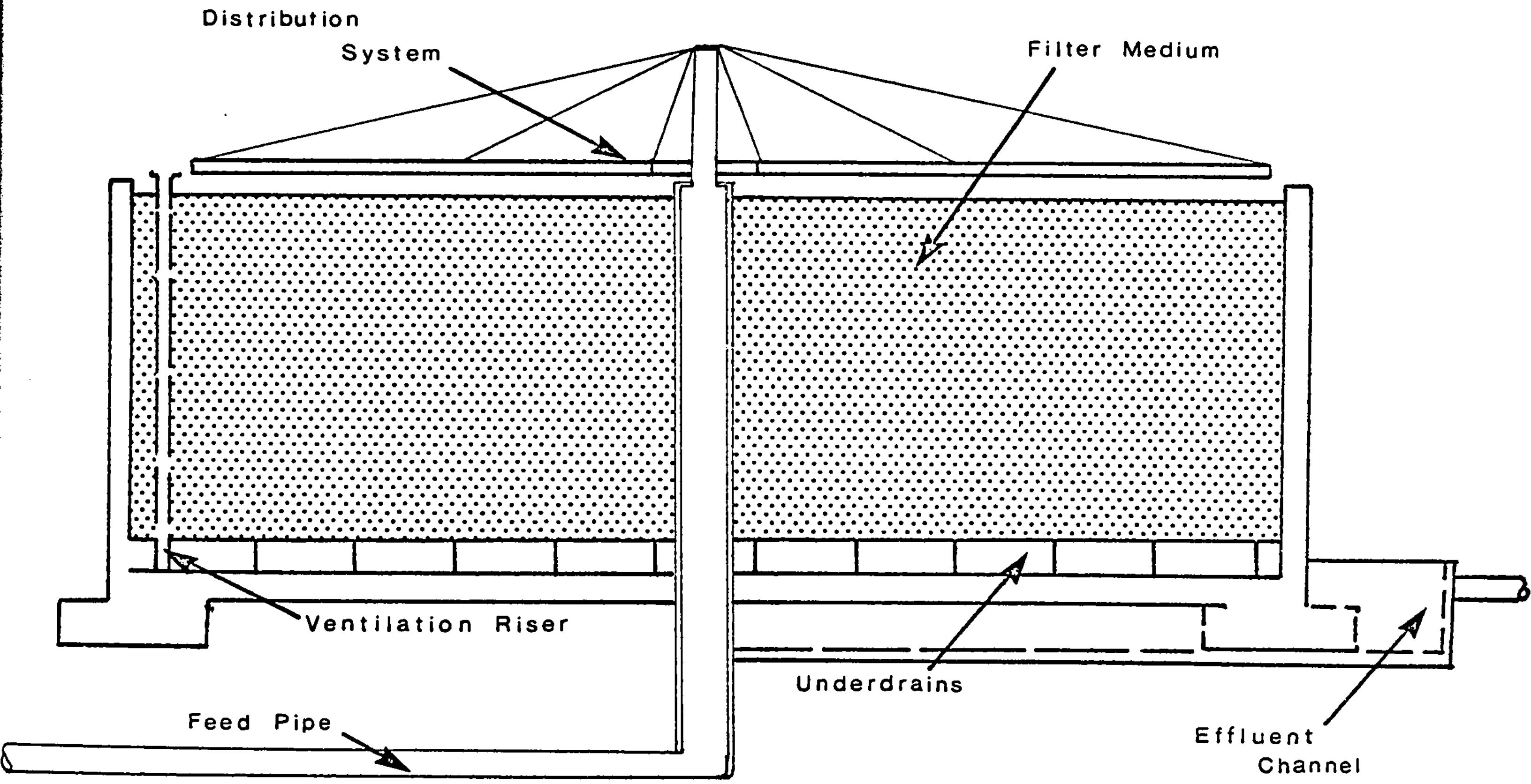
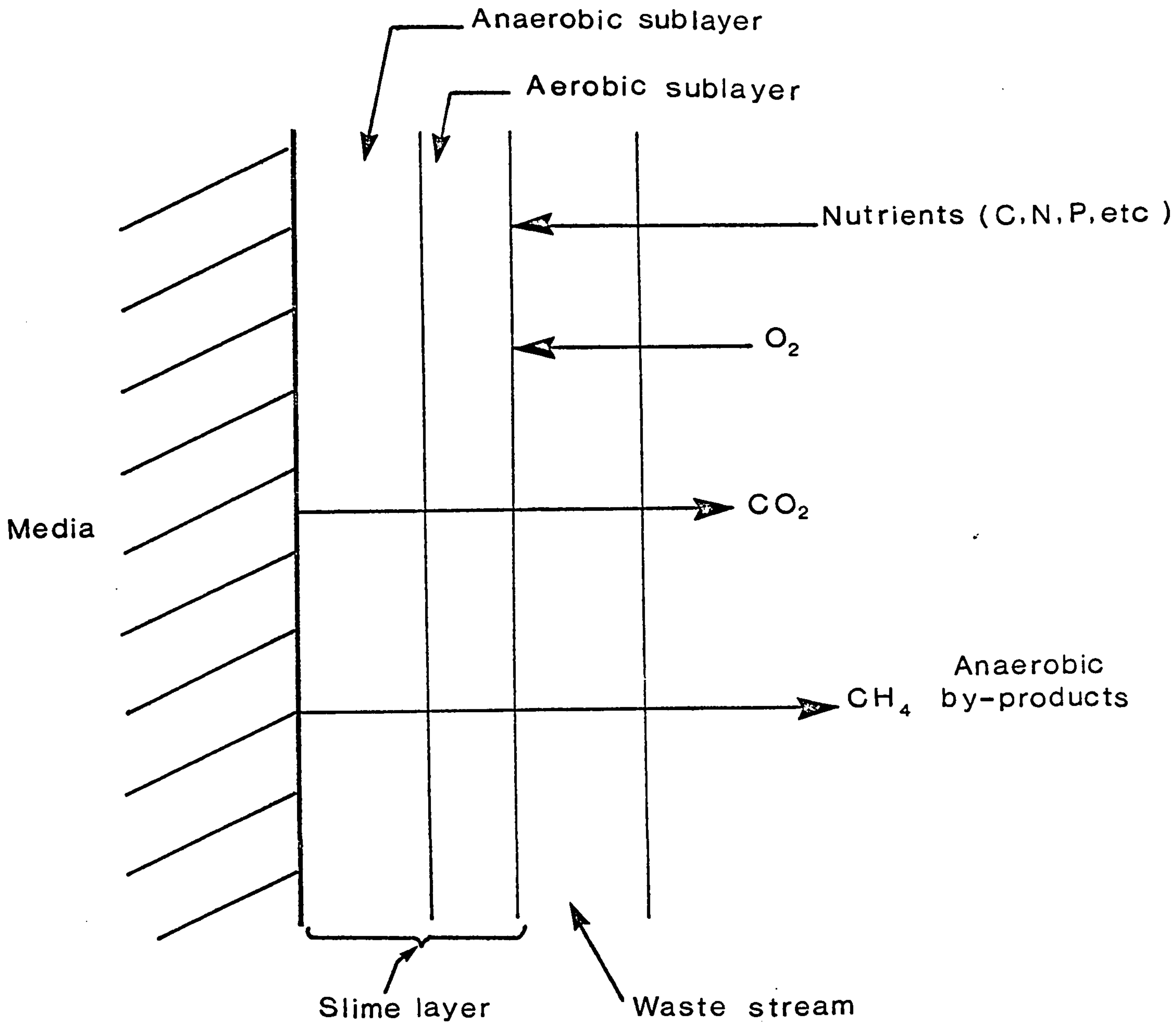


FIGURE 1.5 TRICKLING FILTER REMOVAL MECHANISM



the food (C,O_2, nutrients, etc.) for synthesis, while those in the anaerobic sublayer undergo endogenous respiration.

The microorganism population also varies with filter depth, reflecting the faculative character of the treatment unit. Predominant microorganisms are bacteria. Fungi, being aerobes, are observed only where oxygen is predominant. The surface of the filter can also support algae but the need for sunlight limits the extent of their growth to that section of the filter only. The protozoa are the predominant animal population, with the ciliata observed in all aerobic sections of the filter. Higher order animals such as worms, snails, insects, and larvae are also present, and feed upon the microorganism population. Not essential to the substrate removal mechanism, higher order animals play a more significant role in the sloughing mechanism or, what can be referred to as the rejuvenation of the filter bed (7,1).

Film or slime removal is also an integral part of the trickling filter removal process, in the sense that it rejuvenates the filter bed. Excessively thick film layers inhibit oxygen transfer, interfere with the passage of solid particles, and sometimes result in ponding of the filter bed. Various organisms, along with the high hydraulic loadings, accompanied by some endogenous activity within the anaerobic sublayer, contribute to the sloughing of the slime layer (7, 1). The sloughing may be intermittent as in the case of standard rate filters, or continuous as observed in high rate trickling filter installations.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

2.1.1 Design History

This section will serve to establish the historical trend followed in the design of single stage trickling filter systems. No attempt has been made at this stage to discuss in any great detail the implications and structure of the reported mathematical formulations.

Data collected during World War II, from several trickling filter wastewater treatment plants at various military installations, resulted in the formulation by the National Research Council (U.S.) of a single stage BOD removal equation, referred to as the 'NRC Formula' (Equation #1, Table 2.1)(8).

In a 1948 article, Velz (9) presented what is referred to as the basic law in the trickling filter design. Velz postulated that "the rate of extraction of organic matter per interval depth of a biological filter is proportional to the remaining concentration of organic matter, measured in terms of its removability." Velz's mathematical formulation appears as Equation #2 in Table 2.1.

Applying mass balance principles, and respecting the criterions set forth by the Upper Mississippi River

TABLE 2.1

Common Trickling Filter Design Formulations

#	Equation Name	Mathematical Formulation	Definition of terms
1	NRC	$E_1 = \frac{1}{1 + 0.0085\sqrt{\frac{W}{VF}}}$	E_1 = fractional efficiency of BOD removal for the first stage W = BOD loading in #/D, excluding recirculation V = volume of filter media in acre foot F = factor reflecting increased removal due to recirculation $F = (1 + r_1)/(1 + r_1/10)^2$ r_1 = ratio of recirculation flow to influent flow
2	Velz	$\frac{L_D^*}{L^*} = 10^{-K^1 D}$	L_D^* = removal BOD at depth D, in mg/l L_D^* = total removable fraction of BOD, in mg/l K^1 = rate of removal constant D = depth of filter in feet
3	Rankin	$E_1 = \frac{r_1 + 1}{r_1 + 1.5}$	E_1 = BOD removal efficiency of the first stage r_1 = first stage recirculation

Table 2.1 cont'd

#	Equation Name	Mathematical Formulation	Definition of terms
4	Howland	$\frac{L_e}{L_o} = e^{-K_H D/Q^{2/3}}$	L_e = BOD of filter effluent in mg/1 L_o = BOD applied to the filter in mg/1 K_H = rate constant of Howland D = depth of filter in feet Q = hydraulic rate of flow in MGAD
5	Schulze	$\frac{L_e}{L_o} = 10^{-bK_{20}D/Q^m}$	L_e = BOD of filter effluent in mg/1 L_o = BOD applied to the filter in mg/1 K_{20}= constant = 0.3 D = depth of filter in feet Q = hydraulic rate of flow in MGAD m = 0.67 b = $1.035^{(T_c-20)}$ T_c = sewage temperature in °C
6	Eckenfelder	$\frac{L_e}{L_o} = \frac{1}{1 + C\frac{D^{(1-m)}}{(Q)^n}}$ $L_o = \frac{L_i + r_1 L_e}{1 + r_1}$	L_i = influent BOD in mg/1 L_o = BOD applied to the filter mg/1 L_e = BOD of the effluent from the filter system r_1 = recirculation C = 2.5 D = depth of filter in feet Q = hydraulic rate of flow in MGAD $1-m$ = 0.67 n = 0.5

Table 2.1 cont'd

#	Equation Name	Mathematical Formulation	Definition of terms
7	Stack	$\Delta_{L_r} = XfS + f(L' - XfS)$ $\frac{(N+1)(C_{D-X})}{(1 + NC_{D-X})}$	Δ_{L_r} = removable BOD actually removed in pounds per unit area X = number of saturated unit depths f = coefficient of biosorption S = saturation capacity of a unit volume in pounds per unit volume
8	Stack	$\Delta_{L_r} = XfS + f(L'-XfS)\ (c)$	L' = removable BOD applied in pounds per unit area c = $1 + (1+f) + (1+f)^2 + ...$ C_{D-X} = unitless parameter, function of the coefficient of biosorption N = recirculation ratio
9	Galler and Gotaas	$L_{el} = 0.310L_{ol}^{1.189}\ (\frac{Q}{I})^{.278}$ $(D+1)^{-.669}T_c^{-.154}Q^{-.062}$	L_{el} = BOD leaving the filter system in pounds per day per acre L_{ol} = BOD applied to the filter in pounds per day per acre Q = hydraulic rate of flow in MGAD I = influence rate of flow in MGAD T_c = sewage temperature in degree Centigrade D = depth of filter in feet
10	Ten State Standards	Graphical Method see Figure 2.1	

Boards of State Engineers, Rankin in 1951 presented his formulation of the trickling filter BOD removal process, (Equation #3, Table 2.1).

Howland (11) in 1958 found that the removal of organic matter within a trickling filter unit was a function of the time of contact of the wastewaters with the slime layer attached to the filter media. By establishing mathematically the time of contact in a trickling filter unit, he postulated that the removal of organic matter could be described by Equation #4, Table 2.1.

Schulze (12) in 1960, and Eckenfelder (13) in 1961, following reasoning similar to the one used by Howland, presented their own version of the organic removal process (Equations #5 and #6, in Table 2.1).

Stack (15) has analysed and formulated mathematical models for trickling filter installations with and without recirculation (Equations #7 and #8, Table 2.1). The extent of this application has been mostly restricted to research, and is mainly of academic interest.

It was only in 1964, that a totally new approach was adopted. Galler and Gotaas (16) presented a design model based on the multiple linear regression of some 322 observations obtained from existing trickling filter installations, (Equation #9, Table 2.1). High regression coefficients, along with a wide range of operational data, has given much merit to the work of these researchers from Northwestern University.

The 1971 edition of the Ten State Standards, offers a graphical technique for the design of trickling filter systems discussed and presented in a later section of this chapter.

Therefore, several mathematical formulations are available to practicing engineers in sizing and evaluating organic removal efficiencies within a trickling filter installation.

2.1.2 Controllable Parameter

In contrast with the activated sludge process which is often considered to be a very sensitive and difficult system to operate, a trickling filter plant offers a rather more simple and straightforward operation. As part of the operations within an activated sludge plant the operator has to control the volume of air supplied to the aeration tank, sludge recirculation, and the portion of sludge to be wasted daily. Trickling filter plant operation however offers only the control of the recirculated flow from either the filter effluent, final settling tank effluent, or secondary settling tank sludge, depending on the configuration of the process as shown in Figure 1.2.

Recirculation rates are usually dictated by either: i) the degree of treatment required, ii) the size of the pumps, iii) the size of the settling tanks, iv) the capacity of the distribution system, and v) capital and operating cost (19). There exists, however, much controversy as to whether recirculation benefits or hinders the removal of organic matter as will be pointed out in Section 2.4.3 of this chapter.

2.2 Review of the Formulated Models

2.2.1 General

In attempting to survey the previously developed mathematical models for the removal of BOD within a trickling filter system, the following classification, based upon various approaches used in developing such formulations will be adopted:

i) Graphical or Curve Fitting Approach - Such an approach differs from others in the sense that it is not based on any theoretical derivations; in fact it relies solely on experiment and/or observations and attempts to represent graphically or through curve fitting of the removal of organic matter from a trickling filter system. Models such as the NRC formula, Rankin's, and the Ten State Standards were developed using such a concept.

ii) First Order Reaction Approach - Models developed while assuming that the substrate removal process can be represented by first-order reactions.

iii) Statistical Approach - This approach is rather unique and was presented for the first time in 1964. A general mathematical model generated on the basis of operational results, using multiple linear regression techniques, forms the basis of the technique.

iv) Mechanistic Approach - The mechanistic approach involves the study of the mechanism of substrate removal.

2.2.2 Graphical or Curve Fitting Approach

As reported in a previous section of this chapter the National Research Council (U.S.) developed in 1946, an empirical formulation for the trickling filter removal process, based upon data collected from 34 existing trickling filter plants among various military stations. The efficiency of a single stage plant was reported as:

$$E_1 = \frac{1}{1 + 0.0085\sqrt{\frac{W}{VF}}} \qquad (2.1)$$

where E_1 = fractional efficiency of BOD removal for the first stage.

W = BOD loading of settled raw sewage in pounds per day (excluding recirculation).

F = factor reflecting increased removal due to recirculation $F = (1+r_1)/(1+r_1/10)^2$.

r_1 = ratio of recirculated flow to influent flow.

V = volume of the filter media in acre-foot

and that for second stage could be described as:

$$E_2 = \frac{1}{1 + \frac{0.0085}{(1-E_1)}\sqrt{\frac{W'}{VF}}} \qquad (2.2)$$

where E_2 = fractional efficiency of BOD removal for the second stage.

W' = BOD loading applied to the second stage in pounds per day, exclusive of recirculation.

Equation (2.2), is a transformation of Equation (2.1) and takes into consideration the reduced treatability of the first stage effluent. Examining the components of such a formulation, one realizes immediately that the BOD removal efficiency is dependent upon recirculation and organic loading, while other parameters are kept constant for any specific installation. This therefore implies that significant variations in the hydraulic rate of flow, while organic loading remains constant, through corresponding variations in the BOD concentration, will not affect the removal of organic matter from the wastewaters. Moreover, both Equations (2.1) and (2.2), do not take into consideration the change in the activity of the biological organisms with corresponding wastewater temperature variations.

Rankin (10), formulated the BOD efficiency removal of a single stage trickling filter system as:

$$E_1 = \frac{r_1 + 1}{r_1 + n_1} \tag{2.3}$$

where E_1 = BOD removal efficiency of the first stage.

r_1 = first stage recirculation.

n_1 = $m_1/(m_1-1)$.

m_1 = value appearing to reflect the kinetic properties of the waste.

Subjected to constraints established by the Ten State Standards (17), Rankin assigned a value of 3 to parameter m_1. His reasoning based on a mass balance of the process assumes that the change in BOD between input and output equals the BOD depletion. The efficiency of the second stage was reported as:

$$E_2 = \frac{r_2 + 1}{r_2 + n_2} \tag{2.4}$$

where E_2 = BOD removal efficiency of the second stage.

r_2 = second stage recirculation.

n_2 = $m_2/(m_2-1)$.

m_2 = value appearing to reflect the kinetic properties of the waste entering the second stage.

Again constraints established by the Ten State Standards (17) led Rankin to assign a value of 2 to parameter m_2.

In 1953, Rankin (10) compared his equation with the formulations of Velz and that of the National Research Council (U.S.), using supporting data from existing treatment plants. Because single stage treatment plants are more of interest in the present investigation, only the results of such systems are reported herein. Eight plants formed the basis for the comparison. The actual efficiencies of these single stage treatment plants were reported to vary from 84% to 92%. The models studied presented the following standard deviation:

i) Rankin's Model: 2.53%

ii) NRC Formula : 3.03%

iii) Velz's Formula: 2.10% ,

revealing to some extent the accuracy with which each model was able to predict actual plant performance.

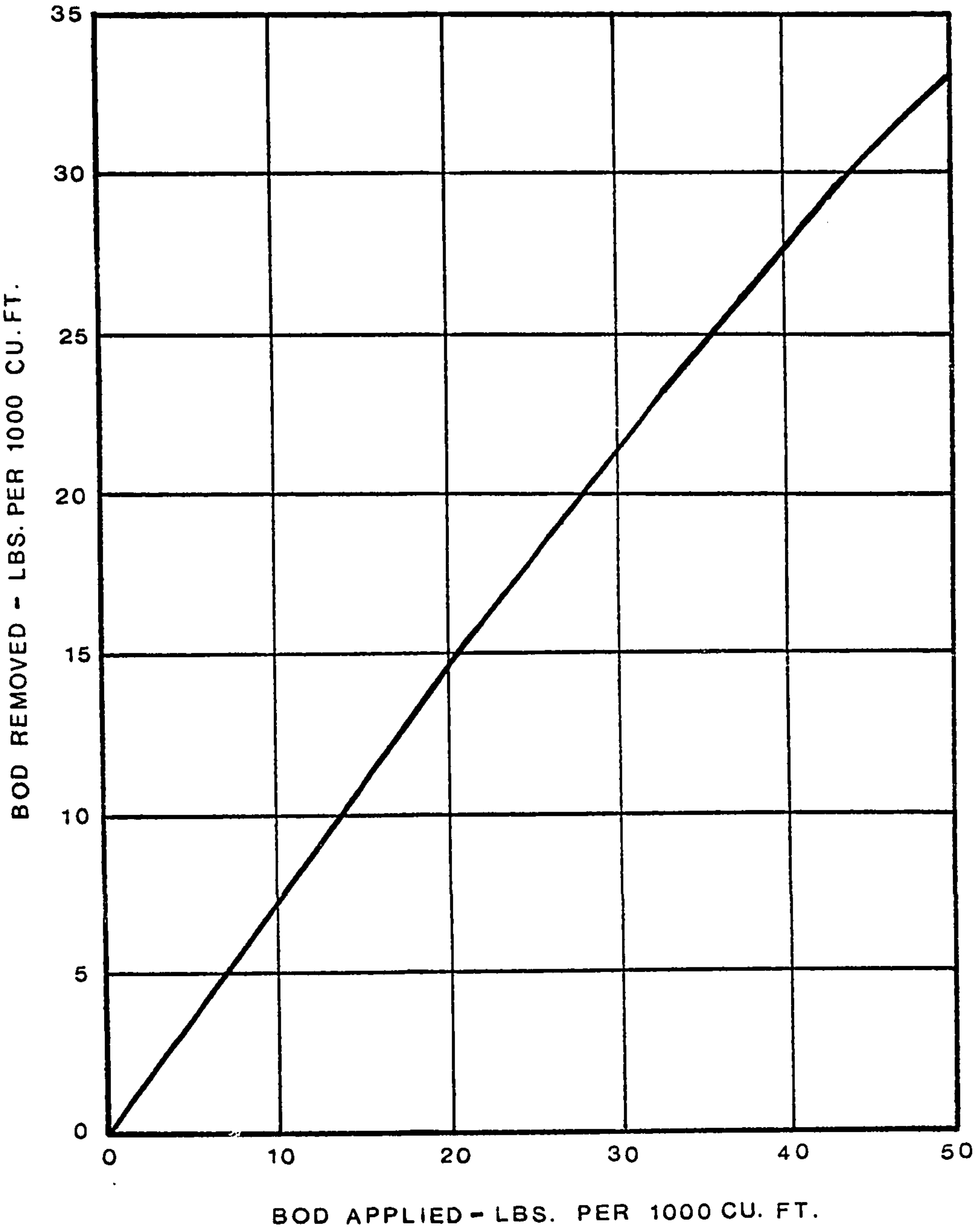
The 1971 edition of the Recommended Standards for Sewage Works (Great Lake-Upper Mississippi River Board of State Engineers) (17) dictates graphically BOD removal efficiency of the trickling filter system, as represented in Figure 2.1. However, the suggested BOD removal offers no consideration whatsoever to the contribution brought about through recirculation. In fact, design curves showing the effects of recirculation have not yet been developed.

Serving merely as a guide to practicing engineers, such a model is evidently an oversimplification of a very complex process. One immediate drawback of the proposed design method is the lack of consideration given to the effects of temperature, hydraulic loading and recirculation. Furthermore, the Ten State Standards design curve was derived using data from the northern regions of the United States, which furthermore limits the applicability of the model.

2.2.3 First Order Reaction Approach

Thériault (20) in 1926, assumed that the BOD exertion could be approximated through a first-order reaction

FIGURE 2.1 TEN STATE STANDARD DESIGN CURVE



formulation such as described by:

$$\frac{dL}{dt} = -kL \qquad (2.5)$$

where L = organic BOD concentration.

t = time.

k = proportionality constant.

A similar reasoning to that of bio-oxidation was applied by Velz (9) in 1948, in attempting to explain theoretically the removal of organic matter within a trickling filter system. In fact he reported that "the rate of extraction of organic matter per interval of depth of a biological bed is proportional to the remaining concentration of organic matter measured in terms of its removability." In deriving his mathematical model, Velz made the following assumptions:

i) The trickling filter is basically a self regenerating absorption tower.

ii) Removable BOD, is the fraction of BOD measured that can be removed by absorption.

iii) Each unit of depth of the filter will remove a constant fraction of the removable BOD applied to it.

iv) The quantity of BOD that can be absorbed by one unit volume of filter has a maximum limit.

Expressed mathematically:

$$\frac{dL^*}{dD} = -K\ L^* \qquad (2.6)$$

or

$$\frac{L_D^*}{L^*} = 10^{-K' D} \qquad (2.7)$$

where L_D^* = removable BOD at depth D in mg/l.

L^* = total removable fraction of BOD in mg/l.

D = depth in feet.

K = rate of removal constant.

K' = rate of removal constant equal to 0.175 for low rate filters or standard rate, and 0.150 for high rate filters.

Other values for K' have been reported elsewhere in the literature based upon a similar reasoning (21).

In 1957, Stack (22) presented a detailed analysis of the theoretical performance of the biological filtration process. Based on the assumptions of Velz, and on the concept of removable BOD Stack derived BOD removal equations for the cases of recirculated and non recirculated effluent.

Performance with no recirculation was described as:

$$\Delta_{L_r} = XfS + f(L'-XfS)(c) \qquad (2.8)$$

where Δ_{L_r} = removable BOD actually removed in pounds per unit area.

X = number of saturated unit depths.

f = coefficient of biosorption.

S = saturation capacity of a unit volume in pounds per unit volume.

L' = removable BOD applied in pounds per unit area.

$c = 1 + (1-f) + (1-f)^2 + \ldots.$

while performance with recirculation was expressed as:

$$\Delta_{L_r} = XfS + f(L'-XfS)\ \frac{(N+1)\ (C_{D-X})}{(1+N\ \ C_{(D-X)}} \qquad (2.9)$$

where N = recirculation ratio.

$C_{(D-X)}$ = unitless parameter function of the coefficient of biosorption.

Conscious of the effects of temperature on the removal of organic matter, Stack suggested it to be reflected into the value of the saturation capacity of a unit depth, referred to as S, and expressed in pounds per unit volume.

The major drawback of the models developed by Stack lies in the fact that BOD removals are expressed as functions of removable BOD, defined earlier, and therefore require the experimental evaluation of the removable BOD, along with the values of S and f appearing in Equations (2.8) and (2.9).

In 1958, Howland (11) postulated that the removal of organic matter from a biological filter bed was a function of the time of contact between the wastewater and the slime layer, or time of travel within the filter bed. It was then established that:

$$t_H = \frac{(1.035^{T_c-20})\ D}{Q^{0.67}} \qquad (2.10)$$

where t_H = time of travel in minutes.

T_c = temperature of the sewage in °C.

D = depth of filter in feet.

Q = hydraulic rate of flow in MGAD.

and BOD removal expressed as:

$$\frac{L_e}{L_o} = e^{-K_H D/Q^{.67}} \tag{2.11}$$

where L_o = BOD applied to the filter in mg/l.

L_e = BOD of the filter system effluent in mg/l.

K_H = rate constant.

Confronted with the fact that recirculation had improved removal efficiencies, Howland suggested three possible explanations to this phenomena: i) a dilution effect, ii) the continuing action of the freely floating film particles, and iii) increased time of contact of a portion of the flow. In summarizing the applicability of his theory to recirculation, the author pointed out that it raised more problems than it solved.

Schulze (12) in 1960, experimentally established a mathematical model for the removal of BOD in a trickling filter system using screen filters instead of the conventional filter media. The developed model was reported as:

$$\frac{L_e}{L_o} = a\ Q^d \tag{2.12}$$

where L_e = BOD in mg/l of the filter system effluent.
L_o = BOD in mg/l applied to the filter.
a = constant equal to 0.079 (experimentally).
d = constant equal to 0.67 (experimentally).
Q = hydraulic rate of flow in MGAD.

Schulze also established statistically that the BOD loading did not affect the BOD removal efficiency of the system. Investigating the effects of recirculation he postulated that "according to the theoretical data, recirculation does not improve the quality of the final effluent," and suggests that the increase in efficiency is attributable to secondary factors. In an attempt to relate BOD removal efficiency to such parameters as depth and temperature, Schulze suggested the following equation:

$$\frac{L_e}{L_o} = 10^{-bK_{20}D/Q^{.67}} \tag{2.13}$$

where L_e = BOD in mg/l, in the filter system effluent.
L_o = BOD in mg/l applied to the filter.
D = depth of the filter in feet.
Q = hydraulic rate of flow in MGAD.
b = 1.035^{T_c-20}.
K_{20} = experimentally established constant equal to 0.3.

This formulation is also corroborated by the work of other researchers (9,14,21).

Grantham (23), pointed out, however, that even though it appears that the BOD removal efficiency is unaffected by changes in the BOD loadings, nitrification of the filter effluent decreases with higher BOD loadings, thereby decreasing the overall BOD quality of the effluent.

In 1961, Eckenfelder (13), described the removal of organics within the trickling filter system using principles established by Velz and Howland. Combining the efforts of these people, Eckenfelder proposed the following equation:

$$\frac{L_e}{L_o} = e^{-K_E(1/D_m)(D/Q^n)} \qquad (2.14)$$

where L_e = BOD of the effluent from the filter system in mg/l.

L_o = BOD applied to the filter in mg/l.

K_E = modified rate constant.

D = depth of the filter in feet.

Q = hydraulic loading in MGAD.

The expression $1/D_m$ is related to the mean active filter film per unit volume throughout the filter depth. If the filter is uniform, the $1/D_m$ approaches 1.0 and Equation (2.14) becomes:

$$\frac{L_e}{L_o} = e^{-K_E D/Q^n} \qquad (2.15)$$

Eckenfelder also suggested that, in the case of complex organic wastes, the removal decreases with concentration, because readily degradable components are removed first. Equation (2.15) was thereby transformed so as to include a retardation effect brought about by such waste characteristics:

$$\frac{L_e}{L_o} = \frac{100}{1 + \frac{C^* D^{1-m}}{Q^n}} \qquad (2.16)$$

From the analysis of filter performance data, Eckenfelder determined the following values: $C^* = 2.5$; $(1-m) = 0.67$, and $n = 0.50$. Commenting on the effects of recirculation, Eckenfelder postulated that it provided only a dilution effect.

Because of the dependence of the process on sewage temperature variations, an equation relating to the thickness of the aerobic film layer (active film thickness) with sewage temperature was also developed by Eckenfelder:

$$h = \sqrt{\frac{D_L C_{O_2}}{K_r}} \qquad (2.17)$$

where h = aerobic film thickness in cm.

D_L = oxygen diffusivity through the film.

C_{O_2} = oxygen concentration.

$K_r = K_{20}(1.08)^{T_c - 20}$ = unit oxygen utilization rate.

T_c = sewage temperature in °C.

2.2.4 Statistical Approach

The only statistical approach, i.e. one based on multiple regression of existing trickling filter installations, was developed by Galler and Gotaas (3,16), in 1964, at Northwestern University. Their objectives were two-fold:
i) develop a mathematical model for the BOD removal process within a trickling filter system, in terms of physical parameters readily available, and based upon existing plant operation data, and ii) optimize the design of the trickling filter system so as to minimize cost while subjected to several specific constraints.

Following a basic mathematical model building procedure, Galler and Gotaas established relationships between variables by plotting assumed independent variables against the percent BOD removal. Investigating the use of multiple linear regression techniques, Galler (3) reported several mathematical formulations. After evaluating the models statistically, the following formulation was proposed as input into the second phase of the investigation:

$$L_{e1} = \frac{0.3099\ L_{o_1}^{1.18896}\ R_*^{0.27762}}{(D+1)^{0.66916} T_c^{0.15440}\ Q^{0.06170}} \qquad (2.18)$$

where L_{e_1} = BOD of the effluent from the filter system in pounds per acre per day.

L_{o_1} = BOD applied to the filter in pounds per acre per day.

R_* = $(1+r_1)$: ratio of the flow through the filter to the flow entering the plant.

T_c = sewage temperature in ^{o}C.

Q = flow through the filter in MGAD.

D = depth of the filter bed in feet.

The model reported yielded a multiple correlation coefficient (R) equal to 0.9743, with a standard error of the estimate (s) of 0.11964, and a range of residuals of 0.802. Galler further reported at this stage that the hydraulic rate of flow had only a 'chance' influence on the BOD removal process, as determined by a 5% α-level 't' test. However, the proposed mathematical formulation included the hydraulic rate of flow as one of its parameters on the basis that the range of residuals was least using such a formulation, i.e. 0.802 as opposed to 0.815.

The latter portion of Galler's investigation dealt with the optimization of trickling filter system. The optimization was subjected to the following set of constraints: i) biological, ii) radius, iii) depth, and iv) recirculation constraints. Four cases were reported: i) a trickling filter unit, ii) a trickling filter system, iii) a deep filter with forced ventilation, and iv) minimization of the BOD remaining in the effluent subjected to limited cost (3). Applying linear programming techniques the following relevant conclusions were reported: i) recirculation ratio and depth were constant for any influent rate having a given BOD and desired BOD reduction, ii) the hydraulic rate of flow should be as high as possible provided recirculation ratio is less than 4:1 and iii) trickling filters should be as deep as possible provided pumping is not required.

Galler's investigation is certainly the latest most significant contribution into the performance evaluation and design of the trickling filter system. It has established grounds for further research in a similar line of thought.

2.2.5 Mechanistic Approach

The mechanistic approach such as the one adopted by Ames et al (24), Maier et al (25), Atkinson et al (26), and others (27,28,29), was developed because of the inability of the former approaches to incorporate all of the significant variables within the process into a single specific model (30). Their objective was therefore to determine and describe mathematically the specific substrate removal mechanisms.

In 1962, Ames, Behn and Collings (24) assuming that first-order reactions were taking place in the metabolism of organic matter within the slime layer, and using mass balance principles, developed a mathematical model incorporating the following parameters: hydraulic loading, BOD concentration, specific surface area of the media, a mass transfer coefficient, and a biological rate constant. This formulation was further modified by Amado (37) and finally resulted in an expression very similar to those presented in Section 2.2.3. No experimental data however were available to correlate actual and predicted performances.

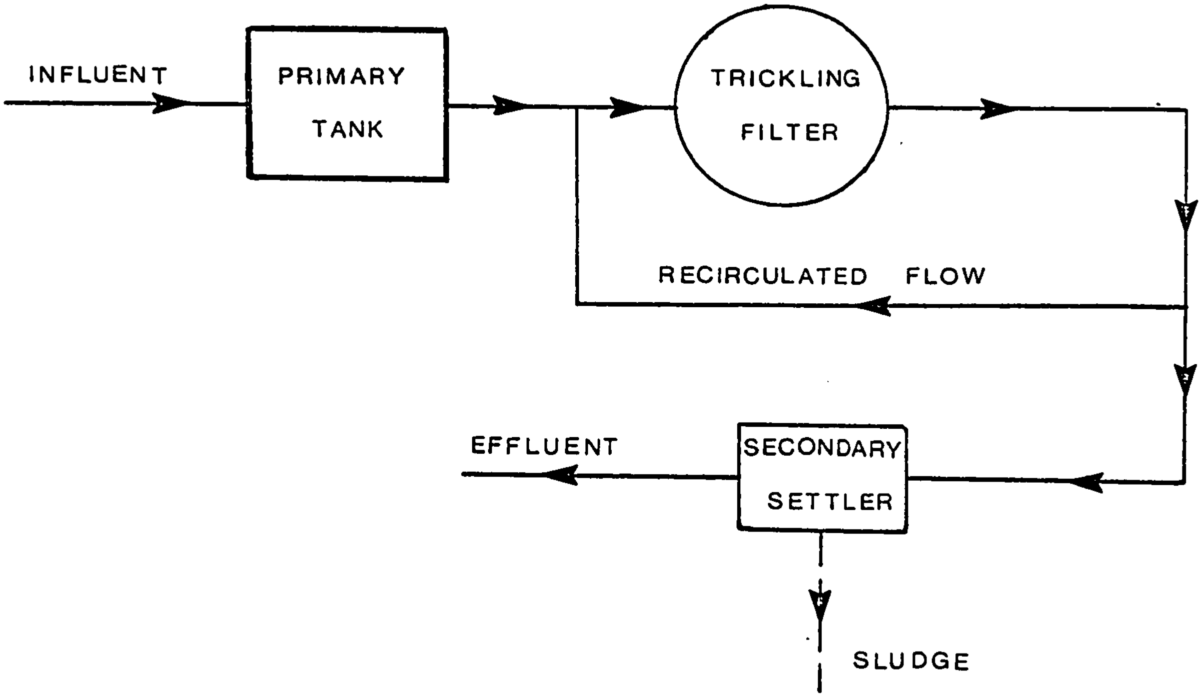
In 1963, Atkinson, Busch and Dawkins (26) using a vertical film flow reactor, differential mass balance and first-order kinetics, developed a mathematical model again similar to those presented in Section 2.2.3. Their model however was of limited applicability, because it assumed that biological reactions were taking place throughout the entire film thickness, rather than through the aerobic sublayer solely. Moreover, they postulated that the time of contact of the wastewaters within the trickling filter media was irrelevant, and served only to confuse the issue.

Atkinson and Swilley (28), developed in 1963 what was referred to as a diffusion controlled model. The model was derived from differential equations describing mass transfer based on molecular diffusion. Monadjemi (27), and Maier (25) also adopted a reasoning similar to that of Atkinson and Swilley. Others have developed reaction controlled models, but these, along with the diffusion controlled models, will not be presented hereafter; instead, a rather detailed and comprehensive résumé appears in Jank (30).

2.3 The Economic Analysis of Roesler and Smith

In a 1969 Federal Water Pollution Control Administration report (31), Roesler and Smith have described a mathematical model for the trickling filter-final settling tank system. The flow diagram of the simulated plant is presented in Figure 2.2.

FIGURE 2.2 ROESLER AND SMITH FLOW DIAGRAM



Their formulation was based on first-order kinetics, and on the work of Howland (11). The following mathematical model was formulated:

$$\frac{L_e}{L_o} = e^{-K^* A_p^{m'} D/Q^{n'}} \qquad (2.19)$$

where L_o = BOD applied to the filter in mg/1.

L_e = BOD of the effluent from the filter sytem in mg/1.

A_p = specific surface area ft^2/ft^3.

Q = hydraulic loading in MGAD.

K^* = constant equal to 0.69.

m' = exponent assumed to equal 1.0.

n' = a function of the specific surface area established at 0.67.

Sewage characteristics at various stations were reported, and stream vectors described a total of seventeen pieces of information. The information offered at each stream vector related to: flow, carbon, nitrogen, and phosphorus content and composition, alkalinity, suspended solids, and BOD.

In addition to performing a mass balance over the complete system, Roesler and Smith reported capital and operating costs as functions of both volume and type of filter media. Final settler cost and pumping cost functions were also reported.

Several technical and economic conclusions based on the performance of the postulated model were presented. The authors were able to illustrate graphically, that increased hydraulic loadings were best handled with media that provided large surface area per unit volume, such as synthetic packings. Even though it might appear beneficial to always provide large surface areas, a graphical representation of depth required for 85% removal of BOD, versus the hydraulic loading, showed that in the neighbourhood of 8 MGAD and over, surface areas in the order of 10 ft^2/ft^3 required the least depth. This phenomenon can best be explained by the fact that at high hydraulic loadings, and low surface area, there exists a greater probability of encountering turbulent flow conditions, thus bringing better contact between the wastewaters and the slime layer, therefore requiring less depth. Such reasoning is also supported by Atkinson, Busch and Dawkins (26), where it is postulated that turbulent flow regime can reduce the required filter volume. Kehrhberger and Busch (29) also point out the possibility of increased BOD removal under turbulent flow conditions.

Thus, the work of Roesler and Smith provides excellent tools to establish preliminary BOD removal efficiencies and cost estimates of proposed trickling filter operations. Because of the assumptions established throughout the report such an analysis should only be considered as a preliminary design.

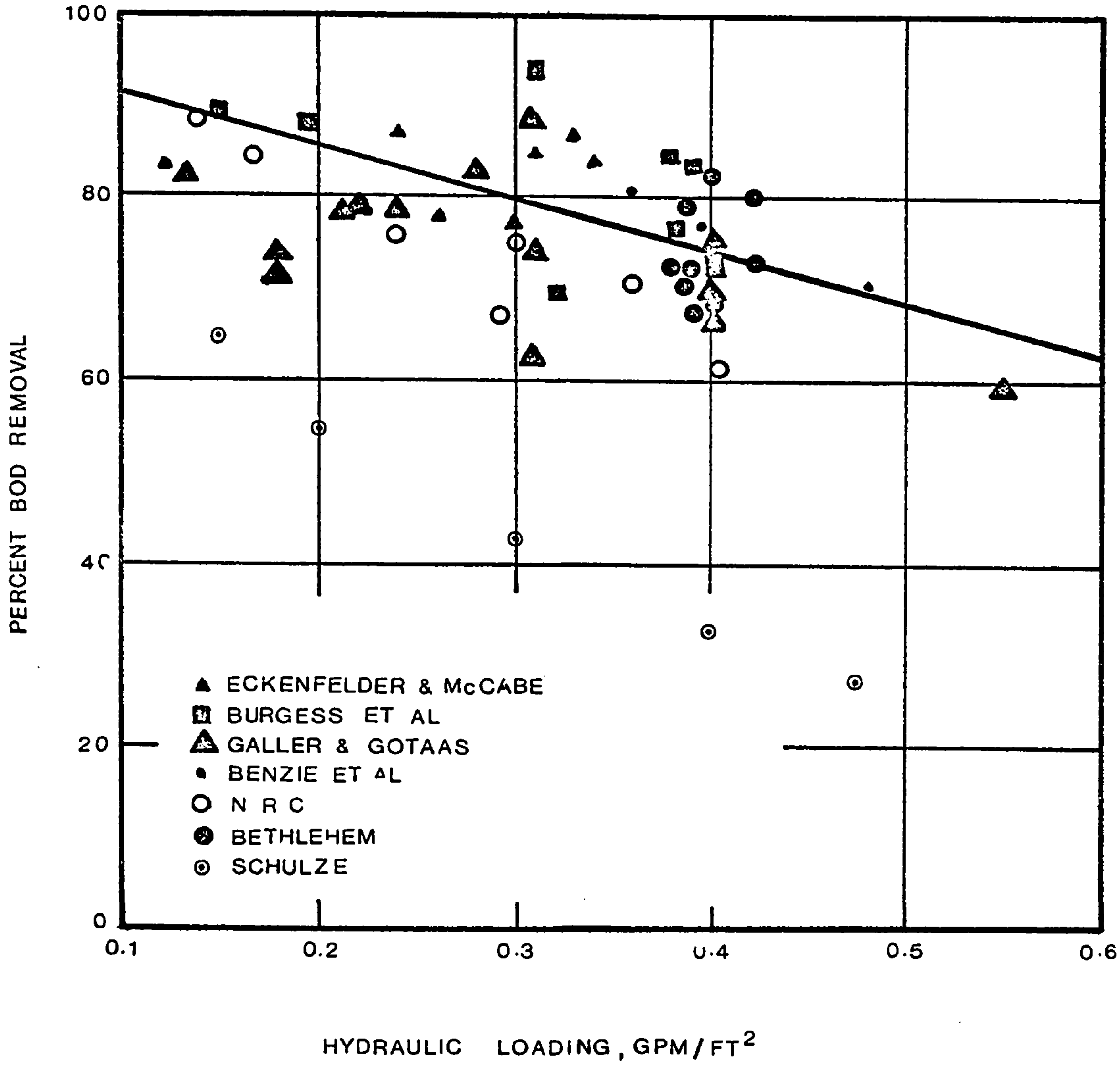
2.4 Trickling Filter Performance Factors

2.4.1 Hydraulic Loading or Hydraulic Rate of Flow

The hydraulic loading has been previously defined as the rate of flow per unit area. There are several controversial opinions as to whether such a parameter influences the removal of organic matter within a trickling filter system. The disparities among opinions are best illustrated graphically in Figure 2.3, taken from a recent report of R. F. Weston Inc. to the Environmental Protection Agency (18). Thus graphically, there appears to be a definite trend within the data to support the hypothesis that the hydraulic rate of flow does bear a direct influence on the removal of organic matter within a trickling filter system. Therefore, as illustrated in Figure 2.3 increased hydraulic loadings have a tendency to hinder BOD removal efficiency of the trickling filter system.

Other have advanced the idea that BOD removal is not sensitive to any hydraulic flow variations, as long as the organic loading remains constant by appropriate BOD concentration variations. In fact Velz's (9) mathematical model is solely a function of the organic loading and of the depth of the filter bed. Stack (15) also reported BOD removal to be independent of the hydraulic loading. In a recent investigation, Galler and Gotaas (16) demonstrated statistically that the hydraulic rate of flow onto a filter had little, if any, influence on the BOD removal process.

FIGURE 2.3 BOD REMOVAL VERSUS HYDRAULIC LOADING



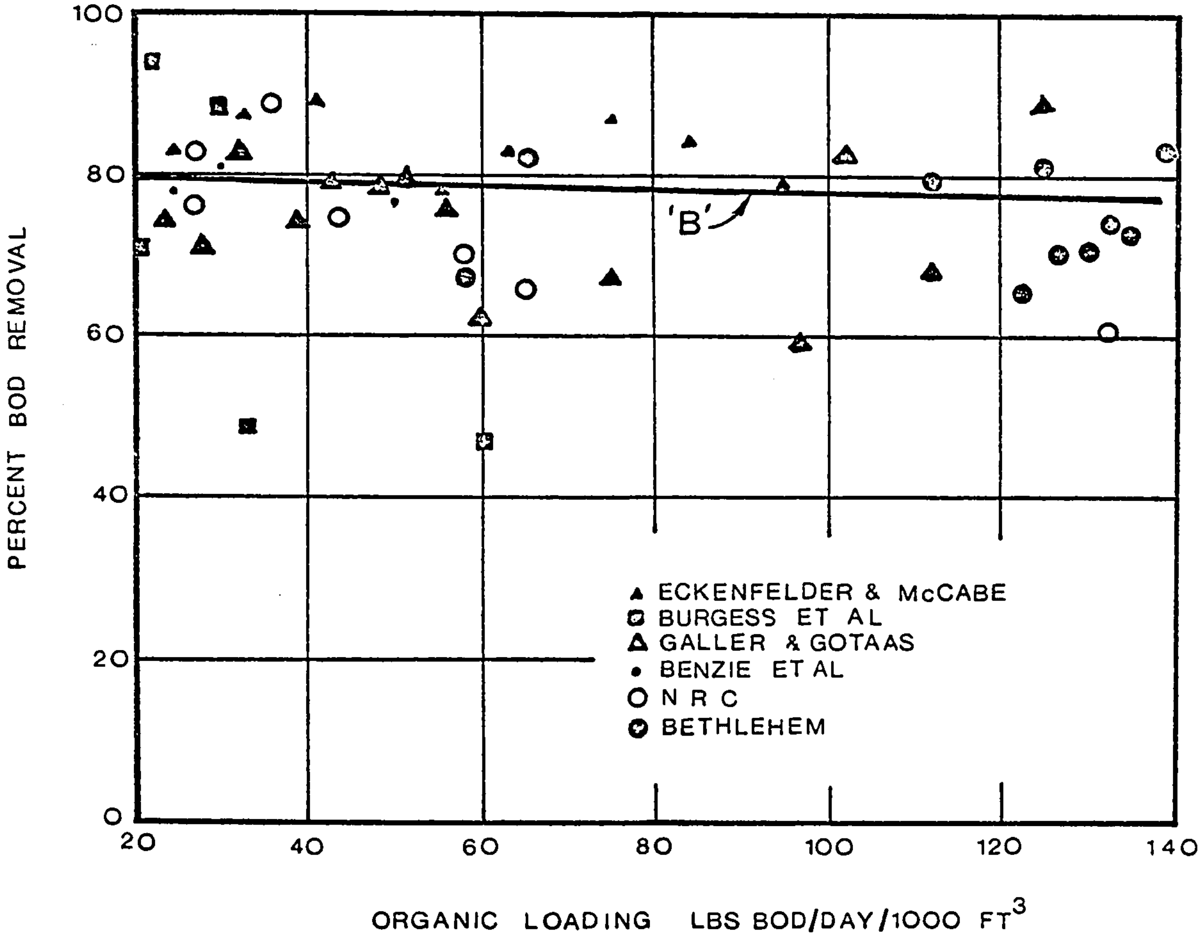
In direct opposition to the above postulate, Schulze (12), Eckenfelder (13), and Howland (11) maintain that the removal of organic matter is a direct function of the hydraulic rate of flow applied to the filter unit. In fact, higher BOD removal was observed under low hydraulic loadings as shown in Figure 2.3.

2.4.2 Organic Loading

Defined as the quantity of organic matter applied per unit volume, the organic loading has been and still is, in some cases, used as the sole basis for establishing required filter media volumes. The graphical analysis of the effects of organic loading variations on the BOD removal efficiency in a trickling filter system, is presented in Figure 2.4, adopted from Weston (18). The almost negligible influence of the organic loading approximated by line 'B' in Figure 2.4 contradicts somewhat the conclusions of Galler and Gotaas (16). This group, in agreement with the assumptions presented by Velz (9), and Stack (15), illustrated statistically that the removal of organic matter was a direct function of the applied organic load. In fact increased organic loadings were observed to decrease organic removal efficiency.

However, as was pointed out by Grantham (23) even though it appears (Figure 2.4) that the removal of organic matter is not affected by variations in the organic loading,

FIGURE 2.4 BOD REMOVAL VERSUS ORGANIC LOADING



the quality of the effluent in terms of BOD, is affected due to a decrease in nitrification. In this respect, variations in the organic loading can be considered to influence effluent BOD quality.

The general trend presented in Figure 2.4 is however supported by many researchers. Eckenfelder (13), Schulze (12) and Howland (11), in their models only give indirect consideration to the effects of organic loading variations upon the BOD removal.

2.4.3 Recirculation

Whether or not recirculation provides a detrimental or beneficial performance efficiency in terms of BOD removal, still has not been categorically answered. Many investigators have postulated the effect to be beneficial, (13,9,16,8,10,26), accounting for the increased BOD removal efficiency in one of several ways: i) a dilution effect, ii) seeding, iii) increased residence time, and iv) the continuing action of the freely floating slime particles in the secondary settler. In fact Moore et al (32) as reported by Galler (3) showed that the greatest increase in plant BOD removal efficiency had been obtained when sludge from the secondary settler was recirculated back to the primary clarifier. A smaller organic matter removal increase resulted when unsettled effluent from the trickling filter effluent was again recirculated to the primary tank. However, no increase in BOD removal efficiency resulted when the clarified effluent from the secondary clarifier was recirculated to the primary tank. Such observations therefore tend to favour the hypotheses of increased BOD removal efficiency through a seeding effect rather than through a dilution effect.

On the other hand, many researchers have postulated the effects of recirculation on the removal of organic matter to be detrimental, (4,11,12,28,29). In fact, Kehrberger and Busch (29) maintain that their theoretical heterogeneous models corroborated such a statement. This group of researchers further report that the overall effects of recirculation were to decrease residence time, and increase resistance to mass transfer. However, they recognized the possibility of a decrease in diffusional resistance with increased volumetric flow. It is however important to realize that their conclusions were related to a heterogeneous film flow reactor consisting of a continuous flow over a plate.

2.4.4 Temperature

The trickling filter process being an adsorption process dependent on the capability of microorganisms to assimilate organic compounds, has steadily been reported to be temperature sensitive.

Schroepfer et al (33), investigated the qualitative and quantitative temperature effects upon the process. The behaviour of the slime producing zooglea bacteria to changes in temperature essentially describes the qualitative portion of the analysis, whereas quantitatively the author examined the BOD removal efficiencies of existing trickling filter installations subjected to sewage temperature variations. Thus, the activity of the most important group of microorganisms within the trickling filter unit was reported to practically double with a 10°C raise in temperature. For the second portion of their investigation, they analysed graphically percentage BOD efficiency removal with sewage temperature in degree Fahrenheit. The slopes of the lines thereby obtained, represented a measure of the temperature effect on BOD removal efficiency. These ranged from 0.18%/°F to 0.74%/°F, with coefficients of correlation in the order of 0.75. Other researchers (13,15,16,34), have also reported in one way or another the sensitivity of the system to sewage temperature variations. In general, all of the researchers that have examined the effects of temperature on the removal of organic matter within a trickling filter system agree in saying that a raise in temperature enhances BOD removal within a trickling filter system, and vice versa.

2.4.5 Ventilation

An adequate supply of air or oxygen is essential to maintain aerobic conditions in a trickling filter unit, because the process is essentially aerobic.

In an intensive study, Johnson (35), concluded that by using a safety factor of 20 in the BOD reduction, a relatively low rate of air flow was required to maintain aerobic conditions. In fact the natural forces in a well designed filter would easily provide these estimated minimum requirements. Where ventilation is concerned the Ten State Standards (17) recommend that all drains, channels, and pipes be sized such that no more than 50% of their cross sectional area be submerged at design hydraulic loadings.

2.4.6 Media

In a 1971 Environmental Protection Agency report R. F. Weston Inc. (18) presented a table comparing the physical properties of several filter media, Table 2.2.

Synthetics, or plastic media filters offer two advantages over the conventional stone media units, as shown in Table 2.2. A larger specific surface area per unit volume, along with an increased percent void space, allow the application of higher hydraulic loadings. Increased void space also permits the application of higher hydraulic loadings and favors oxygen transfer. However, as was pointed out by Roesler and Smith (31), synthetic media will require deeper

TABLE 2.2

Filter Media Characteristics

Packing	Nominal Size inches	Units Per Sq.Ft	Unit Wt. #/ft^3	Specific Surface Area sq.ft/cu.ft	Void %
Plastic Media	20x48	2-3	2-6	25-30	94-97
Del Pak Redwood Media	47½x47½35-3/4	-	10.3	14	-
Granite	1-3	-	90	19	46
Granite	4	-	-	13	60
Blast Furnace Slag	2-3	51	68	20	49

depths at high hydraulic loadings to produce equivalent effluent quality, because of prevailing laminar flow regime.

Many industrial applications have been found for synthetic filter media. These recently introduced media have been shown more economical and more flexible in some instances than the conventional stone filter media. In fact, one of the most important applications might be in the treatment of unsettleable industrial liquids (36).

2.4.7 Depth

Most trickling filter units are designed with depths varying from three to ten feet. Greater depths however offer additional opportunity for waste oxidation and thus enhance BOD removal, as was pointed out by Schulze (12), Velz (9), Eckenfelder (13), Howland (11), Stack (15), and Galler and Gotaas (16).

Some producers of synthetic plastic media maintain that there is no limit to maximum filter depth, except those imposed by physical constraints, such as adequate ventilation and structural requirements (53).

However, deep filters (stone media) often require mechanical ventilation devices so as to maintain aerobic conditions. Galler (3) concluded that "Depth contributes significantly to BOD reduction... Deep filters having forced ventilation are more economical only for very high reductions in BOD and when pumping of the influent to the top of the filter is unnecessary."

CHAPTER 3

THE STUDY AND ITS OBJECTIVES

The controversy evolving in the selection of significant parameters that affect the treatment of wastewaters by means of trickling filters, illustrates that though the process itself is considered as one of the oldest and common methods of treatment in North America, the basic principles underlying its operation are not generally agreed upon. In general, the process is relatively straightforward, but embraces a realm of unknowns which lead to considerable variations in the performance of even similar treatment plants. It would therefore be unwise to consider applying the results of the present investigation to operate and/or design other trickling filter installations, without careful examination of all components and parameters of both systems. Furthermore, this study does not pretend to delineate once and for all the performance dependency of the process, as there exists evidence and data to support practically any conclusions.

Few authors and/or researchers have ever paid much attention to the mathematical formulation of an existing high rate trickling filter plant as a whole, and even fewer have ever considered the mathematical formulation of the removal efficiency of both BOD and suspended solids for the major physical and biological units in a trickling filter plant. In fact, most researchers have analysed the trickling filter-final settling tank process, rather than examining each unit separately. In this investigation, however, separate mathematical models will be developed for both the trickling filter unit and the trickling filter-final settling tank subsystem.

In carrying out this analysis the high rate trickling filter installation of Alexandria, Virginia, U.S.A., will serve as the basis for the building of all mathematical models.

The objectives of the present investigation can be summarized as follows:

i) Collect field data from the presently operating Alexandria sewage treatment plant, and assemble this bulk of information into proper format.

ii) Conceive a computer program to perform a mass balance on the selected trickling filter installation, so as to summarize and manipulate by computer the available information.

iii) Develop mathematical formulations, for both BOD and suspended solids removal efficiencies for most of the important physical and biological treatment units.

iv) Compare under various levels of operation, the performance of the Alexandria Sanitation Authority sewage treatment plant, with other postulated mathematical models currently available for the design of such systems.

v) Examine the overall performance and sensitivity of the plant subjected to both normal and extreme operating conditions. Examine also sewage plant effluent characteristics and sludge production variations within the sensitivity analysis, so as to fully appreciate the extent of the plant's operation.

The relevance of this study is further accentuated by the fact that the plant designed in the early 1950's has now reached its ultimate design flows, predicted for 1973. The careful examination of the reported operational characteristics can yield valuable information as to possible expansion of the plant, assuming the applicability in series or in parallel of the suggested mathematical models. Such an investigation, however, can be considered an extension of the present report, and to be of significance, would constitute a report in itself. However, the present investigation will establish grounds for such an extension.

CHAPTER 4

ALEXANDRIA SANITATION AUTHORITY SEWAGE TREATMENT PLANT

4.1 Geographical Location

Alexandria, with a population of little over 100,000 is located in the north east sector of the State of Virginia, adjacent to the District of Columbia. A map of the State of Virginia is provided in Figure 4.1.

The sewage treatment plant, providing a design flow of 18 MGD, situates itself on the north shore of Hunting Creek, near its junction with the Potomac River. The ultimate design population of 1973 is expected to total 150,000 people, consisting of 105,000 in Alexandria and 45,000 in Fairfax County. Extensions to the plant will enable the handling of an additional 15 MGD, bringing the total plant capacity to 33 MGD (38).

4.2 Treatment Plant Characteristics

The Alexandria Sanitation Authority (ASA) sewage treatment plant, consists of a high rate trickling filter system, recirculating part of its filter effluent back to the primary settling tank influent. A flow diagram of the plant is presented in Figure 4.2.

FIGURE 4.1 MAP OF THE STATE OF VIRGINIA - U.S.A.

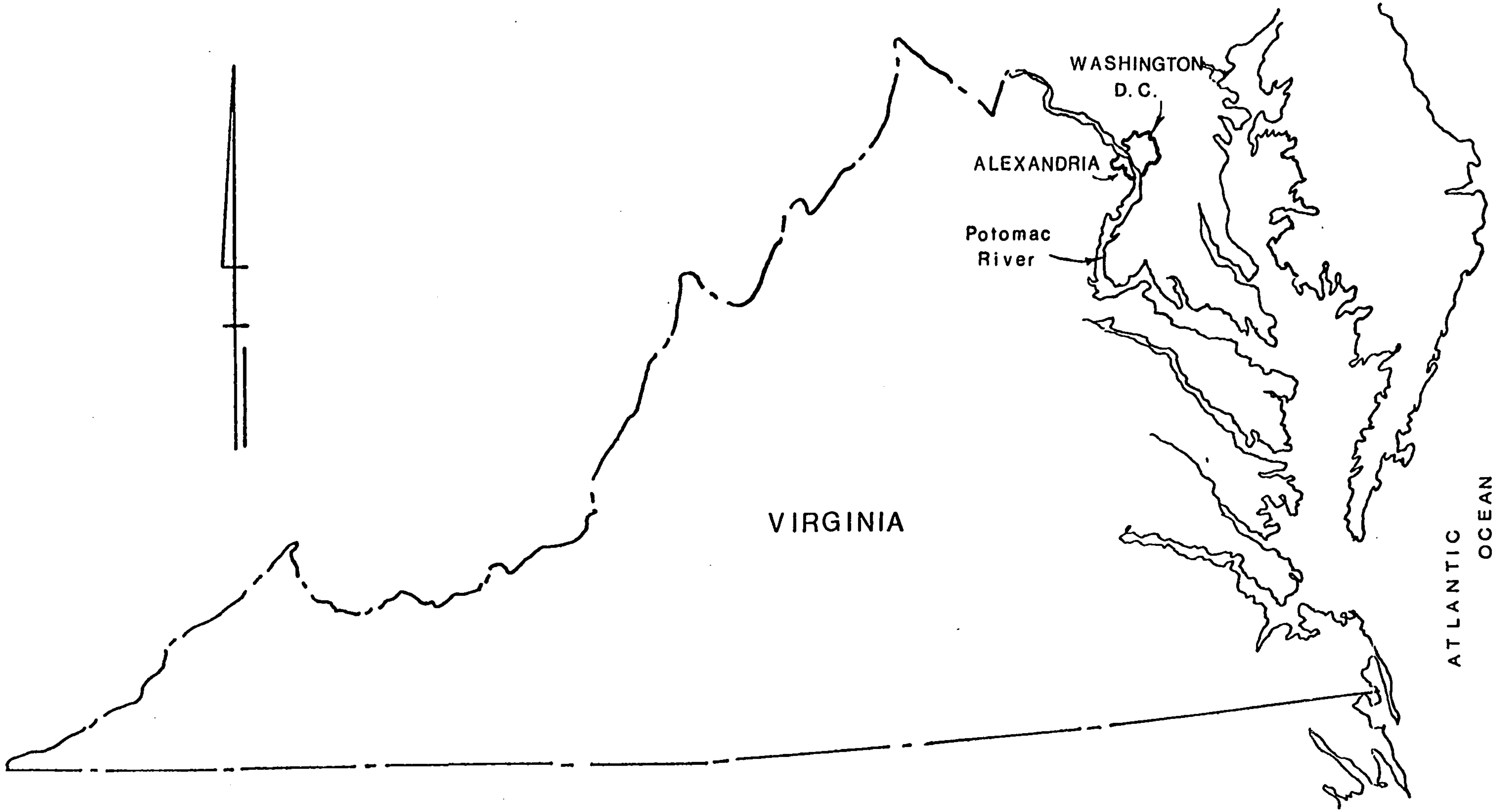
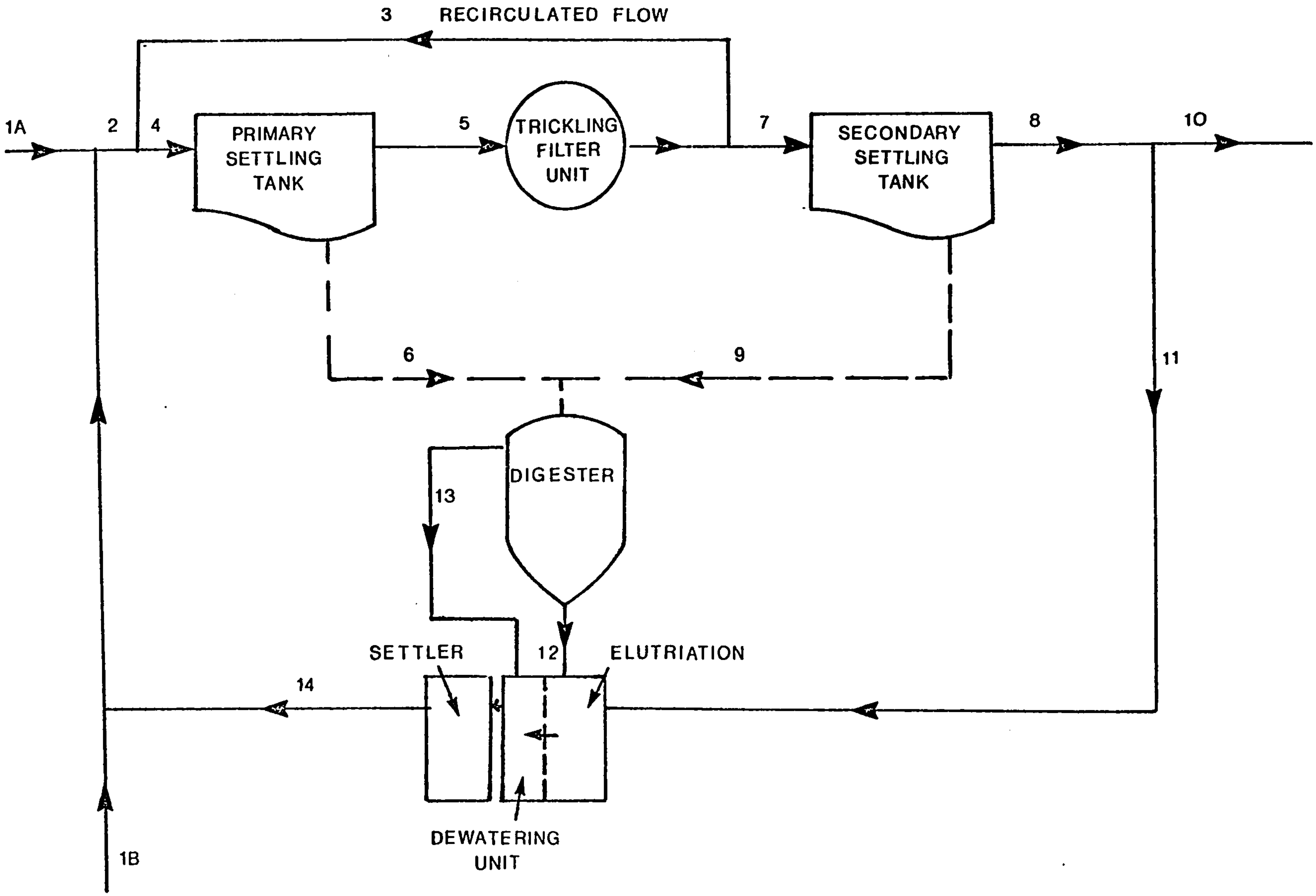


FIGURE 4.2 FLOW DIAGRAM OE THE ALEXANDRIA SEWAGE TREATMENT PLANT



The sewage enters the plant from two different collectors, identified as '1A' and '1B', in Figure 4.2. It is then pumped through mechanically-cleaned screens, where solid particles three quarters of an inch and larger are removed, ground, and returned to the flow. Mechanically cleaned grit chambers are then provided for the removal of sand, gravel, and other inorganic material, to be finally disposed of in a sanitary landfill.

The effluent from the grit chamber then joins with the recirculated trickling filter effluent before entering into the primary settling tanks. These settling tanks, four in all, consist of eight channels, 18' x 173' and 9' deep. The primary sludge is pumped to the digesters while the settled sewage proceeds to the three parallel trickling filter units. Each filter unit is 160' in diameter and 4.25' deep. Of a stone media, the filters provide a total volume of 256,400 cubic feet, with a surface area of 60,300 square feet. Part of the trickling filter effluent is recirculated back to the primary settling tanks, while the rest proceeds to the five final settling tanks. The final or secondary settling tanks, consist of ten channels, 18' x 125' and 10' deep, and allow filter effluent solids to be removed from the wastewaters. The sludge resulting from the settling of the filter effluent is then pumped to the digesters along with the primary sludge.

Two digesters, 95' in diameter and 28' deep, are used for sludge stabilization. The gas produced is used for heating, and to power the main sewage pumps.

Elutriation then follows digestion. This operation proceeds in one of two tanks, the other being used to pre-settle the elutriation effluent and the supernatant liquor from the secondary digester prior to returning to the plant influent through interceptor '1B', in Figure 4.2.

The final physical process is sludge dewatering. This operation is performed on two stainless steel coil spring vacuum filters, 10' in diameter, by 10' in length. The resulting sludge cake is then conveyed to a hopper, loaded into trucks, and finally disposed of in a landfill area (38).

4.3 Operation Data

4.3.1 General

The Environmental Engineering Department, School of Civil Engineering of Purdue University, receives annually copies of the operation report of the Alexandria Sanitation Authority sewage treatment plant. In cooperation with Dr. Pierre Lacroix, a former graduate student of Purdue University and supervisor of the present investigation, and Professor Don E. Bloodgood, Professor Emeritus, Purdue University, copies of the annual reports covering the period from October 1964 to September 1971 were obtained for the present study. Seven years of data constituting a total of 84 monthly average observations served as the basis for this research.

4.3.2 Storage and Retrieval Mechanism

The annual reports of the ASA sewage treatment plant consist of two sections: i) a financial statement, and ii) monthly operation data. The monthly performance of the plant is described using over 90 separate pieces of information. The complete storage of this bulk of information requires the filling of over 8,000 separate entries. Careful examination of the data led to the following conclusions: i) much of the data supplied was irrelevant to the present objectives of the investigation, and ii) many entries were easily reproduced through basic mathematical manipulations. In fact, substantial reduction in the volume of information to be stored was realized. A monthly description of the plant's operation was achieved using 31 separate entries, of which a few could still have been generated within the storage-retrieval mechanism.

A computer storage-retrieval process was adopted. The data totalling over 2,600 entries was punched onto cards, primarily to ease manipulation of this bulk of information, and secondly so as to make it available to others, interested in pursuing research on the same trickling filter installation. Table 4.1 summarizes the various monthly entries giving, name, fortran coding name, location and format for each entry.

TABLE 4.1

Fortran Input Data - Storage Mechanism

Name	Fortran Coding	Location Card-Col.	Format	Units
Month	MONTH(J)	1-(1-8)	A8	-
Days/Month	DAYS(I,J)	1-(9-10)	I2	Days
Avg. Max. Air Temp.	TEMPMA(I,J)	1-(11-12)	I2	^{o}F
Avg. Min. Air Temp.	TEMPMI(I,J)	1-(13-14)	I2	^{o}F
Gross Flow (Influent flow and elutriation flow)	FLOW2(I,J)	1-(21-25)	F5.2	MGD
By Passed Flow	BYFLOW(I,J)	1-(26-31)	F6.2	MG/month
Elutriation Flow	FLOW14(I,J)	1-(32-35)	F4.2	MG/month
Recirculation Flow	FLOW3(I,J)	1-(36-39)	F4.2	MGD
Primary Tank Det. Time	DT1(I,J)	1-(40-43)	F4.2	Hrs.
Secondary Tank Det. Time	DT2(I,J)	1-(44-47)	F4.2	Hrs.
Gross BOD (Influent BOD and elutriation BOD)	BOD2(I,J)	1-(48-50)	I3	mg/1
Primary Effluent BOD	BOD5(I,J)	1-(51-53)	I3	mg/1
Trickling Filter Eff. BOD	BOD7(I,J)	1-(54-56)	I3	mg/1
Secondary Eff. BOD	BOD8(I,J)	1-(57-58)	I2	mg/1
Elutriation BOD	BOD14(I,J)	1-(59-62)	I4	mg/1
Gross S.S. (Influent S.S. and Elutriation S.S.)	SS2(I,J)	1-(63-65)	I3	mg/1

Table 4.1 cont'd

Name	Fortran Coding	Location Card-Col.	Format	Units
Primary Eff. S.S.	SS5(I,J)	1-(66-68)	I3	mg/1
Trickling Filter Eff. S.S.	SS7(I,J)	1-(69-70)	I2	mg/1
Secondary Eff. S.S.	SS8(I,J)	1-(71-72)	I2	mg/1
Elutriation S.S.	SS14(I,J)	1-(73-77)	I5	mg/1
Primary Sludge Flow	FLOW6(I,J)	2-(1-7)	F7.2	1000G/mon
Total Solids in Prim.Sludge	SL1TSP(I,J)	2-(8-11)	F4.2	Percent
Volatile Sludge in Prim. Sludge	SL1VSP(I,J)	2-(12-16)	F5.2	Percent
Secondary Sludge Flow	FLOW9(I,J)	2-(17-23)	F7.2	1000G/mon
Total Solids in Sec.Sludge	SL2TSP(I,J)	2-(24-27)	F4.2	Percent
Volatile Solids in Sec. Sludge	SL2VSP(I,J)	2-(28-32)	F5.2	Percent
Digested Sludge Flow	FLOW12(I,J)	2-(33-39)	F7.2	1000G/mon
Total Solids in Digested Sludge	DSLTSP(I,J)	2-(40-43)	F4.2	Percent
Volatile Solids in Digested Sludge	DSLVSP(I,J)	2-(44-48)	F5.2	Percent
Supernatant Liquor Flow	FLOW13(I,J)	2-(49-55)	F7.2	1000G/mon
Total Solids in Sup. Liq.	SLQTSP(I,J)	2-56-59)	F4.2	Percent
Volatile Solids in Sup. Liq.	SLQVSP(I,J)	2-(60-64)	F5.2	Percent

4.3.3 Data and Mass Balance

From the flow diagram presented in Figure 4.2, a total of sixteen stream stations were identified, of which thirteen were described in physical terms, i.e. station 2 through station 14. The data, previously stored onto cards was manipulated, and a mass balance of the plant performed. A computer program, referred to as MASBAL, written in Fortran IV for use on a 360/65 IBM Computer, performed the required mathematical manipulations.

Stream vectors were selected to describe quantitatively the performance of the plant at every station. Two major categories of stream vectors were adopted, depending on whether the flow consisted of wastewater or of sludge. The components of each category of stream vectors were:

i) wastewater stream vectors: flow, BOD and SS concentrations.

ii) sludge flow stream vectors: flow, total solids and volatile solids in percent.

Listed in Appendix A is both listing and output from the MASBAL program, giving the relevant data required in future chapters of this investigation. Four tables are used to summarize the yearly operation data of the plant:

i) Table 1A: Stream vectors for stations 1,2,3,4,5

ii) Table 2A: Stream vectors for stations 6,7,8,9,10,11

iii) Table 3A: Stream vectors for stations 12,13, 14 plus trickling filter loadings.

iv) Table 4A: BOD removal, SS removal, and miscellaneous information.

4.3.4 Temperature Manipulation

Of all the information reported in the annual reports of the ASA sewage treatment plant, only average maximum, and average minimum air temperatures were reported monthly. In view of the fact that the biological process is dependent on sewage temperature, rather than on air temperature, it was decided to convert reported air temperatures to corresponding sewage temperatures. Using the values of air and sewage temperature from eight activated sludge plants in Indiana (41), it was possible to regress successfully the data so as to obtain a predictive mathematical model for sewage temperature, described as:

$$T_{si} = a_o + a_1T_{ai} + a_2T_{a(i-1)} \tag{4.1}$$

where T_{si} = predicted average monthly sewage temperature for month i, in ^oF.

T_{ai} = reported average monthly air temperature for month i, in ^oF.

$T_{a(i-1)}$ = reported average monthly temperature for month (i-1), in ^oF.

a_o = coefficient equal to 41.96217.

a_1 = coefficient equal to 0.18005.

a_2 = coefficient equal to 0.26993.

The reported model, yielded a multiple correlation coefficient equal to 0.9362, with a standard error of the estimate of 2.81533.

The data presented in Appendix A, show both the reported average air temperature and the predicted average sewage temperature for each month. Tests were performed to determine which of the two temperatures (air or sewage) yielded better regression coefficients. All of the runs confirmed the use of the predicted average monthly sewage temperature based on Equation (4.1).

CHAPTER 5

BASIC CONCEPTS IN MODELLING AND SIMULATION

5.1 Introduction

The objective of this chapter is to familiarize the reader with some fundamental concepts in systems engineering and model building, and summarize important criterions for statistical model evaluation. Terms such as 'systems', 'models', 'parameters', 'elements', etc. are commonly used in every field, because they provide the structure for intelligent, well designed patterns of thought, yielding answers to a variety of realistic problems. The principles underlying such concepts are not mysterious, in fact even though the use of such terms has been accentuated within the last decade, because of the advent of high speed computers, the fundamental concepts have long since been with us (39,40).

Model building and systems simulation have proven extremely valuable tools, when applied intelligently. However, the systems approach to the solution of realistic situations, possesses serious disadvantages or limitations that must be recognized early, in order to avoid possible misapplication of the techniques. It is the application of such concepts to wastewater trickling filter treatment plants, along with some basic statistical techniques that will be discussed hereafter.

5.2 Systems Simulation

5.2.1 Components of a System

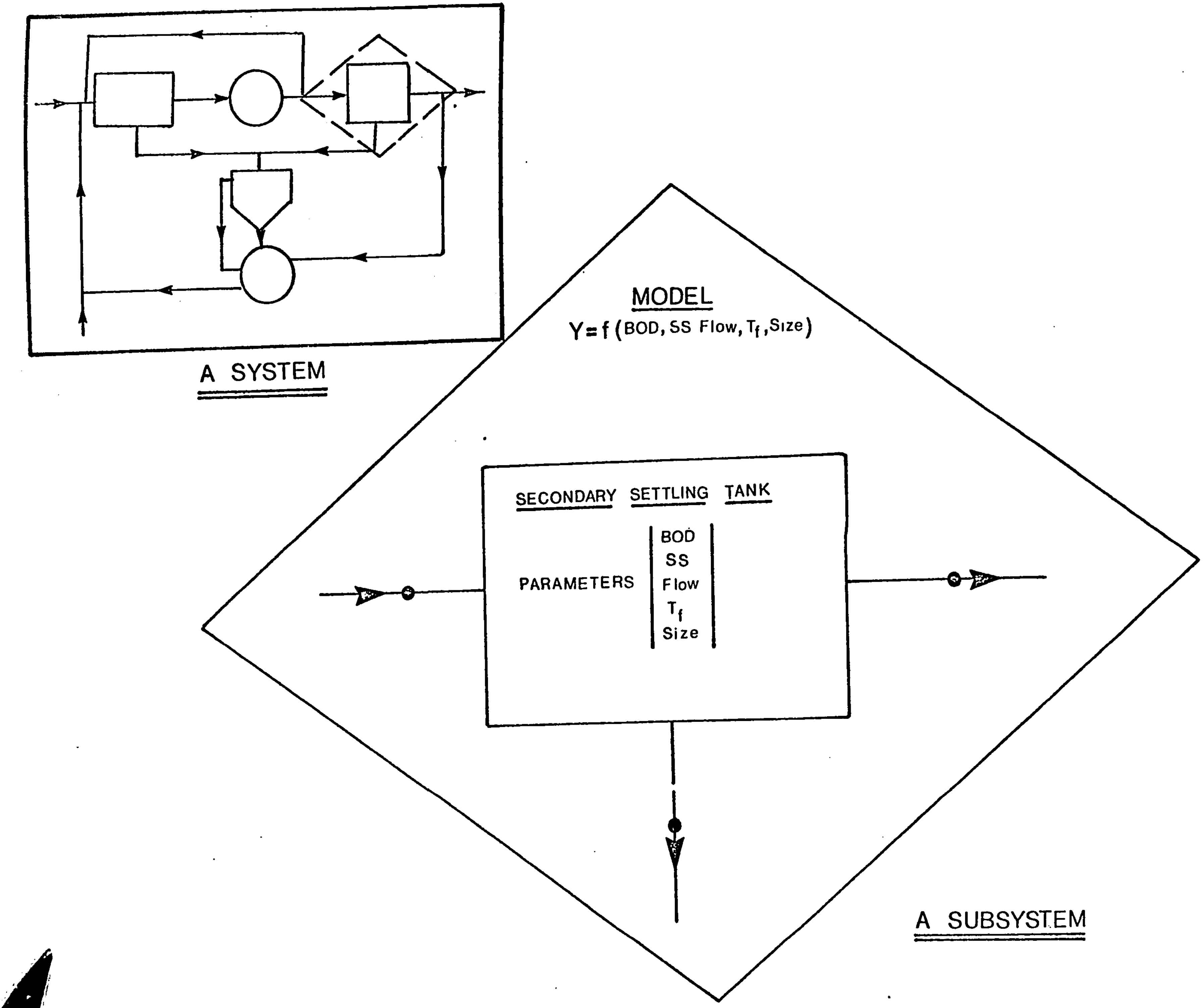
A system can be defined as the "assemblage of elements which are tied together by a common flow of material and/or information" (40). The elements of a system, also referred to as subsystems, interact together so as to determine the output of the entire system. A parameter can then be thought of as a property of the system, which can be assigned specific numerical values (40).

Furthermore, the field of systems engineering is defined by Hall and Dracup (39) as "the art and science of selecting from a large number of feasible alternatives, involving substantial engineering content, the particular set of actions which will accomplish the overall objectives of the decision makers," subjected to specific constraints.

Such concepts can very well be applied to the analysis of wastewater treatment plants. Figure 5.1 illustrates the components of the selected wastewater treatment plant when visualized as a system. It is however important to understand the relative meaning of those terms. What might be referred to herein as a system, for example, a treatment plant, can very well under a different context be referred to as a subsystem or even a parameter.

The ASA sewage treatment plant system is in fact a grouping of several elements or subsystems as illustrated

FIGURE 5.1 COMPONENTS OF A SYSTEM



in Figure 5.1. These subsystems are in turn a function of different parameters that determine their performance. The linkage of these elements with each other, establishes the overall plant performance through a technique known as simulation. The manner in which a system is planned, and its elements defined, is dependent upon the investigator's objectives. These must consequently be clearly established at the outset (39).

5.2.2 A Systems Approach

Because the applications of systems engineering tend to deal more and more with complex realistic problems, the analyst must consequently understand the mechanisms influencing the overall process performance. Himmelblau and Bischoff (40) in attempting to establish the performance dependency of a system, suggest the following steps:

1. Formulation of the problem, and delimitation of the objectives and criterions of importance. Delineation of performance requirements.
2. Inspection and classification of the process in order to break it down into subsystems.
3. Preliminary determination of the relationships among the subsystems.
4. Analysis of the variables and relationships to provide as simple and consistent a set as possible.

5. Mathematical modelling of the relationships in terms of the variables and parameters.

6. Model evaluation.

7. Application of the model and interpretation of the results.

The advantage of a systems approach, as might be inferred through the listing of the suggested steps, is that it will require the gathering and application of a variety of concepts from several disciplines, and only through a well structured program will anything meaningful evolve.

5.2.3 Systems Simulation

Hall and Dracup (39) defined simulation as a measure of reproducing the essence of a system without actually reproducing the system itself. In fact the system or part of it is examined by manipulating the mathematical expressions, i.e. the models representing it.

When the system represents a complex physical process, simulation provides an excellent opportunity to experiment on the process without having to perform such experiments on the prototype. It is in this respect that systems simulation possesses much of its advantages. Other benefits can be derived from simulation and can be described as follows:

1. Computer Control - Performance simulation aids in the operation and performance evaluation of existing

physical processes and was illustrated in the case of activated sludge plants (41).

2. Sensitivity Analysis - The sensitivity of basic parameters can be tested. For example, a 10% change in the input rate can either produce beneficial or detrimental effects on plant performance.

3. System Stability - The stability of the system can be examined when subjected to disturbances within the parameters.

4. Extrapolation - Although very dangerous, extrapolation can be performed so as to appreciate possible plant performance under unusual circumstances.

Obviously as suggested by Hall and Dracup (39) computer simulation can have serious limitations, depending on the particular situations. One of the most serious limitations of the process lies in the validity of the postulated models. Means of evaluating proposed models form an essential part of the systems approach.

5.3 Model Building

5.3.1 The Model and Its Relevance

As mentioned in Section 5.2 a model is a mathematical representation of what is happening in a subsystem or in an element of a system. The components of the model are referred to as parameters. Of the whole concept of systems analysis, model building figures as a key step in the successful implementation of a systems simulation study. If the models are not valid, then computer simulation is totally irrelevant.

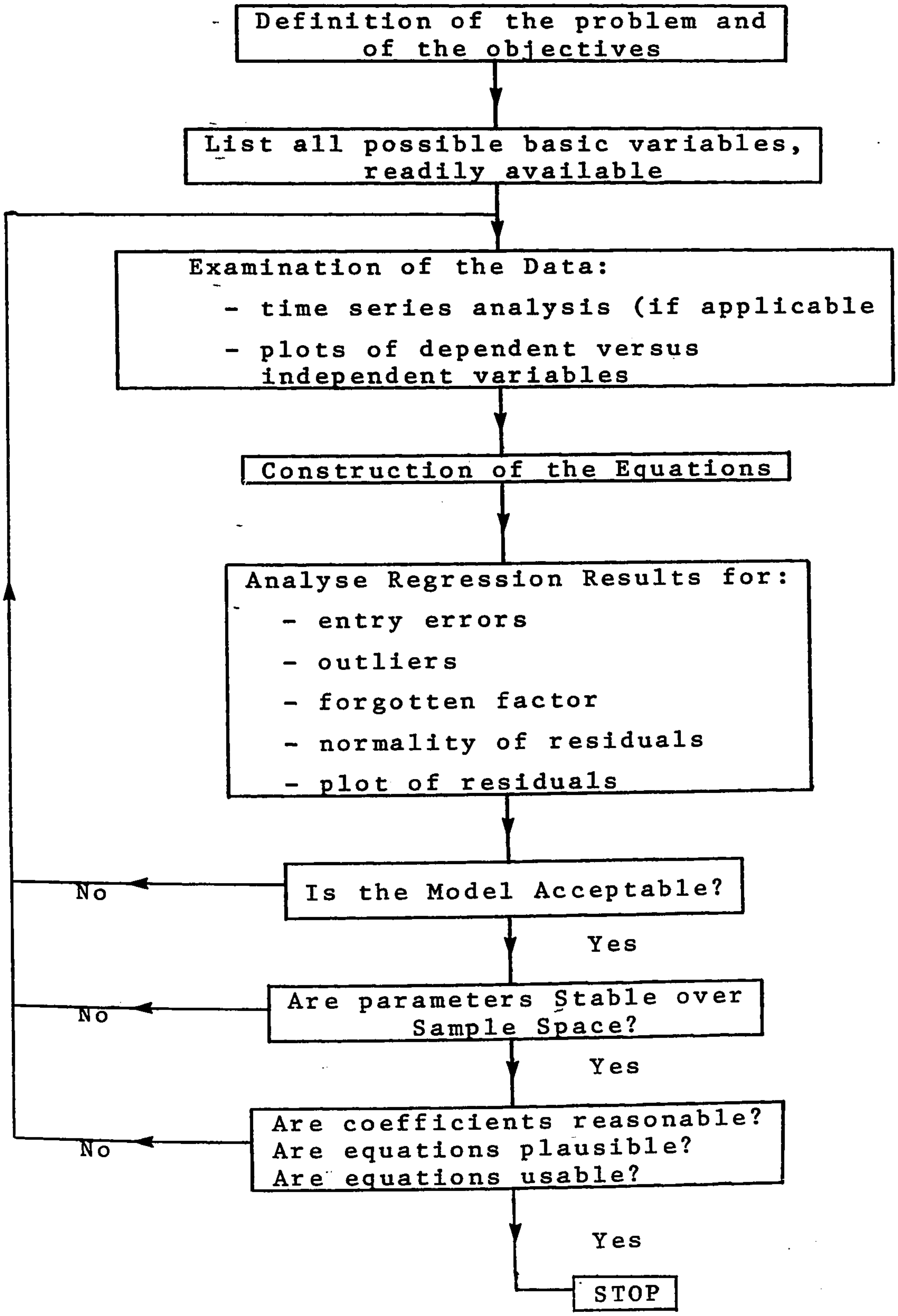
5.3.2 Model Building Approach

A model building procedure which is in fact a combination of the efforts of Draper and Smith (42), and Daniel and Wood (43) is presented in Figure 5.2. Obviously, not all of the suggested steps are relevant to every model building situation. However, these steps are presented here in order to provide guidelines to successful mathematical model formulation.

Many techniques are available to regress data into some specific mathematical expressions. Some of the most common are available in computer program packages such as the BMD series of the Health Sciences Computing Facility of the University of California at Los Angeles, and the Scientific Subroutine Package (SSP) available from IBM. If the problem is one where the parameters are linear, then multiple linear regression techniques must be used. If, however, parameters are non linear, then non linear regression techniques, such as the one presented by Marquardt (44) must be adopted to perform the required manipulations.

FIGURE 5.2

MODEL BUILDING PROCEDURE



5.4 Statistical Concepts

5.4.1 General

It is not the purpose of this section to offer a complete statistical background necessary for the understanding of the latter chapters, but rather to survey some of the most important testing concepts essential in the evaluation of the mathematical models.

5.4.2 Evaluation of the Model

In order to determine whether the postulated mathematical models represent adequately the performance of the subsystems and/or systems, two methods are available: i) plot of residuals, and ii) examination of transformed residuals.

The residuals are defined as the difference between actual and predicted performance. They can be plotted in several ways such as discussed by Draper and Smith (42), in order to possibly detect particular trends. Such patterns would question the validity of the model because of previously established assumptions regarding the statistical characteristics of these residuals.

The use of normal plots and the examination of the 'Unit Normal Deviate' form of the residuals, can also establish the adequacy of a postulated model. Such an analysis is based on the assumption that for least squares regression residuals are usually assumed to follow normal distributions with mean equal to zero, and standard deviation equal to σ^2. Thus, if the postulated model is correct, then the residual mean square

$$s^2 = \frac{\sum_{i=1}^{n} e_i^2}{(n^* - p)} \tag{5.1}$$

where s^2 = residual mean square.

e_i = residual.

n^* = number of observations.

p = number of parameters within the model.

will estimate σ^2. Therefore, the quantity expressed as (e_i/s), and referred to as the Unit Normal Deviate form of the residual, can be examined so as to determine whether $\varepsilon_i/\sigma \approx N(0,1)$. For example, with a 95% confidence level, not more than 5% of the Unit Normal Deviate (UND) form of the residuals must be outside the range of ±1.96.

5.4.3 Evaluation of the Parameters of a Model

Investigators often propose models with several parameters, not knowing, in fact, if all parameters are significant to the characterization of the process. Means of determining if parameters of a model are significant are available.

Consider the following simple linear model:

$$Y_i = B_o + \sum_{j=1}^{p} B_j X_{ji} + e_i \tag{5.2}$$

Y_i = dependent variable.

X'_s = independent variables.

B'_s = coefficients.

p = number of parameters.

e_i = residuals.

and a specific coefficient, say B_j which can be approximated by b_j. Assuming that:

H_o ; $B_J = 0$ (Null Hypothesis)

H_1 ; $B_J \neq 0$

then 't_a' = critical t value at a α probability level,

and 't' = $\dfrac{b_J - B_J}{\text{est. s.e. } (b_J)}$

then if 't' is greater than 't_a', the null hypothesis is rejected, and the parameter is said to be significant in the regression. If, however, the computed 't' value is less than 't_a', then the null hypothesis cannot be rejected, and the parameter is said to have only a chance influence in the regression.

In this manner all parameters within a model can be tested as to their probable chance of having some influence in the mathematical expression.

5.4.4 A Note on the Types of Errors and Probability Levels

When involved in the testing of statistical hypotheses, two types of errors can be made, referred to by statisticians as Type I error (also Type α), and Type II error (also Type β). A Type I error involves the rejection of a null hypothesis that is actually true, and α is referred to as the probability of committing a Type I error. Thus if α is set at 0.05, i.e. 5%, the null hypothesis will be mistakenly rejected 5% of the time. However, the lower the value of α, the more chance there is of committing a Type II error.

Therefore, as can be inferred, a Type II error results when a null hypothesis that is actually false is maintained. The probability of making a Type II error is given by the value of β. Table 5.1 summarizes very clearly the errors previously discussed (45).

Because of the inherent conservatism of engineers and scientists, rejection criterions are set at fairly low levels, which indicates a greater willingness on the part of the researchers not to claim a good result, rather than to claim a false one (46).

Whether a Type I, or a Type II error is made, can never be asserted positively. However, researchers must always be very careful in selecting the rejection and acceptance levels for the testing of statistical hypotheses, as they establish important criterions within the model building process.

TABLE 5.1

Errors in Testing Statistical Hypothesis

	H_o is true	H_o is false
Accept H_o	none	Type β Error
Reject H_o	Type α Error	none

CHAPTER 6

MODEL BUILDING

6.1 A Note on Regression and Probability Levels

Physical and biological processes, such as those described herein, seldom follow true linear relationships, as far as their efficiency and removal characteristics are concerned. In fact, Robertson, Wilson and Liebman (47) examined several trickling filter models, and concluded that most were of the non linear type, i.e. non linear in the parameters.

Many forms of mathematical (linear and non linear) models were investigated in this undertaking before finally adopting the following non linear model presented hereafter:

$$Y = B_o \prod_{i=1}^{p} X_i^{B_i} e_i \qquad (6.1)$$

where Y is the dependent variable.

X_i's are the independent variables.

B_i's are the coefficients to be evaluated.

e_i's are the residuals.

i, and p are related to the number of parameters in the regression equation.

The objective of the least squares regression programs, whether they be linear or non linear, is to minimize the sum of squares of the deviations such that:

$$\phi = \sum_{j=1}^{m} (Y_j - \hat{Y}_j)^2 \qquad (6.2)$$

is minimum. The variable $\hat{Y}$ refers to the predicted value of the dependent variable, while Y refers to the observed value of the dependent variable. The value of m is related to the actual number of observations.

Several methods for solving the non linear parameters are available, of which one has been investigated in this study for the purpose of the possibility of applying it to the present model building process. In cooperation with Draper (48), and Marquardt (49), a non linear algorithm referred to as NONLIN II and developed by Marquardt (50), was used.

The non linear model referred to by Equation (6.1) can be termed as intrinsically linear, because through simple mathematical manipulations the model can be transformed into a linear model, such as described by:

$$Y' = \ln Y = b_o^* + \sum_{i=1}^{p} B_i X_i^* + e_i^* \qquad (6.3)$$

where $b_o^* = \ln B_o$

$X_i^* = \ln X_i$

$e_i^* = \ln e_i$

Examination of both linear and non linear regression techniques, applied to the Alexandria sewage treatment plant data, revealed that by using the linearized form of the model, represented by Equation (6.3), and applying multiple linear regression to the transformed data, produced equally good results, if not better, than those obtained from the non linear regression algorithm of Marquardt. Appendix B, offers a detailed comparison of the two outputs, using the trickling filter unit as an example. It is however important to realize, that such conclusions are only relevant to the present investigation, and generalizations should be avoided.

Several multiple linear regression programs were available from the University of Ottawa Computing Center (UOCC). The BMD series developed at the University of California, offered a variety of techniques to regress data. The multiple linear regression program BMD03R, has been used successfully for the development of the models in the final stages of the investigation. The stepwise regression program, BMD02R, has been used to possibly fit second order polynomials to the data. However relatively poor improvement in the value of the multiple correlation coefficient (R), using second order polynomials, led solely to first-order model building.

As far as the adopted α-level for the possible rejection of the hypotheses, reported values applied to similar modelling processes varied from 5% (3) to 20% (41). Because of i) unknown quality control levels in the laboratory,

ii) possible errors in data transmission, and iii) unknown sampling and preservation techniques, an α-level of probability of 15% was finally decided upon. The author however realizes that a lower α-level for rejection of hypotheses could have been selected, had the data resulted from a carefully planned and controlled laboratory testing investigation.

6.2 Subsystem Arrangements

As indicated in the literature survey, most researchers have considered the analysis of the trickling filter - final settling tank system, rather than the trickling filter unit alone. There are at least two major reasons for such an approach: i) the highly dependent nature of the process on the removal, through settling, of the sewage particles from the trickling filter unit, and ii) most biological filter plants tend to recirculate part of the secondary settling tank sludge back to the primary tank.

However, in view of i) the particular physical layout of the Alexandria sewage treatment plant, ii) the particular interest given to the filter unit, iii) the specific objectives of the investigation, and iv) the need to establish means of comparing the results from the present investigation with other well-known mathematical models, both the trickling filter unit and the trickling filter - final settling tank subsystems were examined.

System configuration No. 1 is presented in Figure 6.1, and consists of a primary settling tank followed by a trickling filter - final settling tank unit. Models for both BOD and suspended solids removal have been developed and the notation referred to in Table 6.1 has been adopted in identifying the particular models.

TABLE 6.1

Labelling of Models in Configuration No. 1

Model	Primary Tank	Trickling Filter Final Settling Tank
BOD	PT1 - BOD	TF1 - BOD
SS	PT1 - SS	TF1 - SS

System configuration No. 2, shown in Figure 6.2 consists of i) a primary settling tank, ii) a trickling filter unit, and iii) a final settling tank. Table 6.2 again summarizes the corresponding model notation.

TABLE 6.2

Labelling of Models in Configuration No. 2

Models	Primary Tank	Trickling Filter	Secondary Tank
BOD	PT2 - BOD	TF2 - BOD	ST2 - BOD
SS	PT2 - SS	TF2 - SS	ST2 - SS

FIGURE 6.1 SUBSYSTEMS IN CONFIGURATION No. 1

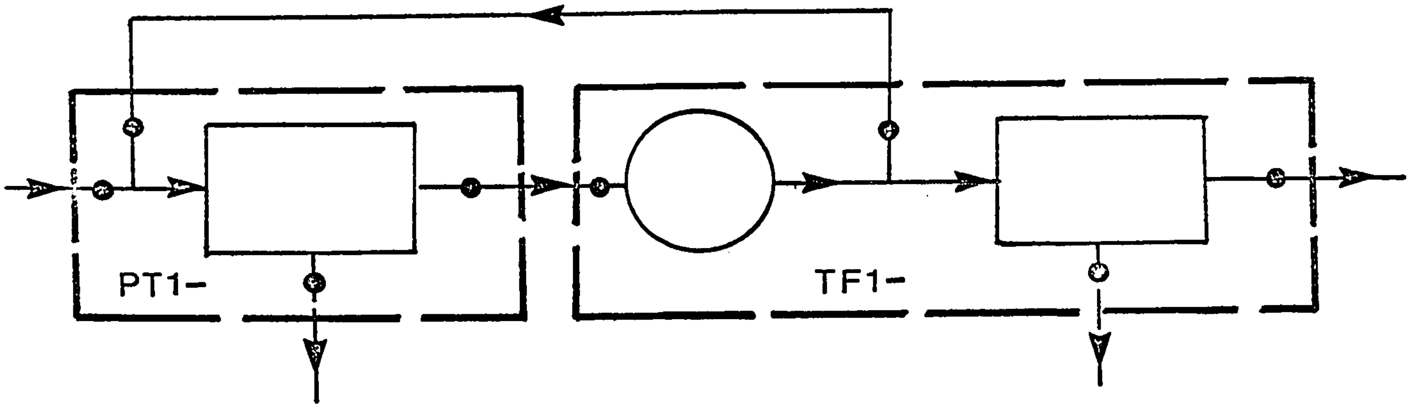
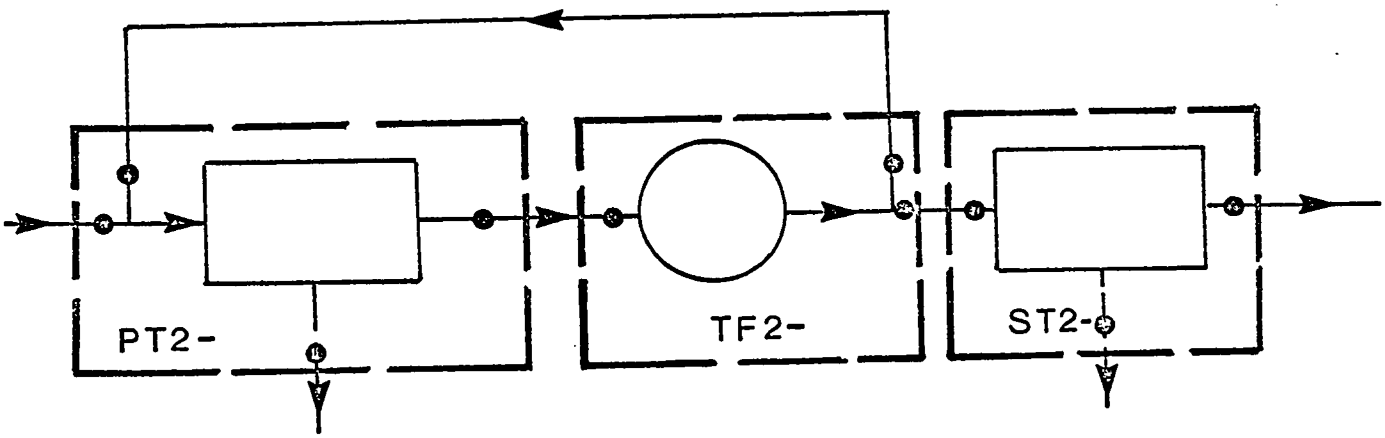


FIGURE 6.2 SUBSYSTEMS IN CONFIGURATION No.2



6.3 Models in Configuration No. 1

6.3.1 Primary Tank

The main purpose of the primary settling tank is the removal of suspended solids from the raw sewage. Because a certain fraction (approximately 70%) (51) of the BOD of domestic sewage is in the form of suspended solids a certain portion of the BOD is thereby removed through settling. Water Pollution Control Federation, Manual of Practice No. 8, (6) reports the range of suspended solids removal in existing primary settlers to vary from 40% to 70%, depending solely on the overflow rate, while BOD removals are reported to range from 20% to 50%.

In general, the effluent BOD from the different treatment units is also made up of certain solids and dissolved portions. Consequently BOD removal models for the various subsystems have taken into consideration, as a possible parameter, the effluent of suspended solids for the corresponding subsystems. This agrees with the work of other researchers that have simulated similar processes (41,51).

A. <u>SS Model (PT1 - SS)</u>

The following parameters have been considered as independent variables for possible inclusion into the primary tank suspended solids removal model (PT1-SS):

1) SS_{po}:suspended solids load applied in pounds per day,

2) OR1:overflow rate in gallons per day per square foot, 3) T_f:sewage temperature in degree Fahrenheit, and 4) R_*: recirculation, defined as the ratio of the flow through the plant (Station 4, Figure 4.2) to the flow entering the system (Station 2).

In analyzing the regression models a summary and extension of the computer output has been presented in table form. The unsuccessful trials, but still of interest in establishing conclusions, have been presented in Appendix C.

Table C-1, of Appendix C, reports the results of the regression analysis using all the parameters suggested previously. However, such an analysis revealed that the recirculation parameter had only a 'chance' influence on the suspended solids removal efficiency. Eliminating the recirculation component from the list of parameters, resulted in a better regression of the data as illustrated in Table 6.3, and expressed as:

$$\underline{\mathrm{PT1 - SS}}: \quad SS_{pe} \doteq \exp(1.84233)\ SS_{po}^{.46764}\ OR1^{.56284}\ T_f^{-0.19160} \qquad (6.4)$$

B. BOD Model (PT1 - BOD)

As reported earlier, the suspended solids in the primary tank effluent have also been considered as having a possible significance in the regression. The list of possible parameters is therefore: 1) L_{po}: BOD applied in

TABLE 6.3

PT1 - SS Model

1. REGRESSION RESULTS

#	Symbol	Units	Regression Coefficient	't' value	Miscellaneous
1	SS_{po}	#/D	0.46764	11.57889	R = 0.9184
2	OR1	GPD/FT^2	0.56284	8.07685	R^2 = 0.8434
3	T_f	^oF	-.19160	-2.86648	RofR = 0.403
4	SS_{pe}	#/D			s = 0.06565
					Intercept = 1.84233

2. TESTS

a) Model

i) Residual: No definite pattern in the residuals was observed.

ii) U.N.D.: The Unit Normal Deviate form of the residual shows that only 2.4% of the residuals fall beyond the allowable range at 5% α-level.

b) Parameters

All computed 't' values are significant in the regression.

3. EQUATION

$$SS_{pe} = \exp(1.84233)\ SS_{po}^{.46764}\ OR1^{.56284}\ T_f^{-.19160}$$

pounds per day, 2) OR1: overflow rate in gallons per day per square foot, 3) T_f: sewage temperature in degree Fahrenheit, 4) R_*: recirculation ratio, 5) SS_{pe}: primary effluent suspended solids in pounds per day.

Table 6.4 summarizes the relevant information pertaining to the adopted model.

$$\underline{\text{PT1 - BOD}}: \quad L_{pe} = \exp(-2.40024)\, L_{po}^{.62517}\, OR1^{.58027}\, T_f^{-.11353}\, R_*^{.30668}\, SS_{pe}^{.23933} \qquad (6.5)$$

6.3.2 Trickling Filter - Final Settling Tank Unit

A. SS Model (TF1 - SS)

The variables considered as possible candidates for inclusion in the TF1 - SS model are: 1) SS_{to}: suspended solids load applied to the filter in pounds per day per thousand cubic foot, 2) HR: hydraulic rate of flow in million gallons per acre per day, 3) R_*: recirculation ratio, 4) OR2: overflow rate in the secondary settling tank, in gallons per square foot per day, 5) T_f: sewage temperature in degree Fahrenheit, and 6) BOD_{to}: BOD load applied to the filter in pounds per day per thousand cubic foot.

The first analysis, considering all of the above variables, revealed that parameters No. 2 and 4, i.e. the

TABLE 6.4

PT1 - BOD Model

I. REGRESSION RESULTS

#	Symbol	Units	Regression Coefficient	't' value	Miscellaneous
1	L_{po}	#/D	0.62517	8.34869	R = 0.9586
2	OR1	GPD/FT^2	0.58027	5.10560	R^2 = 0.9181
3	T_f	^oF	-0.11353	-1.48250	RofR = 0.281
4	R_*	--	0.30668	3.27843	s = 0.06428
5	SS_{pe}	#/D	0.23933	2.29289	Intercept = -2.40023
6	L_{pe}	#/D			

2. TESTS

a) Model

i) Residuals: No definite pattern in the plot of the residuals was observed.

ii) U.N.D.: The Unit Normal Deviate form of the residuals reveal that only 3.6% of the residuals fall beyond the allowable range at 5% α-level.

b) Parameters: Since $t_c = \pm 1.45$, all of the computed values are significant.

3. EQUATION

$$L_{pe} = \exp(-2.40023)\ L_{po}^{.62517}\ OR1^{.58027}\ T_f^{-.11353}$$

$$R_*^{.30668}\ SS_{pe}^{.23933}$$

hydraulic rate of flow over the filter, and the rate of flow through the secondary settling tank, were not significant in the regression analysis, and their influence was attributed to a 'chance' effect. This is best illustrated in Table C-2, of Appendix C. The analysis of the subsystem was also performed by eliminating these variables one at a time so as to examine the possible dependence of the model to the others. In both instances the above mentioned parameters were observed to have only a chance influence. However, the withdrawal of variables No. 2 and 4, produced excellent results which are reported in Table 6.5. The adopted model for subsystem TF1 - SS was expressed as:

$$\underline{\text{TF1 - SS}}: \quad SS_{se} = \exp(0.89311)\ SS_{to}^{1.00295}\ R_{*}^{-1.21150}\ T_{f}^{-0.62581}\ L_{to}^{.26202} \qquad (6.6)$$

B. BOD Model (TF1 - BOD

The variables of possible significance in the efficiency evaluation of subsystem TF1 - BOD were selected as follows: 1) L_{to}: BOD load applied to the filter in pounds per day per thousand cubic foot, 2) HR: hydraulic rate of flow in million gallons per acre per day, 3) R_{*}: recirculation ratio, 4) OR2: overflow rate in the secondary settling tank in gallons per square feet per day, 5) T_f: sewage temperature in degree Fahrenheit and 6) SS_{se}: suspended solids

TABLE 6.5

TF1 - SS Model

1. REGRESSION RESULTS

#	Symbol	Units	Regression Coefficient	't' value	Miscellaneous
1	SS_{to}	$\#/D/1000FT^3$	1.00296	6.74612	R = 0.9635
2	R_*	--	-1.21150	-10.98275	R^2 = 0.9284
3	T_f	^oF	-0.62581	- 5.87339	RofR = 0.413
4	L_{to}	$\#/D/1000FT^3$	0.26202	2.30835	s = 0.09862
5	SS_{se}	$\#/D/1000FT^3$			Intercept = 0.89311

2. TESTS

a) Model

i) Residuals: No definite pattern in the plot of residuals was observed.

ii) U.N.D.: The Unit Normal Deviate form of the residuals shows that 3.6% of the residuals fall beyond the allowable range at 5% α-level.

b) Parameters: Since $t_a = \pm 1.45$, all parameters are significant into the regression.

3. EQUATION

$$SS_{se} = \exp(0.89311)\ SS_{to}^{1.00296}\ R_*^{-1.21150}\ T_f^{-0.62581}\ L_{to}^{0.26202}$$

load in the secondary settling tank effluent in pounds per day per thousand cubic foot.

The first analysis reported in Table C-3, in Appendix C, again revealed that variables No. 2 and 4, i.e. the hydraulic rate of flow over the filter, and the secondary settling tank overflow rate, had only a chance influence on the regression and consequently were classified as non-significant. Table 6.6 summarizes the relevant information pertaining to the adopted model, after the exclusion of the above mentioned parameters. The adopted model was expressed as:

$$\underline{\text{TF1 - BOD}}: \quad L_{se} = \exp(0.47213)\, L_{to}^{0.58288}\, R_{*}^{-1.42804}\, T_{f}^{-0.21815}\, SS_{se}^{.43519} \qquad (6.7)$$

6.4 Models in Configuration No. 2

6.4.1 Primary Tank

As illustrated by the subsystem arrangements in Figures 6.1 and 6.2, the primary tank models for configuration No. 2, i.e. PT2 - BOD, and PT2 - SS, are identical to PT1 - BOD, and PT1 - SS, respectively. The development of these models has been presented in Section 6.3.2.

6.4.2 Trickling Filter Unit

The basic variables selected for possible inclusion

TABLE 6.6

TF1 - BOD Model

1. REGRESSION RESULTS

#	Symbol	Units	Regression Coefficient	't' value	Miscellaneous
1	L_{to}	#/D/1000FT^3	0.58384	7.7058	R = 0.9545
2	R_*	--	-0.99173	-7.31843	R^2 = 0.9770
3	T_f	^{o}F	-0.21830	-2.06022	RofR = 0.399
4	SS_{se}	#/D/1000FT^3	0.43427	5.61691	s = 0.08473
5	L_{se}	#/D/1000FT^3			Intercept = 0.47222

2. TESTS

a) Model

i) Residuals: No definite pattern in the plot of the residuals was observed.

ii) U.N.D.: The Unit Normal Deviate form of the residuals indicates that 4.8% of the residuals fall beyond the allowable range at 5% α-level.

b) Parameters: All computed 't' values imply the significance of the parameters in the regression model.

3. EQUATION

$$L_{se} = \exp(0.47)\ L_{to}^{0.58}\ R_*^{1.42}\ T_f^{-0.218}\ SS_{se}^{0.43}$$

in the suspended solids model for the trickling filter unit are: 1) SS_{to}: suspended solids load applied to the filter unit in pounds per day per thousand cubic foot, 2) HR: hydraulic rate of flow in million gallons per acre per day, 3) R_*: recirculation ratio, 4) T_f: sewage temperature in degree Fahrenheit, and 5) BOD_{to}: BOD load applied to the filter in pounds per day per thousand cubic foot. The analysis with all five variables resulted in the best fit, with a multiple correlation coefficient (R) of 0.9409. Table 6.7 summarizes the relevant information about the regression.

<u>TF2 - SS</u>: $$SS_{te} = \exp(2.11470)\ SS_{to}^{.94714}\ HR^{-.66828}\ R_*^{-.26375}\ T_f^{-.42106}\ L_{to}^{.34868} \qquad (6.8)$$

B. <u>BOD Model (TF2 - BOD)</u>

After careful examination of the TF2 - BOD subsystem, the following variables were considered in the formulation of the trickling filter BOD removal efficiency (TF2 - BOD): 1) L_{to}: BOD applied to the filter in pounds per day per thousand cubic foot, 2) HR: hydraulic rate of flow in million gallons per acre per day, 3) R_*: recirculation ratio, 4) T_f: sewage temperature in degree Fahrenheit, and 5) SS_{te}: suspended solids load leaving the filter unit in pounds per day per thousand cubic foot.

The analysis examining the influence of all five parameters is reported in Table C-4, in Appendix C. This

TABLE 6.7

TF2 - SS Model

I. REGRESSION RESULTS

#	Symbol	Units	Regression Coefficient	't' value	Miscellaneous
1	SS_{to}	#/D/1000FT^3	0.94714	8.51857	R = 0.9409
2	HR	MGAD	-0.66828	-9.46715	R^2 = 0.8853
3	R_*	--	-0.26370	-2.54862	RofR = 0.367
4	T_f	°F	-0.42106	-4.92861	s = 0.0731
5	L_{to}	#/D/1000FT^3	0.34868	3.70537	Intercept = 2.11470
6	SS_{te}	#/D/1000FT^3			

2. TESTS

a) Model

i) Residuals: No definite pattern in the plot of the residuals was observed.

ii) U.N.D.: The Unit Normal Deviate form of the residuals indicates that 3.6% of the residuals fall beyond the allowable range at 5% α-level.

b) Parameters: All of the computed 't' values indicate that the parameters are significant in the regression.

3. EQUATION

$$SS_{te} = \exp(2.11470)\ SS_{to}^{.94714}\ HR^{-.66828}\ R_*^{-.26370}$$

$$T_f^{-.42106}\ L_{to}^{0.34868}$$

analysis revealed that variables No. 3 and 4 were non-significant in the regression. However, a second analysis, considering the effects of all the variables with the exception of recirculation, (variable No. 3), indicated the model to be acceptable. The computed 't' value of the temperature parameter was extremely close to the rejection level, as indicated in Table 6.8. However, the parameter was maintained in the formulation. A summary of the regression output appears in Table 6.8. The adopted model was expressed as:

$$\underline{\text{TF2 - BOD}}: \quad L_{te} = \exp(-0.24521)\ L_{to}^{.69747}\ HR^{-0.32346}\ T_f^{-0.14605}\ SS_{te}^{0.69114} \qquad (6.9)$$

6.4.3 Secondary Settling Tank

In well operated high rate trickling filter plants the 'sloughing off' of the slime layer from the surface of the filter media can be assumed to be continuous. The purpose of the secondary settling tank is therefore to remove the biological mass resulting from the oxidation of the waste within the trickling filter unit. In addition, the tank provides additional settling time and surface area for the removal of inorganic matter still present in the wastewaters. The parameters of possible significance in the removal of both BOD and suspended solids within the secondary

TABLE 6.8

TF2 - BOD Model

1. REGRESSION RESULTS

#	Symbol	Units	Regression Coefficient	't' value	Miscellaneous
1	L_{to}	$\#/D/1000FT^3$	0.69747	6.33457	R = 0.9546
2	HR	MGAD	-0.32346	-2.36075	R^2 = 0.9112
3	T_f	^oF	-0.14605	-1.43501	RofR = 0.465
4	SS_{te}	$\#/D/1000FT^3$	0.69114	7.61130	s = 0.08319
5	L_{te}	$\#/D/1000FT^3$			Intercept = -0.24521

2. TESTS

a) Model

i) Residuals: No definite pattern in the plot of residuals was observed.

ii) U.N.D.: The Unit Normal Deviate form of the residuals indicate that only 1.2% of the transformed residuals fall beyond the allowable range at 5% -level.

b) Parameters: The computed 't' value for the temperature parameter being very close to the rejection level of t_c = 1.45, it was decided to maintain the parameter. All other parameters were observed to be significant in the regression.

3. EQUATION

$$L_{te} = \exp(-0.24521)\ L_{to}^{0.69747}\ HR^{-0.32346}\ T_f^{-0.14605}\ SS_{te}^{0.69114}$$

settling tank can be summarized as follows: overflow rate, sewage temperature, and loadings of both BOD and suspended solids, depending on whatever model is considered. Table 6.9 summarizes the secondary settling tank parameters for both BOD and suspended solids models.

TABLE 6.9

Parameters for Secondary Settling Tank Models

	ST2 Models	
Var. #	BOD Model	SS Model
1	L_{so} (#/DAY)	SS_{so} (#/DAY)
2	OR2 (GPD/FT^2)	OR2 (GPD/FT^2)
3	T_f (^oF)	T_f (^oF)
4	SS_{se_1} (#/DAY)	SS_{se_1} (#/DAY)
5	L_{se_1} (#/DAY)	

A. SS Model (ST2 - SS)

In the suspended solids efficiency removal model for the secondary settling tank, the use of all four variables listed in Table 6.9, did not prove to be the best selection. Table C-5, in Appendix C, indicates that the temperature parameter appears only to have a 'chance' influence on the removal characteristics of the suspended solids from the secondary settler.

Table 6.10, illustrates the regression of the data using variables No. 1, 2 and 4, and summarizes the properties of the suspended solids efficiency removal model for the secondary settler. The adopted model expressed as follows, yielded a R value of 0.9795.

$$\underline{ST2 - SS}: \quad SS_{se_1} = \exp(-2.12146)\ SS_{so}^{1.04553}\ OR2^{.20680} \qquad (6.10)$$

B. <u>BOD Model (ST2 - BOD)</u>

Regression of the data with all five variables appearing in Table 6.9 did not yield the best fit to the data. Moreover, the results of such an analysis, reported in Table C-6, in Appendix C, reveal a chance influence of the sewage temperature parameter on the BOD removal within the final settling tank.

Withdrawal of the sewage temperature variable resulted in an acceptable model, whose characteristics are summarized in Table 6.11. The adopted model described as follows, yielded a R value of 0.9779.

$$\underline{ST2 - BOD}: \quad L_{se_1} = \exp(-1.56093)\ L_{so}^{.45429}\ OR2^{.42325}$$

$$SS_{se_1}^{.38054} \qquad (6.11)$$

TABLE 6.10

ST2 - SS Model

1. REGRESSION RESULTS

#	Symbol	Units	Regression Coefficient	't' value	Miscellaneous
1	SS_{so}	#/D	1.04553	22.12563	R = 0.9795
2	OR2	GPD/FT^2	0.20681	3.36102	R^2 = 0.9594
3	SS_{se_1}	#/D			s = 0.07344
					Intercept = -2.12146

2. TESTS

a) Model

i) Residuals: No definite pattern in the plot of residuals was observed.

ii) U.N.D.: The Unit Normal Deviate form of the residuals revealed that none of the transformed residuals fall beyond the allowable range at 5% α-level.

b) Parameters: All of the computed 't' values indicate that the parameters are all significant in the regression.

3. EQUATION

$$SS_{se_1} = \exp(-2.12146)\ SS_{so}^{1.04553}\ OR2^{0.20681}$$

TABLE 6.11

ST2 - BOD MODEL

1. REGRESSION RESULTS

#	Symbol	Units	Regression Coefficient	't' value	Miscellaneous
1	L_{so}	#/D	0.45429	6.34489	R = 0.9779
2	OR2	GPD/FT^2	0.42325	5.69184	R^2 = 0.9562
3	SS_{se_1}	#/D	0.38054	4.86739	s = 0.08272
4	L_{se_1}	#/D			Intercept = -1.56093

2. TESTS

a) Model

i) Residuals: No definite pattern in the plot of residuals was observed.

ii) U.N.D.: The Unit Normal Deviate form of the residuals reveal that none of the transformed residuals fall beyond the allowable range at 5% α-level.

b) Parameters: All of the computed 't' values indicate that the selected parameters are significant in the regression.

3. EQUATION

$$L_{se_1} = \exp(-1.56093)\ L_{so}^{0.45429}\ OR2^{0.42325}\ SS_{se_1}^{0.38054}$$

6.5 Summary

The mathematical models resulting from the linear regression analysis of the data are summarized in Table 6.12.

The models in subsystem configuration No. 1, (Figure 6.1) are used in a subsequent chapter (Chapter 8) of this report to compare the postulated removal efficiencies with other reported mathematical models commonly used in designing trickling filter installations.

The models in subsystem configuration No. 2, (Figure 6.2) are utilized in the next chapter for the sensitivity analysis and simulation of the treatment plant performance as a whole.

6.6 Discussion on the Actual Structure of the Selected Models

6.6.1 General

This section will attempt to explain and comment on any peculiarities found in the proposed mathematical models. The explanations put forward are based on i) biological and physical mechanisms, governing the processes, and ii) the work and experience of other researchers that have dealt with similar situations.

6.6.2 Primary Tank Models

The overflow rate, affecting the horizontal velocity within the settling tank, and the temperature, governing the viscosity of the water and consequently the

TABLE 6.12

Summary of the Developed Mathematical Models

PT1 - SS $SS_{pe}=\exp(1.84233)\ SS_{po}^{.46764}\ OR1^{.56284}\ T_f^{-.19160}$ R:.9184	PT1 - BOD $L_{pe}=\exp(-2.40023)\ L_{po}^{.62517}\ OR1^{.58027}\ T_f^{-.11353}\ R_*^{.30668}\ SS_{pe}^{.23933}$ R:.9586
TF1 - SS $SS_{se}=\exp(.89311)\ SS_{to}^{1.00296}\ R_*^{-1.21150}\ T_f^{-0.62581}\ L_{to}^{0.26202}$ R:.9635	TF1 - BOD $L_{se}=\exp(0.47213)\ L_{to}^{.58288}\ R_*^{-1.42804}\ T_f^{-0.21815}\ SS_{se}^{.43519}$ R:.9546
TF2 - SS $SS_{te}=\exp(2.11470)\ SS_{to}^{.94714}\ HR^{-.66828}\ R_*^{-.26370}\ T_f^{-.42106}\ L_{to}^{.34864}$ R:.9409	TF2 - BOD $L_{te}=\exp(-0.24521)\ L_{to}^{.69747}\ HR^{-0.32346}\ T_f^{-0.14605}\ SS_{te}^{.69114}$ R:.9546
ST2 - SS $SS_{se_1}=\exp(-2.12146)\ SS_{so}^{1.04553}\ OR2^{0.20681}$ R:.9795	ST2 - BOD $L_{se_1}=\exp(-1.56093)\ L_{so}^{0.45429}\ OR2^{.42325}\ SS_{se_1}^{.38054}$ R:.9779

settleability of the solids, are two parameters of known importance in the BOD and suspended solids removal efficiency of the primary settling tank. Therefore, as expected, both parameters have been included in both the BOD and suspended solids removal efficiency formulations.

Since the recirculated flow from the trickling filter effluent is a direct input into the primary settler, it was decided to test the significance of a dimensionless number representing the ratio of the flow through the tank to the flow entering the plant (recirculation ratio) on both BOD and suspended solids removal efficiencies. The recirculation ratio parameter proved however to be statistically non-significant for the suspended solids removal model. However, statistical evidence indicated its importance in the BOD removal model. Moreover, it was also observed that high recirculation ratios have a detrimental effect on the BOD removal process taking place in the primary tank. Explanations to such a phenomenon appear to lie in the characteristics of the sewage. The BOD of the raw sewage has been reported earlier to be approximately 70% in the suspended solid state and 30% dissolved. Trickling filter effluent is however expected to have a much lower BOD concentration in the suspended solids form with a corresponding higher dissolved BOD fraction. Consequently high recirculation ratios have a tendency to increase the percentage of dissolved BOD fraction. Consequently, high recirculation ratios have a tendency to increase the percentage of dissolved BOD entering the primary tank, which cannot be removed through settling within the settling tank. The lower fraction of suspended solids accompanying high recirculation ratios tends, therefore, to decrease BOD removal efficiencies because large BOD fractions are in the dissolved state.

6.6.3 Trickling Filter - Final Settling Tank

Because of specific BOD removal mechanisms within the stone filter media the TF1 - SS model included as one of its parameters the BOD applied to the trickling filter system. The organic matter is used by the microorganism population for their metabolism. The applied BOD is therefore a direct parameter in the suspended solids removal mechanism because it enhances the production of suspended solids. This does not however imply a net suspended solids production within the trickling filter unit. In fact Grantham (23) observed a net suspended production within the first section of the filter unit, reaching at times as much as 100%. However, such a suspended solids concentration soon decreased well below the applied levels in the latter portions of the filter. In fact, as indicated by the present model, Grantham (23) observed a net suspended solids removal ranging from 40 to 70% within the trickling filter unit alone.

The effluent suspended solids loading was also used as input parameters in the TF1 - BOD model, as explained previously. Both suspended solids and BOD models did not prove to be sensitive to the hydraulic rate of flow, nor did it seem affected by secondary settling tank overflow rate as might have been inferred through the literature survey.

6.6.4 Trickling Filter Unit

The trickling filter unit models, (BOD and suspended solids) differ from one another in only one parameter, i.e. recirculation ratio. Even though it appears ~~that~~ the BOD model is not sensitive to variations in the recirculation ratio, it can very well be established that their exists a recirculation influence reflected within the model. In fact the effluent suspended solids is a function of the recirculation ratio, and because the effluent BOD is also a function of the effluent suspended solids, variations in the recirculation ratio will consequently affect the BOD of the effluent.

Obviously the same comment, concerning the BOD loading applied to the unit, in the suspended solids model reported under Section 6.6.3, still applies to the trickling filter unit model.

6.6.5 Secondary Settling Tank

Secondary settling tank models are not as elaborate as the previous models because of the reduced number of possible parameters in the performance evaluation of BOD and suspended solids removal efficiencies. In fact the overflow rate, sewage temperature and effluent suspended solids were the only possible significant parameters in the mathematical model building process.

The temperature parameter revealed to be non-significant in both the BOD and suspended solids models, while the overflow rate was observed to be the most significant parameters for both removal processes within the secondary settling tank.

CHAPTER 7

SENSITIVITY ANALYSIS

7.1 Theory

The objective of this chapter is to identify parameters of significant or critical importance in the operation of a high rate trickling filter plant, such as described mathematically in Chapter 6. Sensitivity analysis of a system, or of a mathematical model, offers means of delineating such responses. Input components to a system form the core information to the performance simulation and are considered essential to the sensitivity analysis. The concept underlying the technique is relatively straightforward: all of the input parameters are held constant with the exception of one parameter, which is allowed to vary through its entire range. The response, i.e. the system's behaviour to such variations, is observed and analysed.

A procedure adopted by MacBeath and Eliassen (52) has been used to analyse the sensitivity of mathematical models to the various input parameters (or independent variables). The selected technique is presented hereafter:

1. List the independent variables of the model. Provide three values for each - expected high, low and nominal values.

2. Calculate the response surface variable using the nominal value. This value will serve as a reference point.

3. Compute a percentage change in the response surface by substituting one of the high values of one of the independent variables. Replace the high value with the nominal value.

4. Repeat Step 3 for each of the high and low values.

Such a procedure, should then delineate the important parameters in the systems performance. Care should, however, be exercised so as to determine interdependencies among the parameters and thus possibly analyse group variations of the variables.

7.2 Sensitivity Analysis: Sewage Characteristics

7.2.1 Characteristics of the Algorithm

The objective of the algorithm described hereafter, and whose listing appears in Appendix D, is to simulate the operation of the Alexandria sewage treatment plant, so as to delineate parameters of significant importance in the overall BOD and suspended solids removal efficiencies of the system. Stream vectors at various stations are evaluated along with the efficiency of the various units. The performance evaluation proceeds using the mathematical formulations developed from configuration No. 2, in Section 6.3 (Figure 6.2).

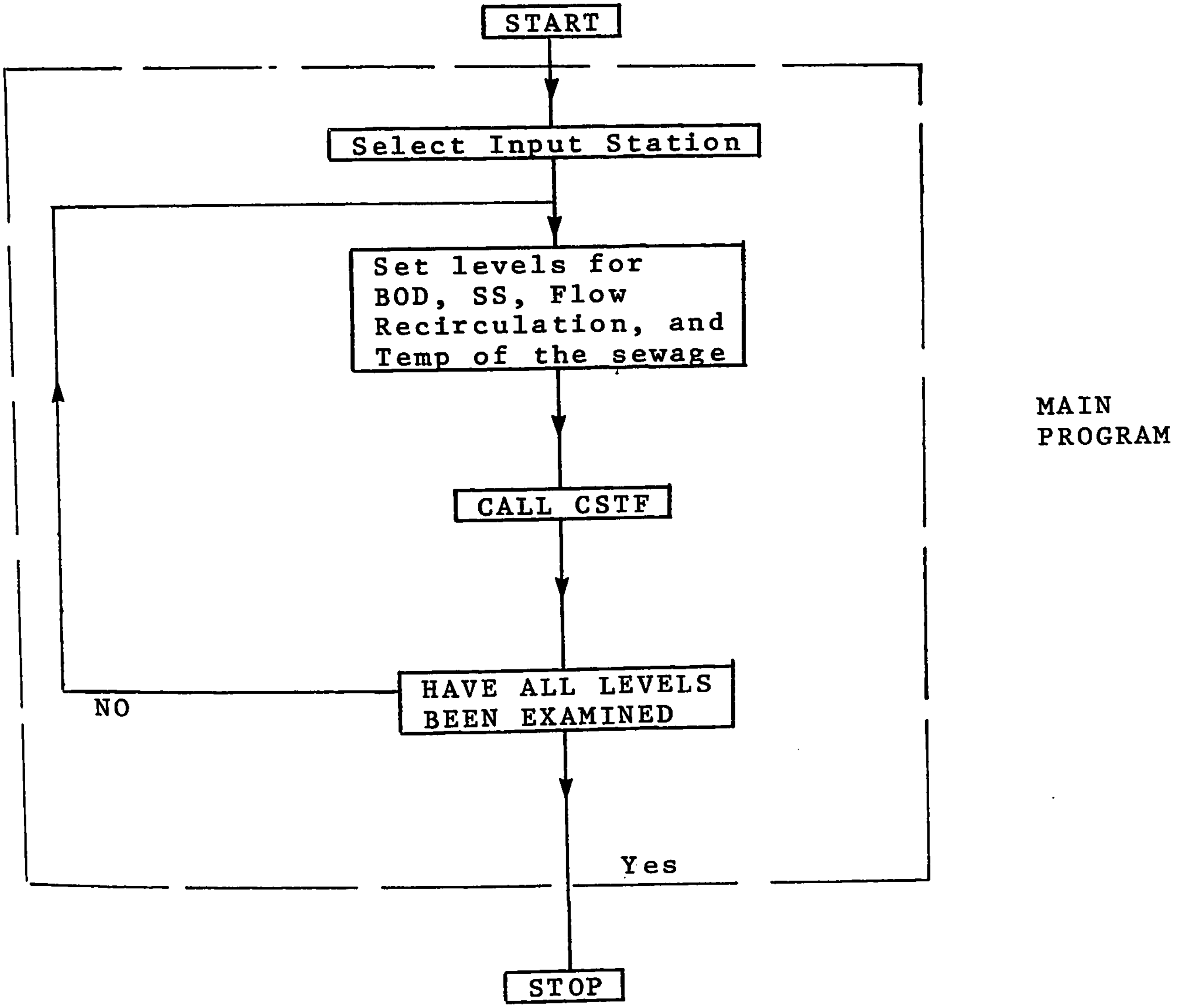
The flow chart, as shown in Figure 7.1, illustrates the principles underlying the calculations. The overall process can be viewed as three groups of equations in series subjected to a convergence criterion in the characteristics (BOD and suspended solids) of the trickling filter recirculated flow. The program referred to as CSTF (Computer Simulation of a Trickling Filter) was written in Fortran IV, for use on an IBM 360/65 computer.

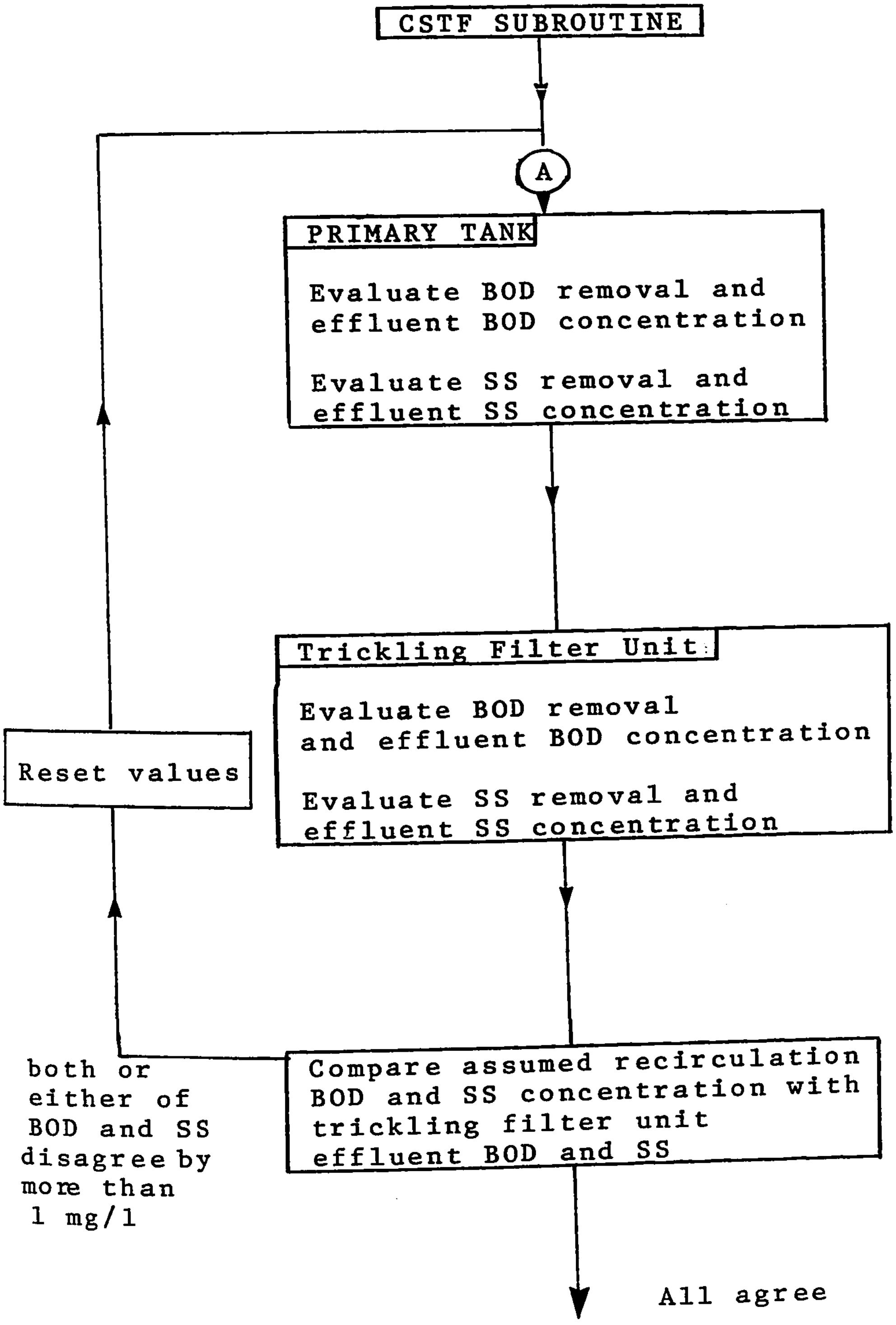
7.2.2 Input Data

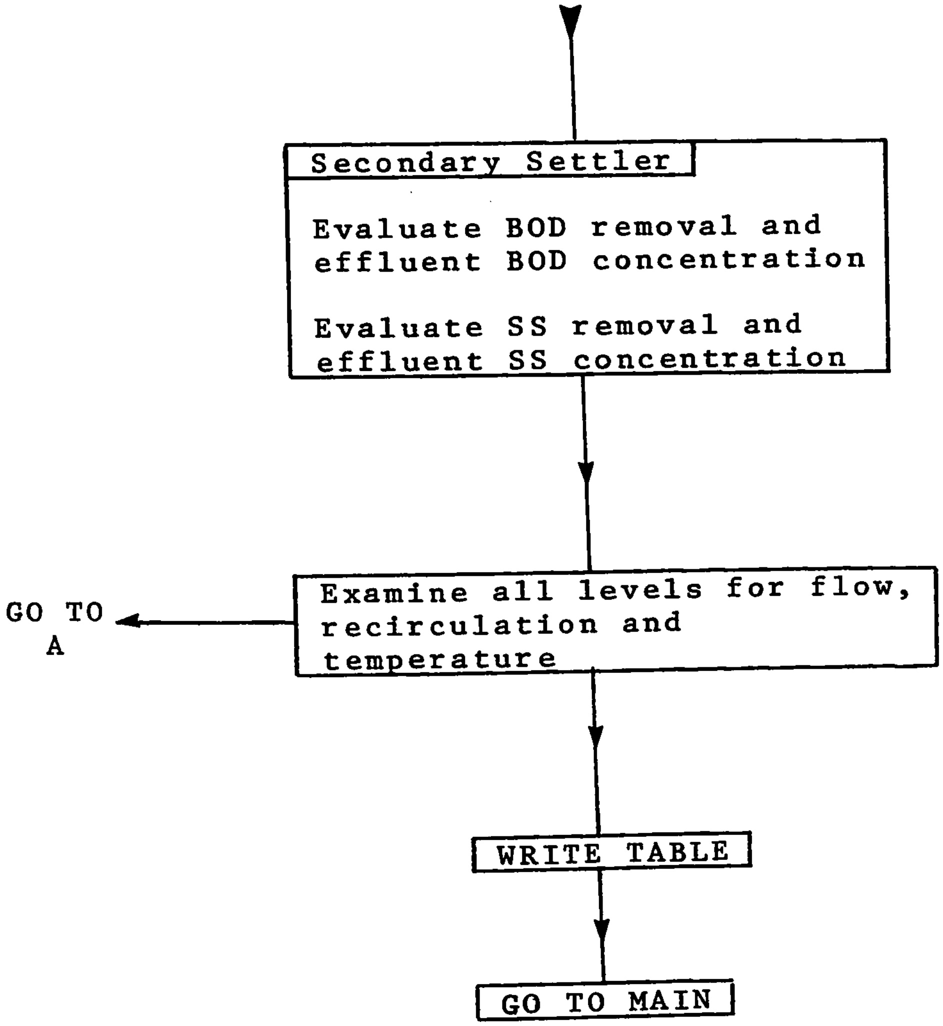
The flow diagram of the Alexandria sewage treatment plant, Figure 4.2, indicates two possible stream vector locations that could be used as input stations to the simulation and sensitivity analysis, namely station No. 2 and station No. 4, of Figure 4.2. Consideration of the objectives, presented in Chapter 3, dictates the selection of station No. 4 as input station. The input station thus selected gives the readers the opportunity to examine and appreciate more explicitly the effects of recirculation on the performance of the plant. Because of the particular physical layout of the treatment plant, the selection of the alternate input station, i.e. station No. 2, would have complicated the objectives somewhat. In fact, a change in the recirculation would have implied a simultaneous change in the flow rate through the plant. Therefore, variations in the

FIGURE 7.1

FLOW CHART FOR THE CSTF PROGRAM




CSTF SUBROUTINE
A
PRIMARY TANK
Evaluate BOD removal and effluent BOD concentration
Evaluate SS removal and effluent SS concentration
Trickling Filter Unit
Evaluate BOD removal and effluent BOD concentration
Evaluate SS removal and effluent SS concentration
Reset values
Compare assumed recirculation BOD and SS concentration with trickling filter unit effluent BOD and SS
both or either of BOD and SS disagree by more than 1 mg/1
All agree


Secondary Settler
Evaluate BOD removal and effluent BOD concentration
Evaluate SS removal and effluent SS concentration
Examine all levels for flow, recirculation and temperature
GO TO A
WRITE TABLE
GO TO MAIN

recirculation ratio parameter would have resulted in a joint variation of the rate of flow, making it difficult to evaluate the origins of the performance variations. The reader must, however, understand that the selection of station No. 4 as the input station, has been selected only because it is the objective of this paper to ascertain whether the ratio of recirculated flow, under constant hydraulic conditions bears some influence on the removal mechanisms. Furthermore, the reader must understand that station No. 4 would not be the selected input station for a true computer performance simulation. Under such circumstances, the selection of input station No. 2 would be dictated and very minor changes in the CSTF program would be necessary. In summary, therefore, input station No. 4 has been selected for the sensitivity analysis of the models, whereas input station No. 2 must be selected for a true performance simulation of the plant as would be required for computer assisted plant operation.

Two separate sensitivity analyses for the changes in sewage characteristics were carried out. The first, consisted in evaluating the percentage change in the sewage characteristics (BOD and suspended solids) through the entire plant subjected to input parameter variations. The second, evaluated the percentage change in BOD and suspended solids removal efficiencies of the individual treatment units for which mathematical models had been developed, subjected to similar input parameter variations.

The input matrix presented in Table 7.1 was utilized for the sensitivity analysis of the treatment plant as a whole. It consists of the three stream vectors, found at station No. 4 (BOD, suspended solids, and flow) plus the recirculation and temperature parameters for high, mean and low expected conditions. A total of 243 simulations, covering all possible levels of operation within the range of the available data resulted from such an analysis. The results of this first sensitivity analysis are reported in Appendix E.

Table 7.2, describes the four input matrices used in the sensitivity analysis of each individual treatment unit, the results of which are summarized in Table 7.4.

TABLE 7.1

Input Matrix for the Sensitivity Analysis of the Treatment Plant as a Whole

Parameters	High	Mean	Low
BOD mg/1	240	169	125
SS mg/1	278	178	119
Flow MGD	31.06	24.29	15.70
Recirculation	1.57	1.31	1.05
Sewage Temp ^{o}F	78	67	56

TABLE 7.2

Input Matrices for the Sensitivity Analysis of the Individual Treatment Units

PRIMARY SETTLING TANK

Parameters	High	Mean	Low
BOD mg/1	240	169	125
SS mg/1	278	178	119
Flow MGD	31.06	24.29	15.70
Recirculation	1.57	1.31	1.05
Sewage Temp °F	78	67	56

SECONDARY SETTLING TANK

Parameters	High	Mean	Low
BOD mg/1	103	79	55
SS mg/1	91	70	49
Flow MGD	24.05	18.50	12.95
Recirculation	1.57	1.31	1.05
Sewage Temp °F	78	67	56

TRICKLING FILTER SYSTEM

Parameters	High	Mean	Low
BOD mg/1	152	117	87
SS mg/1	117	90	63
Flow MGD	31.01	24.25	15.67
Recirculation	1.57	1.31	1.05
Sewage Temp °F	78	67	56

TRICKLING FILTER UNIT

Parameters	High	Mean	Low
BOD mg/1	152	117	87
SS mg/1	117	90	63
Flow MGD	31.01	24.25	15.67
Recirculation	1.57	1.31	1.05
Sewage Temp °F	78	67	56

7.2.3 Analysis and Results

Table 7.3 summarizes the percentage change in the sewage characteristics through the treatment plant when subjected to the input matrix shown in Table 7.1. Table 7.4 offers a summary of the percentage change in the sewage characteristics of each individual treatment units when subjected to specific variations in the input parameters, as described in matrix form in Table 7.2. Moreover, Tables 7.3 and 7.4 also examine the effects of dry and wet weather flow conditions on the sewage characteristics through the treatment plant, and on the efficiency of each treatment units as indicated in Tables 7.3 and 7.4, resepctively. Dry weather flow conditions are characterized by high BOD and suspended solids, accompanied by low flows, while wet weather flow conditions prevail under low BOD and suspended solids, and high flows.

Analysis of the sensitivity test results will hereafter be presented. A response greater than or equal to ±15% has been selected as a criterion for sensitivity (42). Several situations have been considered for both the sensitivity of the treatment plant as a whole and of the treatment units individually. Table 7.5 summarizes these situations, identified as A through F, and corresponding to BOD, suspended solids, recirculation, temperature, and weather variations, respectively.

TABLE 7.3

Progressive Percentage Change in the Sewage Characteristics of the Treatment Plant as a Whole

						Primary Tank Effluent				Trickling Filter Effluent				Secondary Settling Tank Effluent			
						BOD		SS		BOD		SS		BOD		SS	
	BOD	SS	FLOW	R	T	mg/1	% Δ	mg/1	% Δ	mg/1	% Δ	mg/1	% Δ	mg/1	% Δ	mg/1	% Δ
	A	A	A	A	A	117		90		79		70		50		51	
A	+30					146	+24.8	90	0.0	95	+20.3	74	+5.7	56	+12.0	54	+5.9
	-30					97	-17.1	90	0.0	66	-16.4	64	-8.6	45	-10.0	46	-7.9
B		+30				123	+5.1	111	+23.1	93	+17.7	83	+18.5	58	+16.0	61	+19.7
		-30				112	-4.3	75	-18.7	67	-15.2	57	-18.5	43	-14.0	41	-19.7
C			+30			131	+11.9	91	+0.0	82	+3.8	66	-5.7	55	+10.0	55	+7.8
			-30			96	-17.9	89	-2.2	71	-10.2	74	+5.1	42	-16.0	48	-5.9
D				+20		124	+6.0	90	0.0	80	+1.3	71	+1.4	48	-4.0	49	-3.9
				-20		109	-6.8	90	0.0	77	-2.5	71	+1.4	54	+8.0	55	+7.8
E					+15	114	-2.6	88	-3.3	71	-10.2	62	-11.4	46	-8.0	45	-11.8
					-15	120	+3.3	93	+3.3	88	+11.4	76	+ 8.5	55	+10.0	55	+7.8
F	+30	+30	-30			126	+7.7	110	+20.9	103	+30.5	98	+40.0	56	+12.0	65	+27.5
	-30	-30	+30			103	-11.1	75	-17.6	60	-24.1	51	-27.1	43	-14.0	39	-23.6

TABLE 7.4

Percentage Change in the Sewage Characteristics of the Individual Treatment Units

	BOD	SS	FLOW	R	T	Primary Tank		Trickling Filter-Final Settler System		Trickling Filter System		Secondary Setting Tank	
						BOD	SS	BOD	SS	BOD	SS	BOD	SS
A	+30					+24.8	0.0	+19.7	+6.5	+20.0	+6.0	+11.8	0.0
	-30					-17.1	0.0	-19.7	-9.7	-18.0	-8.0	-15.7	0.0
B		+30				+5.1	+23.1	+12.9	+29.8	+12.0	+28.0	+11.8	+33.4
		-30				-4.3	-18.7	-16.1	-32.3	-14.0	-30.0	-13.7	-33.4
C			+30			+11.9	0.0	+3.2	+6.5	+4.0	+6.0	+9.8	+7.8
			-30			-17.9	-2.2	-6.5	-12.9	-6.0	-8.0	-11.8	-7.8
D				+20		+6.0	0.0	-29.0	-19.3	-10.0	-4.0	0.0	0.0
				-20		-6.8	0.0	+54.8	+29.0	+12.0	+4.0	0.0	0.0
E					+15	-2.6	-3.3	-6.5	-9.7	-8.0	-10.0	0.0	0.0
					-15	+3.3	+3.3	+9.7	+12.9	+8.0	+10.0	0.0	0.0
F	+30	+30	-30			+7.7	+20.9	+25.8	+22.6	+26.5	+22.0	+9.8	+19.6
	-30	-30	+30			-11.1	-17.6	-32.3	-35.5	-28.0	-32.0	-19.6	-25.5

Table 7.5

Selected Input Conditions

BOD	SS	Flow	R	T	Analysis	Remark
±30%					A	Individual Variation
	±30%				B	
		±30%			C	
			±20%		D	
				±15%	E	
±30%	±30%	±30%			F	Group Variation

Analysis A: Variations in the BOD concentration entering the primary settling tank, produces significant variations in the effluent BOD leaving both the primary settler and the trickling filter unit, as reported in Table 7.3. In fact, an increase in the BOD concentration at station No. 4, Figure 4.2, results in an increase BOD concentration throughout the entire plant. The effects appear, however, to be attenuated as the wastewaters progress through the units. The BOD of the effluent from the primary tank and trickling filter unit showed significant variations, while the overall BOD plant response can be termed as moderately sensitive. In all cases an increase in the input BOD concentration resulted in an increase BOD from the various units of the treatment plant, and vice versa.

As expected the suspended solids of the sewage throughout the treatment plant appeared only to suffer moderate variations with respect to BOD input changes. An increase in the BOD applied to the treatment plant, resulted in a moderate increase in the suspended solids of the wastewaters throughout, with a similar inverse effect.

As far as the individual units are concerned, most units showed a significant effluent BOD increase, resulting from the application of higher BOD concentrations to the units individually. The secondary settling tank unit, showed the least significant variations but the change is still considered to be significant. In all instances increased input

BOD concentrations resulted in increased effluent BOD concentrations, and vice versa.

The suspended solids concentration in the effluent of the individual unit was either non sensitive to BOD variations (as was observed for the primary settler and secondary settler units), or moderately affected (as observed with the trickling filter unit and the trickling filter system). In both instances, an increased BOD concentrations resulted in higher suspended solids concentrations in the effluent of the individual units, but the effect was not significant.

Analysis B: Variations in the concentration of suspended solids applied to the primary tank produced significant variations in the suspended solids concentration of the effluent throughout the treatment plant. The progressive percentage suspended solids changes, as reported in Table 7.3, were all significant. More specifically, the application of higher suspended solids concentrations produced equivalently higher concentrations of suspended solids in the effluent throughout, and vice versa. In fact, a 30% increase in the applied suspended solids concentration resulted in an overall increase of 19.7% in the effluent suspended solids concentration.

Because of the actual structure of the models and their dependency, high suspended solids resulted in significantly higher trickling filter effluent and final effluent BOD. The opposite variation having, as expected, the inverse effect on the trickling filter and final effluent BOD.

The response of the individual treatment units to suspended solids variations, is reported in Table 7.4. The percentage change in the effluent suspended solids from all of the units revealed significant. In fact, all units showed higher effluent suspended solids concentration corresponding to the application of higher suspended solids concentration, and vice versa. Moreover, the trickling filter unit and the trickling filter system showed similar significant variation in their effluent BOD concentration. The trickling filter system responded by a 16.1% decrease in BOD concentration, corresponding to a 30% decrease in the applied suspended solids concentration. A similar percentage increase was observed with higher suspended solids concentrations.

Analysis C: The effects of flow variations onto the percentage change in the sewage characteristics (BOD and suspended solids) is reported in Table 7.3. As far as the progressive change in effluent BOD throughout the plant is concerned, the upper flow limit yielded higher BOD concentrations throughout, with an overall plant BOD increase of 10%. The behaviour of the plant to lower flow levels was, however, more sensitive, yielding a 16% decrease in the effluent BOD concentration. The effluent suspended solids concentration, however, did not reveal sensitive to flow variations. In fact, the primary settling tank showed negligible responses to flow variations even of the order of ±30%. This phenomena can most probably be accounted for by a fairly conservative hydraulic design, unaffected by flow variations. The overall percentage change in the suspended solids was found to be moderately sensitive, with higher effluent suspended solids accompanying higher flows, and vice versa.

Individually, the treatment units responded differently. Both settling tanks, showed moderate BOD and suspended solids variations accompanying flow variations with the exception of the primary settler suspended solids removal. High flows resulted in moderately higher BOD and suspended solids concentrations. However, the biological unit, i.e. the trickling filter unit, showed a different response. Higher flows in this case appeared to decrease both suspended solids and BOD concentrations, while lower flows produced the opposite effect. Such a response appears to corroborate the theories of increased BOD removal under turbulent flow regime.

Analysis D: The recirculation ratio effects onto the percentage change in the sewage characteristics for the treatment plant as a whole are presented in Table 7.3. Even though high recirculation ratios do not appear to benefit primary tank BOD removal, the overall effect on the treatment plant is, however, different. In fact, higher recirculation ratios have a tendency to decrease plant effluent BOD, while lower recirculation hinders plant performance by increased effluent BOD concentration. The same general pattern is also observed with the suspended solids in the plant effluent, as shown in Table 7.3.

As far as the individual treatment units are concerned, both primary and secondary settling tanks, suspended solids removal, along with the BOD removal in the secondary settler, are not sensitive to recirculation ratio variations. The data in Table 7.4 indicates that high recirculation ratios produce higher primary effluent BOD, and vice versa. However, a considerable decrease in the trickling filter system BOD and suspended solids concentration accompanies higher recirculation ratios. A similar effect is also observed within the trickling filter unit under identical conditions, but to a much lesser extent. The explanation to such a response appears to lie in the fact that lower secondary tank overflow rates accompany high recirculation ratios, thus giving more opportunity for both BOD and suspended solids removal.

Analysis E: The data presented in Table 7.3 illustrates that a better effluent quality, both in BOD and suspended solids, is obtained with higher sewage temperatures. The progressive sewage characteristics, indicate a moderate decrease in effluent BOD and suspended solids concentrations with a rise in sewage temperature of approximately 15%.

Individually, the subsystems follow a similar pattern, with the exception of the final settling tank, which has shown to be non-sensitive to temperature variations. All other units, under individual analysis, have shown a moderate increase in the BOD and suspended solids concentrations, accompanying lower temperatures, and vice versa.

Analysis F: The results of the sensitivity analysis, simulating dry and wet weather flow conditions reveal that overall significant increases in the waste characteristics, both BOD and suspended solids, accompany dry weather flow conditions. Wet weather flow conditions are characterized by a decrease in both BOD and suspended solids concentrations of the wastewaters throughout the treatment plant.

Individually, the subsystems responded in the same manner, showing significant BOD and suspended solids concentration increase when dry weather flow conditions prevailed, and vice versa.

7.3 Sensitivity Analysis: Sludge Production

7.3.1 General

The sludge to be disposed from the treatment plant originates from two different sources: the primary and the secondary settling tanks. Because of the costs, capital and maintenance, associated with the handling and pumping of sludge, a sensitivity analysis examining the change in the total sludge production with corresponding variations in the input parameters was motivated. The input matrix presented in Table 7.1 was used to establish the desired responses. Table 7.6 shows the change in primary, secondary and total sludge production resulting from the different input situations. Moreover, the proportion of primary and secondary sludge is also reported in the Table. The conditions summarized in Table 7.5 have been selected to analyse more systematically the results.

7.3.2 Sludge Production Analysis

The following section summarizes the general sludge production responses to the specified input parameter variations.

Analysis A: The percentage change in the total sludge production, i.e. primary plus secondary, as illustrated in Table 7.6 revealed to be non-sensitive to BOD variations. The negligible trend observed in total sludge production indicated a very small increase in the pounds of sludge to be disposed with high BOD concentrations, and vice versa. The secondary sludge production appeared to be more sensitive. However, secondary sludge production generally accounts for only 10 to 15% of the total sludge production.

TABLE 7.6

Sludge Production

BOD	SS	FLOW	R	T	Primary Sludge			Secondary Sludge			Total Sludge	
					Pounds	%Change	% Comp	Pounds	%Change	%Comp	Pounds	%Change
A	A	A	A	A	17710	0.0	86.0	2883	0.0	14.0	20593	0.0
+30					17710	0.0	85.4	3026	+5.0	14.6	20737	+0.7
-30					17710	0.0	86.9	2665	-7.6	13.1	20375	-1.1
	+30				33714	+90.4	91.0	3343	+16.0	9.0	37057	+80.0
	-30				8906	-49.7	78.7	2408	-16.5	21.3	11314	-45.1
		+30			22469	+26.9	88.6	2891	+0.2	11.4	25360	+22.4
		-30			11603	-34.5	82.15	2521	-12.6	17.85	14124	-31.4
			+20		17710	0.0	86.6	2615	-5.2	13.4	20325	-0.7
			-20		17710	0.0	85.2	3073	6.3	14.8	20783	+0.9
				+15	18236	+3.0	87.6	2591	-10.1	12.4	20826	+1.1
				-15	17068	-3.6	84.6	3098	+7.5	15.4	20166	-2.1
+30	+30	-30			21984	+24.1	87.1	3253	+12.8	12.9	25237	+22.6
-30	-30	+30			11243	-36.5	82.9	2326	-19.3	17.1	13569	-34.1

Analysis B: The results of the sensitivity analysis simulating suspended solids variations, reported in Table 7.6, indicate that noticeable increases in sludge production result from the application of high suspended solids concentration, and vice versa. The sludge production from the primary settling tank is as expected the most affected. Secondary sludge production variation revealed less significant, but the same general pattern was still observed.

Analysis C: The results of the analysis simulating flow variations, indicated sludge production to be sensitive to changes in the rates of flow. In fact, higher rates of flow resulted in an increased total sludge production which can be accounted for by higher applied suspended solids loadings. As expected, lower rates of flow resulted in a decrease in sludge production.

Analysis D: Variations in the recirculation ratios, as reported in Table 7.6, have a negligible influence upon the production of sludge from the treatment plant as a whole. A moderate decrease in secondary sludge production was observed at high recirculation ratios. However, because of the relatively greater importance of primary sludge production the overall effect was observed to be negligible.

Analysis E: Temperature variations also showed a negligible influence upon the total sludge production. The general trend observed, indicated that with a 10% increase in temperature, total sludge production increased by only 1.1%.

Analysis F: Dry and wet weather flow conditions results, reported in Table 7.6, indicate significant sludge production variations. Under dry weather flow conditions sludge production was observed to increase by over 20% while under wet weather flow conditions, sludge handling decreased by nearly 35%.

CHAPTER 8

TRICKLING FILTER EFFICIENCY COMPARISON

8.1 Introduction

The purpose of this chapter is to evaluate the actual BOD performance and efficiency of the Alexandria sewage treatment plant, as described by the mathematical models developed earlier and to compare such performance with other well-known trickling filter models.

Because of the characteristics and features of most mathematical models used in designing trickling filter installations (Table 2.1), the efficiency comparison has been performed by using the trickling filter-final settling tank subsystem. A wide range of operating conditions has been selected to examine the response of the models, thus revealing the overall predictive efficiency. Table 8.1 summarizes the average, maximum and minimum expected input values to the trickling filter-final settling tank subsystem. Even though the predictive performance equations for the Alexandria sewage treatment plant have established BOD removal to be dependent upon the effluent suspended solids loading from the unit, none of the reported design equations have ever considered such a dependency.

Table 8.2 illustrates the thirteen different levels, or input vectors, used to compare the performance of the treatment plant.

TABLE 8.1

Input Parameter Levels

Input Parameter	Minimum	Average	Maximum
BOD (mg/l)	87	117	152
SS (mg/l)	63	90	117
Flow (MGD)	15.67	24.25	31.01
Recirculation	1.05	1.31	1.57
Sewage Temp °F	56	67	78

Six mathematical models, selected from Table 2.1, have been used for comparison with the Alexandria sewage treatment plant. These are the equations of: i) National Research Council (U.S.), ii) Ten State Standards, iii) Velz, iv) Rankin, v) Eckenfelder, and vi) Galler and Gotaas. The analysis therefore has, for the main purpose, the identification of those models that represent most closely actual plant performance, under varied input situations.

8.2 Analysis and Discussion

The response of the various mathematical models to the thirteen input vectors of Table 8.2 has been summarized in Table 8.3. By using the mean of the absolute value of the difference as a measure of the goodness of fit for each mathematical model tested a better appreciation of the

TABLE 8.2

Trickling Filter-Final Settling Tank Input Vectors

	BOD	SS	Flow	Recirculation	Sewage T °F
1	117	90	24.25	1.31	67
2	87	90	24.25	1.31	67
3	152	90	24.25	1.31	67
4	117	63	24.25	1.31	67
5	117	117	24.25	1.31	67
6	117	90	15.67	1.31	67
7	117	90	31.01	1.31	67
8	117	90	24.25	1.05	67
9	117	90	24.25	1.57	67
10	117	90	24.25	1.31	56
11	117	90	24.25	1.31	78
12	152	117	15.67	1.31	67
13	87	63	31.01	1.31	67

TABLE 8.3

Response of the Selected Mathematical Models

BOD	SS	FLOW	R	T	A.S.A.	NRC		VELZ		RANKIN		ECKENFELDER		GALLER AND GOTAAS		TEN STATES STANDARDS*	
					EFF.	EFF.	|DIF.|	EFF.	|DIF.|	EFF.	|DIF.|	EFF.	|DIF.|	EFF.	|DIF.|	EFF.	|DIF.|
A	A	A	A	A	57.3	70.2	12.9	76.9	19.6	72.4	14.6	61.1	3.8	63.2	5.9	-	-
+					60.6	67.4	6.8	76.9	16.3	72.4	11.8	61.1	0.5	61.3	0.7	-	-
-					53.3	73.2	19.9	76.9	23.6	72.4	19.1	61.1	7.8	65.2	11.9	-	-
	+				52.2	70.2	18.0	76.9	24.7	72.4	20.2	61.1	8.9	63.2	11.0	-	-
	-				63.5	70.2	6.7	76.9	13.4	72.4	8.9	61.1	2.4	63.2	0.3	-	-
		+			55.9	67.6	11.7	76.9	21.0	72.4	16.5	58.2	2.3	62.1	6.2	-	-
		-			59.8	74.6	14.8	76.9	17.1	72.4	12.6	66.2	6.4	65.2	5.4	-	-
			+		61.2	73.4	12.2	76.9	15.7	75.8	14.6	61.1	0.1	61.3	0.1	-	-
			-		52.2	66.0	13.8	76.9	24.7	67.7	15.5	61.1	8.9	65.4	13.2	-	-
				+	60.4	70.2	9.8	76.9	16.5	72.4	12.0	61.1	0.7	64.7	4.3	-	-
				-	53.4	70.2	16.8	76.9	23.5	72.4	19.0	61.1	7.7	61.0	7.6	-	-
+	+	-			58.3	72.0	13.7	76.9	18.6	72.4	14.1	66.2	7.9	60.3	2.0	-	-
-	-	+			58.7	70.8	12.1	76.9	18.2	72.4	13.7	58.2	0.5	65.8	7.1	-	-
				∑ =			169.2		252.9		192.6		57.9		75.7		
				MEAN =			13.02		19.46		14.82		4.45		5.82		

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*BOD loading is beyond allowable range, indicating an efficiency less than 68% in all instances.

models will have been gained. These statistics have also been reported in Table 8.3.

Thus, the information presented in Table 8.3 indicates fairly clearly that the models of Eckenfelder and of Galler and Gotaas represent more closely actual plant performance. Even though the models disagree in some particular instances with predicted plant performance, the results reported in Table 8.3 indicate that the mean of the absolute value of the difference for Eckenfelder's model is 4.45% while that for Galler and Gotaas' model is observed to be 5.82%.

The models of Rankin, Velz and the NRC do not agree very well with the estimated plant performance. The lack of agreement between these models and reported plant performance comes about from the actual concepts underlying their development. In fact, BOD removal efficiencies have been established on only a few parameters, some of which do not very clearly influence the BOD removal process.

As far as the Ten State Standards model is concerned, the BOD loadings calculated from the selected input conditions fell beyond the Ten State Standard limit of 50 pounds per thousand cubic feet indicating only that BOD removal must be less than 68% in all instances.

This straightforward analysis has illustrated that even though the process is physically straightforward, the removal (biological and physical) mechanisms are not well defined. It would therefore be impossible to retain one specific mathematical model, to represent under all circumstances the BOD removal efficiency of the trickling filter system. In fact, it can be stated with much certainty that the models, whatever they be, can only approximate the BOD removal process within the trickling filter system, and that no universal model can at this stage be suggested.

CHAPTER 9

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FUTURE RESEARCH

9.1 Summary

Computer simulation of a high rate trickling filter installation was performed through the mathematical model building of eight representative BOD and suspended solids removal efficiency equations, summarized in Table 6.12. Mathematical expressions for all major units of the treatment plant were developed for both BOD and suspended solids removal evaluation. The simulation process is based on seven years of operational data, collected from the Alexandria sewage treatment plant, Virginia, covering a wide range in both sewage characteristics and flow conditions. The relevance of this investigation was further motivated by the fact that the plant, designed in the early 50's will soon (1973) reach ultimate design flow conditions.

Various forms of mathematical models were evaluated, ranging from first and second order polynomials to exponential and multiplicative non linear models. After examining the fitness of the models to the field data, the intrinsically linear multiplicative model was finally adopted to represent the removal efficiencies,for both BOD and suspended solids, of the units. Both linear and non linear regression algorithms were evaluated in regressing the available data. The multiple linear regression technique was observed to best fit the data, and was selected for all of the mathematical formulations.

Because most trickling filter mathematical models evaluate the performance of both the trickling filter unit along with the secondary settling tank, and because the specific performance of the trickling filter unit is also of interest in the present investigation, both arrangements have been considered and analyzed in this study. Two subsystem configurations therefore resulted, each having their own specific characteristics and importance.

A total of eight mathematical models resulted from the analysis of both configurations. Multiple correlation coefficients ranging from 0.9184 to 0.9779 resulted. Parameters were tested for significance and the results reported. Rejection levels for the testing of statistical hypothesis were selected based on the work of other researchers, and on the characteristics of the available data.

The arrangement in series of the mathematical models from configuration No. 2, represented in Figure 6.2, subjected to a convergence criterion in the trickling filter effluent characteristics, essentially describes the computer simulation algorithm referred to as CSTF, and used in the sensitivity analysis of both the treatment plant as a whole and of the treatment units individually. Input matrices describing variations in BOD, suspended solids, flow, recirculation, sewage temperature, and weather flow conditions, were used to examine the stability of the treatment plant as a whole and of the treatment units individually.

Sewage characteristics sensitivity analysis was performed on the treatment plant as a whole, and on the treatment units individually, so as to delineate parameters of significant importance in the performance of the process.

The sludge production within the treatment plant was analyzed so as to determine operation levels that cause additional sludge handling problems.

Lastly, the predictive equations for the trickling filter-final settling tank subsystem were examined and compared with the most common mathematical models available to practicing engineers. The models of Eckenfelder, and Galler and Gotaas appeared to be the most representative mathematical models compared. The formulations of Velz, Rankin, and NRC being functions of less variables did not appear to be very sensitive to input vector variations.

9.2 Conclusions

The following conclusions can be drawn from the studies reported in this dissertation:

1. Simulation and mathematical model building, based on readily available physical variables of an existing trickling filter installation, yielded very satisfactory results. High multiple correlation coefficients, up to 0.9795 were obtained.

2. In all cases BOD removal was obsereved to be a function of the effluent suspended solids of the particular treatment unit, corroborating the work of other researchers in this field.

3. Primary tank BOD removal was observed to be a function of the recirculation ratio, reflecting the importance of the BOD composition (solid BOD and dissolved BOD) entering the primary tank.

4. Recirculation ratio was observed to benefit BOD and suspended solids removal efficiencies of the trickling filter unit, while shown to hinder primary tank performance as far as BOD removal was concerned. The overall effect on the plant was an increase in both BOD and suspended solids removal efficiencies occurred with corresponding increases in the recirculation ratio.

5. As expected, temperature of the sewage was observed to be significant in all but the secondary tank models. BOD and suspended solids concentrations were observed to decrease by 8 and 11.8% respectively with a 15% increase in temperature.

6. Surprisingly, the suspended solids removal in the primary tank was observed to be almost non-sensitive to

variations in the primary tank overflow rate parameter. The other treatment units appeared, however, to be sensitive to the rate of flow applied to them. In fact, increased flow rates were shown to benefit both BOD and suspended solids removal efficiencies within the trickling filter unit, and trickling filter system. Explanations to such a response were accounted for by a more continuous and regular sloughing mechanism, and also by prevailing turbulent flow regime under higher rates of flow.

7. Variations in the BOD loadings resulted in only moderate changes in the sewage characteristics of the plant effluent. In fact, higher BOD loadings accounted for an increase in both BOD and suspended solids concentration in the effluent.

Variations in the suspended solids loading, however, resulted in a more definite change in the sewage characteristics of the plant effluent. Corresponding to higher suspended solids concentrations were noticeable increases in both the effluent BOD and suspended solids concentrations.

8. Weather flow variations as dictated in the sensitivity analysis of both the sewage characteristics and sludge production were observed to have a significant influence upon the plant's performance.

9. The sludge production was observed to be approximately 10 to 15% secondary sludge with primary sludge forming

about 85 to 90% of the total. Sludge production variations were found to be sensitive to suspended solids variations, flow variations, and weather variations.

10. Simulation, through multiple regression of readily available field data is justified and provides both an understanding of the actual removal mechanisms within a complete treatment process, along with supplying the structure for possible computer assisted trickling filter plant operation.

11. Comparison of predicted plant performance with other well known trickling filter design formulations indicated that the models presented by Eckenfelder and Galler and Gotaas represented more closely actual plant performance.

12. Lastly, the study revealed that no single mathematical model exists for the performance evaluation of trickling filter plants.

9.3 Recommendations for Future Research

Three recommendations for future research are hereafter presented. The first consists in performing an economic analysis of the described treatment plant so as to establish the optimum BOD and suspended solids removal efficiencies so as to minimize both operational and maintenance costs.

The second proposition for future research originates from the fact that the plant designed in the early 50's has almost reached its ultimate designed flow conditions. Thus, by assuming the applicability in parallel or in series of the reported mathematical models, possible expansion of the actual treatment plant facilities could be planned with more understanding.

Thirdly, it is suggested that this type of analysis be extended to double filtration so as to appreciate the possible difference in the performance, and therefore analyze the economics between single and double stage filtration.

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APPENDIX A

LISTING OF MASBAL PROGRAM

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OPERATION DATA FROM OCTOBER 64 TO SEPTEMBER 71

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FORTRAN IV G LEVEL  20              MAIN              DATE = 72272          11/16/17               PAGE 0001

 0001             DIMENSION ISS(84)
 0002             REAL NBODRP,NSSRP
 0003             DIMENSION STEMP(8,12)
 0004             DIMENSION  IBOD(84)
 0005             DIMENSION TEMPA(84),TEMPS(84),FLO(84),R(84)
 0006             INTEGER BOD5E,SS5E
 0007             INTEGER ATEMP
 0008             DIMENSION ATEMP(8,12)
 0009             DIMENSION BOD5E(8,12),FLOW5E(8,12),SS5E(8,12)
 0010             DIMENSION FLOWS5(8,12),NSSRP(8,12)
 0011             DIMENSION YEAR(8),MONTH(12),DAYS(8,12),TEMPMA(8,12),TEMPMI(8,12),P
                 1PTN(8,12),SUNP(8,12),FLOW2(8,12),BYFLOW(8,12),FLOW14(8,12),FLOW3(8
                 2,12),DT1(8,12),DT2(8,12),BOD2(8,12),BOD5(8,12),BOD7(8,12),BOD8(8,12),
                 32),BOD14(8,12),SS2(8,12),SS5(8,12),SS7(8,12),SS8(8,12),SS14(8,12),FLOW6(8,
                 4FLOW6(8,12),SL1TSP(8,12),SL1VSP(8,12),FLQW9(8,12),SL2TSP(8,12),SL2VSX(8,12
                 5VSP(8,12),FLOW12(8,12),DSLTSP(8,12),DSLVSP(8,12),FLOW13(8,12),SLQT
                 6SP(8,12),SLQVSP(8,12)
 0012             DIMENSION BOD1(8,12),FLOW1(8,12),SS1(8,12),BOD3(8,12),SS3(8,12),RA
                 1TIO(8,12),BOD4(8,12),SS4(8,12),FLOW4(8,12),FLOW7(8,12),FLOW8(8,12)
                 2,FLOW11(8,12),BOD11(8,12),SS11(8,12),FLOW10(8,12),BOD10(8,12),SS10
                 3(8,12),TFLO1(8,12),TFLO2(8,12),WBOD2(8,12),WBOD10(8,12),WGBODR(8,12),
                 42),RBODRP(8,12),WBOD14(8,12),WBOD1(8,12),WNBODR(8,12),NBODRP(8,12)
                 5,WSS2(8,12),WSS10(8,12),WGSSR(8,12),GSSRP(8,12),WSS14(8,12),WSS1(8
                 6,12),WNSSR(8,12),WSSRP(8,12),DIGTS(8,12),DIGTS1(8,12),DIGVS1(8,12)
                 7,DIGVS2(8,12),DEWTS(8,12),DEWVS(8,12)
 0013             REAL*8 MONTH
 0014             INTEGER YEAR,DAYS,TEMPMA,TEMPMI,SUNP,BOD2,BOD5,BOD7,BOD8,BOD14,SS2
                 1,SS2,SS5,SS7,SS8,SS14
 0015             INTEGER BOD1,BOD3,BOD4,BOD10,BOD11,SS1,SS3,SS4,SS10,SS11
            C
            C     READ IN PHYSICAL CHARACTERISTICS OF TREATMENT PLANT
            C
            C
            C.....PRIMARY SETTLING TANK
            C
 0016           3 NOPST=4
 0017             LPST=173
 0018             WPST=2.*18.
 0019             DPST=9.0
 0020             AREAPT=NOPST*WPST*LPST
 0021             VOLPT=AREAPT*DPST
            C
            C.....TRICKLING FILTER BEDS
```

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                C
 0022                 PI=3.14159
 0023                 RTF=80.
 0024                 DTF=4.25
 0025                 NOTF=3
 0026                 AREATF=NOTF*PI*(RTF**2)
 0027                 VOLTF=AREATF*DTF
                C
                C.....SECONDARY SETTLING TANKS
                C
 0028                 NOSST=5
 0029                 LSST=125
 0030                 WSST=2.*18.
 0031                 DSST=10.
 0032                 AREAST=NOSST*LSST*WSST
 0033                 VOLST=AREAST*DSST
                C
                C.....DIGESTERS
                C
 0034                 NODIG=2
 0035                 RDIG=(95./2.)
 0036                 DDIG=28.
 0037                 VOLDIG=NODIG*PI*(RDIG**2)*DDIG
                C
                C.....DEWATERING: TWO STAINLESS STEEL COIL SPRING
                C
 0038                 NODEW=2
 0039                 DDEW=10.
 0040                 LDEW=10
 0041                 AREADW=2*PI*DDEW*0.25*LDEW
                C
                C.....DATA CHARACTERISTICS
 0042                 NOYEAR=7
 0043                 YEAR(8)=71
 0044                 NOMONT=12
                C
                C..................................................................
                C                                  READ  DATA
                C
 0045                 DO 100 I=1,NOYEAR
 0046                 READ(1,1) YEAR(I)
 0047                 DO 100 J=1,NOMONT
 0048                 READ(1,2) MONTH(J),DAYS(I,J),TEMPMA(I,J),TEMPMI(I,J),PPTN(I,J),SUN
```

```
                 1P(I,J),FLOW2(I,J),BYFLOW(I,J),FLOW14(I,J),FLOW3(I,J),DT1(I,J),DT2(
                 2I,J),BOD2(I,J),BOD5(I,J),BOD7(I,J),BOD8(I,J),BOD14(I,J),SS2(I,J),S
                 4S5(I,J),SS7(I,J),SS8(I,J),SS14(I,J),FLOW6(I,J),SL1TSP(I,J),SL1VSP(
                 5I,J),FLOW9(I,J),SL2TSP(I,J),SL2VSP(I,J),FLOW12(I,J),DSLTSP(I,J),DS
                 6LVSP(I,J),FLOW13(I,J),SLGTSP(I,J),SLGVSP(I,J)
            C
            C     NET FLOW  BOD   SS
            C
 0049             FLOW12(I,J)=FLOW12(I,J)/(DAYS(I,J)*1000,)
 0050             FLOW14(I,J)=FLOW14(I,J)/DAYS(I,J)
 0051             FLOW1(I,J)=FLOW2(I,J)-FLOW14(I,J)
 0052             BOD1(I,J)=(BOD2(I,J)*FLOW2(I,J)-BOD14(I,J)*FLOW14(I,J))/FLOW1(I,J)
 0053             SS1(I,J)=(SS2(I,J)*FLOW2(I,J)-SS14(I,J)*FLOW14(I,J))/FLOW1(I,J)
            C
            C     FLOW  BOD   SS    ENTERING PRIMARY TANKS
            C
 0054             FLOW4(I,J)=FLOW3(I,J)+FLOW2(I,J)
 0055             BOD3(I,J)=BOD7(I,J)
 0056             SS3(I,J)=SS7(I,J)
 0057             BOD4(I,J)=(BOD3(I,J)*FLOW3(I,J)+BOD2(I,J)*FLOW2(I,J))/FLOW4(I,J)
 0058             SS4(I,J)=(SS3(I,J)*FLOW3(I,J)+SS2(I,J)*FLOW2(I,J))/FLOW4(I,J)
            C
            C     PRIMARY SLUDGE TO DIGESTER
            C
 0059             FLOW6(I,J)=FLOW6(I,J)/(DAYS(I,J)*1000)
            C
            C     FLOW ENTERING TRICKLING FILTER
            C
 0060             FLOW5(I,J)=FLOW4(I,J)-FLOW6(I,J)
            C
            C     FLOW ENTERING SECONDARY SETTLER
            C
 0061             FLOW7(I,J)=FLOW5(I,J)-FLOW3(I,J)
            C
            C     SECONDARY SLUDGE TO DIGESTER
            C
 0062             FLOW9(I,J)=FLOW9(I,J)/(DAYS(I,J)*1000)
            C
            C     FLOW LEAVING SECONDARY SETTLER
            C
 0063             FLOW8(I,J)=FLOW7(I,J)-FLOW9(I,J)
            C
            C     WATER FOR DEWATERING, BOD    SS    FLOW
```

```
          C
0064            FLOW13(I,J)=FLOW13(I,J)/(DAYS(I,J)*1000)
0065            FLOW11(I,J)=FLOW14(I,J)-FLOW13(I,J)
0066            BOD11(I,J)=BOD8(I,J)
0067            SS11(I,J)=SS8(I,J)
          C
          C     TRICKLING FILTER
          C
0068            RATIO(I,J)=FLOW3(I,J)/FLOW2(I,J)
0069            TFLO1(I,J)=(FLOW5(I,J)*(10**6))/AREATF
0070            TFLO2(I,J)=(BOD5(I,J)*FLOW5(I,J)*8.34)/(VOLTF/1000.)
          C
          C     BOD   REMOVALS
          C
          C.....GROSS
0071            BOD10(I,J)=BOD8(I,J)
0072            FLOW10(I,J)=FLOW7(I,J)-FLOW9(I,J)-FLOW11(I,J)
0073            WBOD2(I,J)=(FLOW2(I,J)*BOD2(I,J)*DAYS(I,J)*8.34)
0074            WBOD10(I,J)=(FLOW10(I,J)*BOD10(I,J)*DAYS(I,J)*8.34)
0075            WGBODR(I,J)=WBOD2(I,J)-WBOD10(I,J)
0076            RBODRP(I,J)=(WGBODR(I,J)/WBOD2(I,J))*100.
          C.....NET
0077            WBOD14(I,J)=(FLOW14(I,J)*BOD14(I,J)*DAYS(I,J)*8.34)
0078            WBOD1(I,J)=WBOD2(I,J)-WBOD14(I,J)
0079            WNBODR(I,J)=WBOD1(I,J)-WBOD10(I,J)
0080            NBODRP(I,J)=(WNBODR(I,J)/WBOD1(I,J))*100
          C
          C     SS  REMOVAL
          C
          C ....GROSS
          C
0081            SS10(I,J)=SS8(I,J)
0082            WSS2(I,J)=(FLOW2(I,J)*SS2(I,J)*DAYS(I,J)*8.34)
0083            WSS10(I,J)=(FLOW10(I,J)*SS10(I,J)*DAYS(I,J)*8.34)
0084            WGSSR(I,J)=WSS2(I,J)-WSS10(I,J)
0085            GSSRP(I,J)=(WGSSR(I,J)/WSS2(I,J))*100.
          C.....NET
0086            WSS14(I,J)=(FLOW14(I,J)*SS14(I,J)*DAYS(I,J)*8.34)
0087            WSS1(I,J)=WSS2(I,J)-WSS14(I,J)
0088            WNSSR(I,J)=WSS1(I,J)-WSS10(I,J)
0089            NSSRP(I,J)=(WNSSR(I,J)/WSS1(I,J))*100.
          C
          C     DIGESTER LOADING
```

```
                  C
0090                    WTS1=(SL1TSP(I,J)*FLOW6(I,J)*8.34*DAYS(I,J)*1000.)
0091                    WVS1=SL1VSP(I,J)*WTS1
0092                    WTS2=SL2TSP(I,J)*FLOW9(I,J)*8.34*DAYS(I,J)*1000.
0093                    WVS2=SL2VSP(I,J)*WTS2
                  C
                  C     LOADING OF DEWATERING UNIT
                  C
0094                    WTS1=FLOW12(I,J)*DSLTSP(I,J)*8.34
0095                    WVS1=DSLVSP(I,J)*WTS1
0096                    WTS2=FLOW13(I,J)*SLQTSP(I,J)
0097                    WVS2=SLQVSP(I,J)*WTS2
0098                    DEWTS(I,J)=WTS1+WTS2
0099                    DEWVS(I,J)=WVS1+WVS2
0100                    ATEMP(I,J)=(TEMPMA(I,J)+TEMPMI(I,J))/2
0101                    BOD5E(I,J)=BOD3(I,J)
0102                    SS5E(I,J)=SS3(I,J)
0103                    FLOW5E(I,J)=FLOW5(I,J)
0104                100 CONTINUE
0105                    DO 654 I=1,NOYEAR
0106                    DO 654 J=1,NOMONT
0107                    IF(I.EQ.1.AND.J.EQ.1)  TEMPA(1)=ATEMP(1,1)
0108                    IF(I.EQ.1.AND.J.EQ.1) GO TO 654
0109                    IF(I.EQ.1) K=J
0110                    IF(I.GT.1) K=(I-1)*NOMONT +J
0111                    TEMPA(K)=ATEMP(I,J)
0112                    STEMP(I,J)=41.96217+0.18005*TEMPA(K)+0.26993*TEMPA(K-1)
0113                654 CONTINUE
0114                  1 FORMAT(I2)
0115                  2 FORMAT(A8,2X,3I2,F4.2,I2,F5.2,F6.2,4F4.2,3I3,I2,I4,2I3,2I2,I5,/,F7
                       1.2,F4.2,F5.2,F7.2,F4.2,F5.2,2(F7.2,F4.2,F5.2))
0116                    JJ=NOYEAR-1
0117                    DO 110 I=1,NOYEAR
0118                    K=I+1
0119                    WRITE(3,220) YEAR(I),YEAR(K)
0120                220 FORMAT(1H1,58X,'TABLE NO. 1',/,49X,'FROM OCTOBER ',I2,' TO SEPTEMB
                       1ER ',I2)
0121                    WRITE(3,221)
0122                221 FORMAT(3X,'MONTH',3X,'DAYS',7X,'STATION # 1',12X,'STATION # 2',12X
                       1,'STATION # 3',12X,'STATION # 4',12X,'STATION # 5',/,17X,5('FLOW',
                       23X,'B.O.D.',4X,'S.S.',2X),/,17X,5('MGD',4X,'MG/L',6X,'MG/L',2X))
0123                    DO 111 J=1,NOMONT
0124                111 WRITE(3,222) MONTH(J),DAYS(I,J),FLOW1(I,J),BOD1(I,J),SS1(I,J),FLOW
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```
                  12(I,J),BOD2(I,J),SS2(I,J),FLOW3(I,J),BOD3(I,J),SS3(I,J),FLOW4(I,J)
                  2,BOD4(I,J),SS4(I,J),FLOW5(I,J),BOD5(I,J),SS5(I,J)
 0125         222 FORMAT(1X,A8,3X,I2,3X,5(F5.2,3X,I3,6X,I4,2X))
 0126             WRITE(3,232)
 0127         232 FORMAT(/,/,/,/,/,/,/,/)
 0128             WRITE(3,223)  YEAR(I),YEAR(K)
 0129         223 FORMAT(1H0,58X,'TABLE   NO. 2',/,49X,'FROM OCTOBER ',I2,' TO SEPTE
                 1MBER ',I2)
 0130             WRITE(3,224)
 0131         224 FORMAT(3X,'MONTH',3X,'DAYS',7X,'STATION # 6',12X,'STATION # 7',12X,'
                 1,'STATION # 8',12X,'STATION # 9',7X,'STATION #10',2X,'STATION #11',
                 2,/,17X,'FLOW',4X,'TOTAL',3X,'VOL.',3X,2('FLOW',4X,'B.O.D.',4X,'S.S.',2X),
                 3.',2X),'FLOW',4X,'TOTAL',3X,'VOL.',5X,'FLOW',9X,'FLOW',/,17X,'MGD'
                 4,5X,'SOLIDS',2X,'SOLID',2X,2('MGD',5X,'MG/L',6X,'MG/L',2X),'MGD',5
                 5X,'SOLIDS',2X,'SOLID',4X,'MGD',10X,'MGD')
 0132             DO 112 J=1,NOMONT
 0133         112 WRITE(3,225)MONTH(J),DAYS(I,J),FLOW6(I,J),SL1TSP(I,J),SL1VSP(I,J),
                 1FLOW7(I,J),BOD7(I,J),SS7(I,J),FLOW8(I,J),BOD8(I,J),SS8(I,J),FLOW9(
                 2I,J),SL2TSP(I,J),SL2VSP(I,J),FLOW10(I,J),FLOW11(I,J)
 0134         225 FORMAT(1X,A8,3X,I2,3X,F5.2,4X,F4.2,3X,F5.2,2X,2(F5.2,3X,I3,6X,I4,2X),
                 1X),F5.2,4X,F4.2,3X,F5.2,5X,F5.2,8X,F5.2)
 0135             WRITE(3,226) YEAR(I),YEAR(K)
 0136         226 FORMAT(1H1,58X,'TABLE   NO. 3',/,49X,'FROM OCTOBER ',I2,' TO SEPTE
                 1MBER ',I2)
 0137             WRITE(3,227)
 0138         227 FORMAT(3X,'MONTH',5X,'DAYS',9X,'STATION #12',14X,'STATION #13',14X,'STATIO
                 1,'STATION #14',9X,'TRICKLING FILTER LOADING',/,21X,2('FLOW',4X,'TO
                 2TAL',3X,'VOL.',5X),'FLOW',4X,'B.O.D.',4X,'S.S.',4X,'GAL/FT2',8X,'#
                 3 B.O.D./',/,21X,2('MGD',5X,'SOLIDS',2X,'SOLID',4X),'MGD',5X,'MG/L',4X,'MG/
                 4,6X,'MG/L',4X,'PER DAY',6X,'1000FT3/DAY')
 0139             DO 113 J=1,NOMONT
 0140         113 WRITE(3,228) MONTH(J),DAYS(I,J),FLOW12(I,J),DSLTSP(I,J),DSLVSP(I,J)
                 1),FLOW13(I,J),SLQTSP(I,J),SLQVSP(I,J),FLOW14(I,J),BOD14(I,J),SS14(
                 2I,J),TFLO1(I,J),TFLO2(I,J)
 0141         228 FORMAT(1X,A8,5X,I2,5X,2(F5.2,4X,F4.2,3X,F5.2,3X),F5.2,4X,I4,5X,I6,
                 14X,F6.2,10X,F6.2)
 0142             WRITE(3,232)
 0143             WRITE(3,229)YEAR(I),YEAR(K)
 0144         229 FORMAT(1H0,58X,'TABLE   NO. 4',/,49X,'FROM OCTOBER ',I2,' TO SEPTE
                 $MBER ',I2)
 0145             WRITE(3,230)
 0146         230 FORMAT(3X,'MONTH',5X,'DAYS',10X,'B.O.D.   REMOVAL',17X,'S.S.   REM
                 $OVAL',22X,'MISCELLANEOUS',/,21X,'GROSS',6X,'%',5X,'NET',7X,'%',4X,
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                 $'GROSS',6X,'%',5X,'NET',7X,'%',4X,'DIG.SLUDGE',7X,'AVG.TEMP.',2X,'
                 $AVG.TEMP.',/,20X,'WT. REM.',8X,'WT. REM.',8X,'WT. REM.',8X,'WT. REM
                 $M.',8X,'TOTAL VOLATILE',7X,'AIR',6X,'SEWAGE',/,21X,'POUNDS',10X,'POUNDS',1
                 $OUNDS',10X,'POUNDS',10X,'POUNDS')
0147              DO 114 J=1,NOMONT
0148              WRITE(3,231) MONTH(J),DAYS(I,J),WGBODR(I,J),RBODRP(I,J),WNBODR(I,J)
                 $),NBODRP(I,J),WGSSR(I,J),GSSRP(I,J),WNSSR(I,J),NSSRP(I,J),DSLTSP(I,J),
                 $,J),DSLVSP(I,J),ATEMP(I,J),STEMP(I,J)
0149         231 FORMAT(1X,A8,5X,I2,4X,F8.0,2X,F4.1,2X,F8.0,2X,F4.1,2X,F8.0,2X,F4.1,
                 $,2X,F8.0,2X,F4.1,2X,F4.2,'%',2X,F5.2,'%',7X,I2,' F',6X,F4.1,' F')
0150         114 CONTINUE
0151         110 CONTINUE
0152              RETURN
0153              END
```

TABLE NO, 1

FROM OCTOBER 64 TO SEPTEMBER 65

MONTH	DAYS	STATION # 1			STATION # 2			STATION # 3			STATION # 4			STATION # 5		
		FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L
OCTOBER	31	9,60	213	255	9,75	213	260	5,95	72	75	15,70	159	189	15,64	105	89
NOVEMBER	30	10,65	224	254	10,82	226	266	7,37	95	80	18,19	172	190	18,13	117	97
DECEMBER	31	10,81	223	253	10,91	224	263	7,45	82	84	18,36	166	190	18,29	104	98
JANUARY	31	14,34	211	219	14,45	212	226	5,75	97	80	20,20	179	184	20,15	113	90
FEBRUARY	28	15,17	217	231	15,28	220	247	5.39	100	84	20.67	188	204	20,61	111	94
MARCH	31	18,39	178	195	18,51	180	208	5,64	89	75	22,15	165	186	22,09	105	94
APRIL	30	15,91	210	212	16,01	214	246	4,77	89	79	20,78	185	207	20,72	111	95
MAY	31	13,59	199	220	13,70	201	242	6,45	95	79	20,15	167	189	20,09	112	92
JUNE	30	13.04	189	198	13,17	191	209	7.49	68	59	20,66	146	154	20,61	103	81
JULY	31	11,80	191	190	11,90	192	196	7,98	63	56	19,88	140	139	19,82	100	81
AUGUST	31	11,48	1/8	194	11,57	179	198	7,98	56	54	19,55	128	139	19,49	94	78
SEPTEMBE	30	11,82	183	219	11,94	186	260	8,23	60	61	20,17	134	178	20,10	90	88

TABLE NO, 2

FROM OCTOBER 64 TO SEPTEMBER 65

MONTH	DAYS	STATION # 6			STATION # 7			STATION # 8			STATION # 9			STATION #10	STATION #11
		FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	FLOW MGD
OCTOBER	31	0,06	3,72	81,27	9.69	72	75	9.68	47	43	0,01	2,20	72,07	9.58	0,10
NOVEMBER	30	0,06	3,70	82,62	10.76	95	80	10,75	51	53	0,01	2,18	77,30	10,64	0,11
DECEMBER	31	0,07	3,72	79,56	10,84	82	84	10,84	50	50	0.01	2,42	73,06	10,77	0,07
JANUARY	31	0.05	3,75	83,01	14,40	97	80	14,39	52	49	0,01	2,82	75,47	14,30	0,09
FEBRUARY	28	0,06	4,08	81.16	15,22	100	84	15,20	50	48	0,02	2,99	74,33	15,12	0,08
MARCH	31	0,06	3,99	78,84	18,45	89	75	18,43	47	51	0,02	2,91	72,23	18,35	0,08
APRIL	30	0,06	4,14	78,05	15.95	89	79	15.93	47	51	0,02	2,85	73,12	15,89	0,04
MAY	31	0,06	4.19	77,66	13.64	95	79	13,62	45	46	0.02	2,57	74,67	13,57	0,05
JUNE	30	0.05	3,78	77.83	13.12	68	59	13,10	37	37	0,02	2,53	74,83	13,05	0,05
JULY	31	0,06	3,42	77,77	11.84	63	56	11,82	36	36	0,02	2,64	73.55	11,79	0,04
AUGUST	31	0,06	4,23	75,94	11.51	56	54	11,49	32	35	0.02	2,37	74,29	11.45	0,04
SEPTEMBE	30	0,07	4,25	76,18	11,87	60	61	11,85	34	39	0,02	2,64	69,86	11,80	0,05

TABLE NO. 3
FROM OCTOBER 64 TO SEPTEMBER 65

MONTH	DAYS	STATION #12			STATION #13			STATION #14			TRICKLING FILTER LOADING	
		FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	B.O.D. MG/L	S.S. MG/L	GAL/FT2 PER DAY	# B.O.D./ 1000FT3/DAY
OCTOBER	31	0,02	2,84	56,17	0,05	1,33	58,59	0,15	210	590	259,30	53,43
NOVEMBER	30	0,02	3,54	55,21	0,06	1,31	59,23	0,17	290	960	300,50	68,99
DECEMBER	31	0,03	1,97	56,10	0,03	0,53	57,44	0,10	250	1310	303,29	61,90
JANUARY	31	0,03	2,36	58,31	0,02	0,39	59,43	0,11	300	1070	334,05	74,07
FEBRUARY	28	0,04	3,23	59,13	0,03	0,57	67,79	0,11	570	2400	341,71	74,43
MARCH	31	0,02	3,20	57,72	0,04	0,94	60,45	0,12	370	2080	366,26	75,47
APRIL	30	0,00	5,20	55,20	0,06	1,21	58,99	0,10	690	5400	343,47	74,81
MAY	31	0,01	5,09	56,58	0,07	1,02	61,70	0,11	440	2940	333,10	73,21
JUNE	30	0,01	4,53	55,99	0,07	0,73	61,56	0,13	320	1260	341,62	69,05
JULY	31	0,00	5,33	54,71	0,06	0,55	60,26	0,10	260	820	328,67	64,50
AUGUST	31	0,01	5,33	54,40	0,05	0,60	60,36	0,09	239	710	323,08	59,60
SEPTEMBE	30	0,01	7,40	52,57	0,07	1,26	62,27	0,12	430	4300	333,17	58,84

TABLE NO. 4
FROM OCTOBER 64 TO SEPTEMBER 65

MONTH	DAYS	B.O.D. REMOVAL				S.S. REMOVAL				MISCELLANEOUS			
		GROSS WT. REM. POUNDS	%	NET WT. REM. POUNDS	%	GROSS WT. REM. POUNDS	%	NET WT. REM. POUNDS	%	DIG.SLUDGE TOTAL	DIG.SLUDGE VOLATILE	AVG.TEMP. AIR	AVG.TEMP. SEWAGE
OCTOBER	31	420467.	78,3	412568.	78,0	548854.	83,7	526662.	83,2	2,84%	56,17%	53 F	**** F
NOVEMBER	30	476108.	77,8	463556.	77,4	579073.	80,4	537520.	79,2	3,54%	55,21%	50 F	65,3 F
DECEMBER	31	492653.	78,0	486231.	77,7	602659.	81,2	569009.	80,3	1,97%	56,10%	37 F	62,1 F
JANUARY	31	599751.	75,7	591269.	75,5	663146.	78,5	632894.	77,7	2,36%	58,31%	34 F	58,1 F
FEBRUARY	28	608470.	77,5	593971.	77,1	711872.	80,8	650824.	79,3	3,23%	59,13%	37 F	57,8 F
MARCH	31	638368.	74,1	626642.	73,8	753382.	75,7	687463.	74,0	3,20%	57,72%	42 F	59,5 F
APRIL	30	670396.	78,2	652442.	77,7	782679.	79,4	642166.	76,0	5,20%	55,20%	53 F	62,8 F
MAY	31	554023.	77,8	541436.	77,4	695735.	81,2	611633.	79,1	5,09%	56,58%	70 F	68,9 F
JUNE	30	508599.	80,8	498591.	80,5	567911.	82,5	528505.	81,4	4,53%	55,99%	74 F	74,2 F
JULY	31	481004.	81,4	474196.	81,2	493311.	81,8	471837.	81,1	5,33%	54,71%	78 F	76,0 F
AUGUST	31	440697.	82,3	435414.	82,1	488649.	82,5	472957.	82,0	5,33%	54,40%	77 F	76,9 F
SEPTEMBE	30	455289.	81,9	442558.	81,5	661596.	85,2	534286.	82,3	7,40%	52,57%	72 F	75,7 F

TABLE NO. 1

FROM OCTOBER 65 TO SEPTEMBER 66

MONTH	DAYS	STATION # 1			STATION # 2			STATION # 3			STATION # 4			STATION # 5		
		FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L
OCTOBER	31	12.39	189	219	12.49	190	226	8.20	60	57	20.69	138	159	20.63	100	85
NOVEMBER	30	11.85	210	250	11.95	216	281	7.50	70	70	19.45	159	199	19.38	114	97
DECEMBER	31	12.21	272	323	12.34	288	342	5.70	103	91	18.04	229	262	17.98	146	113
JANUARY	31	12.72	222	271	12.82	233	287	6.70	77	78	19.52	179	215	19.46	110	96
FEBRUARY	28	16.81	177	188	16.90	184	203	4.39	89	87	21.29	164	179	21.23	111	101
MARCH	31	15.72	184	201	15.82	193	210	5.25	95	81	21.07	168	177	21.01	118	89
APRIL	30	16.76	162	177	16.89	171	205	3.47	80	77	20.36	155	183	20.30	105	92
MAY	31	17.79	172	177	17.93	176	197	4.44	73	58	22.37	155	169	22.31	102	74
JUNE	30	15.50	179	194	15.63	186	252	7.42	60	59	23.05	145	189	22.98	95	87
JULY	31	14.01	168	218	14.13	172	239	8.20	55	60	22.55	129	173	22.26	95	94
AUGUST	31	13.61	185	219	13.74	189	260	8.62	57	55	22.36	138	180	22.28	106	87
SEPTEMBE	30	16.72	167	266	16.84	173	318	6.29	57	72	23.13	141	251	23.04	104	102

TABLE NO. 2

FROM OCTOBER 65 TO SEPTEMBER 66

MONTH	DAYS	STATION # 6			STATION # 7			STATION # 8			STATION # 9			STATION #10	STATION #11
		FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	FLOW MGD
OCTOBER	31	0.06	3.68	78.19	12.43	60	57	12.41	37	41	0.02	2.59	70.11	12.37	0.04
NOVEMBER	30	0.07	4.12	80.73	11.88	70	70	11.87	47	55	0.02	2.53	74.80	11.82	0.04
DECEMBER	31	0.06	4.02	82.82	12.28	103	91	12.26	61	62	0.02	2.56	76.32	12.20	0.06
JANUARY	31	0.06	3.98	81.92	12.76	77	78	12.74	49	57	0.02	3.15	74.81	12.68	0.06
FEBRUARY	28	0.06	3.91	80.58	16.84	89	87	16.82	56	64	0.02	3.06	73.86	16.77	0.05
MARCH	31	0.06	3.84	79.53	15.76	95	81	15.74	62	63	0.02	2.86	76.98	15.69	0.05
APRIL	30	0.06	4.05	78.70	16.83	80	77	16.81	50	56	0.02	2.96	72.90	16.73	0.08
MAY	31	0.06	4.12	79.43	17.87	73	58	17.85	44	40	0.02	3.11	72.91	17.78	0.07
JUNE	30	0.07	4.80	73.28	15.56	60	59	15.54	39	46	0.02	2.93	69.04	15.47	0.06
JULY	31	0.07	4.20	75.55	14.06	55	60	14.04	35	37	0.02	2.48	70.64	14.00	0.05
AUGUST	31	0.08	4.72	73.62	13.66	57	55	13.64	35	41	0.02	2.58	70.11	13.58	0.06
SEPTEMBE	30	0.09	5.85	68.40	16.75	57	72	16.73	36	50	0.02	3.12	63.52	16.68	0.05

TABLE NO. 3
FROM OCTOBER 65 TO SEPTEMBER 66

MONTH	DAYS	STATION #12			STATION #13			STATION #14			TRICKLING FILTER LOADING	
		FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	B.O.D. MG/L	S.S. MG/L	GAL/FT2 PER DAY	# B.O.D./ 1000FT3/DAY
OCTOBER	31	0.01	6.13	51.49	0.05	0.68	57.09	0.10	310	1070	342.01	67.11
NOVEMBER	30	0.00	5.48	53.25	0.06	1.31	65.10	0.10	830	3730	321.34	71.89
DECEMBER	31	0.00	6.27	61.38	0.07	2.22	67.33	0.13	1810	2110	298.11	85.41
JANUARY	31	0.01	5.42	64.34	0.04	1.05	69.55	0.10	1570	2250	322.65	69.65
FEBRUARY	28	0.01	5.81	60.77	0.04	0.87	78.07	0.09	1310	2870	351.94	76.66
MARCH	31	0.01	5.62	63.25	0.05	1.55	68.37	0.10	1550	1610	348.32	80.66
APRIL	30	0.04	3.07	57.68	0.05	1.28	62.41	0.13	1240	3730	336.51	69.34
MAY	31	0.01	5.34	54.51	0.07	1.20	61.51	0.14	570	2670	369.85	74.03
JUNE	30	0.01	5.09	54.36	0.07	1.75	57.73	0.13	890	6890	380.90	71.01
JULY	31	0.01	6.47	45.30	0.07	0.96	56.04	0.12	620	2760	369.06	68.80
AUGUST	31	0.01	5.81	51.11	0.07	1.34	56.02	0.13	550	4490	369.31	76.82
SEPTEMBE	30	0.00	5.80	57.05	0.07	3.46	55.49	0.12	970	7330	382.01	77.96

TABLE NO. 4
FROM OCTOBER 65 TO SEPTEMBER 66

MONTH	DAYS	B.O.D. REMOVAL				S.S. REMOVAL				MISCELLANEOUS			
		GROSS WT. REM. POUNDS	%	NET WT. REM. POUNDS	%	GROSS WT. REM. POUNDS	%	NET WT. REM. POUNDS	%	DIG.SLUDGE TOTAL	DIG.SLUDGE VOLATILE	AVG.TEMP. AIR	AVG.TEMP. SEWAGE
OCTOBER	31	495236.	80.7	487454.	80.5	598696.	82.0	571835.	81.4	6.13%	51.49%	54 F	71.1 F
NOVEMBER	30	506785.	78.5	485049.	77.7	677463.	80.6	579783.	78.1	5.48%	53.25%	46 F	64.8 F
DECEMBER	31	726355.	79.1	666577.	77.6	895479.	82.1	825794.	80.8	6.27%	61.38%	39 F	61.4 F
JANUARY	31	611589.	79.2	571391.	78.1	764337.	80.4	706728.	79.1	5.42%	64.34%	31 F	58.1 F
FEBRUARY	28	506829.	69.8	479406.	68.6	550480.	68.7	490402.	66.2	5.81%	60.77%	36 F	56.8 F
MARCH	31	537823.	68.1	498266.	66.5	603297.	70.2	562209.	68.7	5.62%	63.25%	45 F	59.8 F
APRIL	30	513361.	71.0	472305.	69.3	631929.	72.9	508429.	68.4	3.07%	57.68%	51 F	63.3 F
MAY	31	613619.	75.2	593321.	74.6	729354.	79.9	634271.	77.5	5.34%	54.51%	63 F	67.1 F
JUNE	30	576415.	79.2	546427.	78.4	807420.	81.9	575271.	76.4	5.09%	54.36%	76 F	72.7 F
JULY	31	501692.	79.8	483129.	79.2	739217.	84.7	656581.	83.1	6.47%	45.30%	81 F	77.1 F
AUGUST	31	548517.	81.7	530123.	81.2	779669.	84.4	629508.	81.4	5.81%	51.11%	78 F	77.9 F
SEPTEMBE	30	578671.	79.4	549063.	78.5	1131181.	84.4	907438.	81.3	5.80%	57.05%	67 F	75.1 F

TABLE NO. 1
FROM OCTOBER 66 TO SEPTEMBER 67

MONTH	DAYS	STATION # 1			STATION # 2			STATION # 3			STATION # 4			STATION # 5		
		FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L
OCTOBER	31	18.04	147	177	18.13	149	194	5.92	52	50	24.05	125	158	23.97	89	75
NOVEMBER	30	15.48	180	232	15.58	182	246	6.02	66	62	21.60	149	194	21.52	111	87
DECEMBER	31	17.78	195	199	17.85	197	204	4.98	70	63	22.83	169	173	22.75	119	90
JANUARY	31	18.89	177	200	18.95	179	207	5.34	67	65	24.29	154	175	24.21	114	89
FEBRUARY	28	20.83	162	163	20.89	165	174	4.78	77	65	25.67	148	153	25.59	116	87
MARCH	31	22.33	178	183	22.41	181	193	3.28	78	64	25.69	167	176	25.61	122	85
APRIL	30	17.31	175	198	17.38	180	211	7.86	70	64	25.24	145	165	25.16	115	84
MAY	31	19.30	161	163	19.40	170	179	6.36	69	58	25.76	145	149	25.68	118	81
JUNE	30	17.67	202	192	17.78	223	251	8.29	91	69	26.07	181	193	25.98	136	90
JULY	31	17.70	231	212	17.76	250	251	8.94	79	60	26.70	192	187	26.62	124	87
AUGUST	31	20.58	244	211	20.69	273	346	6.70	91	69	27.39	228	278	27.29	139	101
SEPTEMBE	30	22.85	213	244	22.96	233	295	5.18	84	62	28.14	205	252	28.05	141	97

TABLE NO. 2
FROM OCTOBER 66 TO SEPTEMBER 67

MONTH	DAYS	STATION # 6			STATION # 7			STATION # 8			STATION # 9			STATION #10	STATION #11
		FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	FLOW MGD
OCTOBER	31	0.08	4.09	79.42	18.05	52	50	18.03	34	39	0.02	2.84	69.04	18.00	0.04
NOVEMBER	30	0.08	3.95	82.44	15.50	66	62	15.48	40	45	0.02	2.29	75.80	15.47	0.01
DECEMBER	31	0.08	3.52	85.32	17.77	70	63	17.75	47	45	0.02	2.49	77.32	17.75	0.00
JANUARY	31	0.08	4.00	84.74	18.87	67	65	18.86	46	46	0.02	2.51	79.29	18.85	0.01
FEBRUARY	28	0.08	3.64	85.49	20.81	77	65	20.79	49	44	0.02	2.78	78.62	20.79	0.01
MARCH	31	0.08	3.79	82.91	22.33	78	64	22.31	52	51	0.02	2.95	78.27	22.30	0.00
APRIL	30	0.08	3.67	83.46	17.30	70	64	17.28	49	49	0.02	2.50	79.05	17.28	0.00
MAY	31	0.08	3.83	82.57	19.32	69	58	19.30	46	44	0.02	2.43	75.24	19.26	0.03
JUNE	30	0.09	4.32	82.03	17.69	91	69	17.67	55	51	0.02	2.85	72.90	17.57	0.10
JULY	31	0.08	4.21	78.36	17.68	79	60	17.66	43	40	0.02	2.69	68.40	17.60	0.06
AUGUST	31	0.10	5.25	74.42	20.59	91	69	20.56	45	51	0.03	3.72	65.92	20.45	0.11
SEPTEMBE	30	0.09	4.53	81.07	22.87	84	62	22.85	55	46	0.02	2.75	74.98	22.77	0.08

TABLE NO, 3
FROM OCTOBER 66 TO SEPTEMBER 67

MONTH	DAYS	STATION #12			STATION #13			STATION #14			TRICKLING FILTER LOADING	
		FLOW MGD	TOTAL SOLIDS	VOL, SOLID	FLOW MGD	TOTAL SOLIDS	VOL, SOLID	FLOW MGD	B,O,D, MG/L	S,S, MG/L	GAL/FT2 PER DAY	# B,O,D,/ 1000FT3/DAY
OCTOBER	31	0,02	5,59	49,57	0,06	0,51	56,66	0,09	470	3280	397,44	69,41
NOVEMBER	30	0,01	5,58	51,10	0,09	0,71	58,82	0,10	370	2280	356,82	77,72
DECEMBER	31	0,01	6,04	53,15	0,07	0,57	62,19	0,07	580	1280	377,24	88,09
JANUARY	31	0,01	5,30	57,57	0,05	0,57	62,19	0,06	602	2100	401,45	89,81
FEBRUARY	28	0,02	5,90	61,61	0,05	0,72	64,83	0,06	1035	3580	424,32	96,59
MARCH	31	0,01	5,22	57,86	0,08	0,65	66,98	0,08	978	2824	424,55	101,64
APRIL	30	0,01	5,83	59,07	0,07	1,10	68,43	0,07	1160	3310	417,15	94,14
MAY	31	0,01	5,08	65,55	0,07	1,11	69,18	0,10	1780	2950	425,69	98,57
JUNE	30	0,02	3,88	72,47	0,01	0,91	60,83	0,11	3480	9750	430,70	114,94
JULY	31	0,0	0,0	0,0	0,0	0,0	0,0	0,06	6125	12400	441,30	107,38
AUGUST	31	0,00	9,62	57,26	0,0	0,0	0,0	0,11	5490	25100	452,42	123,41
SEPTEMBE	30	0,03	5,96	72,18	0,02	1,14	72,23	0,11	4370	11000	465,08	128,69

TABLE NO, 4
FROM OCTOBER 66 TO SEPTEMBER 67

MONTH	DAYS	B,O,D,		REMOVAL		S,S,		REMOVAL		MISCELLANEOUS			
		GROSS WT, REM, POUNDS	%	NET WT, REM, POUNDS	%	GROSS WT, REM, POUNDS	%	NET WT, REM, POUNDS	%	DIG,SLUDGE TOTAL	VOLATILE	AVG,TEMP, AIR	AVG,TEMP, SEWAGE
OCTOBER	31	540225,	77,4	528779,	77,0	727893,	80,0	648016,	78,1	5,59%	49,57%	54 F	69,8 F
NOVEMBER	30	554653,	78,2	545057,	77,9	784783,	81,8	725645,	80,6	5,58%	51,10%	46 F	64,8 F
DECEMBER	31	693425,	76,3	682928,	76,0	734909,	78,1	711743,	77,5	6,04%	53,15%	36 F	60,9 F
JANUARY	31	652850,	74,4	643260,	74,2	790031,	77,9	756579,	77,1	5,30%	57,57%	39 F	58,7 F
FEBRUARY	28	567062,	70,5	552215,	69,9	635237,	74,8	583882,	73,2	5,90%	61,61%	34 F	58,6 F
MARCH	31	748837,	71,4	728038,	70,8	824129,	73,7	764071,	72,2	5,22%	57,86%	44 F	59,1 F
APRIL	30	570887,	72,9	550184,	72,2	705690,	76,9	646614,	75,3	5,83%	59,07%	56 F	63,9 F
MAY	31	623571,	73,1	575475,	71,5	678673,	75,6	598960,	73,2	5,08%	65,55%	60 F	67,9 F
JUNE	30	750199,	75,6	655293,	73,0	892345,	79,9	626445,	73,6	3,88%	72,47%	75 F	71,7 F
JULY	31	952240,	83,0	862334,	81,5	970484,	84,2	788472,	81,2	0,0 %	0,0 %	78 F	76,3 F
AUGUST	31	1222377,	83,7	1063955,	81,7	1581141,	85,4	856847,	76,1	9,62%	57,26%	75 F	76,5 F
SEPTEMBE	30	1025191,	76,6	907835,	74,3	1432621,	84,5	1137218,	81,3	5,96%	72,18%	67 F	74,3 F

TABLE NO. 1
FROM OCTOBER 67 TO SEPTEMBER 68

MONTH	DAYS	STATION # 1			STATION # 2			STATION # 3			STATION # 4			STATION # 5		
		FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L
OCTOBER	31	18,95	219	231	19,07	240	313	6,72	107	96	25,79	205	256	25,70	155	131
NOVEMBER	30	17,49	266	285	17,60	288	348	6,46	112	87	24,06	240	277	23,97	164	108
DECEMBER	31	22,63	190	178	22,75	206	222	4,88	97	85	27,63	186	197	27,53	133	101
JANUARY	31	22,49	189	217	22,55	200	239	4,71	91	75	27,26	181	210	27,16	128	96
FEBRUARY	29	19,66	174	161	19,72	182	185	6,46	91	76	26,18	159	158	26,08	124	100
MARCH	31	24,14	200	168	24,23	208	185	3,37	106	72	27,60	195	171	27,50	133	86
APRIL	30	20,59	155	157	20,67	162	161	4,63	71	57	25,30	145	141	25,21	114	81
MAY	31	20,63	155	158	20,73	169	168	5,93	82	60	26,66	149	143	26,58	104	82
JUNE	30	23,23	204	158	23,43	243	265	4,21	106	92	27,64	222	238	27,52	149	105
JULY	31	19,86	203	112	20,01	221	229	6,24	89	75	26,25	189	192	26,15	125	90
AUGUST	31	18,94	181	180	19,05	184	192	7,04	67	57	26,09	152	155	26,00	114	84
SEPTEMBE	30	18,86	193	173	18,98	196	192	7,34	69	57	26,32	160	154	26,23	121	88

TABLE NO. 2
FROM OCTOBER 67 TO SEPTEMBER 68

MONTH	DAYS	STATION # 6			STATION # 7			STATION # 8			STATION # 9			STATION #10	STATION #11
		FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	FLOW MGD
OCTOBER	31	0,09	5,84	74,07	18,98	107	96	10,96	63	76	0,02	3,08	71,05	18,85	0,11
NOVEMBER	30	0,09	4,23	79,90	17,51	112	87	17,49	66	65	0,02	2,71	74,61	17,41	0,07
DECEMBER	31	0,10	4,84	79,85	22,65	97	85	22,62	57	70	0,03	2,71	73,22	22,56	0,06
JANUARY	31	0,10	4,10	83,61	22,45	91	75	22,43	54	61	0,02	3,00	78,41	22,39	0,04
FEBRUARY	29	0,10	3,84	83,46	19,62	91	76	19,60	53	61	0,02	3,08	76,64	19,57	0,03
MARCH	31	0,10	4,01	82,33	24,13	106	72	24,11	58	58	0,02	3,10	78,07	24,02	0,09
APRIL	30	0,09	3,39	84,95	20,58	71	57	20,56	41	42	0,02	2,30	80,82	20,48	0,08
MAY	31	0,08	3,81	76,24	20,65	82	60	20,62	53	49	0,03	2,52	71,32	20,65	-0,03
JUNE	30	0,12	4,43	71,66	23,31	106	92	23,28	61	68	0,03	2,85	67,62	23,25	0,03
JULY	31	0,10	5,08	73,56	19,91	89	75	19,89	50	58	0,03	2,82	70,46	19,83	0,05
AUGUST	31	0,09	3,71	81,95	18,96	67	57	18,94	39	41	0,02	1,96	77,33	18,83	0,11
SEPTEMBE	30	0,09	4,18	76,84	18,89	69	57	18,86	53	41	0,02	2,53	72,82	18,88	-0,02

TABLE NO, 3
FROM OCTOBER 67 TO SEPTEMBER 68

MONTH	DAYS	STATION #12			STATION #13			STATION #14			TRICKLING FILTER LOADING	
		FLOW MGD	TOTAL SOLIDS	VOL, SOLID	FLOW MGD	TOTAL SOLIDS	VOL, SOLID	FLOW MGD	B,O,D, MG/L	S,S, MG/L	GAL/FT2 PER DAY	# B,O,D,/ 1000FT3/DAY
OCTOBER	31	0,09	5,63	65,35	0,02	2,59	63,31	0,12	3460	12890	426,12	129,61
NOVEMBER	30	0,06	4,51	63,63	0,03	2,17	66,33	0.11	3780	10580	397.35	127,88
DECEMBER	31	0,03	4,46	73,78	0,05	2,24	63,72	0.12	3165	8650	456,37	119,11
JANUARY	31	0,04	5,89	72,21	0,02	3,21	61,39	0.06	3850	7900	450,35	113,12
FEBRUARY	29	0,03	6,10	62,40	0,04	1,01	69,87	0,06	2680	7750	432,39	105,21
MARCH	31	0,06	4,95	67,69	0,0	0,0	0,0	0,09	2320	4720	455,91	118,99
APRIL	30	0,0	0,0	0,0	0,0	0,0	0,0	0,08	1710	1000	417,96	93,50
MAY	31	0,00	6,75	55,72	0,14	1,38	56,26	0,10	2790	2090	440,58	89,92
JUNE	30	0,0	0,0	0,0	0,17	2,36	58,04	0,20	4815	12860	456,22	133,39
JULY	31	0,01	7,95	60,57	0,10	3,16	68,72	0,15	2430	15250	433,57	106,35
AUGUST	31	0,0	0,0	0,0	0,0	0,0	0,0	0,11	520	2200	431,09	96,44
SEPTEMBE	30	0,01	6,65	50,23	0,14	1,93	53,39	0,12	605	3090	434,80	103,24

TABLE NO, 4
FROM OCTOBER 67 TO SEPTEMBER 68

MONTH	DAYS	B,O,D,		REMOVAL		S,S,		REMOVAL		MISCELLANEOUS			
		GROSS WT, REM, POUNDS	%	NET WT, REM, POUNDS	%	GROSS WT, REM, POUNDS	%	NET WT, REM, POUNDS	%	DIG,SLUDGE TOTAL	VOLATILE	AVG,TEMP, AIR	AVG,TEMP, SEWAGE
OCTOBER	31	876212,	74,0	765980,	71,4	1172763,	76,0	762103,	67,3	5,63%	65,35%	57 F	70,3 F
NOVEMBER	30	980706,	77,3	878879,	75,4	1249272,	81,5	964266,	77,3	4,51%	63,63%	41 F	64,7 F
DECEMBER	31	819244,	72,6	784218,	70,2	897542,	68,7	637835,	61,0	4,46%	73,78%	42 F	60,6 F
JANUARY	31	853433,	73,2	791141,	71,7	1040286,	74,7	912467,	72,1	5,89%	72,21%	30 F	58,7 F
FEBRUARY	29	617140,	71,1	577131,	69,7	593576,	67,3	477879,	62,3	6,10%	62,40%	34 F	56,2 F
MARCH	31	942851,	72,4	888674,	71,2	798770,	68,9	688548,	65,7	4,95%	67,69%	48 F	59,8 F
APRIL	30	627709,	74,9	592198,	73,8	617413,	74,2	596646,	73,5	0,0 %	0,0 %	55 F	64,8 F
MAY	31	622811,	68,8	547189,	65,9	638807,	70,9	582157,	69,0	6,75%	55,72%	61 F	67,8 F
JUNE	30	1069717,	75,1	853593,	70,1	1157971,	74,5	527328,	57,1	0,0 %	0,0 %	74 F	71,8 F
JULY	31	886916,	77,6	790449,	75,5	887279,	74,9	281879,	48,7	7,95%	60,57%	80 F	76,3 F
AUGUST	31	716375,	79,0	701196,	78,7	746040,	78,9	681822,	77,4	0,0 %	0,0 %	78 F	77,6 F
SEPTEMBE	30	680379,	73,1	662063,	72,6	718075,	78,8	624528,	76,3	6,65%	50,23%	70 F	75,6 F

TABLE NO. 1
FROM OCTOBER 68 TO SEPTEMBER 69

MONTH	DAYS	STATION # 1			STATION # 2			STATION # 3			STATION # 4			STATION # 5		
		FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L
OCTOBER	31	18.34	180	175	18.47	182	184	7.09	66	60	25.56	149	149	25.49	118	87
NOVEMBER	30	21.05	163	167	21.16	164	172	5.47	72	59	26.63	145	148	26.56	121	88
DECEMBER	31	20.32	180	180	20.43	182	186	5.58	74	68	26.01	158	160	25.93	117	93
JANUARY	31	21.31	187	169	21.45	191	178	4.47	87	83	25.92	173	161	25.84	133	102
FEBRUARY	28	21.46	166	153	21.59	171	156	5.10	79	65	26.69	153	138	26.61	114	82
MARCH	31	22.15	175	170	22.27	180	177	4.34	86	73	26.61	164	160	26.54	128	81
APRIL	30	20.28	186	171	20.39	189	175	5.18	87	67	25.57	168	153	25.49	131	92
MAY	31	20.10	175	167	20.19	183	171	5.57	87	57	25.76	162	146	25.67	130	81
JUNE	30	20.89	195	154	20.99	208	185	5.00	98	68	25.99	186	162	25.91	137	83
JULY	31	20.56	221	145	20.68	237	216	4.80	104	84	25.48	211	191	25.38	152	96
AUGUST	31	23.54	236	201	23.66	254	260	3.68	81	71	27.34	230	234	27.24	134	98
SEPTEMBE	30	22.00	225	214	22.12	240	264	4.48	86	76	26.60	214	232	26.51	128	107

TABLE NO. 2
FROM OCTOBER 68 TO SEPTEMBER 69

MONTH	DAYS	STATION # 6			STATION # 7			STATION # 8			STATION # 9			STATION #10	STATION #11
		FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	FLOW MGD
OCTOBER	31	0.07	3.29	82.83	18.40	66	60	18.38	45	40	0.02	2.31	75.82	18.37	0.01
NOVEMBER	30	0.07	3.16	85.12	21.09	72	59	21.06	46	44	0.02	2.43	79.04	21.06	0.01
DECEMBER	31	0.08	3.40	86.33	20.35	74	68	20.33	55	48	0.02	2.47	79.61	20.32	0.01
JANUARY	31	0.08	3.03	85.28	21.37	87	83	21.35	60	58	0.02	2.46	81.08	21.34	0.01
FEBRUARY	28	0.08	3.06	85.10	21.51	79	65	21.49	56	51	0.02	2.52	81.63	21.46	0.03
MARCH	31	0.07	3.14	85.48	22.20	86	73	22.18	63	58	0.02	2.55	81.54	22.16	0.01
APRIL	30	0.08	3.27	84.96	20.31	87	67	20.29	61	47	0.02	2.66	82.18	20.28	0.01
MAY	31	0.09	3.66	85.01	20.10	87	57	20.09	51	39	0.02	2.16	81.08	20.04	0.05
JUNE	30	0.08	4.62	79.22	20.91	98	68	20.89	69	55	0.02	2.41	75.65	20.79	0.10
JULY	31	0.10	4.72	79.45	20.58	104	84	20.56	70	63	0.02	2.74	72.77	20.44	0.12
AUGUST	31	0.10	4.93	75.02	23.56	81	71	23.54	57	58	0.02	3.01	70.93	23.42	0.12
SEPTEMBE	30	0.09	5.04	77.82	22.03	86	76	22.01	66	67	0.02	2.91	74.49	21.90	0.11

TABLE NO. 3
FROM OCTOBER 68 TO SEPTEMBER 69

MONTH	DAYS	STATION #12			STATION #13			STATION #14			TRICKLING FILTER LOADING	
		FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	B.O.D. MG/L	S.S. MG/L	GAL/FT2 PER DAY	# B.O.D./ 1000FT3/DAY
OCTOBER	31	0.02	6.45	50.37	0.12	0.43	65.58	0.13	398	1420	422.56	97.85
NOVEMBER	30	0.01	5.86	54.06	0.11	0.53	65.08	0.11	299	920	440.26	104.54
DECEMBER	31	0.01	6.18	55.55	0.11	0.55	66.72	0.11	471	1200	429.90	98.70
JANUARY	31	0.01	5.50	57.89	0.13	0.66	65.87	0.14	694	1555	428.39	111.81
FEBRUARY	28	0.01	5.29	70.43	0.10	0.29	57.36	0.15	960	485	441.18	98.70
MARCH	31	0.02	2.94	68.71	0.10	0.40	66.88	0.12	1140	1360	439.95	110.51
APRIL	30	0.02	3.84	66.48	0.10	0.30	67.67	0.11	645	870	422.59	108.64
MAY	31	0.01	7.69	77.37	0.04	0.24	61.47	0.09	1710	890	425.66	108.59
JUNE	30	0.01	9.73	75.25	0.0	0.0	0.0	0.10	3010	6830	429.53	115.48
JULY	31	0.02	4.57	68.49	0.0	0.0	0.0	0.12	2920	12150	420.75	125.50
AUGUST	31	0.01	5.98	71.11	0.0	0.0	0.0	0.12	3760	12210	451.58	118.74
SEPTEMBE	30	0.07	3.43	71.55	0.0	0.0	0.0	0.11	2940	9810	439.51	110.40

TABLE NO. 4
FROM OCTOBER 68 TO SEPTEMBER 69

MONTH	DAYS	B.O.D.		REMOVAL		S.S.		REMOVAL		MISCELLANEOUS			
		GROSS WT. REM. POUNDS	%	NET WT. REM. POUNDS	%	GROSS WT. REM. POUNDS	%	NET WT. REM. POUNDS	%	DIG.SLUDGE TOTAL	VOLATILE	AVG.TEMP. AIR	AVG.TEMP. SEWAGE
OCTOBER	31	655386.	75.4	642042.	75.0	688681.	78.4	641073.	77.1	6.45%	50.37%	60 F	71.7 F
NOVEMBER	30	625882.	72.1	617454.	71.8	678774.	74.5	652840.	73.8	5.86%	54.06%	46 F	66.4 F
DECEMBER	31	672331.	69.9	658700.	69.5	730239.	74.3	695511.	73.4	6.18%	55.35%	34 F	60.5 F
JANUARY	31	728167.	68.7	703915.	68.0	667109.	67.6	612770.	65.7	5.50%	57.89%	31 F	56.7 F
FEBRUARY	28	581512.	67.5	552048.	66.3	530941.	67.5	516056.	66.9	5.29%	70.43%	35 F	56.6 F
MARCH	31	675379.	65.2	641437.	64.0	686757.	67.4	646265.	66.0	2.94%	68.71%	42 F	59.0 F
APRIL	30	654704.	67.9	636253.	67.3	654313.	73.3	629426.	72.5	3.84%	66.48%	58 F	63.7 F
MAY	31	691060.	72.3	649845.	71.1	690582.	77.4	669131.	76.8	7.69%	77.37%	67 F	69.7 F
JUNE	30	733392.	67.1	661596.	64.8	685436.	70.5	522524.	64.6	9.73%	75.25%	76 F	73.7 F
JULY	31	897294.	70.8	805727.	68.5	822000.	71.2	440996.	57.0	4.57%	68.49%	79 F	76.7 F
AUGUST	31	1208528.	77.8	1095951.	76.0	1239174.	77.9	873600.	71.3	5.98%	71.11%	75 F	76.8 F
SEPTEMBE	30	966694.	72.8	882101.	70.9	1094041.	74.9	811778.	68.9	3.43%	71.55%	68 F	74.5 F

TABLE NO. 1
FROM OCTOBER 69 TO SEPTEMBER 70

MONTH	DAYS	STATION # 1			STATION # 2			STATION # 3			STATION # 4			STATION # 5		
		FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L
OCTOBER	31	18,91	223	183	19,01	246	241	6,00	112	86	25,01	213	203	24,94	147	120
NOVEMBER	30	18,35	212	159	18,45	224	213	5.90	113	92	24,35	197	183	24,28	137	105
DECEMBER	31	22,03	192	160	22,09	199	175	4,23	101	76	26,32	183	159	26,28	135	95
JANUARY	31	23,08	209	167	23,18	218	194	3,39	111	85	26,57	204	180	26,49	143	102
FEBRUARY	28	25.56	200	189	25,75	209	211	2,30	109	91	28,05	200	201	27,94	139	101
MARCH	31	25,74	214	217	25,99	223	241	2,19	111	92	28,18	214	229	28,07	129	102
APRIL	30	29,90	183	168	30,12	187	178	0,94	98	81	31,06	184	175	30,94	112	88
MAY	31	25,96	164	159	26,26	167	169	1,87	77	65	28,13	161	162	28,01	112	83
JUNE	30	23,58	189	161	23,89	193	179	2,41	81	61	26,30	182	168	26,20	124	85
JULY	31	23,66	166	145	23,90	169	158	2,14	77	63	26,04	161	150	25,95	107	81
AUGUST	31	21,94	166	173	22,16	167	180	3,00	69	59	25,16	155	165	25,08	104	86
SEPTEMBE	30	21,44	200	176	21,70	202	188	2,92	75	65	24,62	186	173	24,54	124	91

TABLE NO. 2
FROM OCTOBER 69 TO SEPTEMBER 70

MONTH	DAYS	STATION # 6			STATION # 7			STATION # 8			STATION # 9			STATION #10	STATION #11
		FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	FLOW MGD
OCTOBER	31	0,07	4,45	80,01	18,94	112	86	18,91	75	69	0,02	2,87	73,96	18,82	0,09
NOVEMBER	30	0,07	4,46	79,74	18.38	113	92	18,35	67	67	0,02	3,09	76,33	18,26	0.09
DECEMBER	31	0,04	4,09	81,39	22,05	101	76	22,03	69	64	0,02	2,56	79,13	21,96	0,06
JANUARY	31	0,08	3,90	82,02	23,10	111	85	23,08	75	73	0,02	3,00	81,28	23,01	0,07
FEBRUARY	28	0,11	3,53	80,66	25,64	109	91	25,62	76	77	0,02	2,71	79,36	25,51	0,11
MARCH	31	0,11	4,51	83,90	25,88	111	92	25,86	76	74	0,02	2,66	81,79	25,69	0,18
APRIL	30	0,12	4,21	82,52	30,00	98	81	29,98	69	66	0,02	3,12	80,39	29,88	0,11
MAY	31	0,12	3,89	82,63	26,14	77	65	26,12	58	48	0,02	2,47	81,32	25,95	0,17
JUNE	30	0,10	3,85	80,78	23,79	81	61	23,76	59	50	0,02	2,41	77,95	23,58	0,18
JULY	31	0,09	3,81	80,76	23,81	77	63	23,79	49	44	0,02	2,79	75,15	23,66	0,13
AUGUST	31	0,08	3,90	81,39	22,08	69	59	22,05	42	41	0,03	2,38	77,48	21,95	0,10
SEPTEMBE	30	0,08	4,02	81,72	21,62	75	65	21,58	49	48	0,04	2,34	77,22	21,45	0,13

TABLE NO. 3
FROM OCTOBER 69 TO SEPTEMBER 70

MONTH	DAYS	STATION #12			STATION #15			STATION #14			TRICKLING FILTER LOADING	
		FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	B.O.D. MG/L	S.S. MG/L	GAL/FT2 PER DAY	# B.O.D./ 1000FT3/DAY
OCTOBER	31	0.10	4.91	73.54	0.01	0.85	72.90	0.10	4510	11000	413.40	119.25
NOVEMBER	30	0.10	1.98	68.95	0.0	0.0	0.0	0.09	2370	10600	402.51	108.21
DECEMBER	31	0.07	2.97	68.41	0.00	1.63	74.97	0.06	2290	4990	435.62	115.40
JANUARY	31	0.08	2.76	68.51	0.03	0.93	73.91	0.10	2205	6250	439.20	123.25
FEBRUARY	28	0.03	7.34	67.73	0.08	2.85	72.58	0.19	1337	3070	463.24	126.36
MARCH	31	0.04	7.44	62.86	0.08	0.90	73.92	0.25	1130	2670	465.41	117.82
APRIL	30	0.02	5.93	63.55	0.11	0.46	68.63	0.22	712	1460	513.01	112.75
MAY	31	0.01	4.65	56.92	0.12	0.43	67.67	0.30	344	1020	464.34	102.05
JUNE	30	0.01	5.09	54.31	0.13	0.50	64.14	0.31	476	1480	434.31	105.68
JULY	31	0.01	4.74	52.38	0.12	0.38	65.55	0.24	376	1360	430.21	90.33
AUGUST	31	0.01	5.19	51.64	0.12	0.51	65.98	0.22	255	836	415.72	84.84
SEPTEMBE	30	0.01	5.38	53.44	0.13	0.59	65.38	0.26	343	1180	406.82	98.99

TABLE NO. 4
FROM OCTOBER 69 TO SEPTEMBER 70

MONTH	DAYS	B.O.D.		REMOVAL		S.S.		REMOVAL		MISCELLANEOUS			
		GROSS WT. REM. POUNDS	%	NET WT. REM. POUNDS	%	GROSS WT. REM. POUNDS	%	NET WT. REM. POUNDS	%	DIG.SLUDGE TOTAL	VOLATILE	AVG.TEMP. AIR	AVG.TEMP. SEWAGE
OCTOBER	31	844164.	69.8	726434.	66.6	848781.	71.7	561635.	62.6	4.91%	73.54%	56 F	70.4 F
NOVEMBER	30	727942.	70.4	671610.	68.7	677165.	68.9	425214.	58.1	1.98%	68.95%	45 F	65.2 F
DECEMBER	31	744730.	65.5	706723.	64.3	636054.	63.6	553237.	60.4	2.97%	68.41%	35 F	60.4 F
JANUARY	31	860297.	65.8	803472.	64.3	728363.	62.6	567297.	56.6	2.76%	68.51%	29 F	56.6 F
FEBRUARY	28	803925.	64.0	745050.	62.2	809993.	63.8	674805.	59.5	7.34%	67.73%	36 F	56.3 F
MARCH	31	993712.	66.3	919732.	64.6	1127945.	69.7	953142.	66.0	7.44%	62.86%	42 F	59.2 F
APRIL	30	893460.	63.4	854803.	62.4	848060.	63.2	768791.	60.9	5.93%	63.55%	55 F	63.2 F
MAY	31	744739.	65.7	718315.	64.9	825399.	71.9	747051.	69.9	4.65%	56.92%	67 F	68.9 F
JUNE	30	805475.	69.8	767999.	68.8	774899.	72.4	658379.	69.1	5.09%	54.31%	75 F	73.6 F
JULY	31	744537.	71.3	720986.	70.6	707151.	72.4	621970.	69.8	4.74%	52.38%	78 F	76.3 F
AUGUST	31	718462.	75.1	703873.	74.7	798616.	77.4	750787.	76.3	5.19%	51.64%	77 F	76.9 F
SEPTEMBE	30	833734.	76.0	811535.	75.5	763090.	74.8	686723.	72.7	5.38%	53.44%	73 F	75.9 F

TABLE NO, 1
FROM OCTOBER 70 TO SEPTEMBER 71

MONTH	DAYS	STATION # 1			STATION # 2			STATION # 3			STATION # 4			STATION # 5		
		FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L
OCTOBER	31	19,38	194	171	19,64	197	188	4,21	79	64	23,85	176	166	23,77	122	86
NOVEMBER	30	22,55	168	168	22,70	170	177	2,87	61	60	25,57	157	163	25,49	102	88
DECEMBER	31	21,74	166	160	21,87	168	172	3,07	69	66	24,94	155	158	24,86	108	91
JANUARY	31	21,29	170	147	21,42	172	160	2,79	66	60	24,21	159	148	24,13	98	85
FEBRUARY	28	25,12	170	148	25,23	176	153	2,08	70	69	27,31	167	146	27,24	101	85
MARCH	31	24,33	185	161	24,47	194	175	1,53	77	70	26,00	187	168	25,93	113	89
APRIL	30	20,62	175	145	20,76	179	159	3,40	64	68	24,16	162	146	24,09	109	86
MAY	31	21,20	156	156	21,30	157	162	3,91	53	54	25,21	140	145	25,15	95	81
JUNE	30	17,98	178	149	18,11	180	160	4,82	51	51	22,93	152	137	22,87	96	80
JULY	31	15,75	181	156	15,87	182	168	7,30	52	50	23,17	141	130	23,11	99	78
AUGUST	31	16,77	161	145	16,88	162	149	6,67	46	45	23,55	129	119	23,49	89	70
SEPTEMBE	30	21,04	162	154	21,19	163	163	3,81	61	54	25,00	147	146	24,93	106	81

TABLE NO, 2
FROM OCTOBER 70 TO SEPTEMBER 71

MONTH	DAYS	STATION # 6			STATION # 7			STATION # 8			STATION # 9			STATION #10	STATION #11
		FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	B.O.D. MG/L	S.S. MG/L	FLOW MGD	TOTAL SOLIDS	VOL. SOLID	FLOW MGD	FLOW MGD
OCTOBER	31	0,08	3,98	83,66	19,56	79	64	19,53	51	44	0,03	2,13	79,10	19,39	0,14
NOVEMBER	30	0,08	3,73	83,85	22,62	61	60	22,60	46	47	0,02	2,64	79,50	22,56	0,04
DECEMBER	31	0,08	3,84	84,12	21,79	69	66	21,77	50	52	0,02	2,33	81,33	21,66	0,10
JANUARY	31	0,08	3,67	85,76	21,34	66	60	21,32	52	51	0,02	3,34	83,33	21,25	0,08
FEBRUARY	28	0,07	3,51	83,54	25,16	70	69	25,14	54	54	0,02	2,75	82,30	25,04	0,10
MARCH	31	0,07	3,85	84,50	24,40	77	70	24,38	62	57	0,02	2,71	81,72	24,28	0,09
APRIL	30	0,07	3,80	82,77	20,69	64	68	20,67	53	56	0,02	2,72	81,06	20,60	0,07
MAY	31	0,06	3,77	81,36	21,24	53	54	21,22	39	37	0,02	2,50	79,62	21.17	0,05
JUNE	30	0,06	3,57	81,77	18,05	51	51	18,03	38	33	0,02	2,59	76,87	17,98	0,05
JULY	31	0,06	3,68	82,05	15,81	52	50	15,79	36	37	0,02	2,99	74.16	15,75	0,04
AUGUST	31	0,06	3,54	81,40	16,82	46	45	16,80	37	34	0,02	2,69	72,88	16,78	0,02
SEPTEMBE	30	0,07	3,75	83,46	21,12	61	54	21,09	50	39	0,02	2,68	77,20	21,04	0,05

TABLE NO, 3

FROM OCTOBER 70 TO SEPTEMBER 71

MONTH	DAYS	STATION #12			STATION #13			STATION #14			TRICKLING FILTER LOADING	
		FLOW MGD	TOTAL SOLIDS	VOL, SOLID	FLOW MGD	TOTAL SOLIDS	VOL, SOLID	FLOW MGD	B.O.D, MG/L	S.S, MG/L	GAL/FT2 PER DAY	# B.O.D,/ 1000FT3/DAY
OCTOBER	31	0,01	5,28	53,99	0,11	0,61	66,69	0,26	372	1440	394,06	94,34
NOVFMBER	30	0,01	5,72	54,88	0,11	0,41	64,98	0,15	325	1450	422,63	84,59
DECEMBER	31	0,01	5,47	55,42	0,03	0,37	67,34	0,13	382	2110	412,11	87,34
JANUARY	31	0,01	5,95	57,84	0,06	0,37	62,19	0,13	385	2130	400,08	76,94
FEBRUARY	28	0,00	5,58	65,25	0,01	0,59	66,35	0,11	1390	1200	451,55	89,50
MARCH	31	0,01	5,11	68,98	0,05	1,50	71,75	0,14	1673	2500	429,87	95,32
APRIL	30	0,05	3,93	63,94	0,07	0,82	69,62	0,14	629	2100	399,36	85,42
MAY	31	0,03	3,05	62,05	0,05	0,30	65,86	0,10	249	1370	416,93	77,73
JUNE	30	0,02	3,52	60,28	0,08	0,30	63,47	0,13	394	1640	379,18	71,43
JULY	31	0,02	2,79	59,47	0,09	0,26	60,52	0,12	250	1585	383,11	74,43
AUGUST	31	0,01	4,07	55,93	0,08	0,30	65,84	0,11	293	730	389,46	68,02
SEPTEMBE	30	0,02	6,22	56,26	0,09	0,23	62,50	0,15	287	1410	413,24	85,96

TABLE NO, 4

FROM OCTOBER 70 TO SEPTEMBER 71

MONTH	DAYS	B.O.D,		REMOVAL		S.S,		REMOVAL		MISCELLANEOUS			
		GROSS WT, REM, POUNDS	%	NET WT, REM, POUNDS	%	GROSS WT, REM, POUNDS	%	NET WT, REM, POUNDS	%	DIG,SLUDGE TOTAL	VOLATILE	AVG,TEMP, AIR	AVG,TEMP, SEWAGE
OCTOBER	31	744605,	74,4	720065,	73,8	734003,	76,9	639007,	74,3	5,28%	53,99%	61 F	72,7 F
NOVEMBER	30	705881,	73,1	693521,	72,8	739994,	73,6	684850,	72,1	5,72%	54,88%	47 F	66,9 F
DECEMBER	31	669858,	70,5	656637,	70,1	681273,	70,1	608244,	67,6	5,47%	55,42%	39 F	61,7 F
JANUARY	31	666879,	70,0	653682,	69,6	605917,	68,4	532906,	65,5	5,95%	57,84%	30 F	57,9 F
FEBRUARY	28	721228,	69,6	686682,	68,5	585719,	65,0	555895,	63,8	5,58%	65,25%	37 F	56,7 F
MARCH	31	838059,	68,3	777922,	66,6	749249,	67,7	659386,	64,8	5,11%	68,98%	42 F	59,5 F
APRIL	30	656598,	70,6	634670,	69,9	537253,	65,1	464045,	61,7	3,93%	63,94%	54 F	63,0 F
MAY	31	651120,	75,3	644890,	75,1	689601,	77,3	655324,	76,4	3,05%	62,05%	64 F	68,1 F
JUNE	30	644607,	79,0	632285,	78,7	576484,	79,5	525193,	78,0	3,52%	60,28%	76 F	72,9 F
JULY	31	600141,	80,4	592072,	80,2	538627,	78,1	487470,	76,4	2,79%	59,47%	78 F	76,5 F
AUGUST	31	546472,	77,3	538433,	77,0	502753,	77,3	482723,	76,6	4,07%	55,93%	75 F	76,5 F
SEPTEMBE	30	600989,	69,5	590505,	69,2	658892,	76,2	607386,	74,7	6,22%	56,26%	72 F	75,2 F

APPENDIX B

LINEAR VERSUS NON LINEAR REGRESSION

APPENDIX B

LINEAR VERSUS NON LINEAR REGRESSION

B.1 General

The intrinsically linear model defined as

$$Y = B_o \prod_{i=1}^{n} X_i^{B_i} e_i \tag{B-1}$$

represents the adopted general form for the BOD and suspended solids removal models of the Alexandria sewage treatment plant. Using the original form (Equation B-1) data must be regressed by the use of non linear regression techniques such as defined in Chapter 5. However, through basic mathematical manipulations the intrinsically linear model can be reduced to one with linear parameters. Thus, Equation B-1 can be transformed to:

$$Y' = \ln Y = \ln B_o + \sum_{i=1}^{n} B_i \ln X_i + \ln e_i \tag{B-2}$$

It must however be emphasized that the requirements for valid tests of significance and confidence interval estimate are now $\ln \varepsilon \approx N(0, I\sigma^2)$, rather than $\varepsilon \approx N(0, I\sigma^2)$

B.2 Results

Linear and non linear regression outputs for the TF2-BOD model have been included herein so as to illustrate actual test results. Such results will hereafter be summarized so as to clearly point the characteristics of each regression.

B-2-1 Linear Regression

Model: TF2-BOD (linear)
No. of cases: 83
No. of independent variables: 4
No. of original variables: 5
Multiple correlation coefficient (R): 0.9546
Coefficient of determination (R^2): 0.9112
Standard error of the estimate(s): 0.08319
Variance of the estimate (s^2): 0.00692
Range of residuals: 0.465

B-2-2 Non Linear Regression

Model: TF2-BOD (non linear)
No. of cases: 83
No. of independent variables: 4
No. of original variables: 5
Multiple correlation coefficient (R): 0.9533
Coefficient of determination (R^2): 0.9088
Standard error of the estimate: 5.27928

B.3 Conclusions

Not only does the linearized form of the model yield slightly better regression results than the non linear form, probably due to the rounding-off errors within the convergence technique, but the use of linear regression algorithms makes it much easier to prepare the data for regression. Thus, because in all cases tested, the trend reported above was also observed, it was decided to adopt the linear regression algorithms to fit the equations to the data.

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BMD03R - MULTIPLE REGRESSION WITH CASE COMBINATIONS - REVISED AUGUST 22, 1969
HEALTH SCIENCES COMPUTING FACILITY, UCLA


NO. OF SUBSAMPLES ............ 1
NO. OF ORIGINAL VARIABLES .... 5
TOT. COMB. SAMP. SIZE ....    83
ALTERNATE TAPE NO. ........... 5
NO. OF VAR. FORMAT CARDS ..... 1
THE VARIABLE FORMAT IS  (2E13.6,13X,E13.6,/,/,52X,2E13.6)


SELECTION NO.    1- 0
SUB-SAMPLES SELECTED  1


SUMS
          374.92188          237.26555          348.57520          330.27905          341.76050


SUM OF SQUARES
         1697.44971          679.42505         1464.88330         1317.88965         1413.31030


CROSS PRODUCT SUMS

ROW   1
         1697.44971         1073.49902         1574.40015         1494.93213         1548.02856

ROW   2
         1073.49902          679.42505          996.44580          945.32300          978.61304

ROW   3
         1574.40015          996.44580         1464.88330         1386.33423         1434.52710

ROW   4
         1494.93213          945.32300         1386.33423         1317.88965         1364.29004

ROW   5
         1548.02856          978.61304         1434.52710         1364.29004         1413.31030


CROSS PRODUCTS OF DEVIATIONS
```

```
ROW  1    3,87915     1,73999    -0,15918     3,01880     4,25244
ROW  2    1,73999     1,17285     0,00171     1,18091     1,65015
ROW  3   -0,15918     0,00171     0,97217    -0,73877    -0,76416
ROW  4    3,01880     1,18091    -0,73877     3,62158     4,33447
ROW  5    4,25244     1,65015    -0,76416     4,33447     6,07935
```

```
SELECTION NO.    1- 1


CORRELATION COEFFICIENTS

ROW    1
 1.000     0.8157     -.8197E-010.8054     0.8757

ROW    2
0.8157      1.000     0.1600E-020.5730     0.6180

ROW    3
-.8197E-010.1600E-02 1.000      -.3937     -.3143

ROW    4
0.8054     0.5730     -.3937      1.000     0.9238

ROW    5
0.8757     0.6180     -.3143     0.9238      1.000


INVERSE OF CORRELATION COEFFICIENT MATRIX

ROW    1
 6.795     -3.239     -1.020     -4.019

ROW    2
-3.239      3.182     0.4586E-010.8037

ROW    3
-1.020     0.4586E-01 1.455      1.368

ROW    4
-4.019     0.8037      1.368      4.315
```

```
SELECTION NO,    1- 1

SAMPLE SIZE      83
NO, OF VARIABLES  5      NO, OF VARIABLES DELETED  0  (FOR VARIABLES DELETED, SEE BELOW)
DEPENDENT VARIABLE IS NOW NO,  5

COEFFICIENT OF DETERMINATION  0,9112
MULTIPLE CORR, COEFFICIENT    0,9546

SUM OF SQUARES ATTRIBUTABLE TO REGRESSION          5,53953
SUM OF SQUARES OF DEVIATION FROM REGRESSION        0,53981

VARIANCE OF ESTIMATE       0,00692
STD, ERROR OF ESTIMATE     0,08319

INTERCEPT (A VALUE)    -0,24521


              ANALYSIS OF VARIANCE FOR THE MULTIPLE
                    LINEAR  REGRESSION
     SOURCE OF VARIATION       D,F,     SUM OF        MEAN        F
                                        SQUARES      SQUARES     VALUE
DUE TO REGRESSION,...........   4       5,53953      1,38488    200,1080
DEVIATION ABOUT REGRESSION,..  78       0,53981      0,00692
                     TOTAL...  82       6,07935


VARIABLE     MEAN        STD,        REG,      STD,ERROR     COMPUTED     PARTIAL      SUM OF SQ,   PROP, VAR,
  NO,                 DEVIATION     COEFF,    OF REG,COE,   T VALUE    CORR, COE,      ADDED         CUM,
   1       4,51713    0,21750     0,69747     0,11011      6,33457      0,58283      4,66165      0,76680
   2       2,85862    0,11960    -0,32346     0,13702     -2,36075     -0,25824      0,16870      0,02775
   3       4,19970    0,10888    -0,14605     0,10177     -1,43501     -0,16039      0,30826      0,05071
   4       3,97927    0,21016     0,69114     0,09080      7,61130      0,65283      0,40093      0,06595
   5       4,11760    0,27228

COMP, CHECK ON FINAL COEFF,          0,69114


VARIABLES DELETED...  0
```

```
                     TABLE OF RESIDUALS

OBSERVATION      Y VALUE        Y ESTIMATE       RESIDUAL
     1           4,02595         3,92956          0,09639
     2           3,88758         3,89772         -0,01014
     3           4,15242         4,03489          0,11753
     4           4,20545         4,08088          0,12457
     5           4,15827         4,03340          0,12487
     6           4,09424         4,03192          0,06232
     7           4,12860         3,99191          0,13669
     8           3,81979         3,74810          0,07169
     9           3,70433         3,64629          0,05804
    10           3,56976         3,55839          0,01137
    11           3,66957         3,64737          0,02220
    12           3,69560         3,71083         -0,01523
    13           3,78724         3,89118         -0,10394
    14           4,09849         4,17312         -0,07463
    15           3,88667         3,96151         -0,07484
    16           4,11856         4,13922         -0,02066
    17           4,17338         4,11395          0,05943
    18           3,96715         3,95259          0,01456
    19           3,97000         3,82862          0,14138
    20           3,80347         3,81070         -0,00723
    21           3,68463         3,77979         -0,09516
    22           3,72125         3,79550         -0,07425
    23           3,75479         4,00943         -0,25464
    24           3,70255         3,70163          0,00092
    25           3,83314         3,90027         -0,06713
    26           3,94757         4,02828         -0,08071
    27           3,96596         4,09147         -0,12551
    28           4,16051         4,16287         -0,00236
    29           4,17420         4,18704         -0,01285
    30           4,04825         4,11540         -0,06715
    31           4,05432         4,07834         -0,02402
    32           4,34269         4,30184          0,04085
    33           4,22562         4,15767          0,06795
    34           4,39188         4,35988          0,03200
    35           4,33931         4,32952          0,00979
    36           4,49382         4,61253         -0,11871
    37           4,46981         4,52171         -0,05190
    38           4,46449         4,51665         -0,05216
    39           4,38711         4,39364         -0,00653
    40           4,34653         4,34383          0,00270
    41           4,55213         4,40273          0,14940
    42           4,06443         4,02933          0,03510
    43           4,26138         4,05057          0,21081
    44           4,55286         4,62550         -0,07264
    45           4,32699         4,29835          0,02864
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46          [illegible]        [illegible]      [illegible]
47          4,07551            4,09063          -0,01513
48          4,00245            4,08595          -0,08350
49          4,13058            4,14668          -0,01610
50          4,13397            4,20947          -0,07550
51          4,29234            4,44235          -0,15001
52          4,22524            4,19739           0,02785
53          4,30750            4,34969          -0,04219
54          4,27870            4,25220           0,02650
55          4,28574            4,12963           0,15611
56          4,41410            4,28982           0,12428
57          4,45286            4,48056          -0,02770
58          4,27364            4,35160          -0,07796
59          4,30637            4,34228          -0,03591
60          4,50948            4,46739           0,04209
61          4,49155            4,44755           0,04400
62          4,45843            4,40065           0,05778
63          4,56080            4,53607           0,02473
64          4,59591            4,62111          -0,02520
65          4,61874            4,57402           0,04472
66          4,59152            4,48169           0,10983
67          4,25087            4,21109           0,03978
68          4,23471            4,15743           0,07728
69          4,17448            4,06140           0,11308
70          4,03068            3,95870           0,07198
71          4,09230            4,12703          -0,03473
72          4,11238            4,07739           0,03499
73          3,92367            3,99438          -0,07071
74          4,02187            4,08533          -0,06346
75          3,94762            3,92918           0,01844
76          4,12769            4,17891          -0,05122
77          4,17371            4,20765          -0,03394
78          3,91518            4,07571          -0,16053
79          3,76965            3,85513          -0,08548
80          3,63616            3,71164          -0,07548
81          3,66601            3,72349          -0,05748
82          3,55972            3,59378          -0,03406
83          3,90145            3,90768          -0,00623


TEST OF EXTREME RESIDUALS

RANGE OF RESIDUALS................                0,465
RANGE / STD, ERROR OF ESTIMATE....                5,595
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N =  83       K =    5       P =    0       M =    4
FF =  0,400E 01      T =  0,200E 01      E =  0,500E-04      TAU =  0,100E-02

PARAMETERS     0,65158933E 00   -0,21281338E 00   -0,11840910E 00    0,67507821E 00    0,668757O2E 00
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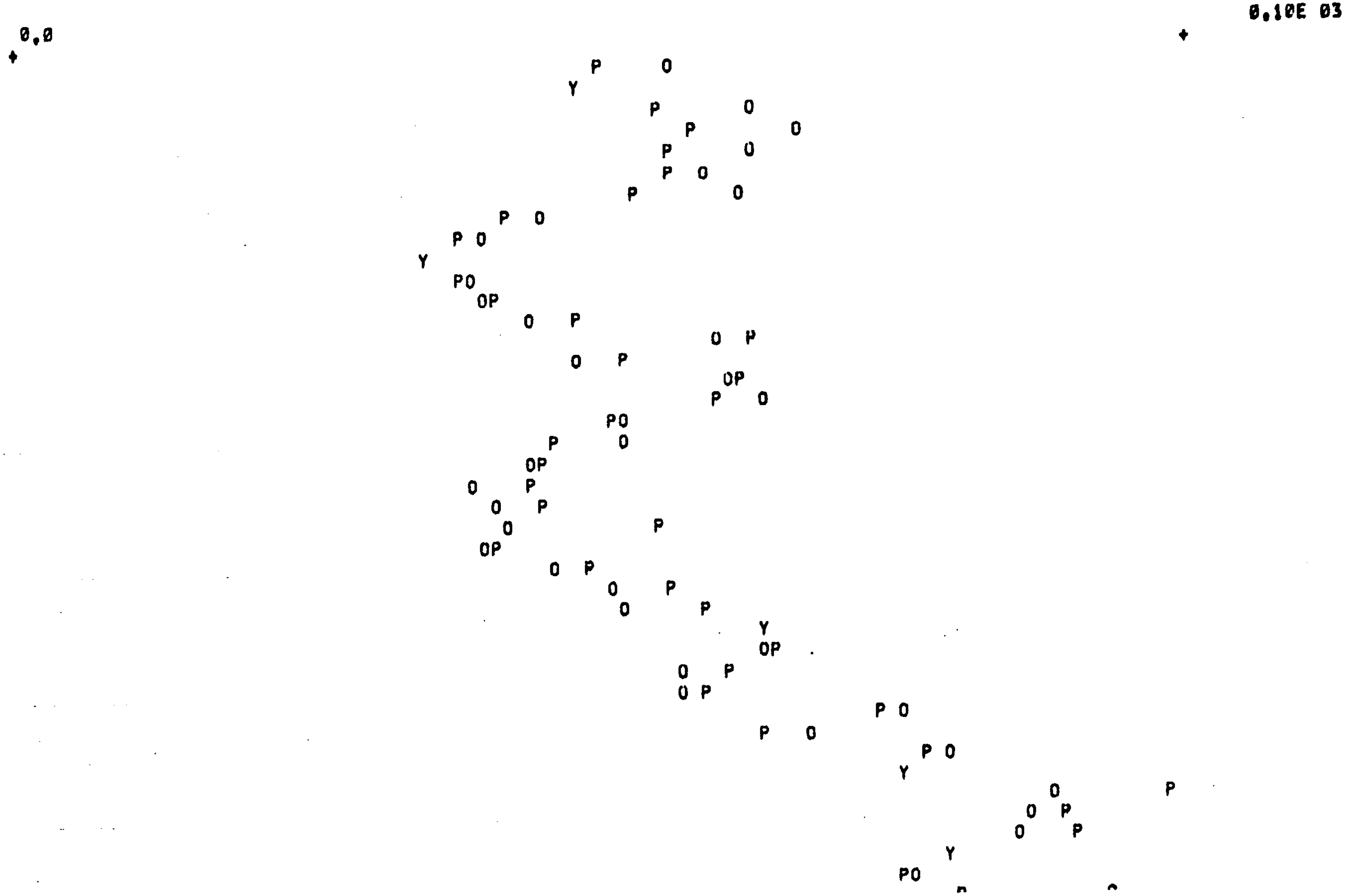

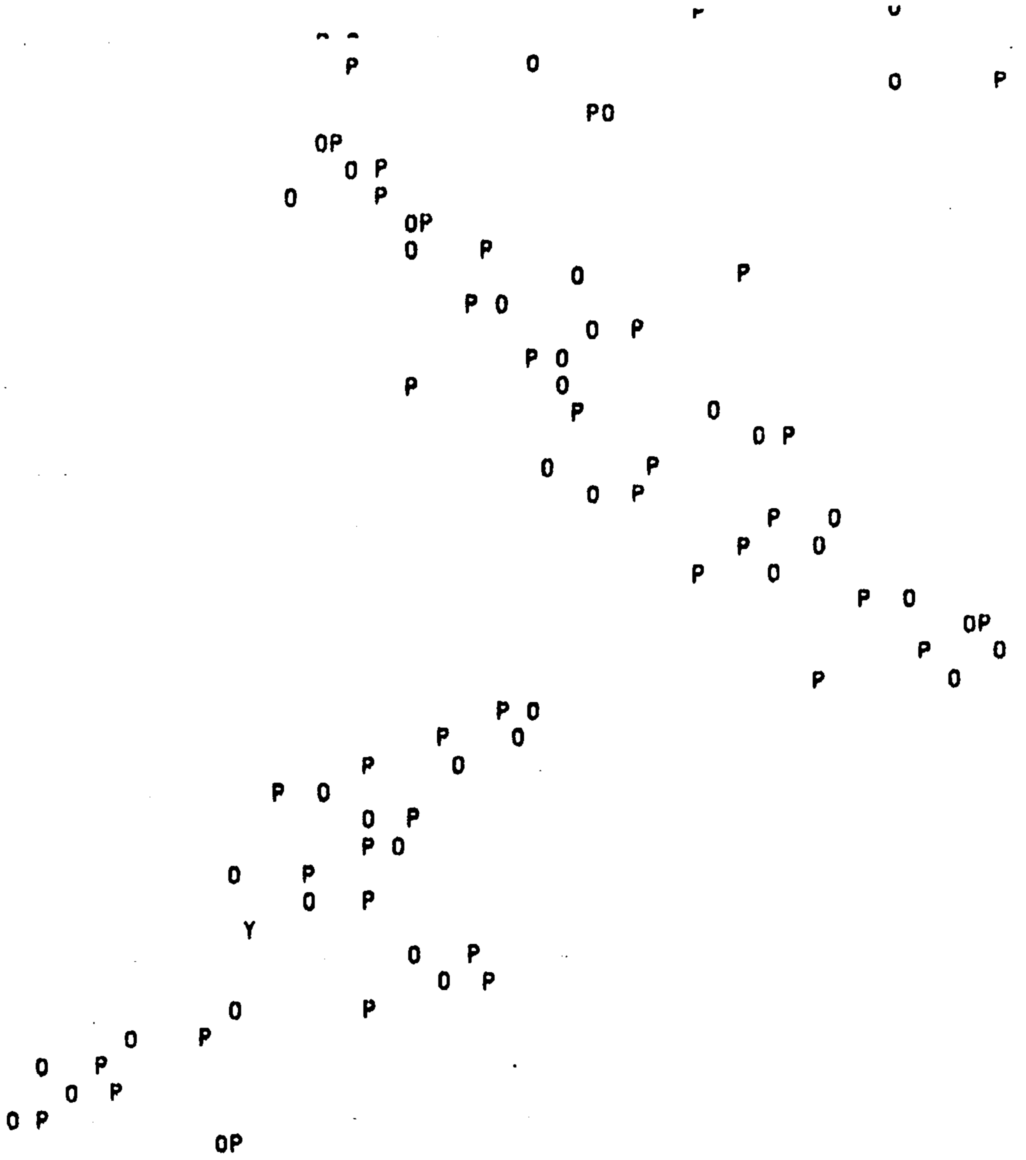

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PARAMETERS    0.65158933E 00   -0.21281338E 00   -0.11840910E 00    0.67507821E 00    0.66875702E 00

        OBS            PRED             DIFF
   0.56033493E 02   0.50215546E 02   0.58179474E 01    0.69009689E 02    0.13092899E 02    0.65270889E 02
                                                       0.47186096E 02
   0.48792587E 02   0.48820984E 02  -0.28396606E-01    0.61883286E 02    0.13208400E 02    0.62120499E 02
```

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                                                              0,4[illegible] 02
0,6[illegible] 02  0,[illegible] 02    0,[illegible]E [illegible]  0,740[illegible]5E [illegible]  0,14[illegible]  02  0,5[illegible] 02
                                                              0,52443497E 02
0,67050797E 02     0,58683334E 02     0,83674622E 01     0,74426392E 02     0,14883800E 02     0,57801590E 02
                                                              0,56322693E 02
0,63960495E 02     0,56442963E 02     0,75175323E 01     0,75459091E 02     0,15952700E 02     0,59511597E 02
                                                              0,53899292E 02
0,59993698E 02     0,56078690E 02     0,39150085E 01     0,74823700E 02     0,14963300E 02     0,62841797E 02
                                                              0,53252899E 02
0,62091187E 02     0,53912262E 02     0,81789246E 01     0,73202286E 02     0,14508300E 02     0,68871887E 02
                                                              0,51633698E 02
0,45594589E 02     0,42750610E 02     0,28439789E 01     0,69062393E 02     0,14883800E 02     0,74180893E 02
                                                              0,39559998E 02
0,40622894E 02     0,38648880E 02     0,19740143E 01     0,64480698E 02     0,14313299E 02     0,75980896E 02
                                                              0,36109192E 02
0,35507996E 02     0,35500824E 02     0,71716309E-02     0,59602692E 02     0,14075000E 02     0,76880493E 02
                                                              0,34239899E 02
0,39234985E 02     0,38847717E 02     0,38726807E 00     0,58852493E 02     0,14515499E 02     0,75710297E 02
                                                              0,39888885E 02
0,40269485E 02     0,41219482E 02    -0,94999695E 00     0,67115891E 02     0,14898299E 02     0,71119797E 02
                                                              0,38256088E 02
0,44134491E 02     0,48634796E 02    -0,45003052E 01     0,71876190E 02     0,13995600E 02     0,64820587E 02
                                                              0,44134491E 02
0,60249496E 02     0,63153152E 02    -0,29036560E 01     0,85402191E 02     0,12984599E 02     0,61400894E 02
                                                              0,53230087E 02
0,48748398E 02     0,52025040E 02    -0,32766418E 01     0,69640488E 02     0,14053399E 02     0,58070999E 02
                                                              0,49381393E 02
0,61470398E 02     0,62234055E 02    -0,76365662E 00     0,76665390E 02     0,15331599E 02     0,56811798E 02
                                                              0,60089096E 02
0,64934586E 02     0,60635147E 02     0,42994385E 01     0,80655594E 02     0,15172700E 02     0,59781891E 02
                                                              0,55365295E 02
0,52833786E 02     0,51913605E 02     0,92018127E 00     0,69344391E 02     0,14660000E 02     0,63291489E 02
                                                              0,50852585E 02
0,52984497E 02     0,46418488E 02     0,65660095E 01     0,74033096E 02     0,16111496E 02     0,67071686E 02
                                                              0,42097290E 02
0,44856796E 02     0,45897354E 02    -0,10405579E 01     0,71023193E 02     0,16595398E 02     0,72651489E 02
                                                              0,44109085E 02
0,39830399E 02     0,44492462E 02    -0,46620636E 01     0,68797897E 02     0,16075394E 02     0,77060898E 02
                                                              0,43451294E 02
0,41315796E 02     0,45048218E 02    -0,37324219E 01     0,76832993E 02     0,16089890E 02     0,77870392E 02
                                                              0,39866196E 02
0,42725189E 02     0,55635635E 02    -0,12910446E 02     0,77954697E 02     0,16638687E 02     0,75079987E 02
                                                              0,53968597E 02
0,40550598E 02     0,41427124E 02    -0,87652588E 00     0,69403992E 02     0,17310287E 02     0,69770096E 02
                                                              0,38990997E 02
0,46207489E 02     0,49486542E 02    -0,32790527E 01     0,77712585E 02     0,15540999E 02     0,64820587E 02
                                                              0,43406998E 02
0,51809097E 02     0,56104935E 02    -0,42958374E 01     0,88075485E 02     0,16429291E 02     0,60860687E 02
                                                              0,46628189E 02
0,52771088E 02     0,59974014E 02    -0,72029266E 01     0,89789597E 02     0,17483597E 02     0,58701599E 02
                                                              0,51195786E 02
[illegible]        [illegible]        [illegible]        [illegible]        [illegible]        [illegible]
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0,64987595E 02   0,65991655E 02   -0,10040588E 01   0,10164699E 03   0,18494690E 02   0,59061996E 02
                                                    0,55323196E 02
0,57297394E 02   0,61677490E 02   -0,43800964E 01   0,94131485E 02   0,18169693E 02   0,63921890E 02
                                                    0,52386200E 02
0,57646194E 02   0,59615417E 02   -0,19692230E 01   0,98583298E 02   0,18545197E 02   0,67881195E 02
                                                    0,48456192E 02
0,76914291E 02   0,74008316E 02    0,29059753E 01   0,11494899E 03   0,18761887E 02   0,71661697E 02
                                                    0,58319595E 02
0,68416595E 02   0,64676208E 02    0,37403870E 01   0,10738799E 03   0,19224091E 02   0,76250793E 02
                                                    0,51961990E 02
0,80792587E 02   0,78682419E 02    0,21101685E 01   0,12340799E 03   0,19707886E 02   0,76520386E 02
                                                    0,61260300E 02
0,76654587E 02   0,76450378E 02    0,20420837E 00   0,12867000E 03   0,20256790E 02   0,74270187E 02
                                                    0,56578400E 02
0,89462997E 02   0,99734390E 02   -0,10271393E 02   0,12959599E 03   0,18559692E 02   0,70310287E 02
                                                    0,80265900E 02
0,87339798E 02   0,90468109E 02   -0,31283112E 01   0,12789000E 03   0,17310287E 02   0,64730194E 02
                                                    0,67844299E 02
0,86876892E 02   0,91363403E 02   -0,44865112E 01   0,11912000E 03   0,19881195E 02   0,60591385E 02
                                                    0,76129288E 02
0,80407700E 02   0,80968887E 02   -0,56118774E 00   0,11310100E 03   0,19613998E 02   0,58700699E 02
                                                    0,66270096E 02
0,77210297E 02   0,76885391E 02    0,32490540E 00   0,10520999E 03   0,18834091E 02   0,56181686E 02
                                                    0,64483292E 02
0,94834198E 02   0,81709412E 02    0,13124786E 02   0,11898999E 03   0,19859589E 02   0,59782196E 02
                                                    0,64415695E 02
0,58231491E 02   0,56746307E 02    0,14851837E 01   0,93498398E 02   0,18205795E 02   0,64821487E 02
                                                    0,46749191E 02
0,70907990E 02   0,58383560E 02    0,12524429E 02   0,89932098E 02   0,19195190E 02   0,67791290E 02
                                                    0,51883896E 02
0,94903198E 02   0,10168358E 03   -0,67803802E 01   0,13340199E 03   0,19873993E 02   0,71751587E 02
                                                    0,82368790E 02
0,75716095E 02   0,74090500E 02    0,16255951E 01   0,10634299E 03   0,18884598E 02   0,76340988E 02
                                                    0,63805695E 02
0,56672791E 02   0,57492477E 02   -0,81968689E 00   0,96428391E 02   0,18776291E 02   0,77600388E 02
                                                    0,48214188E 02
0,58880798E 02   0,60543091E 02   -0,16622925E 01   0,10325499E 03   0,18942398E 02   0,75620193E 02
                                                    0,48640686E 02
0,54731888E 02   0,60106216E 02   -0,53743286E 01   0,97853897E 02   0,18407990E 02   0,71660187E 02
                                                    0,49756195E 02
0,62213791E 02   0,63808441E 02   -0,15946503E 01   0,10455399E 03   0,19180695E 02   0,66440186E 02
                                                    0,50980789E 02
0,62425293E 02   0,67638107E 02   -0,52128143E 01   0,98699493E 02   0,18725800E 02   0,60500595E 02
                                                    0,57363785E 02
0,73137192E 02   0,84438004E 02   -0,11300812E 02   0,11180699E 03   0,18660797E 02   0,56721298E 02
                                                    0,69774597E 02
0,68390900E 02   0,66916489E 02    0,14744110E 01   0,98690689E 02   0,19216797E 02   0,56631699E 02
                                                    0,56270996E 02
0,74254990E 02   0,77443466E 02   -0,31884766E 01   0,11051900E 03   0,19166290E 02   0,58971786E 02
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                                                     0,55561096E 02
0,72655991E 02   0,62536118E 02   0,10119873E 02   0,10856599E 03   0,18537994E 02   0,69681396E 02
                                                     0,47602188E 02
0,82607590E 02   0,73165131E 02   0,94424591E 01   0,11548199E 03   0,18711288E 02   0,73731186E 02
                                                     0,57319489E 02
0,85871994E 02   0,87827179E 02  -0,19551849E 01   0,12550499E 03   0,18328598E 02   0,76700790E 02
                                                     0,69358093E 02
0,71782486E 02   0,78130325E 02  -0,63478394E 01   0,11875099E 03   0,19671799E 02   0,76790390E 02
                                                     0,62920486E 02
0,74171097E 02   0,77314362E 02  -0,31432648E 01   0,11039400E 03   0,19144592E 02   0,74450287E 02
                                                     0,65546585E 02
0,90874298E 02   0,86498810E 02   0,43754883E 01   0,11927199E 03   0,18010788E 02   0,70400192E 02
                                                     0,69778397E 02
0,89259293E 02   0,84690598E 02   0,45686951E 01   0,10821700E 03   0,17534195E 02   0,65180496E 02
                                                     0,72671295E 02
0,86352188E 02   0,81256409E 02   0,50957794E 01   0,11542099E 03   0,18978485E 02   0,60410690E 02
                                                     0,64977890E 02
0,95660187E 02   0,92498520E 02   0,31616669E 01   0,12323799E 03   0,19130188E 02   0,56631088E 02
                                                     0,73253296E 02
0,99078491E 02   0,10097430E 03  -0,18958130E 01   0,12634799E 03   0,20177292E 02   0,56271896E 02
                                                     0,82716888E 02
0,10136600E 03   0,96802917E 02   0,45630798E 01   0,11780399E 03   0,20271194E 02   0,59241699E 02
                                                     0,84014999E 02
0,98644485E 02   0,89604370E 02   0,90401154E 01   0,11273700E 03   0,22343796E 02   0,63201996E 02
                                                     0,81532700E 02
0,70166595E 02   0,68433136E 02   0,17334595E 01   0,10206099E 03   0,20227890E 02   0,68871597E 02
                                                     0,59231491E 02
0,69041885E 02   0,64528549E 02   0,45133362E 01   0,10569398E 03   0,18920792E 02   0,73551193E 02
                                                     0,51994492E 02
0,65006195E 02   0,59019043E 02   0,59871521E 01   0,90333298E 02   0,18740189E 02   0,76250793E 02
                                                     0,53186890E 02
0,56299286E 02   0,53308121E 02   0,29911652E 01   0,84856888E 02   0,18111893E 02   0,76880493E 02
                                                     0,48139999E 02
0,59877289E 02   0,62387726E 02  -0,25104370E 01   0,98997086E 02   0,17721985E 02   0,75890396E 02
                                                     0,51893692E 02
0,61091797E 02   0,59261597E 02   0,18302002E 01   0,94344193E 02   0,17165894E 02   0,72650085E 02
                                                     0,49491989E 02
0,50585495E 02   0,55109726E 02  -0,45242310E 01   0,84585587E 02   0,18407990E 02   0,66890198E 02
                                                     0,49756195E 02
0,55805389E 02   0,59898849E 02  -0,40934601E 01   0,87347687E 02   0,17952988E 02   0,61670792E 02
                                                     0,53379089E 02
0,51811691E 02   0,51382370E 02   0,42932129E 00   0,76932495E 02   0,17425888E 02   0,57890900E 02
                                                     0,47101486E 02
0,62034195E 02   0,66071762E 02  -0,40375671E 01   0,89506592E 02   0,19671799E 02   0,56721893E 02
                                                     0,61147995E 02
0,64956085E 02   0,67560623E 02  -0,26045380E 01   0,95325089E 02   0,18725800E 02   0,59511597E 02
                                                     0,59050888E 02
0,50158295E 02   0,59216583E 02  -0,90582886E 01   0,85425888E 02   0,17396988E 02   0,63021896E 02
                                                     0,53293198E 02
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0,37945694E 02    0,41640793E 02    -0,36950989E 01    0.71427185E 02    0.16515900E 02    0.72921494E 02
                                                       0,37945694E 02
0,39095688E 02    0,42168945E 02    -0,30732574E 01    0.74432297E 02    0.16689285E 02    0.76520691E 02
                                                       0,37591995E 02
0,35153397E 02    0,37312988E 02    -0,21595917E 01    0.68014191E 02    0,16963699E 02    0.76520386E 02
                                                       0,34389191E 02
0,49474197E 02    0,50637939E 02    -0,11637421E 01    0,85971497E 02    0,18003586E 02    0,75170486E 02
                                                       0,43796799E 02

     PHI                S E           LAMBDA       ESTIMATED PARTIALS USED
0,21739265E 04    0,52792854E 01    0,100E 02

     SSY          R SQUARED
0,23848000E 05      0,9088

PTP INVERSE
  1     0,16612110E-03   -0,10259959E-03   -0,19866784E-04   -0,72757350E-04   -0,65183718E-04
  2    -0,10256526E-03    0,29989099E-03   -0,55756696E-04   -0,48560862E-04    0,28651120E-04
  3    -0,19875180E-04   -0,55721728E-04    0,89126610E-04    0,27807138E-04   -0,14873547E-03
  4    -0,72773371E-04   -0,48518399E-04    0,27801550E-04    0,11824296E-03   -0,81246355E-04
  5    -0,65182438E-04    0,28546405E-04   -0,14867928E-03   -0,81230028E-04    0,77156769E-03

PARAMETER CORRELATION MATRIX
     1    1,0000   -0,4597   -0,1633   -0,5191   -0,1821
     2   -0,4595    1,0000   -0,3410   -0,2579    0,0596
     3   -0,1633   -0,3408    1,0000    0,2709   -0,5672
     4   -0,5192   -0,2577    0,2708    1,0000   -0,2690
     5   -0,1821    0,0593   -0,5670   -0,2689    1,0000

                                 ONE - PARAMETER                      SUPPORT PLANE
           STD                                                   
  B       ERROR              LOWER            UPPER              LOWER            UPPER
  1    0,68043590E-01    0,51550215E 00    0,78767651E 00    0,34728920E 00    0,95588946E 00
  2    0,91423273E-01   -0,39565992E 00   -0,29966831E-01   -0,62167060E 00    0,19604385E 00
  3    0,49840096E-01   -0,21808928E 00   -0,18728912E-01   -0,34130073E 00    0,10448253E 00
  4    0,57406727E-01    0,56026477E 00    0,78989166E 00    0,41834760E 00    0,93180883E 00
  5    0,14664322E 00    0,37547058E 00    0,96204346E 00    0,12948692E-01    0,13245649E 01

NONLINEAR CONFIDENCE LIMITS

PHI CRITICAL =  0,27313420E 04

 PARA      LOWER B           LOWER PHI          UPPER B           UPPER PHI
   1     0,64062476E 00    0,30438015E 04    0,65938681E 00    0,26577117E 04
   2    -0,22940320E 00    0,29629819E 04   -0,19968706E 00    0,27126970E 04
   3    -0,12927556E 00    0,28796563E 04   -0,10943997E 00    0,27003047E 04
   4     0,66366190E 00    0,29153352E 04    0,68431062E 00    0,27045046E 04
   5     0,64236963E 00    0.27314351E 04    0,69514507E 00    0,27313411E 04
```

APPENDIX C

MODEL BUILDING EQUATIONS (TABLE FORM)

TABLE C.1

PT1 - SS Model

1. REGRESSION RESULTS

#	Symbol	Units	Regression Coefficient	't' value	Miscellaneous
1	SS_{po}	#/D	0.46666	11.52473	R = 0.9191
2	OR1	GPD/FT^2	0.61539	6.44145	R^2 = 0.8447
3	T	°F	-0.21988	-2.90769	s = 0.0660
4	R	--	0.07259	0.80612	RofR = 0.395
5	SS_{pe}	#/D			

2. TESTS

a) Model

i) Residuals: No definite pattern in the plot of the residuals was observed.

ii) U.N.D.: The Unit Normal Deviate form of the residuals indicate that 3.6% of the transformed residuals fall beyond the allowable range at 5% α-level.

b) Parameters: Since $t_c = \pm 1.45$, variable #4 has only a chance influence on the regression.

3. EQUATION

$$SS_{pe} = \exp(1.59103)\ SS_{po}^{.46666}\ OR1^{0.61539}\ T^{-.21988}$$

$$R^{0.07259}$$

TABLE C. 2

TF1 - SS Model

1. REGRESSION RESULTS

#	Symbol	Units	Regression Coefficient	't' value	Miscellaneous
1	SS_{to}	#/D/1000cf	1.02175	6.85495	R = 0.9647
2	HR	MGAD	-0.43305	-0.92743	R^2 = 0.9307
3	R	--	-1.25568	-2.76700	s = 0.09829
4	OR2	GPD/sf	0.09772	0.22756	RofR = 0.393
5	T	°F	-0.55533	-4.77846	Intercept: 0.68404
6	L_{to}	#/D/1000cf	0.35640	2.83366	
7	SS_{se}				

2. TESTS

a) Model

i) Residuals: No definite pattern in the plot of the residuals was observed.

ii) U.N.D.: The Unit Normal Deviate form of the residuals reveal that only 3.6% of the transformed residuals fall beyond the allowable range at 5% α-level.

b) Parameters: Since $t_c = \pm 1.45$ variables #2, and #4, are thereby not significant into the regression.

3. EQUATION

$$SS_{te} = \exp(0.68404)\ SS_{to}^{1.02175}\ HR^{-0.43305}\ R^{-1.25568}\ OR2^{0.09772}\ T^{-0.55533}\ L_{to}^{0.35640}$$

TABLE C. 3

TF1 - BOD Model

1. REGRESSION RESULTS

#	Symbol	Units	Regression Coefficient	't' value	Miscellaneous
1	L_{to}	#/D/1000cf	0.62734	5.99397	R = 0.9772
2	HR	MGAD	-0.17092	-0.41828	R^2 = 0.9548
3	R	--	-1.00072	-2.49060	RofR = 0.392
4	OR2	GPD/sf	0.04968	0.13315	s = 0.08555
5	T	^oF	-0.19942	-1.16272	Intercept: 0.37351
6	SS_{se}	#/D/1000cf	0.42843	5.45227	
7	L_{se}	#/D/1000cf			

2. TESTS

a) Model

i) Residuals: No definite pattern in the plot of residuals was observed.

ii) U.N.D.: The Unit Normal Deviate form of the transresiduals indicate that only 4.8% of the transformed residuals fall beyond the allowable range at 5% α-level.

b) Parameters: Since $t_c = \pm 1.45$, variables #2, and #4, appear only to have a chance influence on the regression.

3. EQUATION

$$L_{se} = \exp(0.37351)\ L_{to}^{0.62734}\ HR^{-0.17092}\ R^{-1.00072}$$

$$OR2^{0.04968}\ T^{-0.19942}\ SS_{se}^{0.42843}$$

TABLE C.4

TF2 - BOD Model

I. REGRESSION RESULTS

#	Symbol	Units	Regression Coefficient	't' value	Miscellaneous
1	L_{to}	#/D/1000cf	0.72372	6.38392	R = 0.9551
2	HR	MGAD	-0.43194	-2.44933	R^2 = 0.9123
3	R	--	-0.11691	-0.97755	RofR = 0.472
4	T	^oF	-0.11311	-1.05473	s = 0.08322
5	SS_{te}	#/D/1000cf	0.67326	7.26619	Intercept: -0.0952
6	L_{to}				

2. TESTS

a) Model

i) Residuals: No definite patterns in the plot of residuals was observed.

ii) U.N.D.: The Unit Normal Deviate form of the residuals indicated that 1.2% of the transformed residuals fall beyond the allowable range at 5% α-level.

b) Parameters: Since $t_c = \pm 1.45$, variables #3, and #4, are not significant into the regression.

3. EQUATION

$$L_{te} = \exp(-0.09052)\ L_{to}^{0.72372}\ HR^{-0.43194}\ R^{-0.11691}$$

$$T^{-0.11311}\ SS_{te}^{0.67326}$$

TABLE C. 5

ST2 - SS Model

1. REGRESSION RESULTS

#	Symbol	Units	Regression Coefficient	't' value	Miscellaneous
1	SS_{so}	#/D	1.02147	18.97592	R = 0.9599
2	OR2	GPD/sf	0.22673	3.47982	R^2 = 0.9797
3	T	°F	-0.08032	-0.93589	RofR = 0.394
4	SS_{se}	#/D			s = 0.07349
					Intercept: -1.69498

2. TESTS

a) Model

i) Residuals: No definite patterms in the plot of residuals was observed.

ii) U.N.D.: The Unit Normal Deviate form of the residuals indicate that none of the transformed residuals fall beyond the allowable range at 5% α-level.

b) Parameters: Since $t_c = \pm 1.45$, variable #3, has only a chance influence in the regression.

3. EQUATION

$$SS_{se} = \exp(-1.69498)\ SS_{so}^{1.02147}\ OR2^{0.22673}\ T^{-0.08032}$$

TABLE C. 6

ST2 - BOD Model

1. REGRESSION RESULTS

#	Symbol	Units	Regression Coefficient	't' value	Miscellaneous
1	L_{so}	#/D	0.45573	6.36815	R = 0.9782
2	OR1	GPD/sf	0.45153	5.71500	R^2 = 0.9569
3	T	^oF	-0.10172	-1.05373	RofR = 0.388
4	SS_{se}	#/D	0.35228	4.26469	s = 0.08267
5	L_{se}	#/D			Intercept: -1.08414

2. TESTS

a) Model

i) Residuals: No definite pattern in the plot of residuals was observed.

ii) U.N.D.: The Unit Normal Deviate form of the residuals indicate that none of the transformed residuals fall beyond the allowable range at 5% α-level.

b) Parameters: Since $t_c = \pm 1.45$, variable #3 has only a chance influence on the regression.

3. EQUATION

$$L_{se} = \exp(-1.08414)\ L_{so}^{0.45573}\ OR2^{6.36815}\ T^{-0.10172}\ SS_{se}^{0.35228}$$

APPENDIX D

LISTING OF CSTF PROGRAM

```
FORTRAN IV G LEVEL  20                MAIN              DATE = 72272        11/14/07            PAGE 0001

                  C
                  C.....MAIN PROGRAM FOR CSTF( COMPUTER SIMULATION OF TRICKLING FILTER)
                  C
                  C
 0001                   INTEGER BOD,SS,T,BODIN,SSIN
 0002                   DIMENSION BOD(3),SS(3),FLOW(3),R(3),T(3)
 0003                   N=3
 0004                   READ(1,1) (BOD(I),SS(I),FLOW(I),R(I),T(I),I=1,N)
 0005                   ISET=1
 0006                   DO 100 I=1,N
 0007                   DO 100 J=1,N
 0008                   BODIN=BOD(I)
 0009                   SSIN=SS(J)
                  C
 0010                   CALL COTF(BODIN,SSIN,FLOW,R,T,N,ISET)
                  C
 0011                   ISET=ISET+1
 0012               100 CONTINUE
 0013                 1 FORMAT(I3,I3,F5.2,F4.2,I2)
 0014                   RETURN
 0015                   END
```

```
                                                COTF                    DATE = 72272          11/14/07                PAGE 0001
FORTRAN IV G LEVEL  20
 0001                  SUBROUTINE COTF(BOD,SS,FLOW,R,T,N,ISET)
 0002                  INTEGER BOD,SS,T,BOD2,SS2,BOD3,SS3,BOD4,SS4,BOD5,SS5,BOD7,SS7,BOD8
                      1,SS8,BOD9,SS9
 0003                  DIMENSION FLOW(3),R(3),T(3),FLOW2(27),BOD2(27),SS2(27),BOD3(27),SS3(27),
                      13(27),BOD4(27),SS4(27),FLOW4(27),FLOW5(27),BOD5(27),SS5(27),FLOW6(27),
                      227),FLOW7(27),BOD7(27),SS7(27),FLOW8(27),BOD8(27),SS8(27),FLOW9(27),
                      3),BOD9(27),SS9(27),BOD2L(27),BOD3L(27),BOD4L(27),BOD5L(27),BOD7L(27),
                      47),BOD8L(27),BOD9L(27),SS2L(27),SS3L(27),SS4L(27),SS5L(27),SS7L(27),
                      5),SS8L(27),SS9L(27),BOD5R(27),SS5R(27),PBOD5R(27),PSS5R(27),BOD9R(
                      627),SS9R(27),PBOD9R(27),PSS9R(27),CPBODR(27),CPSSR(27),FLOW10(27),
                      7OBODR(27),OSSR(27)
 0004                  DIMENSION BOD8R(27),SS8R(27),PBOD8R(27),PSS8R(27)
 0005                  DIMENSION FLOW3(27)
 0006                  ITERMA=150
 0007                  AREAST=22500.
 0008                  AREATF=60318.51/43560.
 0009                  VOLTF=256.35363
 0010                  AREAPT=24912.
 0011               25 II=1
 0012                  DO 100 K=1,N
 0013                  DO 100 L=1,N
 0014                  DO 100 M=1,N
 0015                  JJ=0
 0016                  BOD3(II)=80
 0017                  SS3(II)=76
                 C.....STATION # 4
 0018              500 JJ=JJ+1
 0019                  FLOW4(II)=FLOW(K)
 0020                  BOD4(II)=BOD
 0021                  SS4(II)=SS
 0022                  BOD4L(II)=BOD4(II)*8.34*FLOW4(II)
 0023                  SS4L(II)=SS4(II)*8.34*FLOW4(II)
                 C
                 C.....STATION # 2
 0024                  FLOW2(II)=FLOW4(II)/R(L)
 0025                  FLOW3(II)=FLOW4(II)-FLOW2(II)
 0026                  BOD2(II)=(BOD4(II)*FLOW4(II)-BOD3(II)*FLOW3(II))/FLOW2(II)
 0027                  SS2(II)=(SS4(II)*FLOW4(II)-SS3(II)*FLOW3(II))/FLOW2(II)
 0028                  BOD2L(II)=BOD2(II)*8.34*FLOW2(II)
 0029                  SS2L(II)=SS2(II)*8.34*FLOW2(II)
 0030                  BOD3L(II)=BOD3(II)*8.34*FLOW3(II)
 0031                  SS3L(II)=SS3(II)*8.34*FLOW3(II)
                 C
```

```
             C.....PRIMARY  TANK
 0032              OR1=(FLOW4(II)*(10**6))/AREAPT
 0033              B0=1.84233
 0034              B1=0.46764
 0035              B2=-0.19160
 0036              B3=0.56284
 0037              SS5L(II)=(EXP(B0))*(SS4L(II)**B1)*(T(M)**B2)*(OR1**B3)
 0038              FLOW6(II)=(SS4L(II)-SS5L(II))/((0.050)*(8.34))
 0039              FLOW5(II)=(FLOW4(II)-(FLOW6(II)/1000000.))
 0040              SS5(II)=SS5L(II)/(8.34*FLOW5(II))
 0041              SS5R(II)=SS4L(II)-SS5L(II)
 0042              A0=-2.40023
 0043              A1=0.62517
 0044              A2=0.58027
 0045              A3=-0.11353
 0046              A4=0.30668
 0047              A5=0.23933
 0048              BOD5L(II)=(EXP(A0))*(BOD4L(II)**A1)*(OR1**A2)*(T(M)**A3)*(H(L)**A4)
                  $)*(SS5L(II)**A5)
 0049              BOD5(II)=BOD5L(II)/(8.34*FLOW5(II))
 0050              BOD5R(II)=BOD4L(II)-BOD5L(II)
 0051              PBOD5R(II)=(FLOAT(BOD4(II)-BOD5(II))/FLOAT(BOD4(II)))*100.
 0052              PSS5R(II)=(FLOAT(SS4(II)-SS5(II))/FLOAT(SS4(II)))*100.
             C
             C.....TRICKLING   FILTER
 0053              SSTFL=SS5L(II)/VOLTF
 0054              HRTF=FLOW5(II)/AREATF
 0055              BODTFL=BOD5L(II)/VOLTF
 0056              B0=2.11470
 0057              B1=0.94714
 0058              B2=-0.66828
 0059              B3=-0.26370
 0060              B4=-0.42106
 0061              B5=0.34868
 0062              SSTFE=(EXP(B0))*(SSTFL**B1)*(HRTF**B2)*(R(L)**B3)*(T(M)**B4)*(BODT
                  1FL**B5)
 0063              SS9L(II)=SSTFE*VOLTF
 0064              SS9(II)=SS9L(II)/(8.34*FLOW5(II))
 0065              SS9R(II)=SS5L(II)-SS9L(II)
 0066              PSS9R(II)=(SS9R(II)/SS5L(II))*100.
 0067              CPSSR(II)=(FLOAT(SS2(II)-SS9(II))/FLOAT(SS2(II)))*100.
 0068              A0=-0.24521
 0069              A1=0.69747
```

```
0070              A2=-0.32346
0071              A3=-0.14605
0072              A4=0.69114
0073              BODTFE=(EXP(A0))*(BODTFL**A1)*(HRTF**A2)*(T(M)**A3)*(SSTFE**A4)
0074              BOD9L(II)=BODTFE*VOLTF
0075              BOD9(II)=BOD9L(II)/(8.34*FLOW5(II))
0076              BOD9R(II)=BOD5L(II)-BOD9L(II)
0077              PBOD9R(II)=(BOD9R(II)/BOD5L(II))*100.
0078              CPBODR(II)=(FLOAT(BOD2(II)-BOD9(II))/FLOAT(BOD2(II)))*100.
0079              LIMIT=2
0080              DIF1=IABS(SS9(II)-SS3(II))
0081              DIF2= IABS(BOD9(II)-BOD3(II))
0082              IF(DIF1.GE.LIMIT.AND.SS9(II).GT.SS3(II)) GO TO 600
0083              IF(DIF1.GE.LIMIT.AND.SS9(II).LT.SS3(II)) GO TO 601
0084              IF(DIF1.LT.LIMIT) GO TO 602
0085          600 SS3(II)=SS3(II)+0.50*(SS9(II)-SS3(II))
0086              GO TO 602
0087          601 SS3(II)=SS3(II)+0.50*(SS9(II)-SS3(II))
0088              GO TO 602
0089          602 IF(DIF2.GE.LIMIT.AND.BOD9(II).GT.BOD3(II)) GO TO 603
0090              IF(DIF2.GE.LIMIT.AND.BOD9(II).LT.BOD3(II)) GO TO 604
0091              IF(DIF2.LT.LIMIT) GO TO 605
0092          603 BOD3(II)=BOD3(II)+0.50*(BOD9(II)-BOD3(II))
0093              IF(JJ.GT.ITERMA) GO TO 700
0094              GO TO 500
0095          604 BOD3(II)=BOD3(II)+0.50*(BOD9(II)-BOD3(II))
0096              IF(JJ.GT.ITERMA) GO TO 700
0097              GO TO 500
0098          605 CONTINUE
              C
              C.....STATION # 7
0099              FLOW7(II)=FLOW5(II)-FLOW3(II)
0100              BOD7(II)=BOD3(II)
0101              SS7(II)=SS3(II)
0102              BOD7L(II)=BOD7(II)*8.34*FLOW7(II)
0103              SS7L(II)=SS7(II)*8.34*FLOW7(II)
              C
              C.....SECONDARY SETTLING TANKS
0104              OR2=(FLOW7(II)*(10**6))/AREAST
0105              B0=-2.12146
0106              B1=1.04553
0107              B2=0.20681
0108              SSBL(II)=(EXP(B0))*(SS7L(II)**B1)*(OR2**B2)
```

```
 0109          FLOW10(II)=(SS7L(II)-SS8L(II))/(0.032*8.34)
 0110          FLOW8(II)=FLOW7(II)-(FLOW10(II)/1000000.)
 0111          SS8R(II)=SS7L(II)-SS8L(II)
 0112          PSS8R(II)=SS8R(II)/(SS7L(II))*100.
 0113          SS8(II)=SS8L(II)/(8.34*FLOW8(II))
 0114          OSSR(II)=(FLOAT(SS2(II)-SS8(II))/FLOAT(SS2(II)))*100.
 0115          A0=-1.56093
 0116          A1=0.45429
 0117          A2=0.42325
 0118          A3=0.38054
 0119          BOD8L(II)=(EXP(A0))*(BOD7L(II)**A1)*(OR2**A2)*(SS8L(II)**A3)
 0120          BOD8R(II)=BOD7L(II)-BOD8L(II)
 0121          PBOD8R(II)=(BOD8R(II)/BOD7L(II))*100.
 0122          BOD8(II)=BOD8L(II)/(8.34*FLOW8(II))
 0123          OBODR(II)=(FLOAT(BOD2(II)-BOD8(II))/FLOAT(BOD2(II)))*100.
 0124          II=II+1
 0125      100 CONTINUE
         C
         C
         C.....WRITE TABLE 1
         C
 0126          WRITE(3,400) ISET,SS,BOD
 0127          II=1
 0128          DO 101 K=1,N
 0129          DO 101 L=1,N
 0130          DO 101 M=1,N
 0131          IF(FLOW4(II).LT.15.70.OR.FLOW4(II).GT.31.06) GO TO 680
 0132          WRITE(3,401) II,SS,BOD,FLOW(K),R(L),T(M),FLOW2(II),BOD2(II),SS2(II),
              1),FLOW3(II),BOD3(II),SS3(II),FLOW4(II),BOD4(II),SS4(II),FLOW5(II),
              2BOD5(II),SS5(II),FLOW7(II),BOD7(II),SS7(II),FLOW8(II),BOD8(II),SS8
              3(II)
 0133          GO TO 681
 0134      680 WRITE(3,404) II,SS,BOD,FLOW(K),R(L),T(M),FLOW2(II),BOD2(II),SS2(II),
              1),FLOW3(II),BOD3(II),SS3(II),FLOW4(II),BOD4(II),SS4(II),FLOW5(II),
              2BOD5(II),SS5(II),FLOW7(II),BOD7(II),SS7(II),FLOW8(II),BOD8(II),SS8
              3(II)
 0135      681 II=II+1
 0136      101 CONTINUE
 0137          WRITE(3,403)
         C
         C
         C.....WRITE TABLE 2
         C
```

```
0138              WRITE(3,405)
0139              II=1
0140              DO 102 K=1,N
0141              DO 102 L=1,N
0142              DO 102 M=1,N
0143              IF(FLOW4(II).LT.15.70.OR.FLOW4(II).GT.31.06) GO TO 682
0144              WRITE(3,406) II,SS,BOD,FLOW(K),R(L),T(M),BOD4L(II),BOD5L(II),BOD5R(II),PBO
                 1(II),PBOD5R(II),SS4L(II),SS5L(II),SS5R(II),PSS5R(II),FLOW6(II)
0145              GO TO 683
0146          682 WRITE(3,408) II,SS,BOD,FLOW(K),R(L),T(M),BOD4L(II),BOD5L(II),BOD5R
                 1(II),PBOD5R(II),SS4L(II),SS5L(II),SS5R(II),PSS5R(II),FLOW6(II)
0147          683 II=II+1
0148          102 CONTINUE
0149              WRITE(3,407)
            C
            C
            C.....WRITE TABLE 3
            C
0150              WRITE(3,410)
0151              II=1
0152              DO 103 K=1,N
0153              DO 103L=1,N
0154              DO 103 M=1,N
0155              IF(FLOW4(II).LT.15.70.OR.FLOW4(II).GT.31.06) GO TO 684
0156              WRITE(3,411) II,SS,BOD,FLOW(K),R(L),T(M),BOD5L(II),BOD9L(II),BOD9R(II),PBO
                 1(II),PBOD9R(II),SS5L(II),SS9L(II),SS9R(II),PSS9R(II),CPBODR(II),CP
                 2SSR(II)
0157              GO TO 685
0158          684 WRITE(3,413) II,SS,BOD,FLOW(K),R(L),T(M),BOD5L(II),BOD9L(II),BOD9R(II),PBO
                 1(II),PBOD9R(II),SS5L(II),SS9L(II),SS9R(II),PSS9R(II),CPBODR(II),CP
                 2SSR(II)
0159          685 II=II+1
0160          103 CONTINUE
0161              WRITE(3,412)
            C
            C
            C.....WRITE TABLE 4
            C
0162              WRITE(3,415)
0163              II=1
0164              DO 104 K=1,N
0165              DO 104 L=1,N
0166              DO 104 M=1,N
```

```
 0167              IF(FLOW4(II).LT.15.70.OR.FLOW4(II).GT.31.06) GO TO 686
 0168              WRITE(3,416) II,SS,BOD,FLOW(K),R(L),T(M),BOD7L(II),BOD8L(II),BOD8R(II),PBO
                  1(II),PBOD8R(II),SS7L(II),SS8L(II),SS8R(II),PSS8R(II),FLOW10(II),OBODR(II
                  2ODR(II),OSSR(II)
 0169              GO TO 687
 0170          686 WRITE(3,418) II,SS,BOD,FLOW(K),R(L),T(M),BOD7L(II),BOD8L(II),BOD8R(
                  1(II),PBOD8R(II),SS7L(II),SS8L(II),SS8R(II),PSS8R(II),FLOW10(II),OBOD
                  2ODR(II),OSSR(II)
 0171          687 II=II+1
 0172          104 CONTINUE
 0173              WRITE(3,417)
 0174              GO TO 801
 0175          700 WRITE(3,800) SS,BOD,FLOW(K),R(L),T(M),K,L,M,II,BOD3(II),BOD9(II)
             C
             C....F O R M A T    S T A T E M E N T S
 0176          400 FORMAT(1H1,/,40X,'COMPUTER SIMULATION OF TRICKLING FILTER OPERATION
                  1N',/,/,32X,'ALEXANDRIA SANITATION AUTHORITY HIGH RATE TRICKLING FI
                  2LTER SYSTEM',/,/,53X,'SET # ',I2,' :  SS =',I3,' MG/L',/,64X,'BOD
                  $=',I3,' MG/L',/,/, 12X,'INPUT VECTORS',16X,'O U T P U T   --   S T
                  3 R E A M   V E C T O R S',/,12X,'*************',16X,'*************
                  4*****************************',/,/1X,'TRIAL*',28X,'*  STATION
                  5# 2',5X,
                  $     'STATION # 3   STATION # 4   STATION # 5   STATION # 7   STAT
                  6ION # 8 *',/,3X,'#  *SS   BOD  FLOW   RECIRC  T  * FLOW   BOD SS
                  7 FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS
                  8 SS *',1X,'REMARK',/)
 0177          401 FORMAT(2X,I2,2X,'*',I3,2X,I3,2X,F5.2,3X,F4.2,3X,I2,1X,'*',F5.2,3X,I3
                  1I3,1X,I3,1X,5(' ',F5.2,1X,I3,1X,I3),'*')
 0178          403 FORMAT(1H0,/,51X,'NOTE:  FLOWS ARE IN MGD',/,58X,'BOD & SS ARE IN
                  $MG/L',/,58X,'O.O.R.=MEANSFLOW THRU THE PLANT IS OUT OF THE ',/,65X
                  $,'RANGE OF THE ESTABLISHED OPERATION',/,65X,'MIN=15.70,MAX=31.06')
 0179          404 FORMAT(2X,I2,2X,'*',I3,2X,I3,2X,F5.2,3X,F4.2,3X,I2,1X,'*',F5.2,3X,
                  1I3,1X,I3,1X,5(' ',F5.2,1X,I3,1X,I3),'*',1X,'O.O.R.')
             C
             C
 0180          405 FORMAT(1H1,/,/,/,12X,'INPUT VECTORS',16X,'O U T P U T   --   P R I
                  1M A R Y   T A N K   C H A R A C T E R I S T I C S',/,12X,'********
                  2*****',16X,'**********************************************
                  4********************',
                  $                /,/,1X,'TRIAL*',44X,'B O D',28X,'SUSPENDED         SOL
                  4LIDS',/,3X,'#  *SS   BOD  FLOW   RECIRC  T  *  #  IN',5X,'# OUT',5
                  5X,'# REM',5X,'%',4X,'*',2X,
                  5                        '#  IN',5X,'# OUT',5X,'# REM',5X,'%',4X,'SLUDG
```

```
                 $E',2X,'REMARK',/)
0181          406 FORMAT(2X,I2,2X,'*',I3,2X,I3,2X,F5.2,3X,F4.2,3X,I2,1X,'*',1X,F7.1,
                 13X,F7.1,3X,F7.1,3X,F4.1,2X,'*',1X,
                 $                              F7.1,3X,F7.1,3X,F7.1,3X,F4.1,1X,F7.0)
0182          407 FORMAT(1H0,/,51X,'NOTE:  # IN  =POUNDS ENTERING',/,58X,'# OUT =POUNDS LEAV
                 $NDS LEAVING',/,58X,'# REM =POUNDS REMOVED',/,58X,'%     =PERCENTAGE
                 $E REMOVED FOR THAT UNIT',/,58X,'SLUDGE=GALLONS OF SLUDGE PRODUCED
                 $ ASSUMING 5.0% SOLIDS',/,58X,'O.O.R.=MEANS FLOW THRU THE PLANT IS
                 $OUT OF THE',/,65X,'RANGE OF THE ESTABLISHED PLANT OPERATION',/,65X,
                 $'MIN=15.70,MAX=31.06')
0183          408 FORMAT(2X,I2,2X,'*',I3,2X,I3,2X,F5.2,3X,F4.2,3X,I2,1X,'*',1X,F7.1,
                 13X,F7.1,3X,F7.1,3X,F4.1,2X,'*',1X,
                 $                              F7.1,3X,F7.1,3X,F7.1,3X,F4.1,1X,F7.0,2X,
                 $,'O.O.R.')
              C
              C
0184          410 FORMAT(1H1,/,/,/,12X,'INPUT VECTORS',16X,'O U T P U T  --  T R I C K L
                 1 C K L I N G   F I L T E R   C H A R A C T E R I S T I C S ',/,12X
                 2,'*************',16X,'********************************************
                 4*************************************  ',/,1X,'TRIAL*',44X,'B O D
                 5D',28X,'SUSPENDED          SOLIDS',/,3X,'#  *SS   BOD  FLOW   RECIRC
                 6  T  *  #  IN',5X,'# OUT',5X,'# REM',5X,'%',4X,'*',2X,
                 $                                                   '#  IN',5X,'# OUT',
                 85X,'# REM',5X,'%',3X,'OVERALL % REM'/,111X,'BOD    S.S.',1X,'REMARK')
                 $K')
0185          411 FORMAT(2X,I2,2X,'*',I3,2X,I3,2X,F5.2,3X,F4.2,3X,I2,1X,'*',1X,F7.1,
                 13X,F7.1,3X,F7.1,3X,F4.1,2X,'*',1X,
                 $                              F7.1,3X,F7.1,3X,F7.1,3X,F4.1,2X,F4.1,3X,
                 2,F4.1)
0186          412 FORMAT(1H0,/,51X,'NOTE:  # IN  =POUNDS ENTERING',/,58X,'# OUT =POUNDS LEAV
                 $NDS LEAVING',/,58X,'# REM =POUNDS REMOVED',/,58X,'%     =PERCENTAG
                 $E REMOVED FOR THAT UNIT',/,58X,'OVER.% REM=OVERALL EFFICIENCY COMP
                 $ARING THE OUTPUT FOR',/,69X,'THIS UNIT INPUT AT STATION # 2',/,58X
                 $,'O.O.R.=MEANS FLOW THRU THE PLANT IS OUT OF THE',/,65X,'RANGE OF THE ESTA
                 $THE ESTABLISHED OPERATION',/,65X,'MIN=15.70,MAX=31.06')
0187          413 FORMAT(2X,I2,2X,'*',I3,2X,I3,2X,F5.2,3X,F4.2,3X,I2,1X,'*',1X,F7.1,
                 13X,F7.1,3X,F7.1,3X,F4.1,2X,'*',1X,
                 $                              F7.1,3X,F7.1,3X,F7.1,3X,F4.1,2X,F4.1,3X,
                 2,F4.1,1X,'O.O.R.')
              C
              C
0188          415 FORMAT(1H1,/,/,/,12X,'INPUT VECTORS',16X,'O U T P U T  --  S E C O N D
                 1 O N D A R Y   T A N K   C H A R A C T E R I S T I C S',/,12X,'****
```

```
             1***********',16X,'*************************************************
             2*******************************',/,1X,'TRIAL*',44X,'B O D',28X,'SUSP
             3ENDED        SOLIDS',/,3X,'#  *SS   BOD  FLOW   RECIRC  T  *  #  IN',5
             4N',4X,'# OUT',4X,'# REM',4X,'%',3X,'*',2X,
             $                                    '#  IN',4X,'# OUT',4X,'# REM',6
             6X,'%',2X,'SLUDGE',2X,'PLANT EFF',/,6X,'*',105X,'BOD  S.S.',2X,'REM
             $ARK')
0189       416 FORMAT(2X,I2,2X,'*',I3,2X,I3,2X,F5.2,3X,F4.2,3X,I2,1X,'*',F7.1,2X,
             1F7.1,2X,F7.1,3X,F4.1,1X,'*',1X,
             $                       F7.1,2X,F7.1,2X,F7.1,3X,F4.1,1X,F7.0,1X,F4.
             2.1,1X,F4.1)
0190       417 FORMAT(1H0,/,51X,'NOTE:  # IN  =POUNDS ENTERING',/,58X,'# OUT =POU
             $NDS LEAVING',/,58X,'# REM =POUNDS REMOVED',/,58X,'%     =PERCENTAG
             $E REMOVED FOR THAT UNIT',/,58X,'SLUDGE=GALLONS OF SLUDGE PRODUCED
             $ ASSUMING 3.2% SOLIDS',/,58X,'PLANT EFF= OVERALL PLANT EFFICIENCY'
             $,/,58X,'O.O.R.=MEANS FLOW THRU THE PLANT IS OUT OF THE',/,65X,'RANGE
             $GE OF THE ESTABLISHED OPERATION',/,65X,'MIN=15.70,MAX=31.06')
0191       418 FORMAT(2X,I2,2X,'*',I3,2X,I3,2X,F5.2,3X,F4.2,3X,I2,1X,'*',F7.1,2X,
             1F7.1,2X,F7.1,3X,F4.1,1X,'*',1X,
             $                       F7.1,2X,F7.1,2X,F7.1,3X,F4.1,1X,F7.0,1X,F4.
             2.1,1X,F4.1,2X,'O.O.R.')
         C
         C
0192       800 FORMAT(1H0,/,/,10X,'SS=',I3,2X,'BOD=',I3,2X,'FLOW=',F5.2,2X,'RECIRC=',F4.2
             1C=',F4.2,2X,'TEMP=',I2,2X,'K=',I1,2X,'L=',I1,2X,'M=',I1,2X,'TRIAL=
             2',I2,2X,'BOD3=',I3,2X,'BOD9=',I3,2X,'SYSTEM UNSTABLE')
         C
         C
0193       801 RETURN
               END
```

APPENDIX E

SENSITIVITY ANALYSIS OUTPUT

```
                              COMPUTER SIMULATION OF TRICKLING FILTER OPERATION

                         ALEXANDRIA SANITATION AUTHORITY HIGH RATE TRICKLING FILTER SYSTEM

                                               SET #  1 :  SS =119 MG/L
                                                           BOD =125 MG/L

            INPUT VECTORS                  O U T P U T  --  S T R E A M   V E C T O R S
            *************                  *********************************************
                                     *  STATION # 2    STATION # 3  STATION # 4  STATION # 5  STATION # 7  STATION # 8 *
TRIAL*                               * FLOW   BOD SS   FLOW BOD SS FLOW  BOD SS  FLOW BOD SS  FLOW BOD SS  FLOW BOD SS * REMARK
  #  *SS   BOD  FLOW   RECIRC  T

  1  *119  125  15,70   1,05   56 *14,95  128 121   0,75  56  67 15,70 125 119 15,69  73  76 14,94  56  67 14,93  39  46*
  2  *119  125  15,70   1,05   67 *14,95  128 121   0,75  49  59 15,70 125 119 15,69  71  74 14,94  49  59 14,93  35  40*
  3  *119  125  15,70   1,05   78 *14,95  129 122   0,75  44  54 15,70 125 119 15,69  69  71 14,94  44  54 14,93  32  37*
  4  *119  125  15,70   1,31   56 *11,98  146 135   3,72  57  65 15,70 125 119 15,69  78  76 11,97  57  65 11,96  36  42*
  5  *119  125  15,70   1,31   67 *11,98  148 138   3,72  50  57 15,70 125 119 15,69  76  74 11,97  50  57 11,96  32  37*
  6  *119  125  15,70   1,31   78 *11,98  149 139   3,72  45  52 15,70 125 119 15,69  74  71 11,97  45  52 11,96  30  33*
  7  *119  125  15,70   1,57   56 *10,00  163 150   5,70  58  63 15,70 125 119 15,69  83  76  9,99  58  63  9,98  34  39*
  8  *119  125  15,70   1,57   67 *10,00  167 154   5,70  51  56 15,70 125 119 15,69  80  74  9,99  51  56  9,98  30  34*
  9  *119  125  15,70   1,57   78 *10,00  170 157   5,70  46  51 15,70 125 119 15,69  78  71  9,99  46  51  9,98  28  31*
 10  *119  125  24,29   1,05   56 *23,13  128 121   1,16  62  62 24,29 125 119 24,27  89  77 23,11  62  62 23,10  47  47*
 11  *119  125  24,29   1,05   67 *23,13  128 122   1,16  55  55 24,29 125 119 24,27  86  75 23,11  55  55 23,10  42  42*
 12  *119  125  24,29   1,05   78 *23,13  128 122   1,16  49  50 24,29 125 119 24,27  84  72 23,11  49  50 23,10  38  38*
 13  *119  125  24,29   1,31   56 *18,54  143 137   5,75  64  60 24,29 125 119 24,27  95  77 18,52  64  60 18,51  43  43*
 14  *119  125  24,29   1,31   67 *18,54  146 139   5,75  56  53 24,29 125 119 24,27  92  75 18,52  56  53 18,51  39  38*
 15  *119  125  24,29   1,31   78 *18,54  147 141   5,75  51  48 24,29 125 119 24,27  90  72 18,52  51  48 18,51  35  34*
 16  *119  125  24,29   1,57   56 *15,47  159 153   8,82  65  58 24,29 125 119 24,27 101  77 15,45  65  58 15,44  40  40*
 17  *119  125  24,29   1,57   67 *15,47  163 157   8,82  57  51 24,29 125 119 24,27  98  75 15,45  57  51 15,44  36  35*
 18  *119  125  24,29   1,57   78 *15,47  167 160   8,82  51  47 24,29 125 119 24,27  95  72 15,45  51  47 15,44  33  32*
 19  *119  125  31,06   1,05   56 *29,58  127 121   1,48  66  59 31,06 125 119 31,03  99  78 29,56  66  59 29,55  51  48*
 20  *119  125  31,06   1,05   67 *29,58  128 122   1,48  58  52 31,06 125 119 31,03  97  75 29,55  58  52 29,55  46  42*
 21  *119  125  31,06   1,05   78 *29,58  128 122   1,48  52  47 31,06 125 119 31,03  94  73 29,55  52  47 29,54  42  38*
 22  *119  125  31,06   1,31   56 *23,71  142 137   7,35  68  57 31,06 125 119 31,03 106  78 23,68  68  57 23,68  47  44*
 23  *119  125  31,06   1,31   67 *23,71  145 140   7,35  60  51 31,06 125 119 31,03 103  75 23,68  60  51 23,67  43  39*
 24  *119  125  31,06   1,31   78 *23,71  147 141   7,35  54  46 31,06 125 119 31,03 101  73 23,68  54  46 23,67  39  35*
 25  *119  125  31,06   1,57   56 *19,78  156 154  11,28  69  55 31,06 125 119 31,03 112  78 19,76  69  55 19,75  44  40*
 26  *119  125  31,06   1,57   67 *19,78  161 158  11,28  61  49 31,06 125 119 31,03 109  75 19,76  61  49 19,75  40  35*
 27  *119  125  31,06   1,57   78 *19,78  164 160  11,28  55  45 31,06 125 119 31,03 107  73 19,76  55  45 19,75  37  32*

                                        NOTE:  FLOWS ARE IN MGD
                                               BOD & SS ARE IN MG/L
                                               O,O,R,=MEANSFLOW THRU THE PLANT IS OUT OF THE
                                                      RANGE OF THE ESTABLISHED OPERATION
                                                      MIN=15,70,MAX=31,06
```

```
                                          O U T P U T  --  P R I M A R Y   T A N K   C H A R A C T E R I S T I C S
      INPUT VECTORS                       ************************************************************************
      *************
                                                      B O D                                    SUSPENDED        SOLIDS
TRIAL*                                                # OUT     # REM      %      *  # IN       # OUT     # REM      %     SLUDGE   REMARK
  #  *SS   BOD  FLOW   RECIRC  T  *  # IN

  1  *119  125  15,70   1,05  56 * 16367,2    9598,4    6768,8   41,6   * 15581,6   10033,7    5548,0   36,1   13304,
  2  *119  125  15,70   1,05  67 * 16367,2    9328,0    7039,3   43,2   * 15581,6    9694,7    5886,9   37,8   14117,
  3  *119  125  15,70   1,05  78 * 16367,2    9104,7    7262,6   44,8   * 15581,6    9416,4    6165,2   40,3   14785,
  4  *119  125  15,70   1,31  56 * 16367,2   10272,3    6095,0   37,6   * 15581,6   10033,7    5548,0   36,1   13304,
  5  *119  125  15,70   1,31  67 * 16367,2    9982,8    6384,4   39,2   * 15581,6    9694,7    5886,9   37,8   14117,
  6  *119  125  15,70   1,31  78 * 16367,2    9743,8    6623,4   40,8   * 15581,6    9416,4    6165,2   40,3   14785,
  7  *119  125  15,70   1,57  56 * 16367,2   10858,8    5508,5   33,6   * 15581,6   10033,7    5548,0   36,1   13304,
  8  *119  125  15,70   1,57  67 * 16367,2   10552,8    5814,5   36,0   * 15581,6    9694,7    5886,9   37,8   14117,
  9  *119  125  15,70   1,57  78 * 16367,2   10300,2    6067,1   37,6   * 15581,6    9416,4    6165,2   40,3   14785,
 10  *119  125  24,29   1,05  56 * 25322,3   18088,7    7233,6   28,8   * 24106,8   15731,3    8375,6   35,3   20085,
 11  *119  125  24,29   1,05  67 * 25322,3   17579,0    7743,3   31,2   * 24106,8   15199,9    8906,9   37,0   21360,
 12  *119  125  24,29   1,05  78 * 25322,3   17158,2    8164,2   32,8   * 24106,8   14763,6    9343,3   39,5   22406,
 13  *119  125  24,29   1,31  56 * 25322,3   19358,6    5963,7   24,0   * 24106,8   15731,3    8375,6   35,3   20085,
 14  *119  125  24,29   1,31  67 * 25322,3   18813,1    6509,2   26,4   * 24106,8   15199,9    8906,9   37,0   21360,
 15  *119  125  24,29   1,31  78 * 25322,3   18362,7    6959,6   28,0   * 24106,8   14763,6    9343,3   39,5   22406,
 16  *119  125  24,29   1,57  56 * 25322,3   20463,8    4858,5   19,2   * 24106,8   15731,3    8375,6   35,3   20085,
 17  *119  125  24,29   1,57  67 * 25322,3   19887,2    5435,1   21,6   * 24106,8   15199,9    8906,9   37,0   21360,
 18  *119  125  24,29   1,57  78 * 25322,3   19411,1    5911,2   24,0   * 24106,8   14763,6    9343,3   39,5   22406,
 19  *119  125  31,06   1,05  56 * 32380,0   25849,3    6530,7   20,8   * 30825,8   20267,1   10558,7   34,5   25321,
 20  *119  125  31,06   1,05  67 * 32380,0   25120,9    7259,1   22,4   * 30825,8   19582,5   11243,3   37,0   26962,
 21  *119  125  31,06   1,05  78 * 32380,0   24519,6    7860,5   24,8   * 30825,8   19020,4   11805,4   38,7   28310,
 22  *119  125  31,06   1,31  56 * 32380,0   27664,0    4716,0   15,2   * 30825,8   20267,1   10558,7   34,5   25321,
 23  *119  125  31,06   1,31  67 * 32380,0   26884,5    5495,6   17,6   * 30825,8   19582,5   11243,3   37,0   26962,
 24  *119  125  31,06   1,31  78 * 32380,0   26240,9    6139,1   19,2   * 30825,8   19020,4   11805,4   38,7   28310,
 25  *119  125  31,06   1,57  56 * 32380,0   29243,5    3136,5   10,4   * 30825,8   20267,1   10558,7   34,5   25321,
 26  *119  125  31,06   1,57  67 * 32380,0   28419,4    3960,6   12,8   * 30825,8   19582,5   11243,3   37,0   26962,
 27  *119  125  31,06   1,57  78 * 32380,0   27739,1    4640,9   14,4   * 30825,8   19020,4   11805,4   38,7   28310,

                                  NOTE:  # IN  =POUNDS ENTERING
                                         # OUT =POUNDS LEAVING
                                         # REM =POUNDS REMOVED
                                         %     =PERCENTAGE REMOVED FOR THAT UNIT
                                         SLUDGE=GALLONS OF SLUDGE PRODUCED  ASSUMING 5,0% SOLIDS
                                         O,O,R,=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                RANGE OF THE ESTABLISHED PLANT OPERATION
                                                MIN=15,70,MAX=31,06
```

```
                 INPUT VECTORS               O U T P U T  --  T R I C K L I N G   F I L T E R   C H A R A C T E R I S T I C S
                 *************               ****************************************************************************
                                                     B O D                                   SUSPENDED      SOLIDS
TRIAL*                                                                                                                OVERALL % REM
  #   *SS   BOD  FLOW   RECIRC  T  *  #  IN    # OUT     # REM     %     *  #  IN      # OUT     # REM     %     BOD   S.S.  REMARK

  1  *119  125  15.70   1.05   56 *  9598.4    7250.3    2348.1   24.5  * 10033.7    8671.9    1361.7   13.6   57.0   45.5
  2  *119  125  15.70   1.05   67 *  9328.0    6381.4    2946.6   31.6  *  9694.7    7706.8    1988.0   20.5   62.5   52.1
  3  *119  125  15.70   1.05   78 *  9104.7    5726.9    3377.8   37.1  *  9416.4    6973.3    2443.2   25.9   66.7   56.6
  4  *119  125  15.70   1.31   56 * 10272.3    7421.6    2850.7   27.8  * 10033.7    8376.3    1657.4   16.5   61.6   52.6
  5  *119  125  15.70   1.31   67 *  9982.8    6532.1    3450.7   34.6  *  9694.7    7444.0    2250.7   23.2   66.9   59.4
  6  *119  125  15.70   1.31   78 *  9743.8    5862.2    3881.7   39.8  *  9416.4    6735.6    2680.9   28.5   70.5   63.3
  7  *119  125  15.70   1.57   56 * 10858.8    7564.8    3294.0   30.3  * 10033.7    8141.9    1891.8   18.9   65.0   58.7
  8  *119  125  15.70   1.57   67 * 10552.8    6658.2    3894.6   36.9  *  9694.7    7235.7    2459.0   25.4   70.1   64.3
  9  *119  125  15.70   1.57   78 * 10300.2    5975.3    4324.9   42.0  *  9416.4    6547.1    2869.4   30.5   73.5   68.2
 10  *119  125  24.29   1.05   56 * 18088.7   12520.6    5568.1   30.8  * 15731.3   12370.6    3360.6   21.4   52.3   49.6
 11  *119  125  24.29   1.05   67 * 17579.0   11020.0    6559.0   37.3  * 15199.9   10993.8    4206.1   27.7   57.8   55.7
 12  *119  125  24.29   1.05   78 * 17158.2    9889.8    7268.4   42.4  * 14763.6    9947.5    4816.1   32.6   62.5   59.8
 13  *119  125  24.29   1.31   56 * 19358.6   12816.4    6542.2   33.8  * 15731.3   11948.9    3782.3   24.0   55.9   56.9
 14  *119  125  24.29   1.31   67 * 18813.1   11280.4    7532.7   40.0  * 15199.9   10619.0    4580.8   30.1   62.3   62.6
 15  *119  125  24.29   1.31   78 * 18362.7   10123.4    8239.3   44.9  * 14763.6    9608.4    5155.2   34.9   66.0   66.7
 16  *119  125  24.29   1.57   56 * 20463.8   13063.7    7400.2   36.2  * 15731.3   11614.6    4116.7   26.2   59.7   62.7
 17  *119  125  24.29   1.57   67 * 19887.2   11493.0    8389.2   42.2  * 15199.9   10321.9    4878.0   32.1   65.6   68.2
 18  *119  125  24.29   1.57   78 * 19411.1   10318.8    9092.4   46.8  * 14763.6    9339.5    5424.0   36.7   70.1   71.2
 19  *119  125  31.06   1.05   56 * 25849.3   17033.1    8816.3   34.1  * 20267.1   15111.4    5155.7   25.4   48.8   52.1
 20  *119  125  31.06   1.05   67 * 25120.9   14991.7   10129.2   40.3  * 19582.5   13429.6    6152.9   31.4   55.5   58.2
 21  *119  125  31.06   1.05   78 * 24519.6   13454.1   11065.4   45.1  * 19020.4   12151.4    6869.0   36.1   60.2   62.3
 22  *119  125  31.06   1.31   56 * 27664.0   17435.5   10228.6   37.0  * 20267.1   14596.3    5670.8   28.0   52.8   59.1
 23  *119  125  31.06   1.31   67 * 26884.5   15345.9   11538.6   42.9  * 19582.5   12971.8    6610.7   33.8   59.3   64.3
 24  *119  125  31.06   1.31   78 * 26240.9   13772.0   12468.9   47.5  * 19020.4   11737.2    7283.2   38.3   63.9   68.1
 25  *119  125  31.06   1.57   56 * 29243.5   17771.9   11471.6   39.2  * 20267.1   14187.8    6079.3   30.0   56.4   64.9
 26  *119  125  31.06   1.57   67 * 28419.4   15642.0   12777.5   45.0  * 19582.5   12608.8    6973.7   35.6   62.7   69.6
 27  *119  125  31.06   1.57   78 * 27739.1   14037.7   13701.4   49.4  * 19020.4   11408.8    7611.6   40.0   67.1   72.5

                                     NOTE:  # IN  =POUNDS ENTERING
                                            # OUT =POUNDS LEAVING
                                            # REM =POUNDS REMOVED
                                            %     =PERCENTAGE REMOVED FOR THAT UNIT
                                            OVER.% REM=OVERALL EFFICIENCY COMPARING THE OUTPUT FOR
                                                   THIS UNIT INPUT AT STATION # 2
                                            O.O.R.=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                   RANGE OF THE ESTABLISHED OPERATION
                                                   MIN=15.70,MAX=31.06
```

```
                                         O U T P U T  --  S E C O N D A R Y   T A N K   C H A R A C T E R I S T I C S
            INPUT VECTORS                **************************************************************************
            *************                                                        SUSPENDED          SOLIDS
                                                      B O D                                                          PLANT EFF
TRIAL*                                                                                                                BOD  S.S.   REMARK
 #   *SS    BOD  FLOW    RECIRC  T  *  #  IN   # OUT    # REM    %   *  #  IN   # OUT    # REM    %   SLUDGE
     *
 1   *119   125  15.70   1.05   56 * 6977.1   4948.4   2028.8   29.1 *  8347.7   5786.5   2561.1   30.7   9596.  69.5 62.0
 2   *119   125  15.70   1.05   67 * 6104.7   4427.0   1677.6   27.5 *  7350.5   5065.9   2284.7   31.1   8561.  72.7 66.9
 3   *119   125  15.70   1.05   78 * 5481.5   4069.6   1411.9   25.8 *  6727.3   4617.6   2109.7   31.4   7905.  75.2 69.7
 4   *119   125  15.70   1.31   56 * 5691.0   3651.6   2039.4   35.8 *  6489.7   4248.3   2241.4   34.5   8399.  75.3 68.9
 5   *119   125  15.70   1.31   67 * 4991.7   3265.1   1726.6   34.6 *  5690.6   3702.9   1987.7   34.9   7448.  78.4 73.2
 6   *119   125  15.70   1.31   78 * 4492.3   3000.6   1491.7   33.2 *  5191.1   3363.7   1827.4   35.2   6847.  79.9 76.3
 7   *119   125  15.70   1.57   56 * 4830.8   2843.9   1986.9   41.1 *  5247.2   3276.7   1970.5   37.6   7384.  79.1 74.0
 8   *119   125  15.70   1.57   67 * 4247.4   2559.4   1688.0   39.7 *  4663.8   2896.7   1767.1   37.9   6621.  82.0 77.9
 9   *119   125  15.70   1.57   78 * 3830.7   2352.8   1478.0   38.6 *  4247.1   2626.6   1620.5   38.2   6072.  83.5 80.3
10   *119   125  24.29   1.05   56 *11951.4   9073.9   2877.5   24.1 * 11951.4   9216.5   2734.9   22.9  10248.  63.3 61.2
11   *119   125  24.29   1.05   67 *10601.5   8192.7   2408.8   22.7 * 10601.5   8130.9   2470.5   23.3   9257.  67.2 65.6
12   *119   125  24.29   1.05   78 * 9444.5   7484.1   1960.4   20.8 *  9637.2   7359.3   2277.9   23.6   8535.  70.3 68.9
13   *119   125  24.29   1.31   56 * 9886.2   6732.3   3154.0   31.9 *  9268.3   6748.9   2519.4   27.2   9440.  69.9 68.6
14   *119   125  24.29   1.31   67 * 8649.9   6030.3   2619.5   30.3 *  8186.5   5927.5   2259.0   27.6   8465.  73.3 72.7
15   *119   125  24.29   1.31   78 * 7877.1   5555.6   2321.5   29.5 *  7413.7   5343.7   2070.0   27.9   7756.  76.2 75.9
16   *119   125  24.29   1.57   56 * 8376.1   5233.2   3142.9   37.5 *  7474.1   5191.0   2283.0   30.5   8555.  74.8 73.9
17   *119   125  24.29   1.57   67 * 7344.6   4683.6   2661.0   36.2 *  6571.5   4537.4   2034.1   31.0   7622.  77.9 77.7
18   *119   125  24.29   1.57   78 * 6571.0   4310.1   2261.0   34.4 *  6055.7   4165.7   1890.0   31.2   7082.  80.2 80.0
19   *119   125  31.06   1.05   56 *16268.6  12768.8   3499.8   21.5 * 14543.1  11906.1   2637.0   18.1   9881.  59.8 60.3
20   *119   125  31.06   1.05   67 *14295.9  11449.9   2845.9   19.9 * 12817.0  10432.7   2384.3   18.6   8934.  64.1 65.6
21   *119   125  31.06   1.05   78 *12816.4  10465.6   2350.8   18.3 * 11584.0   9385.7   2198.4   19.0   8237.  67.2 68.9
22   *119   125  31.06   1.31   56 *13432.0   9459.1   3972.9   29.6 * 11259.2   8703.0   2556.2   22.7   9578.  66.9 67.9
23   *119   125  31.06   1.31   67 *11851.0   8548.7   3302.3   27.9 * 10073.3   7746.9   2326.4   23.1   8717.  70.3 72.1
24   *119   125  31.06   1.31   78 *10665.2   7820.7   2844.5   26.7 *  9085.2   6954.1   2131.1   23.5   7985.  73.5 75.2
25   *119   125  31.06   1.57   56 *11370.0   7344.5   4025.4   35.4 *  9063.0   6681.4   2381.7   26.3   8924.  71.8 74.0
26   *119   125  31.06   1.57   67 *10050.9   6632.0   3418.9   34.0 *  8073.7   5920.7   2153.0   26.7   8067.  75.2 77.8
27   *119   125  31.06   1.57   78 * 9061.7   6115.9   2945.8   32.5 *  7414.1   5415.8   1998.3   27.0   7487.  77.4 80.0

                                 NOTE:  # IN  =POUNDS ENTERING
                                        # OUT =POUNDS LEAVING
                                        # REM =POUNDS REMOVED
                                        %     =PERCENTAGE REMOVED FOR THAT UNIT
                                        SLUDGE=GALLONS OF SLUDGE PRODUCED  ASSUMING 3.2% SOLIDS
                                        PLANT EFF= OVERALL PLANT EFFICIENCY
                                        O.O.R.=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                               RANGE OF THE ESTABLISHED OPERATION
                                               MIN=15.70,MAX=31.06
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                        COMPUTER SIMULATION OF TRICKLING FILTER OPERATION

               ALEXANDRIA SANITATION AUTHORITY HIGH RATE TRICKLING FILTER SYSTEM

                                  SET #  2 :  SS =178 MG/L
                                              BOD =125 MG/L

         INPUT VECTORS              O U T P U T  --  S T R E A M   V E C T O R S
         *************              ********************************************
TRIAL*                            *  STATION # 2   STATION # 3   STATION # 4   STATION # 5   STATION # 7   STATION # 8 *
  #  *SS  BOD  FLOW   RECIRC  T  * FLOW   BOD SS   FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS * REMARK

  1  *178 125  15,70   1,05  56 *14,95  127 182   0,75  66  79 15,70 125 178 15,67  76  92 14,93  66  79 14,91  45  55*
  2  *178 125  15,70   1,05  67 *14,95  128 183   0,75  58  72 15,70 125 178 15,67  74  89 14,92  58  72 14,91  41  50*
  3  *178 125  15,70   1,05  78 *14,95  128 183   0,75  52  65 15,70 125 178 15,67  72  86 14,92  52  65 14,91  37  45*
  4  *178 125  15,70   1,31  56 *11,98  142 209   3,72  68  76 15,70 125 178 15,67  82  92 11,96  68  76 11,95  42  50*
  5  *178 125  15,70   1,31  67 *11,98  145 211   3,72  60  70 15,70 125 178 15,67  79  89 11,96  60  70 11,95  38  45*
  6  *178 125  15,70   1,31  78 *11,98  147 213   3,72  53  63 15,70 125 178 15,67  77  86 11,96  53  63 11,95  34  41*
  7  *178 125  15,70   1,57  56 *10,00  156 236   5,70  69  76 15,70 125 178 15,67  86  92  9,97  69  76  9,96   9  47*
  8  *178 125  15,70   1,57  67 *10,00  161 240   5,70  61  68 15,70 125 178 15,67  84  89  9,97  61  68  9,96  36  42*
  9  *178 125  15,70   1,57  78 *10,00  165 244   5,70  54  61 15,70 125 178 15,67  82  86  9,97  54  61  9,96  32  38*
 10  *178 125  24,29   1,05  56 *23,13  127 183   1,16  74  75 24,29 125 178 24,25  93  93 23,09  74  75 23,08  55  58*
 11  *178 125  24,29   1,05  67 *23,13  127 183   1,16  65  67 24,29 125 178 24,25  90  90 23,09  65  67 23,08  49  51*
 12  *178 125  24,29   1,05  78 *23,13  128 183   1,16  58  60 24,29 125 178 24,25  88  88 23,09  58  60 23,08  45  46*
 13  *178 125  24,29   1,31  56 *18,54  140 210   5,75  75  72 24,29 125 178 24,25 100  93 18,50  75  72 18,49  50  52*
 14  *178 125  24,29   1,31  67 *18,54  143 213   5,75  66  64 24,29 125 178 24,25  97  90 18,50  66  64 18,49  45  46*
 15  *178 125  24,29   1,31  78 *18,54  145 215   5,75  60  58 24,29 125 178 24,25  94  88 18,50  60  58 18,49  41  42*
 16  *178 125  24,29   1,57  56 *15,47  152 239   8,82  77  70 24,29 125 178 24,25 105  93 15,43  77  70 15,42  47  49*
 17  *178 125  24,29   1,57  67 *15,47  157 243   8,82  68  63 24,29 125 178 24,25 102  90 15,43  68  63 15,42  42  43*
 18  *178 125  24,29   1,57  78 *15,47  161 246   8,82  61  57 24,29 125 178 24,25 100  88 15,43  61  57 15,42  39  39*
 19  *178 125  31,06   1,05  56 *29,58  127 183   1,48  78  71 31,06 125 178 31,01 104  94 29,53  78  71 29,52  60  58*
 20  *178 125  31,06   1,05  67 *29,58  127 183   1,48  69  64 31,06 125 178 31,01 101  91 29,53  69  64 29,52  54  52*
 21  *178 125  31,06   1,05  78 *29,58  128 183   1,48  62  58 31,06 125 178 31,00  99  88 29,53  62  58 29,52  50  47*
 22  *178 125  31,06   1,31  56 *23,71  138 209   7,35  80  72 31,06 125 178 31,01 111  94 23,66  80  72 23,65  56  56*
 23  *178 125  31,06   1,31  67 *23,71  141 213   7,35  71  61 31,06 125 178 31,01 108  91 23,66  71  61 23,65  50  47*
 24  *178 125  31,06   1,31  78 *23,71  144 215   7,35  63  56 31,06 125 178 31,00 106  88 23,65  63  56 23,64  45  43*
 25  *178 125  31,06   1,57  56 *19,78  150 236  11,28  80  71 31,06 125 178 31,01 118  94 19,73  80  71 19,72  52  52*
 26  *178 125  31,06   1,57  67 *19,78  155 244  11,28  72  60 31,06 125 178 31,01 114  91 19,73  72  60 19,72  47  44*
 27  *178 125  31,06   1,57  78 *19,78  159 248  11,28  65  54 31,06 125 178 31,00 112  88 19,73  65  54 19,72  43  39*

                              NOTE:  FLOWS ARE IN MGD
                                     BOD & SS ARE IN MG/L
                                     O.O.R.=MEANSFLOW THRU THE PLANT IS OUT OF THE
                                            RANGE OF THE ESTABLISHED OPERATION
                                            MIN=15,70,MAX=31,06
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             INPUT VECTORS                          O U T P U T  **  P R I M A R Y   T A N K   C H A R A C T E R I S T I C S
             *************                          **********************************************************************

                                                            B O D                                    SUSPENDED        SOLIDS
TRIAL*                                                     # OUT      # REM      %      *   #  IN      # OUT      # REM      %      SLUDGE   REMARK
  #   *SS   BOD   FLOW    RECIRC   T  *   #   IN

  1  *178  125  15,70    1,05    56 * 16367,2   10040,9   6326,3   39,2  * 23307,0   12112,6   11194,4   48,3   26845,
  2  *178  125  15,70    1,05    67 * 16367,2    9757,9   6609,3   40,8  * 23307,0   11703,4   11603,5   50,0   27826,
  3  *178  125  15,70    1,05    78 * 16367,2    9524,4   6842,9   42,4  * 23307,0   11367,5   11939,5   51,7   28632,
  4  *178  125  15,70    1,31    56 * 16367,2   10745,8   5621,4   34,4  * 23307,0   12112,6   11194,4   48,3   26845,
  5  *178  125  15,70    1,31    67 * 16367,2   10443,0   5924,3   36,8  * 23307,0   11703,4   11603,5   50,0   27826,
  6  *178  125  15,70    1,31    78 * 16367,2   10193,0   6174,2   38,4  * 23307,0   11367,5   11939,5   51,7   28632,
  7  *178  125  15,70    1,57    56 * 16367,2   11359,3   5007,9   31,2  * 23307,0   12112,6   11194,4   48,3   26845,
  8  *178  125  15,70    1,57    67 * 16367,2   11039,2   5328,0   32,8  * 23307,0   11703,4   11603,5   50,0   27826,
  9  *178  125  15,70    1,57    78 * 16367,2   10775,0   5592,3   34,4  * 23307,0   11367,5   11939,5   51,7   28632,
 10  *178  125  24,29    1,05    56 * 25322,3   18922,5   6399,8   25,6  * 36059,0   18990,7   17068,3   47,8   40931,
 11  *178  125  24,29    1,05    67 * 25322,3   18389,3   6933,0   28,0  * 36059,0   18349,2   17709,7   49,4   42469,
 12  *178  125  24,29    1,05    78 * 25322,3   17949,1   7373,2   29,6  * 36059,0   17822,5   18236,5   50,6   43733,
 13  *178  125  24,29    1,31    56 * 25322,3   20250,9   5071,4   20,0  * 36059,0   18990,7   17068,3   47,8   40931,
 14  *178  125  24,29    1,31    67 * 25322,3   19680,3   5642,0   22,4  * 36059,0   18349,2   17709,7   49,4   42469,
 15  *178  125  24,29    1,31    78 * 25322,3   19209,2   6113,1   24,8  * 36059,0   17822,5   18236,5   50,6   43733,
 16  *178  125  24,29    1,57    56 * 25322,3   21407,2   3915,1   16,0  * 36059,0   18990,7   17068,3   47,8   40931,
 17  *178  125  24,29    1,57    67 * 25322,3   20803,9   4518,4   18,4  * 36059,0   18349,2   17709,7   49,4   42469,
 18  *178  125  24,29    1,57    78 * 25322,3   20305,9   5016,4   20,0  * 36059,0   17822,5   18236,5   50,6   43733,
 19  *178  125  31,06    1,05    56 * 32380,0   27040,9   5339,1   16,8  * 46109,2   24466,4   21642,8   47,2   51901,
 20  *178  125  31,06    1,05    67 * 32380,0   26278,9   6101,1   19,2  * 46109,2   23639,9   22469,2   48,9   53883,
 21  *178  125  31,06    1,05    78 * 32380,0   25649,9   6730,2   20,8  * 46109,2   22961,3   23147,9   50,6   55510,
 22  *178  125  31,06    1,31    56 * 32380,0   28939,3   3440,8   11,2  * 46109,2   24466,4   21642,8   47,2   51901,
 23  *178  125  31,06    1,31    67 * 32380,0   28123,8   4256,3   13,6  * 46109,2   23639,9   22469,2   48,9   53883,
 24  *178  125  31,06    1,31    78 * 32380,0   27450,5   4929,5   15,2  * 46109,2   22961,3   23147,9   50,6   55510,
 25  *178  125  31,06    1,57    56 * 32380,0   30591,5   1788,5    5,6  * 46109,2   24466,4   21642,8   47,2   51901,
 26  *178  125  31,06    1,57    67 * 32380,0   29729,5   2650,6    8,8  * 46109,2   23639,9   22469,2   48,9   53883,
 27  *178  125  31,06    1,57    78 * 32380,0   29017,8   3362,2   10,4  * 46109,2   22961,3   23147,9   50,6   55510,

                                          NOTE:  # IN   =POUNDS ENTERING
                                                 # OUT  =POUNDS LEAVING
                                                 # REM  =POUNDS REMOVED
                                                 %      =PERCENTAGE REMOVED FOR THAT UNIT
                                                 SLUDGE=GALLONS OF SLUDGE PRODUCED  ASSUMING 5,0% SOLIDS
                                                 O,O,R,=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                        RANGE OF THE ESTABLISHED PLANT OPERATION
                                                        MIN=15,70,MAX=31,06
```

```
                                                   O U T P U T  --  T R I C K L I N G   F I L T E R   C H A R A C T E R I S T I C S
                 INPUT VECTORS                     ***************************************************************************
                 *************                                    B O D                                    SUSPENDED          *  SOLIDS
TRIAL*                                                                                                                                    OVERALL % REM
  #   *SS   BOD  FLOW   RECIRC  T  *  #   IN      # OUT     # REM      %     *  #   IN       # OUT       # REM      %       BOD    S.S. REMARK
  1  *178  125  15.70   1.05   56 * 10040.9     8561.5    1479.4    14.7   * 12112.6     10535.2     1577.4    13.0    48.8    56.0
  2  *178  125  15.70   1.05   67 *  9757.9     7535.5    2222.4    22.8   * 11703.4      9362.8     2340.6    20.0    55.5    61.2
  3  *178  125  15.70   1.05   78 *  9524.4     6762.7    2761.7    29.0   * 11367.5      8471.7     2895.8    25.5    60.2    65.0
  4  *178  125  15.70   1.31   56 * 10745.8     8763.8    1982.0    18.4   * 12112.6     10176.1     1936.5    16.0    52.8    63.2
  5  *178  125  15.70   1.31   67 * 10443.0     7713.5    2729.5    26.1   * 11703.4      9043.6     2659.8    22.7    59.3    67.3
  6  *178  125  15.70   1.31   78 * 10193.0     6922.5    3270.5    32.1   * 11367.5      8182.9     3184.5    28.0    64.6    70.9
  7  *178  125  15.70   1.57   56 * 11359.3     8932.9    2426.5    21.4   * 12112.6      9891.3     2221.2    18.3    56.4    68.2
  8  *178  125  15.70   1.57   67 * 11039.2     7862.4    3176.9    28.8   * 11703.4      8790.6     2912.9    24.9    62.7    72.1
  9  *178  125  15.70   1.57   78 * 10775.0     7056.0    3718.9    34.5   * 11367.5      7953.9     3413.5    30.0    67.9    75.4
 10  *178  125  24.29   1.05   56 * 18922.5    14784.9    4137.7    21.9   * 18990.7     15028.7     3962.0    20.9    42.5    59.6
 11  *178  125  24.29   1.05   67 * 18389.3    13013.0    5376.3    29.2   * 18349.2     13356.1     4993.1    27.2    49.6    63.9
 12  *178  125  24.29   1.05   78 * 17949.1    11678.5    6270.6    34.9   * 17822.5     12085.0     5737.5    32.2    55.5    67.8
 13  *178  125  24.29   1.31   56 * 20250.9    15134.2    5116.8    25.3   * 18990.7     14516.4     4474.4    23.6    47.1    66.2
 14  *178  125  24.29   1.31   67 * 19680.3    13320.5    6359.8    32.3   * 18349.2     12900.8     5448.4    29.7    54.5    70.4
 15  *178  125  24.29   1.31   78 * 19209.2    11954.4    7254.8    37.8   * 17822.5     11673.1     6149.4    34.5    59.3    73.5
 16  *178  125  24.29   1.57   56 * 21407.2    15426.1    5981.0    27.9   * 18990.7     14110.1     4880.6    25.7    50.0    71.1
 17  *178  125  24.29   1.57   67 * 20803.9    13577.5    7226.4    34.7   * 18349.2     12539.8     5809.4    31.7    57.3    74.5
 18  *178  125  24.29   1.57   78 * 20305.9    12185.0    8120.9    40.0   * 17822.5     11346.4     6476.1    36.3    62.7    77.2
 19  *178  125  31.06   1.05   56 * 27040.9    20113.3    6927.6    25.6   * 24466.4     18358.3     6108.0    25.0    39.4    61.7
 20  *178  125  31.06   1.05   67 * 26278.9    17703.0    8575.9    32.6   * 23639.9     16315.3     7324.7    31.0    46.5    65.6
 21  *178  125  31.06   1.05   78 * 25649.9    15887.4    9762.4    38.1   * 22961.3     14762.5     8198.8    35.7    52.3    68.9
 22  *178  125  31.06   1.31   56 * 28939.3    20588.6    8350.7    28.9   * 24466.4     17732.5     6733.9    27.5    42.8    67.5
 23  *178  125  31.06   1.31   67 * 28123.8    18121.2   10002.5    35.6   * 23639.9     15759.1     7880.8    33.3    50.4    71.8
 24  *178  125  31.06   1.31   78 * 27450.5    16262.8   11187.8    40.8   * 22961.3     14259.3     8702.0    37.9    56.9    74.4
 25  *178  125  31.06   1.57   56 * 30591.5    20985.8    9605.8    31.4   * 24466.4     17236.3     7230.1    29.6    46.0    72.0
 26  *178  125  31.06   1.57   67 * 29729.5    18470.9   11258.6    37.9   * 23639.9     15318.1     8321.8    35.2    54.2    75.8
 27  *178  125  31.06   1.57   78 * 29017.8    16576.6   12441.2    42.9   * 22961.3     13860.3     9101.0    39.6    59.7    78.6

                                                NOTE:  # IN  =POUNDS ENTERING
                                                       # OUT =POUNDS LEAVING
                                                       # REM =POUNDS REMOVED
                                                       %     =PERCENTAGE REMOVED FOR THAT UNIT
                                                       OVER.% REM=OVERALL EFFICIENCY COMPARING THE OUTPUT FOR
                                                                 THIS UNIT INPUT AT STATION # 2
                                                       O.O.R.=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                              RANGE OF THE ESTABLISHED OPERATION
                                                              MIN=15.70,MAX=31.06
```

```
             INPUT VECTORS                        O U T P U T  --  S E C O N D A R Y   T A N K   C H A R A C T E R I S T I C S
             *************                        ***********************************************************************
                                                                  B O D                                   SUSPENDED        SOLIDS
TRIAL*                                                                                                                     %  SLUDGE  PLANT EFF
  #  *SS    BOD  FLOW    RECIRC   T  *  #   IN     # OUT     # REM      %    *  #   IN    # OUT     # REM                     BOD  S,S,   REMARK
      *
  1  *178   125  15,70    1,05   56 *  8215,6    5686,1    2529,5    30,8 *   9833,8   6866,5    2967,3    30,2  11119, 64,6 69,8
  2  *178   125  15,70    1,05   67 *  7219,3    5167,1    2052,2    28,4 *   8961,9   6231,2    2730,7    30,5  10232, 68,0 72,7
  3  *178   125  15,70    1,05   78 *  6472,1    4720,6    1751,5    27,1 *   8090,2   5598,9    2491,3    30,8   9335, 71,1 75,4
  4  *178   125  15,70    1,31   56 *  6781,6    4203,9    2577,7    38,0 *   7579,4   4995,6    2583,8    34,1   9681, 70,4 76,1
  5  *178   125  15,70    1,31   67 *  5983,2    3843,2    2140,0    35,8 *   6980,4   4583,5    2396,9    34,3   8981, 73,8 78,7
  6  *178   125  15,70    1,31   78 *  5284,8    3483,2    1801,7    34,1 *   6282,0   4105,1    2176,9    34,7   8157, 76,9 80,8
  7  *178   125  15,70    1,57   56 *  5739,1    3309,7    2429,4    42,3 *   6321,4   3979,9    2341,4    37,0   8773, 75,0 80,1
  8  *178   125  15,70    1,57   67 *  5073,2    2993,7    2079,6    41,0 *   5655,4   3542,6    2112,9    37,4   7917, 77,6 82,5
  9  *178   125  15,70    1,57   78 *  4490,7    2712,3    1778,4    39,6 *   5072,8   3161,9    1910,9    37,7   7160, 80,6 84,4
 10  *178   125  24,29    1,05   56 * 14251,7   10594,1    3657,6    25,7 *  14444,3  11233,4    3210,9    22,2  12031, 56,7 68,3
 11  *178   125  24,29    1,05   67 * 12517,5    9548,8    2968,7    23,7 *  12902,7   9982,9    2919,8    22,6  10941, 61,4 72,1
 12  *178   125  24,29    1,05   78 * 11168,9    8677,0    2491,9    22,3 *  11554,0   8894,5    2659,5    23,0   9965, 64,8 74,9
 13  *178   125  24,29    1,31   56 * 11572,4    7767,7    3804,6    32,9 *  11109,5   8154,7    2954,8    26,6  11072, 64,3 75,2
 14  *178   125  24,29    1,31   67 * 10182,9    6993,2    3189,7    31,3 *   9874,3   7209,1    2665,2    27,0   9987, 68,5 78,4
 15  *178   125  24,29    1,31   78 *  9256,5    6439,0    2817,5    30,4 *   8948,0   6503,5    2444,5    27,3   9159, 71,7 80,5
 16  *178   125  24,29    1,57   56 *  9909,1    6079,8    3829,3    38,6 *   9008,3   6308,2    2700,0    30,0  10117, 69,1 79,5
 17  *178   125  24,29    1,57   67 *  8750,0    5509,4    3240,6    37,0 *   8106,6   5649,5    2457,1    30,3   9207, 73,2 82,3
 18  *178   125  24,29    1,57   78 *  7848,6    5038,8    2809,8    35,8 *   7334,0   5087,7    2246,2    30,6   8417, 75,8 84,1
 19  *178   125  31,06    1,05   56 * 19209,2   14810,6    4398,7    22,9 *  17485,3  14432,7    3052,6    17,5  11438, 52,8 68,3
 20  *178   125  31,06    1,05   67 * 16991,6   13440,3    3551,4    20,9 *  15760,4  12947,4    2813,0    17,8  10540, 57,5 71,6
 21  *178   125  31,06    1,05   78 * 15267,0   12310,1    2956,9    19,4 *  14282,0  11680,3    2601,8    18,2   9749, 60,9 74,3
 22  *178   125  31,06    1,31   56 * 15784,6   11158,9    4625,7    29,3 *  14206,2  11095,2    3111,0    21,9  11657, 59,4 73,2
 23  *178   125  31,06    1,31   67 * 14007,7    9894,2    4113,5    29,4 *  12034,8   9328,4    2706,3    22,5  10141, 64,5 77,9
 24  *178   125  31,06   .1,31   78 * 12428,5    9056,8    3371,7    27,1 *  11047,6   8529,8    2517,8    22,8   9434, 68,8 80,0
 25  *178   125  31,06    1,57   56 * 13164,9    8679,2    4485,7    34,1 *  11683,8   8711,2    2972,6    25,4  11138, 65,3 78,0
 26  *178   125  31,06    1,57   67 * 11847,2    7736,5    4110,7    34,7 *   9872,7   7304,4    2568,2    26,0   9623, 69,7 82,0
 27  *178   125  31,06    1,57   78 * 10694,5    7081,3    3613,2    33,8 *   8884,7   6541,9    2342,8    26,4   8778, 73,0 84,3

                                       NOTE:  # IN  =POUNDS ENTERING
                                              # OUT =POUNDS LEAVING
                                              # REM =POUNDS REMOVED
                                              %     =PERCENTAGE REMOVED FOR THAT UNIT
                                              SLUDGE=GALLONS OF SLUDGE PRODUCED  ASSUMING 3,2% SOLIDS
                                              PLANT EFF= OVERALL PLANT EFFICIENCY
                                              O,O,R,=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                   RANGE OF THE ESTABLISHED OPERATION
                                                   MIN=15,70,MAX=31,06
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                     COMPUTER SIMULATION OF TRICKLING FILTER OPERATION

              ALEXANDRIA SANITATION AUTHORITY HIGH RATE TRICKLING FILTER SYSTEM

                                SET #  3 :  SS =278 MG/L
                                            BOD =125 MG/L

                              O U T P U T  --  S T R E A M   V E C T O R S
        INPUT VECTORS         *********************************************
        *************
                              *  STATION # 2    STATION # 3   STATION # 4   STATION # 5   STATION # 7   STATION # 8 *
TRIAL*                                                                                                                  
 #  *SS   BOD  FLOW  RECIRC  T  * FLOW   BOD SS  FLOW BOD SS  FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS * REMARK

 1  *278  125  15,70  1,05  56 *14,95  127 287  0,75  79  94 15,70 125 278 15,65  80 114 14,90  79  94 14,89  53  66*
 2  *278  125  15,70  1,05  67 *14,95  127 287  0,75  70  88 15,70 125 278 15,65  78 110 14,90  70  88 14,89  48  61*
 3  *278  125  15,70  1,05  78 *14,95  128 287  0,75  63  79 15,70 125 278 15,65  76 107 14,90  63  79 14,89  44  55*
 4  *278  125  15,70  1,31  56 *11,98  138 340  3,72  80  86 15,70 125 278 15,65  86 114 11,93  80  86 11,92  47  57*
 5  *278  125  15,70  1,31  67 *11,98  141 338  3,72  72  85 15,70 125 278 15,65  84 110 11,93  72  85 11,92  45  56*
 6  *278  125  15,70  1,31  78 *11,98  143 340  3,72  64  76 15,70 125 278 15,65  82 107 11,93  64  76 11,92  41  50*
 7  *278  125  15,70  1,57  56 *10,00  150 388  5,70  81  89 15,70 125 278 15,65  91 114  9,95  61  89  9,94  45  56*
 8  *278  125  15,70  1,57  67 *10,00  154 389  5,70  73  82 15,70 125 278 15,65  88 110  9,95  73  82  9,94  42  51*
 9  *278  125  15,70  1,57  78 *10,00  158 393  5,70  66  76 15,70 125 278 15,65  86 107  9,95  66  76  9,94  38  47*
10  *278  125  24,29  1,05  56 *23,13  126 287  1,16  87  91 24,29 125 278 24,21  98 115 23,05  87  91 23,04  63  71*
11  *278  125  24,29  1,05  67 *23,13  127 287  1,16  78  80 24,29 125 278 24,21  95 111 23,05  78  80 23,04  57  62*
12  *278  125  24,29  1,05  78 *23,13  127 288  1,16  70  75 24,29 125 278 24,21  93 108 23,05  70  75 23,04  53  58*
13  *278  125  24,29  1,31  56 *18,54  136 336  5,75  89  88 24,29 125 278 24,21 105 115 18,46  89  88 18,45  58  65*
14  *278  125  24,29  1,31  67 *18,54  138 340  5,75  80  77 24,29 125 278 24,21 102 111 18,46  80  77 18,45  53  56*
15  *278  125  24,29  1,31  78 *18,54  141 341  5,75  72  72 24,29 125 278 24,21 100 108 18,46  72  72 18,45  49  52*
16  *278  125  24,29  1,57  56 *15,47  144 388  8,82  90  85 24,29 125 278 24,21 111 115 15,39  90  85 15,38  54  60*
17  *278  125  24,29  1,57  67 *15,47  150 393  8,82  80  76 24,29 125 278 24,21 108 111 15,39  80  76 15,38  49  53*
18  *278  125  24,29  1,57  78 *15,47  154 396  8,82  73  70 24,29 125 278 24,21 105 108 15,39  73  70 15,38  46  49*
19  *278  125  31,06  1,05  56 *29,58  126 287  1,48  92  87 31,06 125 278 30,96 110 116 29,48  92  87 29,47  70  72*
20  *278  125  31,06  1,05  67 *29,58  127 288  1,48  81  77 31,06 125 278 30,96 106 112 29,48  81  77 29,47  63  63*
21  *278  125  31,06  1,05  78 *29,58  127 288  1,48  75  71 31,06 125 278 30,96 104 109 29,48  75  71 29,46  59  58*
22  *278  125  31,06  1,31  56 *23,71  134 338  7,35  94  84 31,06 125 278 30,96 117 116 23,61  94  84 23,60  64  66*
23  *278  125  31,06  1,31  67 *23,71  138 340  7,35  83  76 31,06 125 278 30,96 114 112 23,61  83  76 23,59  58  59*
24  *278  125  31,06  1,31  78 *23,71  140 342  7,35  76  69 31,06 125 278 30,96 111 109 23,61  76  69 23,59  54  53*
25  *278  125  31,06  1,57  56 *19,78  141 390 11,28  96  81 31,06 125 278 30,96 124 116 19,68  96  81 19,67  60  60*
26  *278  125  31,06  1,57  67 *19,78  147 394 11,28  85  74 31,06 125 278 30,96 121 112 19,68  85  74 19,67  55  55*
27  *278  125  31,06  1,57  78 *19,78  151 395 11,28  78  68 31,06 125 278 30,96 118 109 19,68  78  68 19,67  51  50*

                                NOTE:  FLOWS ARE IN MGD
                                       BOD & SS ARE IN MG/L
                                       O.O.R.=MEANSFLOW THRU THE PLANT IS OUT OF THE
                                               RANGE OF THE ESTABLISHED OPERATION
                                               MIN=15.70,MAX=31.06
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         INPUT VECTORS                 O U T P U T  --  P R I M A R Y   T A N K   C H A R A C T E R I S T I C S
         *************                 *************************************************************************
                                                      B O D                                    SUSPENDED         SOLIDS
TRIAL*                                                                                                                  
  #  *SS   BOD  FLOW   RECIRC  T  *  #  IN     # OUT     # REM      %    *  #  IN     # OUT     # REM      %     SLUDGE  REMARK

  1  *278  125  15,70   1,05   56 * 16367,2   10554,6   5812,6   36,0  * 36400,8   14920,5   21480,3   59,0   51511.
  2  *278  125  15,70   1,05   67 * 16367,2   10257,2   6110,0   37,6  * 36400,8   14416,5   21984,2   60,4   52720.
  3  *278  125  15,70   1,05   78 * 16367,2   10011,7   6355,6   39,2  * 36400,8   14002,7   22398,1   61,5   53712.
  4  *278  125  15,70   1,31   56 * 16367,2   11295,6   5071,6   31,2  * 36400,8   14920,5   21480,3   59,0   51511.
  5  *278  125  15,70   1,31   67 * 16367,2   10977,3   5389,9   32,8  * 36400,8   14416,5   21984,2   60,4   52720.
  6  *278  125  15,70   1,31   78 * 16367,2   10714,5   5652,7   34,4  * 36400,8   14002,7   22398,1   61,5   53712.
  7  *278  125  15,70   1,57   56 * 16367,2   11940,5   4426,7   27,2  * 36400,8   14920,5   21480,3   59,0   51511.
  8  *278  125  15,70   1,57   67 * 16367,2   11604,0   4763,2   29,6  * 36400,8   14416,5   21984,2   60,4   52720.
  9  *278  125  15,70   1,57   78 * 16367,2   11326,3   5041,0   31,2  * 36400,8   14002,7   22398,1   61,5   53712.
 10  *278  125  24,29   1,05   56 * 25322,3   19890,7   5431,6   21,6  * 56316,8   23393,1   32923,7   58,6   78954.
 11  *278  125  24,29   1,05   67 * 25322,3   19330,2   5992,1   24,0  * 56316,8   22603,0   33713,9   60,1   80849.
 12  *278  125  24,29   1,05   78 * 25322,3   18867,5   6454,9   25,6  * 56316,8   21954,1   34362,7   61,2   82405.
 13  *278  125  24,29   1,31   56 * 25322,3   21287,1   4035,2   16,0  * 56316,8   23393,1   32923,7   58,6   78954.
 14  *278  125  24,29   1,31   67 * 25322,3   20687,2   4635,1   18,4  * 56316,8   22603,0   33713,9   60,1   80849.
 15  *278  125  24,29   1,31   78 * 25322,3   20192,0   5130,3   20,0  * 56316,8   21954,1   34362,7   61,2   82405.
 16  *278  125  24,29   1,57   56 * 25322,3   22502,4   2819,9   11,2  * 56316,8   23393,1   32923,7   58,6   78954.
 17  *278  125  24,29   1,57   67 * 25322,3   21868,3   3454,0   13,6  * 56316,8   22603,0   33713,9   60,1   80849.
 18  *278  125  24,29   1,57   78 * 25322,3   21344,9   3977,4   16,0  * 56316,8   21954,1   34362,7   61,2   82405.
 19  *278  125  31,06   1,05   56 * 32380,0   28424,4   3955,6   12,0  * 72013,2   30138,1   41875,1   58,3  100420.
 20  *278  125  31,06   1,05   67 * 32380,0   27623,4   4756,6   15,2  * 72013,2   29120,1   42893,1   59,7  102861.
 21  *278  125  31,06   1,05   78 * 32380,0   26962,2   5417,8   16,8  * 72013,2   28284,2   43729,0   60,8  104866.
 22  *278  125  31,06   1,31   56 * 32380,0   30419,9   1960,1    6,4  * 72013,2   30138,1   41875,1   58,3  100420.
 23  *278  125  31,06   1,31   67 * 32380,0   29562,7   2817,4    8,8  * 72013,2   29120,1   42893,1   59,7  102861.
 24  *278  125  31,06   1,31   78 * 32380,0   28855,0   3525,0   11,2  * 72013,2   28284,2   43729,0   60,8  104866.
 25  *278  125  31,06   1,57   56 * 32380,0   32156,7    223,3    0,8  * 72013,2   30138,1   41875,1   58,3  100420.
 26  *278  125  31,06   1,57   67 * 32380,0   31250,6   1129,5    3,2  * 72013,2   29120,1   42893,1   59,7  102861.
 27  *278  125  31,06   1,57   78 * 32380,0   30502,5   1877,5    5,6  * 72013,2   28284,2   43729,0   60,8  104866.

                                      NOTE: # IN  =POUNDS ENTERING
                                            # OUT =POUNDS LEAVING
                                            # REM =POUNDS REMOVED
                                            %     =PERCENTAGE REMOVED FOR THAT UNIT
                                            SLUDGE=GALLONS OF SLUDGE PRODUCED  ASSUMING 5,0% SOLIDS
                                            O,O,R,=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                   RANGE OF THE ESTABLISHED PLANT OPERATION
                                                   MIN=15,70,MAX=31,06
```

```
              INPUT VECTORS                        O U T P U T  ==  T R I C K L I N G   F I L T E R   C H A R A C T E R I S T I C S
              *************                        ***************************************************************************************
                                                                 B O D                                  SUSPENDED       SOLIDS
TRIAL*                                                                                                                                 OVERALL  % REM
 #  *SS   BOD  FLOW    RECIRC  T  *  #   IN      # OUT      # REM      %     *  #   IN     # OUT       # REM       %    BOD      S,S, REMARK

 1  *278  125  15,70   1.05   56 * 10554,6    10296,7      257,9     2,4   * 14920,5    13074,3     1846,2    12,4   38,6     65,2
 2  *278  125  15,70   1,05   67 * 10257,2     9062,8     1194,4    11,6   * 14416,5    11619,4     2797,1    19,4   45,7     69,0
 3  *278  125  15,70   1,05   78 * 10011,7     8133,5     1878,2    18,8   * 14002,7    10513,7     3489,0    24,9   51,6     72,1
 4  *278  125  15,70   1.31   56 * 11295,6    10539,9      755,6     6,7   * 14920,5    12628,6     2291,9    15,4   42,0     71,8
 5  *278  125  15,70   1,31   67 * 10977,3     9276,9     1700,4    15,5   * 14416,5    11223,3     3193,2    22,1   49,6     74,6
 6  *278  125  15,70   1.31   78 * 10714,5     8325,6     2388,9    22,3   * 14002,7    10155,3     3847,4    27,5   55,9     77,4
 7  *278  125  15,70   1.57   56 * 11940,5    10743,3     1197,2    10,0   * 14920,5    12275,2     2645,3    17,7   45,3     75,8
 8  *278  125  15,70   1.57   67 * 11604,0     9455,9     2148,1    18,5   * 14416,5    10909,2     3507,3    24,3   53,2     78,7
 9  *278  125  15,70   1,57   78 * 11326,3     8486,3     2840,0    25,1   * 14002,7     9871,1     4131,6    29,5   58,9     80,9
10  *278  125  24,29   1,05   56 * 19890,7    17781,2     2109,4    10,6   * 23393,1    18650,6     4742,5    20,3   30,2     67,9
11  *278  125  24,29   1,05   67 * 19330,2    15650,5     3679,7    19,0   * 22603,0    16575,1     6027,8    26,7   39,4     71,4
12  *278  125  24,29   1,05   78 * 18867,5    14045,6     4821,8    25,6   * 21954,1    14997,8     6956,3    31,7   45,7     74,3
13  *278  125  24,29   1,31   56 * 21287,1    18201,4     3085,7    14,5   * 23393,1    18014,9     5378,3    23,0   33,8     73,5
14  *278  125  24,29   1,31   67 * 20687,2    16020,2     4667,0    22,6   * 22603,0    16010,1     6592,8    29,2   42,8     76,8
15  *278  125  24,29   1,31   78 * 20192,0    14377,4     5814,6    28,8   * 21954,1    14486,6     7467,6    34,0   49,6     79,2
16  *278  125  24,29   1,57   56 * 22502,4    18552,6     3949,9    17,6   * 23393,1    17510,7     5882,4    25,1   36,8     77,8
17  *278  125  24,29   1,57   67 * 21868,3    16329,3     5539,0    25,3   * 22603,0    15562,1     7040,9    31,2   46,7     80,4
18  *278  125  24,29   1,57   78 * 21344,9    14654,8     6690,0    31,3   * 21954,1    14081,2     7872,9    35,9   53,2     82,6
19  *278  125  31,06   1,05   56 * 28424,4    24189,6     4234,9    14,9   * 30138,1    22782,6     7355,5    24,4   26,2     69,3
20  *278  125  31,06   1,05   67 * 27623,4    21290,9     6332,5    22,9   * 29120,1    20247,4     8872,7    30,5   35,4     72,9
21  *278  125  31,06   1,05   78 * 26962,2    19107,6     7854,6    29,1   * 28284,2    18320,6     9963,6    35,2   41,7     75,7
22  *278  125  31,06   1,31   56 * 30419,9    24761,1     5658,9    18,6   * 30138,1    22006,0     8132,1    27,0   29,1     74,9
23  *278  125  31,06   1,31   67 * 29562,7    21793,9     7768,8    26,3   * 29120,1    19557,2     9562,9    32,8   39,1     77,9
24  *278  125  31,06   1,31   78 * 28855,0    19559,1     9296,0    32,2   * 28284,2    17696,1    10588,1    37,4   46,4     80,1
25  *278  125  31,06   1,57   56 * 32156,7    25238,8     6917,9    21,5   * 30138,1    21390,2     8747,9    29,0   31,2     79,0
26  *278  125  31,06   1,57   67 * 31250,6    22214,5     9036,1    28,9   * 29120,1    19009,9    10110,2    34,7   41,5     81,5
27  *278  125  31,06   1,57   78 * 30502,5    19936,5    10566,0    34,6   * 28284,2    17200,9    11083,3    39,2   49,0     83,3

                                      NOTE!  # IN  =POUNDS ENTERING
                                             # OUT =POUNDS LEAVING
                                             # REM =POUNDS REMOVED
                                             %     =PERCENTAGE REMOVED FOR THAT UNIT
                                             OVER,% REM=OVERALL EFFICIENCY COMPARING THE OUTPUT FOR
                                                     THIS UNIT INPUT AT STATION # 2
                                             O,O,R,=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                  RANGE OF THE ESTABLISHED OPERATION
                                                  MIN=15,70,MAX=31,06
```

```
                 INPUT VECTORS                    O U T P U T  --  S E C O N D A R Y   T A N K   C H A R A C T E R I S T I C S
                 *************                    ***************************************************************************
                                                              B O D                                  SUSPENDED          SOLIDS
TRIAL*                                                                                                                         PLANT EFF
  #  *SS   BOD  FLOW   RECIRC  T  *  #  IN     # OUT     # REM      %    *  #  IN     # OUT     # REM      %  SLUDGE    BOD  S,S,  REMARK
      *
  1  *278  125  15,70   1,05  56 *  9817,6    6597,1    3220,5    32,8 * 11681,7    8218,2    3463,5   29,6  12978,  58,3 77,0
  2  *278  125  15,70   1,05  67 *  8698,4    6082,0    2616,4    30,1 * 10935,2    7669,8    3265,4   29,9  12236,  62,2 78,7
  3  *278  125  15,70   1,05  78 *  7828,1    5553,6    2274,4    29,1 *  9816,1    6851,0    2965,1   30,2  11110,  65,6 80,8
  4  *278  125  15,70   1,31  56 *  7961,8    4740,8    3221,0    40,5 *  8559,0    5670,1    2888,8   33,8  10824,  65,9 83,2
  5  *278  125  15,70   1,31  67 *  7164,9    4497,7    2667,2    37,2 *  8458,6    5600,5    2858,1   33,8  10709,  68,1 83,4
  6  *278  125  15,70   1,31  78 *  6368,3    4077,2    2291,1    36,0 *  7562,4    4981,5    2580,8   34,1   9670,  71,3 85,3
  7  *278  125  15,70   1,57  56 *  6720,6    3778,0    2942,6    43,8 *  7384,4    4679,8    2704,6   36,6  10134,  70,0 85,6
  8  *278  125  15,70   1,57  67 *  6056,1    3487,5    2568,6    42,4 *  6802,7    4295,0    2507,7   36,9   9396,  72,7 86,9
  9  *278  125  15,70   1,57  78 *  5474,8    3231,7    2243,1    41,0 *  6304,4    3966,5    2337,8   37,1   8760,  75,9 88,0
 10  *278  125  24,29   1,05  56 *16727,8   12286,8    4441,0    26,5 * 17496,9   13722,0    3774,9   21,6  14145,  50,0 75,3
 11  *278  125  24,29   1,05  67 *14996,1   11106,7    3889,4    25,9 * 15380,6   11991,5    3389,1   22,0  12699,  55,1 78,4
 12  *278  125  24,29   1,05  78 *13457,1   10304,9    3152,2    23,4 * 14418,3   11208,1    3210,2   22,3  12029,  58,3 79,9
 13  *278  125  24,29   1,31  56 *13704,3    9068,3    4636,0    33,8 * 13550,4   10032,4    3517,9   26,0  13182,  57,4 80,7
 14  *278  125  24,29   1,31  67 *12317,3    8191,4    4125,8    33,5 * 11855,4    8724,1    3131,3   26,4  11733,  61,6 83,5
 15  *278  125  24,29   1,31  78 *11084,6    7601,9    3482,7    31,4 * 11084,6    8131,8    2952,8   26,6  11064,  65,2 84,8
 16  *278  125  24,29   1,57  56 *11553,5    7027,0    4526,6    39,2 * 10911,6    7704,2    3207,5   29,4  12018,  62,5 84,5
 17  *278  125  24,29   1,57  67 *10268,5    6369,7    3898,8    38,0 *  9755,1    6852,4    2902,7   29,8  10877,  67,3 86,5
 18  *278  125  24,29   1,57  78 * 9369,1    5912,7    3456,4    36,9 *  8984,0    6287,0    2697,0   30,0  10106,  70,1 87,6
 19  *278  125  31,06   1,05  56 *22619,8   17269,9    5349,9    23,7 * 21390,5   17812,9    3577,6   16,7  13405,  44,4 74,9
 20  *278  125  31,06   1,05  67 *19913,6   15524,6    4389,0    22,0 * 18930,2   15676,4    3253,8   17,2  12192,  50,4 78,1
 21  *278  125  31,06   1,05  78 *18437,3   14513,7    3923,6    21,3 * 17454,0   14400,3    3053,6   17,5  11442,  53,5 79,9
 22  *278  125  31,06   1,31  56 *18508,9   12731,2    5777,7    31,2 * 16539,9   13002,1    3537,8   21,4  13256,  52,2 80,5
 23  *278  125  31,06   1,31  67 *16341,3   11560,1    4781,2    29,3 * 14963,1   11708,8    3254,3   21,7  12194,  58,0 82,6
 24  *278  125  31,06   1,31  78 *14961,8   10686,4    4275,5    28,6 * 13583,8   10582,6    3001,2   22,1  11245,  61,4 84,5
 25  *278  125  31,06   1,57  56 *15759,0    9903,1    5855,9    37,2 * 13296,6    9967,2    3329,5   25,0  12476,  57,4 84,6
 26  *278  125  31,06   1,57  67 *13951,5    9037,9    4913,6    35,2 * 12146,1    9067,0    3079,1   25,4  11537,  62,6 86,0
 27  *278  125  31,06   1,57  78 *12801,3    8403,2    4398,1    34,4 * 11160,1    8298,8    2861,3   25,6  10721,  66,2 87,3

                                            NOTE:  # IN  =POUNDS ENTERING
                                                   # OUT =POUNDS LEAVING
                                                   # REM =POUNDS REMOVED
                                                   %      =PERCENTAGE REMOVED FOR THAT UNIT
                                                   SLUDGE=GALLONS OF SLUDGE PRODUCED  ASSUMING 3,2% SOLIDS
                                                   PLANT EFF= OVERALL PLANT EFFICIENCY
                                                   O,O,R,=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                         RANGE OF THE ESTABLISHED OPERATION
                                                         MIN=15,70,MAX=31,06
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                         COMPUTER SIMULATION OF TRICKLING FILTER OPERATION

                   ALEXANDRIA SANITATION AUTHORITY HIGH RATE TRICKLING FILTER SYSTEM

                                      SET #  4 :  SS =119 MG/L
                                                  BOD =169 MG/L

           INPUT VECTORS                   O U T P U T  --  S T R E A M   V E C T O R S
           *************                   ********************************************
                                        *  STATION # 2    STATION # 3  STATION # 4  STATION # 5  STATION # 7  STATION # 8 *
TRIAL*                                                                                                             
  #  *SS   BOD  FLOW   RECIRC   T   * FLOW    BOD SS    FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS * REMARK

  1  *119  169  15,70   1,05   56 *14,95    174 121    0,75   67  71 15,70 169 119 15,69  88  76 14,94  67  71 14,93  44  49*
  2  *119  169  15,70   1,05   67 *14,95    174 121    0,75   59  63 15,70 169 119 15,69  86  74 14,94  59  63 14,93  39  43*
  3  *119  169  15,70   1,05   78 *14,95    174 122    0,75   53  57 15,70 169 119 15,69  84  71 14,94  53  57 14,93  36  39*
  4  *119  169  15,70   1,31   56 *11,98    200 134    3,72   68  69 15,70 169 119 15,69  94  76 11,97  68  69 11,96  40  45*
  5  *119  169  15,70   1,31   67 *11,98    202 136    3,72   60  61 15,70 169 119 15,69  92  74 11,97  60  61 11,96  36  39*
  6  *119  169  15,70   1,31   78 *11,98    204 138    3,72   54  55 15,70 169 119 15,69  89  71 11,97  54  55 11,96  33  35*
  7  *119  169  15,70   1,57   56 *10,00    225 148    5,70   70  67 15,70 169 119 15,69 100  76  9,99  70  67  9,98  38  41*
  8  *119  169  15,70   1,57   67 *10,00    230 152    5,70   61  60 15,70 169 119 15,69  97  74  9,99  61  60  9,98  34  37*
  9  *119  169  15,70   1,57   78 *10,00    233 156    5,70   55  54 15,70 169 119 15,69  95  71  9,99  55  54  9,98  31  33*
 10  *119  169  24,29   1,05   56 *23,13    173 121    1,16   74  66 24,29 169 119 24,27 107  77 23,11  74  66 23,10  52  51*
 11  *119  169  24,29   1,05   67 *23,13    174 121    1,16   65  59 24,29 169 119 24,27 104  75 23,11  65  59 23,10  47  45*
 12  *119  169  24,29   1,05   78 *23,13    174 122    1,16   59  53 24,29 169 119 24,27 102  72 23,11  59  53 23,10  43  40*
 13  *119  169  24,29   1,31   56 *18,54    197 135    5,75   76  64 24,29 169 119 24,27 115  77 18,52  76  64 18,51  48  46*
 14  *119  169  24,29   1,31   67 *18,54    200 137    5,75   67  57 24,29 169 119 24,27 112  75 18,52  67  57 18,51  43  41*
 15  *119  169  24,29   1,31   78 *18,54    202 140    5,75   60  51 24,29 169 119 24,27 109  72 18,52  60  51 18,51  39  36*
 16  *119  169  24,29   1,57   56 *15,47    220 148    8,82   78  64 24,29 169 119 24,27 122  77 15,45  78  64 15,44  45  44*
 17  *119  169  24,29   1,57   67 *15,47    226 154    8,82   68  55 24,29 169 119 24,27 118  75 15,45  68  55 15,44  40  38*
 18  *119  169  24,29   1,57   78 *15,47    230 158    8,82   61  50 24,29 169 119 24,27 115  72 15,45  61  50 15,44  37  34*
 19  *119  169  31,06   1,05   56 *29,58    173 121    1,48   79  65 31,06 169 119 31,03 120  78 29,56  79  65 29,54  58  53*
 20  *119  169  31,06   1,05   67 *29,58    173 122    1,48   70  56 31,06 169 119 31,03 117  75 29,55  70  56 29,54  52  45*
 21  *119  169  31,06   1,05   78 *29,58    174 122    1,48   63  51 31,06 169 119 31,03 114  73 29,55  63  51 29,54  47  41*
 22  *119  169  31,06   1,31   56 *23,71    196 132    7,35   80  68 31,06 169 119 31,03 129  78 23,68  80  68 23,67  55  53*
 23  *119  169  31,06   1,31   67 *23,71    199 138    7,35   71  54 31,06 169 119 31,03 125  75 23,68  71  54 23,67  47  41*
 24  *119  169  31,06   1,31   78 *23,71    201 140    7,35   64  49 31,06 169 119 31,03 122  73 23,68  64  49 23,67  43  37*
 25  *119  169  31,06   1,57   56 *19,78    219 143   11,28   80  67 31,06 169 119 31,03 136  78 19,76  80  67 19,75  51  49*
 26  *119  169  31,06   1,57   67 *19,78    223 155   11,28   73  53 31,06 169 119 31,03 132  75 19,76  73  53 19,75  45  39*
 27  *119  169  31,06   1,57   78 *19,78    228 159   11,28   65  48 31,06 169 119 31,03 129  73 19,76  65  48 19,75  41  35*

                                     NOTE:  FLOWS ARE IN MGD
                                            BOD & SS ARE IN MG/L
                                            O.O.R.=MEANSFLOW THRU THE PLANT IS OUT OF THE
                                                   RANGE OF THE ESTABLISHED OPERATION
                                                   MIN=15,70,MAX=31,06
```

```
             INPUT VECTORS                      O U T P U T  --  P R I M A R Y   T A N K   C H A R A C T E R I S T I C S
             *************                      *****************************************************************************
                                                              B O D                                   SUSPENDED        SOLIDS
TRIAL*                                                                                                                         SLUDGE   REMARK
  #   *SS   BOD  FLOW   RECIRC  T  *  #   IN    # OUT      # REM       %     *  #   IN      # OUT      # REM       %
                                                                                  
  1  *119  169  15,70   1,05   56 * 22128,5   11590,0    10538,5    47,9   * 15581,6    10033,7    5548,0    36,1   13304,
  2  *119  169  15,70   1,05   67 * 22128,5   11263,4    10865,1    49,1   * 15581,6     9694,7    5886,9    37,8   14117,
  3  *119  169  15,70   1,05   78 * 22128,5   10993,8    11134,8    50,3   * 15581,6     9416,4    6165,2    40,3   14785,
  4  *119  169  15,70   1,31   56 * 22128,5   12403,6     9724,9    44,4   * 15581,6    10033,7    5548,0    36,1   13304,
  5  *119  169  15,70   1,31   67 * 22128,5   12054,1    10074,4    45,6   * 15581,6     9694,7    5886,9    37,8   14117,
  6  *119  169  15,70   1,31   78 * 22128,5   11765,6    10363,0    47,3   * 15581,6     9416,4    6165,2    40,3   14785,
  7  *119  169  15,70   1,57   56 * 22128,5   13111,8     9016,7    40,8   * 15581,6    10033,7    5548,0    36,1   13304,
  8  *119  169  15,70   1,57   67 * 22128,5   12742,3     9386,2    42,6   * 15581,6     9694,7    5886,9    37,8   14117,
  9  *119  169  15,70   1,57   78 * 22128,5   12437,3     9691,2    43,8   * 15581,6     9416,4    6165,2    40,3   14785,
 10  *119  169  24,29   1,05   56 * 34235,8   21841,9    12393,9    36,7   * 24106,8    15731,3    8375,6    35,3   20085,
 11  *119  169  24,29   1,05   67 * 34235,8   21226,4    13009,4    38,5   * 24106,8    15199,9    8906,9    37,0   21360,
 12  *119  169  24,29   1,05   78 * 34235,8   20718,3    13517,5    39,6   * 24106,8    14763,6    9343,3    39,5   22406,
 13  *119  169  24,29   1,31   56 * 34235,8   23375,2    10860,5    32,0   * 24106,8    15731,3    8375,6    35,3   20085,
 14  *119  169  24,29   1,31   67 * 34235,8   22716,5    11519,2    33,7   * 24106,8    15199,9    8906,9    37,0   21360,
 15  *119  169  24,29   1,31   78 * 34235,8   22172,7    12063,0    35,5   * 24106,8    14763,6    9343,3    39,5   22406,
 16  *119  169  24,29   1,57   56 * 34235,8   24709,9     9525,9    27,8   * 24106,8    15731,3    8375,6    35,3   20085,
 17  *119  169  24,29   1,57   67 * 34235,8   24013,5    10222,2    30,2   * 24106,8    15199,9    8906,9    37,0   21360,
 18  *119  169  24,29   1,57   78 * 34235,8   23438,7    10797,1    32,0   * 24106,8    14763,6    9343,3    39,5   22406,
 19  *119  169  31,06   1,05   56 * 43777,8   31212,7    12565,1    29,0   * 30825,8    20267,1   10558,7    34,5   25321,
 20  *119  169  31,06   1,05   67 * 43777,8   30333,2    13444,6    30,8   * 30825,8    19582,5   11243,3    37,0   26962,
 21  *119  169  31,06   1,05   78 * 43777,8   29607,1    14170,7    32,5   * 30825,8    19020,4   11805,4    38,7   28310,
 22  *119  169  31,06   1,31   56 * 43777,8   33404,0    10373,8    23,7   * 30825,8    20267,1   10558,7    34,5   25321,
 23  *119  169  31,06   1,31   67 * 43777,8   32462,7    11315,1    26,0   * 30825,8    19582,5   11243,3    37,0   26962,
 24  *119  169  31,06   1,31   78 * 43777,8   31685,6    12092,2    27,8   * 30825,8    19020,4   11805,4    38,7   28310,
 25  *119  169  31,06   1,57   56 * 43777,8   35311,2     8466,7    19,5   * 30825,8    20267,1   10558,7    34,5   25321,
 26  *119  169  31,06   1,57   67 * 43777,8   34316,1     9461,7    21,9   * 30825,8    19582,5   11243,3    37,0   26962,
 27  *119  169  31,06   1,57   78 * 43777,8   33494,7    10283,1    23,7   * 30825,8    19020,4   11805,4    38,7   28310,

                                         NOTE:  # IN  =POUNDS ENTERING
                                                # OUT =POUNDS LEAVING
                                                # REM =POUNDS REMOVED
                                                %     =PERCENTAGE REMOVED FOR THAT UNIT
                                                SLUDGE=GALLONS OF SLUDGE PRODUCED  ASSUMING 5,0% SOLIDS
                                                O,O,R,=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                       RANGE OF THE ESTABLISHED PLANT OPERATION
                                                       MIN=15,70,MAX=31,06
```

```
                INPUT VECTORS                       O U T P U T  --  T R I C K L I N G   F I L T E R   C H A R A C T E R I S T I C S
                *************                       ******************************************************************************
                                                              B O D                                 SUSPENDED        SOLIDS
TRIAL*                                                                                                                           OVERALL % REM
 #   *SS   BOD  FLOW    RECIRC  T  *  #   IN      # OUT      # REM      %     *  #   IN      # OUT      # REM      %        BOD    S,S, REMARK

 1  *119   169  15,70    1,05   56 * 11590,0     8653,7     2936,3    25,3   * 10033,7     9261,2      772,5     7,7  62,1   42,1
 2  *119   169  15,70    1,05   67 * 11263,4     7616,5     3646,9    32,4   *  9694,7     8230,4     1464,3    15,1  66,7   48,8
 3  *119   169  15,70    1,05   78 * 10993,8     6835,4     4158,4    37,8   *  9416,4     7447,1     1969,3    20,9  70,1   54,1
 4  *119   169  15,70    1,31   56 * 12403,6     8858,1     3545,5    28,6   * 10033,7     8945,5     1088,2    10,8  66,5   49,3
 5  *119   169  15,70    1,31   67 * 12054,1     7796,5     4257,6    35,3   *  9694,7     7949,9     1744,9    18,0  70,8   55,9
 6  *119   169  15,70    1,31   78 * 11765,6     6996,9     4768,7    40,5   *  9416,4     7193,2     2223,2    23,6  74,0   60,9
 7  *119   169  15,70    1,57   56 * 13111,8     9029,0     4082,8    31,1   * 10033,7     8695,1     1338,5    13,3  69,3   55,4
 8  *119   169  15,70    1,57   67 * 12742,3     7946,9     4795,4    37,6   *  9694,7     7727,4     1967,3    20,3  73,9   61,2
 9  *119   169  15,70    1,57   78 * 12437,3     7131,9     5305,5    42,7   *  9416,4     6991,9     2424,5    25,7  76,8   66,0
10  *119   169  24,29    1,05   56 * 21841,9    14944,0     6897,9    31,6   * 15731,3    13211,2     2520,1    16,0  57,8   46,3
11  *119   169  24,29    1,05   67 * 21226,4    13153,0     8073,4    38,0   * 15199,9    11740,8     3459,1    22,8  63,2   52,1
12  *119   169  24,29    1,05   78 * 20718,3    11804,0     8914,2    43,0   * 14763,6    10623,4     4140,2    28,0  66,7   57,4
13  *119   169  24,29    1,31   56 * 23375,2    15297,1     8078,1    34,6   * 15731,3    12760,9     2970,4    18,9  61,9   53,3
14  *119   169  24,29    1,31   67 * 22716,5    13463,8     9252,8    40,7   * 15199,9    11340,6     3859,3    25,4  67,0   59,1
15  *119   169  24,29    1,31   78 * 22172,7    12082,9    10089,8    45,5   * 14763,6    10261,3     4502,3    30,5  70,8   64,3
16  *119   169  24,29    1,57   56 * 24709,9    15592,2     9117,6    36,9   * 15731,3    12403,8     3327,5    21,2  65,0   58,8
17  *119   169  24,29    1,57   67 * 24013,5    13723,5    10290,0    42,9   * 15199,9    11023,3     4176,6    27,5  70,4   64,9
18  *119   169  24,29    1,57   78 * 23438,7    12316,0    11122,7    47,5   * 14763,6     9974,1     4789,4    32,4  73,9   69,0
19  *119   169  31,06    1,05   56 * 31212,7    20329,9    10882,8    34,9   * 20267,1    16138,2     4128,9    20,4  54,9   48,8
20  *119   169  31,06    1,05   67 * 30333,2    17893,4    12439,8    41,0   * 19582,5    14342,1     5240,4    26,8  60,1   54,9
21  *119   169  31,06    1,05   78 * 29607,1    16058,3    13548,8    45,8   * 19020,4    12977,1     6043,3    31,8  64,4   59,0
22  *119   169  31,06    1,31   56 * 33404,0    20810,2    12593,7    37,7   * 20267,1    15588,1     4679,0    23,1  59,2   54,5
23  *119   169  31,06    1,31   67 * 32462,7    18316,2    14146,5    43,6   * 19582,5    13853,2     5729,3    29,3  64,8   61,6
24  *119   169  31,06    1,31   78 * 31685,6    16437,7    15247,9    48,1   * 19020,4    12534,7     6485,6    34,1  68,7   65,7
25  *119   169  31,06    1,57   56 * 35311,2    21211,8    14099,4    39,9   * 20267,1    15151,9     5115,2    25,2  63,0   59,4
26  *119   169  31,06    1,57   67 * 34316,1    18669,6    15646,5    45,6   * 19582,5    13465,6     6117,0    31,2  67,7   66,5
27  *119   169  31,06    1,57   78 * 33494,7    16754,8    16739,9    50,0   * 19020,4    12184,0     6836,4    35,9  71,9   70,4

                                           NOTE:  # IN  =POUNDS ENTERING
                                                  # OUT =POUNDS LEAVING
                                                  # REM =POUNDS REMOVED
                                                  %     =PERCENTAGE REMOVED FOR THAT UNIT
                                                  OVER,% REM=OVERALL EFFICIENCY COMPARING THE OUTPUT FOR
                                                          THIS UNIT INPUT AT STATION # 2
                                                  O,O,R,=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                        RANGE OF THE ESTABLISHED OPERATION
                                                        MIN=15,70,MAX=31,06
```

```
                INPUT VECTORS                O U T P U T  --  S E C O N D A R Y   T A N K   C H A R A C T E R I S T I C S
                *************                ****************************************************************************
                                                        B O D                                  SUSPENDED        SOLIDS
TRIAL*                                                                                                          %  SLUDGE  PLANT EFF
 #  *SS    BOD  FLOW    RECIRC  T  *  #  IN    # OUT     # REM      %   *  #  IN   # OUT     # REM                           BOD  S.S.   REMARK
     *
 1  *119   169  15.70   1.05   56 * 8347.7   5493.7    2853.9    34.2 *  8846.0   6148.2    2697.8    30.5  10109.  74.7 59.5
 2  *119   169  15.70   1.05   67 * 7350.5   4944.1    2406.4    32.7 *  7848.9   5425.5    2423.4    30.9   9080.  77.6 64.5
 3  *119   169  15.70   1.05   78 * 6602.7   4524.9    2077.8    31.5 *  7101.0   4886.2    2214.9    31.2   8299.  79.3 68.0
 4  *119   169  15.70   1.31   56 * 6789.2   4051.5    2737.7    40.3 *  6889.1   4522.0    2367.1    34.4   8870.  80.0 66.4
 5  *119   169  15.70   1.31   67 * 5990.1   3644.1    2346.0    39.2 *  6089.9   3975.0    2114.9    34.7   7925.  82.2 71.3
 6  *119   169  15.70   1.31   78 * 5390.8   3333.3    2057.5    38.2 *  5490.6   3566.9    1923.7    35.0   7208.  83.8 74.6
 7  *119   169  15.70   1.57   56 * 5830.2   3174.3    2655.9    45.6 *  5580.4   3494.5    2085.9    37.4   7816.  83.1 72.3
 8  *119   169  15.70   1.57   67 * 5080.2   2853.5    2226.7    43.8 *  4996.9   3113.4    1883.5    37.7   7058.  85.2 75.7
 9  *119   169  15.70   1.57   78 * 4580.2   2610.4    1969.8    43.0 *  4496.9   2788.4    1708.5    38.0   6402.  86.7 78.8
10  *119   169  24.29   1.05   56 *14264.6  10081.1    4183.5    29.3 * 12722.4   9839.1    2883.3    22.7  10804.  69.9 57.9
11  *119   169  24.29   1.05   67 *12529.0   9089.0    3440.0    27.5 * 11372.5   8750.2    2622.3    23.1   9826.  73.0 62.8
12  *119   169  24.29   1.05   78 *11371.9   8333.9    3038.0    26.7 * 10215.5   7821.6    2393.9    23.4   8970.  75.3 67.2
13  *119   169  24.29   1.31   56 *11739.9   7468.2    4271.7    36.4 *  9886.2   7220.0    2666.2    27.0   9990.  75.6 65.9
14  *119   169  24.29   1.31   67 *10348.9   6734.4    3614.6    34.9 *  8804.3   6396.0    2408.4    27.4   9024.  78.5 70.1
15  *119   169  24.29   1.31   78 * 9267.2   6127.4    3139.8    33.9 *  7877.1   5693.4    2183.7    27.7   8182.  80.7 74.3
16  *119   169  24.29   1.57   56 *10051.3   5912.1    4139.2    41.2 *  8247.3   5753.8    2493.5    30.2   9343.  79.5 70.3
17  *119   169  24.29   1.57   67 * 8762.0   5229.3    3532.7    40.3 *  7086.9   4910.1    2176.8    30.7   8156.  82.3 75.3
18  *119   169  24.29   1.57   78 * 7859.5   4791.8    3067.7    39.0 *  6442.2   4444.1    1998.1    31.0   7487.  83.9 78.5
19  *119   169  31.06   1.05   56 *19473.0  14399.9    5073.1    26.1 * 16022.1  13174.9    2847.2    17.8  10668.  66.5 56.2
20  *119   169  31.06   1.05   67 *17253.6  12844.3    4409.3    25.6 * 13802.9  11273.1    2529.8    18.3   9479.  69.9 63.1
21  *119   169  31.06   1.05   78 *15527.5  11796.0    3731.5    24.0 * 12569.9  10222.4    2347.5    18.7   8796.  73.0 66.4
22  *119   169  31.06   1.31   56 *15802.4  10924.6    4877.7    30.9 * 13432.0  10466.3    2965.7    22.1  11113.  71.9 59.8
23  *119   169  31.06   1.31   67 *14023.6   9440.3    4583.3    32.7 * 10665.9   8224.0    2441.9    22.9   9150.  76.4 70.3
24  *119   169  31.06   1.31   78 *12640.3   8663.3    3976.9    31.5 *  9677.7   7429.0    2248.7    23.2   8426.  78.6 73.6
25  *119   169  31.06   1.57   56 *13182.6   8496.7    4685.9    35.5 * 11040.4   8212.6    2827.8    25.6  10596.  76.7 65.7
26  *119   169  31.06   1.57   67 *12028.1   7423.9    4604.2    38.3 *  8732.8   6426.9    2305.9    26.4   8640.  79.8 74.8
27  *119   169  31.06   1.57   78 *10709.2   6769.7    3939.5    36.8 *  7908.4   5793.9    2114.5    26.7   7923.  82.0 78.0

                                        NOTE:  # IN  =POUNDS ENTERING
                                               # OUT =POUNDS LEAVING
                                               # REM =POUNDS REMOVED
                                               %     =PERCENTAGE REMOVED FOR THAT UNIT
                                               SLUDGE=GALLONS OF SLUDGE PRODUCED  ASSUMING 3.2% SOLIDS
                                               PLANT EFF= OVERALL PLANT EFFICIENCY
                                               O.O.R.=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                    RANGE OF THE ESTABLISHED OPERATION
                                                    MIN=15.70,MAX=31.06
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                       COMPUTER SIMULATION OF TRICKLING FILTER OPERATION

                 ALEXANDRIA SANITATION AUTHORITY HIGH RATE TRICKLING FILTER SYSTEM

                                     SET #  5 :  SS =178 MG/L
                                                 BOD =169 MG/L

        INPUT VECTORS               O U T P U T  --  S T R E A M   V E C T O R S
        *************               **********************************************

TRIAL*                                  *  STATION # 2      STATION # 3   STATION # 4   STATION # 5   STATION # 7   STATION # 8 *
 #   *SS   BOD  FLOW    RECIRC  T   * FLOW    BOD SS    FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS * REMARK

  1  *178  169  15,70   1,05   56 *14,95   173 182   0,75  79  83 15,70 169 178 15,67  92  92 14,93  79  83 14,91  50  58*
  2  *178  169  15,70   1,05   67 *14,95   173 183   0,75  69  76 15,70 169 178 15,67  90  89 14,92  69  76 14,91  45  53*
  3  *178  169  15,70   1,05   78 *14,95   174 183   0,75  62  70 15,70 169 178 15,67  87  86 14,92  62  70 14,91  42  48*
  4  *178  169  15,70   1,31   56 *11,98   196 209   3,72  80  79 15,70 169 178 15,67  99  92 11,96  80  79 11,95  46  52*
  5  *178  169  15,70   1,31   67 *11,98   199 210   3,72  71  74 15,70 169 178 15,67  96  89 11,96  71  74 11,95  42  48*
  6  *178  169  15,70   1,31   78 *11,98   201 212   3,72  64  67 15,70 169 178 15,67  94  86 11,96  64  67 11,95  39  43*
  7  *178  169  15,70   1,57   56 *10,00   219 236   5,70  80  78 15,70 169 178 15,67 104  92  9,97  80  78  9,96  43  49*
  8  *178  169  15,70   1,57   67 *10,00   224 238   5,70  72  72 15,70 169 178 15,67 101  89  9,97  72  72  9,96  39  45*
  9  *178  169  15,70   1,57   78 *10,00   228 242   5,70  65  65 15,70 169 178 15,67  99  86  9,97  65  65  9,96  36  40*
 10  *178  169  24,29   1,05   56 *23,13   173 182   1,16  86  78 24,29 169 178 24,25 112  93 23,09  86  78 23,08  59  60*
 11  *178  169  24,29   1,05   67 *23,13   173 183   1,16  77  71 24,29 169 178 24,25 109  90 23,09  77  71 23,08  54  55*
 12  *178  169  24,29   1,05   78 *23,13   173 183   1,16  69  64 24,29 169 178 24,25 107  88 23,09  69  64 23,08  50  49*
 13  *178  169  24,29   1,31   56 *18,54   194 209   5,75  88  76 24,29 169 178 24,25 120  93 18,50  88  76 18,49  55  55*
 14  *178  169  24,29   1,31   67 *18,54   196 210   5,75  79  70 24,29 169 178 24,25 117  90 18,50  79  70 18,49  50  51*
 15  *178  169  24,29   1,31   78 *18,54   199 213   5,75  71  62 24,29 169 178 24,25 114  88 18,50  71  62 18,49  46  45*
 16  *178  169  24,29   1,57   56 *15,47   214 236   8,82  90  75 24,29 169 178 24,25 127  93 15,43  90  75 15,42  52  52*
 17  *178  169  24,29   1,57   67 *15,47   219 236   8,82  80  71 24,29 169 178 24,25 124  90 15,43  80  71 15,42  48  49*
 18  *178  169  24,29   1,57   78 *15,47   224 244   8,82  72  60 24,29 169 178 24,25 121  88 15,43  72  60 15,42  43  41*
 19  *178  169  31,06   1,05   56 *29,58   172 183   1,48  91  76 31,06 169 178 31,01 126  94 29,53  91  76 29,52  66  62*
 20  *178  169  31,06   1,05   67 *29,58   173 183   1,48  80  71 31,06 169 178 31,01 122  91 29,53  80  71 29,52  60  58*
 21  *178  169  31,06   1,05   78 *29,58   173 183   1,48  74  62 31,06 169 178 31,00 119  88 29,53  74  62 29,52  55  50*
 22  *178  169  31,06   1,31   56 *23,71   192 210   7,35  94  74 31,06 169 178 31,01 135  94 23,66  94  74 23,65  61  57*
 23  *178  169  31,06   1,31   67 *23,71   195 212   7,35  82  66 31,06 169 178 31,01 131  91 23,66  82  66 23,65  55  51*
 24  *178  169  31,06   1,31   78 *23,71   197 213   7,35  76  60 31,06 169 178 31,00 128  88 23,65  76  60 23,64  51  46*
 25  *178  169  31,06   1,57   56 *19,78   211 238  11,28  95  72 31,06 169 178 31,01 142  94 19,73  95  72 19,72  57  53*
 26  *178  169  31,06   1,57   67 *19,78   217 242  11,28  84  64 31,06 169 178 31,01 138  91 19,73  84  64 19,72  51  47*
 27  *178  169  31,06   1,57   78 *19,78   221 244  11,28  77  59 31,06 169 178 31,00 135  88 19,73  77  59 19,72  48  43*

                                   NOTE:  FLOWS ARE IN MGD
                                          BOD & SS ARE IN MG/L
                                          O,O,R,=MEANSFLOW THRU THE PLANT IS OUT OF THE
                                                 RANGE OF THE ESTABLISHED OPERATION
                                                 MIN=15,70,MAX=31,06
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     INPUT VECTORS                      O U T P U T  --  P R I M A R Y   T A N K   C H A R A C T E R I S T I C S
     *************                      ***********************************************************************
                                                    B O D                                     SUSPENDED        SOLIDS
TRIAL*                                          # OUT       # REM       %      *   #  IN      # OUT       # REM       %     SLUDGE   REMARK
 #  *SS   BOD  FLOW    RECIRC  T  *  #  IN

 1  *178  169  15.70   1.05   56 * 22128.5    12124.3    10004.3    45.6   * 23307.0    12112.6    11194.4    48.3   26845.
 2  *178  169  15.70   1.05   67 * 22128.5    11782.6    10345.9    46.7   * 23307.0    11703.4    11603.5    50.0   27826.
 3  *178  169  15.70   1.05   78 * 22128.5    11500.5    10628.0    48.5   * 23307.0    11367.5    11939.5    51.7   28632.
 4  *178  169  15.70   1.31   56 * 22128.5    12975.4     9153.1    41.4   * 23307.0    12112.6    11194.4    48.3   26845.
 5  *178  169  15.70   1.31   67 * 22128.5    12609.8     9518.7    43.2   * 23307.0    11703.4    11603.5    50.0   27826.
 6  *178  169  15.70   1.31   78 * 22128.5    12307.9     9820.6    44.4   * 23307.0    11367.5    11939.5    51.7   28632.
 7  *178  169  15.70   1.57   56 * 22128.5    13716.2     8412.3    38.5   * 23307.0    12112.6    11194.4    48.3   26845.
 8  *178  169  15.70   1.57   67 * 22128.5    13329.7     8798.8    40.2   * 23307.0    11703.4    11603.5    50.0   27826.
 9  *178  169  15.70   1.57   78 * 22128.5    13010.6     9117.9    41.4   * 23307.0    11367.5    11939.5    51.7   28632.
10  *178  169  24.29   1.05   56 * 34235.8    22848.7    11387.0    33.7   * 36059.0    18990.7    17068.3    47.8   40931.
11  *178  169  24.29   1.05   67 * 34235.8    22204.9    12030.9    35.5   * 36059.0    18349.2    17709.7    49.4   42469.
12  *178  169  24.29   1.05   78 * 34235.8    21673.3    12562.5    36.7   * 36059.0    17822.5    18236.5    50.6   43733.
13  *178  169  24.29   1.31   56 * 34235.8    24452.8     9783.0    29.0   * 36059.0    18990.7    17068.3    47.8   40931.
14  *178  169  24.29   1.31   67 * 34235.8    23763.7    10472.1    30.8   * 36059.0    18349.2    17709.7    49.4   42469.
15  *178  169  24.29   1.31   78 * 34235.8    23194.8    11040.9    32.5   * 36059.0    17822.5    18236.5    50.6   43733.
16  *178  169  24.29   1.57   56 * 34235.8    25848.9     8386.9    24.9   * 36059.0    18990.7    17068.3    47.8   40931.
17  *178  169  24.29   1.57   67 * 34235.8    25120.5     9115.3    26.6   * 36059.0    18349.2    17709.7    49.4   42469.
18  *178  169  24.29   1.57   78 * 34235.8    24519.1     9716.6    28.4   * 36059.0    17822.5    18236.5    50.6   43733.
19  *178  169  31.06   1.05   56 * 43777.8    32651.5    11126.3    25.4   * 46109.2    24466.4    21642.8    47.2   51901.
20  *178  169  31.06   1.05   67 * 43777.8    31731.4    12046.4    27.8   * 46109.2    23639.9    22469.2    48.9   53883.
21  *178  169  31.06   1.05   78 * 43777.8    30971.9    12805.9    29.6   * 46109.2    22961.3    23147.9    50.6   55510.
22  *178  169  31.06   1.31   56 * 43777.8    34943.8     8834.0    20.1   * 46109.2    24466.4    21642.8    47.2   51901.
23  *178  169  31.06   1.31   67 * 43777.8    33959.1     9818.7    22.5   * 46109.2    23639.9    22469.2    48.9   53883.
24  *178  169  31.06   1.31   78 * 43777.8    33146.2    10631.6    24.3   * 46109.2    22961.3    23147.9    50.6   55510.
25  *178  169  31.06   1.57   56 * 43777.8    36938.9     6838.9    16.0   * 46109.2    24466.4    21642.8    47.2   51901.
26  *178  169  31.06   1.57   67 * 43777.8    35898.0     7879.8    18.3   * 46109.2    23639.9    22469.2    48.9   53883.
27  *178  169  31.06   1.57   78 * 43777.8    35038.7     8739.1    20.1   * 46109.2    22961.3    23147.9    50.6   55510.

                                      NOTE:  # IN  =POUNDS ENTERING
                                             # OUT =POUNDS LEAVING
                                             # REM =POUNDS REMOVED
                                             %     =PERCENTAGE REMOVED FOR THAT UNIT
                                             SLUDGE=GALLONS OF SLUDGE PRODUCED  ASSUMING 5.0% SOLIDS
                                             O.O.R.=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                    RANGE OF THE ESTABLISHED PLANT OPERATION
                                                    MIN=15.70,MAX=31.06
```

```
                                              O U T P U T  --  T R I C K L I N G   F I L T E R   C H A R A C T E R I S T I C S
            INPUT VECTORS                     ******************************************************************************
            *************                                 B O D                                  SUSPENDED       SOLIDS
TRIAL*                                                                                                                          OVERALL % REM
 #  *SS   BOD  FLOW    RECIRC  T  *  #  IN     # OUT       # REM      %     *  #  IN     # OUT        # REM     %     BOD     S,S, REMARK

 1  *178  169  15,70   1,05   56 * 12124,3   10218,6     1905,6    15,7   * 12112,6   11251,1      861,5    7,1    54,9    52,7
 2  *178  169  15,70   1,05   67 * 11782,6    8994,1     2788,5    23,7   * 11703,4    9999,0     1704,4   14,6    60,7    58,5
 3  *178  169  15,70   1,05   78 * 11500,5    8071,7     3428,9    29,8   * 11367,5    9047,4     2320,1   20,4    64,9    62,3
 4  *178  169  15,70   1,31   56 * 12975,4   10460,1     2515,3    19,4   * 12112,6   10867,6     1245,0   10,3    59,2    60,3
 5  *178  169  15,70   1,31   67 * 12609,8    9206,6     3403,2    27,0   * 11703,4    9658,1     2045,3   17,5    64,8    65,2
 6  *178  169  15,70   1,31   78 * 12307,9    8262,4     4045,6    32,9   * 11367,5    8739,0     2628,5   23,1    68,7    68,9
 7  *178  169  15,70   1,57   56 * 13716,2   10661,9     3054,3    22,3   * 12112,6   10563,5     1549,1   12,8    63,0    66,1
 8  *178  169  15,70   1,57   67 * 13329,7    9384,2     3945,5    29,6   * 11703,4    9387,9     2315,6   19,8    68,3    70,2
 9  *178  169  15,70   1,57   78 * 13010,6    8421,8     4588,9    35,3   * 11367,5    8494,4     2873,1   25,3    71,9    73,6
10  *178  169  24,29   1,05   56 * 22848,7   17646,6     5202,1    22,8   * 18990,7   16049,9     2940,9   15,5    49,7    56,6
11  *178  169  24,29   1,05   67 * 22204,9   15531,8     6673,1    30,1   * 18349,2   14263,7     4085,6   22,3    56,1    61,7
12  *178  169  24,29   1,05   78 * 21673,3   13938,9     7734,4    35,7   * 17822,5   12906,2     4916,3   27,6    60,7    65,6
13  *178  169  24,29   1,31   56 * 24452,8   18063,5     6389,3    26,1   * 18990,7   15502,7     3488,0   18,4    54,1    63,6
14  *178  169  24,29   1,31   67 * 23763,7   15898,8     7864,9    33,1   * 18349,2   13777,5     4571,8   24,9    60,2    67,6
15  *178  169  24,29   1,31   78 * 23194,8   14268,3     8926,6    38,5   * 17822,5   12466,3     5356,3   30,1    64,8    71,4
16  *178  169  24,29   1,57   56 * 25848,9   18412,0     7436,9    28,8   * 18990,7   15068,9     3921,8   20,7    57,5    68,6
17  *178  169  24,29   1,57   67 * 25120,5   16205,5     8915,0    35,5   * 18349,2   13391,9     4957,3   27,0    63,5    72,0
18  *178  169  24,29   1,57   78 * 24519,1   14543,5     9975,6    40,7   * 17822,5   12117,4     5705,1   32,0    68,3    75,8
19  *178  169  31,06   1,05   56 * 32651,5   24006,4     8645,1    26,5   * 24466,4   19605,8     4860,6   19,9    46,5    59,0
20  *178  169  31,06   1,05   67 * 31731,4   21129,5    10601,9    33,4   * 23639,9   17423,9     6216,1   26,3    53,2    63,4
21  *178  169  31,06   1,05   78 * 30971,9   18962,6    12009,3    38,8   * 22961,3   15765,6     7195,7   31,3    57,8    67,2
22  *178  169  31,06   1,31   56 * 34943,8   24573,6    10370,2    29,7   * 24466,4   18937,4     5528,9   22,6    50,5    65,2
23  *178  169  31,06   1,31   67 * 33959,1   21628,7    12330,4    36,3   * 23639,9   16829,9     6810,0   28,8    57,4    69,3
24  *178  169  31,06   1,31   78 * 33146,2   19410,6    13735,6    41,4   * 22961,3   15228,2     7733,1   33,7    61,9    72,8
25  *178  169  31,06   1,57   56 * 36938,9   25047,7    11891,2    32,2   * 24466,4   18407,5     6058,9   24,8    54,5    70,2
26  *178  169  31,06   1,57   67 * 35898,0   22046,0    13852,0    38,6   * 23639,9   16359,0     7281,0   30,8    60,8    74,0
27  *178  169  31,06   1,57   78 * 35038,7   19785,1    15253,6    43,5   * 22961,3   14802,1     8159,2   35,5    65,6    76,6

                                         NOTE:  # IN  =POUNDS ENTERING
                                                # OUT =POUNDS LEAVING
                                                # REM =POUNDS REMOVED
                                                %     =PERCENTAGE REMOVED FOR THAT UNIT
                                                OVER,% REM=OVERALL EFFICIENCY COMPARING THE OUTPUT FOR
                                                        THIS UNIT INPUT AT STATION # 2
                                                O,O,R,=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                       RANGE OF THE ESTABLISHED OPERATION
                                                       MIN=15,70,MAX=31,06
```

```
              INPUT VECTORS                   O U T P U T  --  S E C O N D A R Y   T A N K   C H A R A C T E R I S T I C S
              *************                   ************************************************************************
                                                          B O D                                  SUSPENDED         SOLIDS
TRIAL*                                                                                                               PLANT EFF
 #   *SS    BOD   FLOW   RECIRC   T  *   #   IN    # OUT     # REM     %   *   #   IN    # OUT     # REM       %  SLUDGE   BOD  S.S.   REMARK
     *
 1   *178   169   15.70   1.05   56 *  9833.8    6292.5    3541.4    36.0 * 10331.8    7230.4    3101.3    30.0  11621.  71.1 68.1
 2   *178   169   15.70   1.05   67 *  8588.5    5712.9    2875.6    33.5 *  9459.8    6593.6    2866.2    30.3  10740.  74.0 71.0
 3   *178   169   15.70   1.05   78 *  7716.8    5266.3    2450.4    31.8 *  8712.5    6049.9    2662.6    30.6   9977.  75.9 73.8
 4   *178   169   15.70   1.31   56 *  7978.3    4596.2    3382.1    42.4 *  7878.6    5202.0    2676.6    34.0  10029.  76.5 75.1
 5   *178   169   15.70   1.31   67 *  7080.2    4241.4    2838.8    40.1 *  7379.3    4857.7    2521.6    34.2   9448.  78.9 77.1
 6   *178   169   15.70   1.31   78 *  6381.7    3888.8    2492.9    39.1 *  6680.8    4378.0    2302.8    34.5   8629.  80.6 79.7
 7   *178   169   15.70   1.57   56 *  6654.1    3576.6    3077.5    46.3 *  6487.7    4089.5    2398.2    37.0   8986.  80.4 79.2
 8   *178   169   15.70   1.57   67 *  5988.1    3302.1    2686.0    44.9 *  5988.1    3760.7    2227.4    37.2   8346.  82.6 81.1
 9   *178   169   15.70   1.57   78 *  5405.5    3026.2    2379.3    44.0 *  5405.5    3379.0    2026.5    37.5   7593.  84.2 83.5
10   *178   169   24.29   1.05   56 * 16562.8   11521.0    5041.8    30.4 * 15022.1   11703.6    3318.5    22.1  12434.  65.9 67.0
11   *178   169   24.29   1.05   67 * 14828.5   10553.5    4275.0    28.8 * 13673.0   10606.9    3066.1    22.4  11489.  68.8 69.9
12   *178   169   24.29   1.05   78 * 13287.1    9633.5    3653.6    27.5 * 12324.3    9515.4    2808.9    22.8  10525.  71.1 73.2
13   *178   169   24.29   1.31   56 * 13578.3    8534.4    5043.8    37.1 * 11726.7    8628.9    3097.7    26.4  11607.  71.6 73.7
14   *178   169   24.29   1.31   67 * 12188.6    7863.7    4324.8    35.5 * 10800.0    7917.2    2882.8    26.7  10802.  74.5 75.7
15   *178   169   24.29   1.31   78 * 10953.5    7137.7    3815.9    34.8 *  9565.1    6973.1    2591.9    27.1   9712.  76.9 78.9
16   *178   169   24.29   1.57   56 * 11582.1    6708.0    4874.1    42.1 *  9651.7    6780.1    2871.6    29.8  10760.  75.7 78.0
17   *178   169   24.29   1.57   67 * 10294.1    6220.5    4073.6    39.6 *  9136.0    6401.7    2734.4    29.9  10246.  78.1 79.2
18   *178   169   24.29   1.57   78 *  9264.0    5545.0    3719.0    40.1 *  7720.0    5368.0    2351.9    30.5   8813.  80.8 83.2
19   *178   169   31.06   1.05   56 * 22410.8   16320.9    6089.9    27.2 * 18716.7   15497.1    3219.6    17.2  12064.  61.6 66.1
20   *178   169   31.06   1.05   67 * 19700.4   14980.6    4719.9    24.0 * 17484.2   14431.5    3052.6    17.5  11438.  65.3 68.3
21   *178   169   31.06   1.05   78 * 18221.9   13699.1    4522.8    24.8 * 15267.0   12523.8    2743.2    18.0  10279.  68.2 72.7
22   *178   169   31.06   1.31   56 * 18546.9   12138.8    6408.2    34.6 * 14600.8   11417.6    3183.1    21.8  11927.  68.2 72.9
23   *178   169   31.06   1.31   67 * 16177.9   10899.6    5278.3    32.6 * 13021.2   10129.3    2891.9    22.2  10836.  71.8 75.9
24   *178   169   31.06   1.31   78 * 14993.1   10137.0    4856.1    32.4 * 11836.7    9167.8    2668.8    22.5  10000.  74.1 78.4
25   *178   169   31.06   1.57   56 * 15633.3    9436.3    6197.0    39.6 * 11848.4    8839.5    3008.9    25.4  11274.  73.0 77.7
26   *178   169   31.06   1.57   67 * 13821.7    8513.5    5308.2    38.4 * 10530.8    7814.3    2716.5    25.8  10179.  76.5 80.6
27   *178   169   31.06   1.57   78 * 12668.9    7922.1    4746.8    37.5 *  9707.3    7176.5    2530.8    26.1   9483.  78.3 82.4

                                     NOTE:  # IN  =POUNDS ENTERING
                                            # OUT =POUNDS LEAVING
                                            # REM =POUNDS REMOVED
                                            %     =PERCENTAGE REMOVED FOR THAT UNIT
                                            SLUDGE=GALLONS OF SLUDGE PRODUCED  ASSUMING 3.2% SOLIDS
                                            PLANT EFF= OVERALL PLANT EFFICIENCY
                                            O.O.R.=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                   RANGE OF THE ESTABLISHED OPERATION
                                                   MIN=15.70,MAX=31.06
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                              COMPUTER SIMULATION OF TRICKLING FILTER OPERATION

                        ALEXANDRIA SANITATION AUTHORITY HIGH RATE TRICKLING FILTER SYSTEM

                                             SET #  6 :  SS =278 MG/L
                                                        BOD =169 MG/L

          INPUT VECTORS                O U T P U T  =-  S T R E A M   V E C T O R S
          *************                ********************************************

TRIAL*                                *  STATION # 2    STATION # 3   STATION # 4   STATION # 5   STATION # 7   STATION # 8 *
  #  *SS   BOD  FLOW    RECIRC  T  * FLOW    BOD SS   FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS * REMARK

  1  *278  169  15,70    1,05  56 *14,95   172 286   0,75  93 105 15,70 169 278 15,65  97 114 14,90  93 105 14,89  59  74*
  2  *278  169  15,70    1,05  67 *14,95   173 287   0,75  81  90 15,70 169 278 15,65  94 110 14,90  81  90 14,89  52  63*
  3  *278  169  15,70    1,05  78 *14,95   173 287   0,75  75  84 15,70 169 278 15,65  92 107 14,90  75  84 14,89  49  58*
  4  *278  169  15,70    1,31  56 *11,98   191 332   3,72  95 102 15,70 169 278 15,65 104 114 11,93  95 102 11,92  55  68*
  5  *278  169  15,70    1,31  67 *11,98   195 337   3,72  83  89 15,70 169 278 15,65 101 110 11,93  83  89 11,92  49  59*
  6  *278  169  15,70    1,31  78 *11,98   197 339   3,72  77  82 15,70 169 278 15,65  99 107 11,93  77  82 11,92  45  54*
  7  *278  169  15,70    1,57  56 *10,00   210 380   5,70  97  99 15,70 169 278 15,65 110 114  9,95  97  99  9,94  51  63*
  8  *278  169  15,70    1,57  67 *10,00   216 386   5,70  85  88 15,70 169 278 15,65 107 110  9,95  85  88  9,94  46  55*
  9  *278  169  15,70    1,57  78 *10,00   220 391   5,70  78  79 15,70 169 278 15,65 104 107  9,95  78  79  9,94  42  49*
 10  *278  169  24,29    1,05  56 *23,13   172 287   1,16 104  97 24,29 169 278 24,21 118 115 23,05 104  97 23,04  71  76*
 11  *278  169  24,29    1,05  67 *23,13   172 287   1,16  91  86 24,29 169 278 24,21 115 111 23,05  91  86 23,04  63  67*
 12  *278  169  24,29    1,05  78 *23,13   173 287   1,16  82  78 24,29 169 278 24,21 112 108 23,05  82  78 23,04  58  60*
 13  *278  169  24,29    1,31  56 *18,54   188 335   5,75 106  94 24,29 169 278 24,21 127 115 18,46 106  94 18,45  65  69*
 14  *278  169  24,29    1,31  67 *18,54   192 338   5,75  93  83 24,29 169 278 24,21 123 111 18,46  93  83 18,45  58  61*
 15  *278  169  24,29    1,31  78 *18,54   195 340   5,75  83  76 24,29 169 278 24,21 120 108 18,46  83  76 18,45  53  55*
 16  *278  169  24,29    1,57  56 *15,47   203 384   8,82 108  91 24,29 169 278 24,21 134 115 15,39 108  91 15,38  61  64*
 17  *278  169  24,29    1,57  67 *15,47   211 390   8,82  95  81 24,29 169 278 24,21 130 111 15,39  95  81 15,38  55  57*
 18  *278  169  24,29    1,57  78 *15,47   216 393   8,82  85  75 24,29 169 278 24,21 127 108 15,39  85  75 15,38  50  52*
 19  *278  169  31,06    1,05  56 *29,58   171 287   1,48 110  93 31,06 169 278 30,96 132 116 29,48 110  93 29,47  78  77*
 20  *278  169  31,06    1,05  67 *29,58   172 287   1,48  97  82 31,06 169 278 30,96 129 112 29,48  97  82 29,47  70  68*
 21  *278  169  31,06    1,05  78 *29,58   173 288   1,48  87  76 31,06 169 278 30,96 126 109 29,48  87  76 29,46  64  62*
 22  *278  169  31,06    1,31  56 *23,71   186 336   7,35 113  90 31,06 169 278 30,96 142 116 23,61 113  90 23,60  72  71*
 23  *278  169  31,06    1,31  67 *23,71   190 339   7,35  99  79 31,06 169 278 30,96 138 112 23,61  99  79 23,59  64  61*
 24  *278  169  31,06    1,31  78 *23,71   193 341   7,35  89  74 31,06 169 278 30,96 134 109 23,61  89  74 23,59  59  57*
 25  *278  169  31,06    1,57  56 *19,78   199 386  11,28 115  87 31,06 169 278 30,96 150 116 19,68 115  87 19,67  67  65*
 26  *278  169  31,06    1,57  67 *19,78   207 392  11,28 101  77 31,06 169 278 30,96 146 112 19,68 101  77 19,67  60  57*
 27  *278  169  31,06    1,57  78 *19,78   213 395  11,28  91  72 31,06 169 278 30,96 142 109 19,68  91  72 19,67  56  53*

                                   NOTE:  FLOWS ARE IN MGD
                                          BOD & SS ARE IN MG/L
                                          O,O,R,=MEANSFLOW THRU THE PLANT IS OUT OF THE
                                                 RANGE OF THE ESTABLISHED OPERATION
                                                 MIN=15,70,MAX=31,06
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         INPUT VECTORS               O U T P U T  --  P R I M A R Y   T A N K   C H A R A C T E R I S T I C S
         *************               ************************************************************************
                                                   B O D                                   SUSPENDED        SOLIDS
TRIAL*                                                                                                                        
  #  *SS  BOD  FLOW  RECIRC  T  *  #  IN      # OUT      # REM      %     *  #  IN       # OUT      # REM     %     SLUDGE   REMARK

  1  *278 169  15.70  1.05  56 * 22128.5    12744.6     9383.9    42.6   * 36400.8    14920.5    21480.3   59.0   51511.
  2  *278 169  15.70  1.05  67 * 22128.5    12385.4     9743.1    44.4   * 36400.8    14416.5    21984.2   60.4   52720.
  3  *278 169  15.70  1.05  78 * 22128.5    12089.0    10039.6    45.6   * 36400.8    14002.7    22398.1   61.5   53712.
  4  *278 169  15.70  1.31  56 * 22128.5    13639.3     8489.2    38.5   * 36400.8    14920.5    21480.3   59.0   51511.
  5  *278 169  15.70  1.31  67 * 22128.5    13254.9     8873.6    40.2   * 36400.8    14416.5    21984.2   60.4   52720.
  6  *278 169  15.70  1.31  78 * 22128.5    12937.6     9190.9    41.4   * 36400.8    14002.7    22398.1   61.5   53712.
  7  *278 169  15.70  1.57  56 * 22128.5    14418.0     7710.5    34.9   * 36400.8    14920.5    21480.3   59.0   51511.
  8  *278 169  15.70  1.57  67 * 22128.5    14011.7     8116.8    36.7   * 36400.8    14416.5    21984.2   60.4   52720.
  9  *278 169  15.70  1.57  78 * 22128.5    13676.3     8452.2    38.5   * 36400.8    14002.7    22398.1   61.5   53712.
 10  *278 169  24.29  1.05  56 * 34235.8    24017.8    10218.0    30.2   * 56316.8    23393.1    32923.7   58.6   78954.
 11  *278 169  24.29  1.05  67 * 34235.8    23340.9    10894.8    32.0   * 56316.8    22603.0    33713.9   60.1   80849.
 12  *278 169  24.29  1.05  78 * 34235.8    22782.2    11453.5    33.7   * 56316.8    21954.1    34362.7   61.2   82405.
 13  *278 169  24.29  1.31  56 * 34235.8    25703.9     8531.9    24.9   * 56316.8    23393.1    32923.7   58.6   78954.
 14  *278 169  24.29  1.31  67 * 34235.8    24979.6     9256.2    27.2   * 56316.8    22603.0    33713.9   60.1   80349.
 15  *278 169  24.29  1.31  78 * 34235.8    24381.6     9854.2    29.0   * 56316.8    21954.1    34362.7   61.2   82405.
 16  *278 169  24.29  1.57  56 * 34235.8    27171.4     7064.3    20.7   * 56316.8    23393.1    32923.7   58.6   78954.
 17  *278 169  24.29  1.57  67 * 34235.8    26405.8     7830.0    23.1   * 56316.8    22603.0    33713.9   60.1   80849.
 18  *278 169  24.29  1.57  78 * 34235.8    25773.7     8462.1    24.9   * 56316.8    21954.1    34362.7   61.2   82405.
 19  *278 169  31.06  1.05  56 * 43777.8    34322.2     9455.6    21.9   * 72013.2    30138.1    41875.1   58.3  100420.
 20  *278 169  31.06  1.05  67 * 43777.8    33355.0    10422.9    23.7   * 72013.2    29120.1    42893.1   59.7  102861.
 21  *278 169  31.06  1.05  78 * 43777.8    32556.5    11221.3    25.4   * 72013.2    28284.2    43729.0   60.8  104866.
 22  *278 169  31.06  1.31  56 * 43777.8    36731.7     7046.1    16.0   * 72013.2    30138.1    41875.1   58.3  100420.
 23  *278 169  31.06  1.31  67 * 43777.8    35696.6     8081.2    18.3   * 72013.2    29120.1    42893.1   59.7  102861.
 24  *278 169  31.06  1.31  78 * 43777.8    34842.1     8935.7    20.7   * 72013.2    28284.2    43729.0   60.8  104866.
 25  *278 169  31.06  1.57  56 * 43777.8    38828.9     4948.9    11.2   * 72013.2    30138.1    41875.1   58.3  100420.
 26  *278 169  31.06  1.57  67 * 43777.8    37734.7     6043.2    13.6   * 72013.2    29120.1    42893.1   59.7  102861.
 27  *278 169  31.06  1.57  78 * 43777.8    36831.4     6946.4    16.0   * 72013.2    28284.2    43729.0   60.8  104866.

                                  NOTE:  # IN  =POUNDS ENTERING
                                         # OUT =POUNDS LEAVING
                                         # REM =POUNDS REMOVED
                                         %     =PERCENTAGE REMOVED FOR THAT UNIT
                                         SLUDGE=GALLONS OF SLUDGE PRODUCED  ASSUMING 5.0% SOLIDS
                                         O.O.R.=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                RANGE OF THE ESTABLISHED PLANT OPERATION
                                                MIN=15.70,MAX=31.06
```

```
                  INPUT VECTORS              O U T P U T  --  T R I C K L I N G   F I L T E R   C H A R A C T E R I S T I C S
                  *************              ****************************************************************************
                                                            B O D                                SUSPENDED      SOLIDS
TRIAL*                                                                                                                    OVERALL  % REM
 #  *SS   BOD  FLOW    RECIRC   T  *  #  IN    # OUT     # REM      %     *  #  IN     # OUT       # REM       %      BOD     S.S.  REMARK

 1  *278  169  15.70   1.05    56 * 12744.6   12289.7     454.9    3.6   * 14920.5   13962.7      957.8      6.4    45.3    62.9
 2  *278  169  15.70   1.05    67 * 12385.4   10817.0    1568.4   12.7   * 14416.5   12408.9     2007.6     13.9    52.6    66.9
 3  *278  169  15.70   1.05    78 * 12089.0    9707.8    2381.2   19.7   * 14002.7   11228.1     2774.6     19.8    57.2    70.0
 4  *278  169  15.70   1.31    56 * 13639.3   12580.0    1059.3    7.8   * 14920.5   13486.7     1433.8      9.6    49.7    69.0
 5  *278  169  15.70   1.31    67 * 13254.9   11072.6    2182.4   16.5   * 14416.5   11985.9     2430.6     16.9    56.9    73.0
 6  *278  169  15.70   1.31    78 * 12937.6    9937.1    3000.5   23.2   * 14002.7   10845.3     3157.4     22.5    61.4    75.5
 7  *278  169  15.70   1.57    56 * 14418.0   12822.8    1595.3   11.1   * 14920.5   13109.3     1811.2     12.1    53.3    73.7
 8  *278  169  15.70   1.57    67 * 14011.7   11286.2    2725.5   19.5   * 14416.5   11650.5     2766.0     19.2    60.2    76.9
 9  *278  169  15.70   1.57    78 * 13676.3   10128.8    3547.5   25.9   * 14002.7   10541.8     3460.9     24.7    65.0    79.5
10  *278  169  24.29   1.05    56 * 24017.8   21223.0    2794.8   11.6   * 23393.1   19917.9     3475.2     14.9    39.0    65.9
11  *278  169  24.29   1.05    67 * 23340.9   18679.8    4661.1   20.0   * 22603.0   17701.4     4901.5     21.7    46.5    69.7
12  *278  169  24.29   1.05    78 * 22782.2   16764.2    6018.0   26.4   * 21954.1   16016.9     5937.2     27.0    52.0    72.5
13  *278  169  24.29   1.31    56 * 25703.9   21724.4    3979.5   15.5   * 23393.1   19239.0     4154.2     17.8    43.1    71.6
14  *278  169  24.29   1.31    67 * 24979.6   19121.1    5858.5   23.5   * 22603.0   17098.0     5505.0     24.4    51.0    75.1
15  *278  169  24.29   1.31    78 * 24381.6   17160.3    7221.3   29.6   * 21954.1   15470.9     6483.2     29.5    56.9    77.6
16  *278  169  24.29   1.57    56 * 27171.4   22143.5    5027.9   18.5   * 23393.1   18700.6     4692.6     20.1    46.3    76.0
17  *278  169  24.29   1.57    67 * 26405.8   19490.0    6915.7   26.2   * 22603.0   16619.5     5983.4     26.5    54.5    79.0
18  *278  169  24.29   1.57    78 * 25773.7   17491.4    8282.3   32.1   * 21954.1   15038.0     6916.1     31.5    60.2    81.2
19  *278  169  31.06   1.05    56 * 34322.2   28871.6    5450.5   15.9   * 30138.1   24330.7     5807.4     19.3    35.1    67.2
20  *278  169  31.06   1.05    67 * 33355.0   25412.0    7943.0   23.8   * 29120.1   21623.2     7496.9     25.7    43.0    71.1
21  *278  169  31.06   1.05    78 * 32556.5   22806.1    9750.4   29.9   * 28284.2   19565.5     8718.7     30.8    49.1    74.0
22  *278  169  31.06   1.31    56 * 36731.7   29553.8    7177.9   19.5   * 30138.1   23501.3     6636.8     22.0    38.7    72.9
23  *278  169  31.06   1.31    67 * 35696.6   26012.3    9684.2   27.1   * 29120.1   20886.1     8234.0     28.3    47.4    76.4
24  *278  169  31.06   1.31    78 * 34842.1   23344.9   11497.2   33.0   * 28284.2   18898.5     9385.6     33.2    53.4    78.6
25  *278  169  31.06   1.57    56 * 38828.9   30124.0    8704.9   22.4   * 30138.1   22843.7     7294.4     24.2    41.7    77.2
26  *278  169  31.06   1.57    67 * 37734.7   26514.2   11220.4   29.7   * 29120.1   20301.6     8818.5     30.3    50.7    80.1
27  *278  169  31.06   1.57    78 * 36831.4   23795.3   13036.1   35.4   * 28284.2   18369.7     9914.5     35.1    56.8    82.0

                                        NOTE:  # IN  =POUNDS ENTERING
                                               # OUT =POUNDS LEAVING
                                               # REM =POUNDS REMOVED
                                               %     =PERCENTAGE REMOVED FOR THAT UNIT
                                               OVER.% REM=OVERALL EFFICIENCY COMPARING THE OUTPUT FOR
                                                       THIS UNIT INPUT AT STATION # 2
                                               O.O.R.=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                      RANGE OF THE ESTABLISHED OPERATION
                                                      MIN=15.70,MAX=31.06
```

```
                    INPUT VECTORS                    O U T P U T  --  S E C O N D A R Y   T A N K   C H A R A C T E R I S T I C S
                    *************                    *****************************************************************************
                                                                   B O D                                  SUSPENDED          SOLIDS
TRIAL*                                                                                                                  %  SLUDGE  PLANT EFF
  #   *SS   BOD  FLOW    RECIRC  T  *  #   IN     # OUT     # REM      %    *  #  IN      # OUT      # REM                      BOD  S.S.   REMARK
      *
  1   *278  169  15,70    1,05   56 *11557,4    7424,4    4133,0    35,8 * 13048,7    9226,2     3822,5    29,3  14323, 65,7 74,1
  2   *278  169  15,70    1,05   67 *10065,3    6557,3    3508,0    34,9 * 11183,7    7852,1     3331,6    29,8  12483, 69,9 78,0
  3   *278  169  15,70    1,05   78 * 9319,1    6160,0    3159,1    33,9 * 10437,4    7305,0     3132,4    30,0  11737, 71,7 79,8
  4   *278  169  15,70    1,31   56 * 9454,7    5485,9    3968,8    42,0 * 10151,4    6777,5     3373,9    33,2  12642, 71,2 79,5
  5   *278  169  15,70    1,31   67 * 8259,6    4886,4    3373,2    40,8 *  8856,7    5876,4     2980,3    33,7  11167, 74,9 82,5
  6   *278  169  15,70    1,31   78 * 7661,9    4570,6    3091,2    40,3 *  8159,4    5393,5     2765,9    33,9  10364, 77,2 84,1
  7   *278  169  15,70    1,57   56 * 8048,1    4277,8    3770,3    46,8 *  8214,1    5230,9     2983,1    36,3  11178, 75,7 83,4
  8   *278  169  15,70    1,57   67 * 7051,6    3843,6    3208,0    45,5 *  7300,5    4624,1     2676,4    36,7  10028, 78,7 85,8
  9   *278  169  15,70    1,57   78 * 6470,3    3540,7    2929,6    45,3 *  6553,2    4130,4     2422,8    37,0   9078, 80,9 87,5
 10   *278  169  24,29    1,05   56 *19996,4   13667,4    6329,0    31,7 * 18650,5   14669,3     3981,2    21,3  14918, 58,7 73,5
 11   *278  169  24,29    1,05   67 *17495,4   12260,1    5235,4    29,9 * 16534,1   12933,4     3600,8    21,8  13492, 63,4 76,7
 12   *278  169  24,29    1,05   78 *15764,1   11247,0    4517,0    28,7 * 14995,1   11677,3     3317,8    22,1  12432, 66,5 79,1
 13   *278  169  24,29    1,31   56 *16322,0   10078,8    6243,2    38,3 * 14474,3   10748,7     3725,6    25,7  13960, 65,4 79,4
 14   *278  169  24,29    1,31   67 *14318,8    9037,1    5281,7    36,9 * 12779,1    9436,0     3343,1    26,2  12527, 69,8 82,0
 15   *278  169  24,29    1,31   78 *12778,1    8285,4    4492,7    35,2 * 11700,4    8604,7     3095,7    26,5  11599, 72,8 83,8
 16   *278  169  24,29    1,57   56 *13864,2    7843,7    6020,5    43,4 * 11681,9    8273,6     3408,2    29,2  12771, 70,0 83,3
 17   *278  169  24,29    1,57   67 *12193,9    7063,7    5130,2    42,1 * 10396,9    7324,4     3072,5    29,6  11513, 73,9 85,4
 18   *278  169  24,29    1,57   78 *10909,2    6512,2    4397,0    40,3 *  9625,8    6757,3     2868,5    29,8  10748, 76,9 86,8
 19   *278  169  31,06    1,05   56 *27045,4   19234,0    7811,4    28,9 * 22865,7   19099,2     3766,4    16,5  14113, 54,4 73,2
 20   *278  169  31,06    1,05   67 *23847,2   17276,5    6570,7    27,6 * 20159,5   16742,2     3417,3    17,0  12805, 59,3 76,3
 21   *278  169  31,06    1,05   78 *21387,3   15952,2    5435,1    25,4 * 18683,1   15462,3     3220,8    17,2  12069, 63,0 78,5
 22   *278  169  31,06    1,31   56 *22250,1   14226,9    8023,1    36,1 * 17721,3   13974,7     3746,6    21,1  14039, 61,3 78,9
 23   *278  169  31,06    1,31   67 *19491,4   12718,3    6773,1    34,7 * 15553,7   12192,5     3361,3    21,6  12595, 66,3 82,0
 24   *278  169  31,06    1,31   78 *17521,1   11805,2    5715,9    32,6 * 14568,1   11385,6     3182,4    21,8  11925, 69,4 83,3
 25   *278  169  31,06    1,57   56 *18878,0   11059,8    7818,2    41,4 * 14281,6   10740,4     3541,2    24,8  13269, 66,3 83,2
 26   *278  169  31,06    1,57   67 *16577,7    9930,3    6647,4    40,1 * 12638,5    9451,7     3186,8    25,2  11941, 71,0 85,5
 27   *278  169  31,06    1,57   78 *14934,8    9220,0    5714,8    38,3 * 11816,6    8809,8     3006,8    25,4  11266, 73,7 86,6

                                                    NOTE:  # IN  =POUNDS ENTERING
                                                           # OUT =POUNDS LEAVING
                                                           # REM =POUNDS REMOVED
                                                           %     =PERCENTAGE REMOVED FOR THAT UNIT
                                                           SLUDGE=GALLONS OF SLUDGE PRODUCED  ASSUMING 3,2% SOLIDS
                                                           PLANT EFF= OVERALL PLANT EFFICIENCY
                                                           O,O,R,=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                                  RANGE OF THE ESTABLISHED OPERATION
                                                                  MIN=15,70,MAX=31,06
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                         COMPUTER SIMULATION OF TRICKLING FILTER OPERATION

                  ALEXANDRIA SANITATION AUTHORITY HIGH RATE TRICKLING FILTER SYSTEM

                                      SET #  7 :  SS =119 MG/L
                                                  BOD =240 MG/L

          INPUT VECTORS           O U T P U T  --  S T R E A M   V E C T O R S
          *************           ***********************************************

TRIAL*                           *  STATION # 2     STATION # 3   STATION # 4    STATION # 5    STATION # 7    STATION # 8 *
  #  *SS   BOD  FLOW   RECIRC  T * FLOW    BOD SS  FLOW  BOD SS  FLOW  BOD SS   FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS * REMARK

  1 *119  240  15,70   1,05  56 *14,95  247 121   0,75  80  76 15,70 240 119 15,69 110  76 14,94  80  76 14,93  49  53*
  2 *119  240  15,70   1,05  67 *14,95  248 121   0,75  72  68 15,70 240 119 15,69 107  74 14,94  72  68 14,93  44  47*
  3 *119  240  15,70   1,05  78 *14,95  248 121   0,75  65  62 15,70 240 119 15,69 104  71 14,94  65  62 14,93  41  42*
  4 *119  240  15,70   1,31  56 *11,98  288 132   3,72  82  74 15,70 240 119 15,69 118  76 11,97  82  74 11,96  45  48*
  5 *119  240  15,70   1,31  67 *11,98  291 135   3,72  74  66 15,70 240 119 15,69 114  74 11,97  74  66 11,96  41  43*
  6 *119  240  15,70   1,31  78 *11,98  293 136   3,72  66  60 15,70 240 119 15,69 111  71 11,97  66  60 11,96  37  39*
  7 *119  240  15,70   1,57  56 *10,00  329 145   5,70  83  72 15,70 240 119 15,69 124  76  9,99  83  72  9,98  42  45*
  8 *119  240  15,70   1,57  67 *10,00  334 149   5,70  75  64 15,70 240 119 15,69 121  74  9,99  75  64  9,98  38  40*
  9 *119  240  15,70   1,57  78 *10,00  338 153   5,70  67  58 15,70 240 119 15,69 118  71  9,99  67  58  9,98  35  36*
 10 *119  240  24,29   1,05  56 *23.13  247 121   1,16  89  71 24,29 240 119 24,27 134  77 23,11  89  71 23,10  58  55*
 11 *119  240  24,29   1,05  67 *23.13  247 121   1,16  80  69 24,29 240 119 24,27 130  75 23,11  80  69 23,10  55  53*
 12 *119  240  24,29   1,05  78 *23.13  248 122   1,16  72  57 24,29 240 119 24,27 127  72 23,11  72  57 23,10  48  43*
 13 *119  240  24,29   1,31  56 *18,54  286 134   5,75  91  69 24,29 240 119 24,27 143  77 18,52  91  69 18,51  54  50*
 14 *119  240  24,29   1,31  67 *18,54  289 132   5,75  80  68 24,29 240 119 24,27 139  75 18,52  80  68 18,51  50  49*
 15 *119  240  24,29   1,31  78 *18,54  291 137   5,75  74  56 24,29 240 119 24,27 136  72 18,52  74  56 18,51  45  40*
 16 *119  240  24,29   1,57  56 *15,47  323 148   8,82  93  67 24,29 240 119 24,27 152  77 15,45  93  67 15,44  50  46*
 17 *119  240  24,29   1,57  67 *15,47  330 151   8,82  82  60 24,29 240 119 24,27 147  75 15,45  82  60 15,44  45  41*
 18 *119  240  24,29   1,57  78 *15,47  334 153   8,82  75  55 24,29 240 119 24,27 144  72 15,45  75  55 15,44  42  38*
 19 *119  240  31,06   1,05  56 *29,58  247 121   1,48  95  68 31,06 240 119 31,03 150  78 29,56  95  68 29,54  64  56*
 20 *119  240  31,06   1,05  67 *29,58  247 121   1,48  83  61 31,06 240 119 31,03 145  75 29,55  83  61 29,54  58  50*
 21 *119  240  31,06   1,05  78 *29,58  248 121   1,48  77  56 31,06 240 119 31,03 142  73 29,55  77  56 29,54  54  45*
 22 *119  240  31,06   1,31  56 *23,71  284 135   7,35  97  66 31,06 240 119 31,03 160  78 23,68  97  66 23,67  59  51*
 23 *119  240  31,06   1,31  67 *23,71  288 137   7,35  85  58 31,06 240 119 31,03 156  75 23,68  85  58 23,67  53  44*
 24 *119  240  31,06   1,31  78 *23,71  289 136   7,35  79  58 31,06 240 119 31,03 152  73 23,68  79  58 23,67  51  44*
 25 *119  240  31,06   1,57  56 *19,78  320 150  11,28  99  64 31,06 240 119 31,03 169  78 19,76  99  64 19,75  55  47*
 26 *119  240  31,06   1,57  67 *19,78  327 153  11,28  87  57 31,06 240 119 31,03 165  75 19,76  87  57 19,75  50  42*
 27 *119  240  31,06   1,57  78 *19,78  331 143  11,28  80  63 31,06 240 119 31,03 161  73 19,76  80  63 19,75  50  46*

                                      NOTE:  FLOWS ARE IN MGD
                                             BOD & SS ARE IN MG/L
                                             O.O.R.=MEANSFLOW THRU THE PLANT IS OUT OF THE
                                                    RANGE OF THE ESTABLISHED OPERATION
                                                    MIN=15.70,MAX=31,06
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       INPUT VECTORS                     O U T P U T  --  P R I M A R Y   T A N K   C H A R A C T E R I S T I C S
       *************                     ************************************************************************
                                                      B O D                                       SUSPENDED      SOLIDS
TRIAL#                                                                                                                    SLUDGE  REMARK
  #  #SS  BOD  FLOW   RECIRC  T  *  #  IN      # OUT     # REM      %    *  #  IN     # OU,     # REM      %
  1  *119 240  15,70  1,05   56 * 31425,1   14431,5   16993,6   54,2  * 15581,6   10033,7   5548,0   36,1  13304,
  2  *119 240  15,70  1,05   67 * 31425,1   14024,8   17400,3   55,4  * 15581,6    9694,7   5886,9   37,8  14117,
  3  *119 240  15,70  1,05   78 * 31425,1   13689,1   17736,0   56,7  * 15581,6    9416,4   6165,2   40,3  14785,
  4  *119 240  15,70  1,31   56 * 31425,1   15444,7   15980,5   50,8  * 15581,6   10033,7   5548,0   36,1  13304,
  5  *119 240  15,70  1,31   67 * 31425,1   15009,4   16415,7   52,5  * 15581,6    9694,7   5886,9   37,8  14117,
  6  *119 240  15,70  1,31   78 * 31425,1   14650,1   16775,0   53,7  * 15581,6    9416,4   6165,2   40,3  14785,
  7  *119 240  15,70  1,57   56 * 31425,1   16326,5   15098,6   48,3  * 15581,6   10033,7   5548,0   36,1  13304,
  8  *119 240  15,70  1,57   67 * 31425,1   15866,4   15558,7   49,6  * 15581,6    9694,7   5886,9   37,8  14117,
  9  *119 240  15,70  1,57   78 * 31425,1   15486,6   15938,5   50,8  * 15581,6    9416,4   6165,2   40,3  14785,
 10  *119 240  24,29  1,05   56 * 48618,8   27196,9   21422,0   44,2  * 24106,8   15731,3   8375,6   35,3  20085,
 11  *119 240  24,29  1,05   67 * 48618,8   26430,5   22188,4   45,8  * 24106,8   15199,9   8906,9   37,0  21360,
 12  *119 240  24,29  1,05   78 * 48618,8   25797,8   22821,1   47,1  * 24106,8   14763,6   9343,3   39,5  22406,
 13  *119 240  24,29  1,31   56 * 48618,8   29106,2   19512,7   40,4  * 24106,8   15731,3   8375,6   35,3  20085,
 14  *119 240  24,29  1,31   67 * 48618,8   28286,0   20332,9   42,1  * 24106,8   15199,9   8906,9   37,0  21360,
 15  *119 240  24,29  1,31   78 * 48618,8   27608,8   21010,0   43,3  * 24106,8   14763,6   9343,3   39,5  22406,
 16  *119 240  24,29  1,57   56 * 48618,8   30768,0   17850,9   36,7  * 24106,8   15731,3   8375,6   35,3  20085,
 17  *119 240  24,29  1,57   67 * 48618,8   29900,9   18717,9   38,7  * 24106,8   15199,9   8906,9   37,0  21360,
 18  *119 240  24,29  1,57   78 * 48618,8   29185,2   19433,7   40,0  * 24106,8   14763,6   9343,3   39,5  22406,
 19  *119 240  31,06  1,05   56 * 62169,7   38865,2   23304,5   37,5  * 30825,8   20267,1  10558,7   34,5  25321,
 20  *119 240  31,06  1,05   67 * 62169,7   37770,0   24399,7   39,6  * 30825,8   19582,5  11243,3   37,0  26962,
 21  *119 240  31,06  1,05   78 * 62169,7   36865,9   25303,8   40,8  * 30825,8   19020,4  11805,4   38,7  28310,
 22  *119 240  31,06  1,31   56 * 62169,7   41593,7   20576,0   33,3  * 30825,8   20267,1  10558,7   34,5  25321,
 23  *119 240  31,06  1,31   67 * 62169,7   40421,6   21748,1   35,0  * 30825,8   19582,5  11243,3   37,0  26962,
 24  *119 240  31,06  1,31   78 * 62169,7   39454,0   22715,7   36,7  * 30825,8   19020,4  11805,4   38,7  28310,
 25  *119 240  31,06  1,57   56 * 62169,7   43968,4   18201,3   29,6  * 30825,8   20267,1  10558,7   34,5  25321,
 26  *119 240  31,06  1,57   67 * 62169,7   42729,4   19440,2   31,3  * 30825,8   19582,5  11243,3   37,0  26962,
 27  *119 240  31,06  1,57   78 * 62169,7   41706,6   20463,1   32,9  * 30825,8   19020,4  11805,4   38,7  28310,

                                       NOTE:  # IN  =POUNDS ENTERING
                                              # OUT =POUNDS LEAVING
                                              # REM =POUNDS REMOVED
                                              %     =PERCENTAGE REMOVED FOR THAT UNIT
                                              SLUDGE=GALLONS OF SLUDGE PRODUCED  ASSUMING 5,0% SOLIDS
                                              O,O,R,=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                     RANGE OF THE ESTABLISHED PLANT OPERATION
                                                     MIN=15,70,MAX=31,06
```

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                 INPUT VECTORS                 O U T P U T  --  T R I C K L I N G   F I L T E R   C H A R A C T E R I S T I C S
                 *************                 **************************************************************************************
                                                                   B O D                                  SUSPENDED       SOLIDS
TRIAL*                                                                                                                               OVERALL % REM
 #   *SS   BOD  FLOW   RECIRC  T  *  #  IN     # OUT      # REM      %     *  #  IN     # OUT     # REM      %     BOD   S.S. REMARK
 1   *119  240  15.70   1.05   56 * 14431.5   10630.8    3800.7    26.3   * 10033.7    9997.0      36.6     0.4   67.2  37.2
 2   *119  240  15.70   1.05   67 * 14024.8    9356.8    4668.1    33.3   *  9694.7    8884.4     810.4     8.4   71.4  44.6
 3   *119  240  15.70   1.05   78 * 13689.1    8397.1    5292.0    38.7   *  9416.4    8038.8    1377.6    14.6   74.2  49.6
 4   *119  240  15.70   1.31   56 * 15444.7   10882.0    4562.6    29.5   * 10033.7    9656.2     377.4     3.8   71.2  44.7
 5   *119  240  15.70   1.31   67 * 15009.4    9577.8    5431.6    36.2   *  9694.7    8581.5    1113.2    11.5   74.9  51.9
 6   *119  240  15.70   1.31   78 * 14650.1    8595.5    6054.6    41.3   *  9416.4    7764.8    1651.7    17.5   77.8  56.6
 7   *119  240  15.70   1.57   56 * 16326.5   11092.0    5234.5    32.1   * 10033.7    9386.0     647.6     6.5   74.5  51.0
 8   *119  240  15.70   1.57   67 * 15866.4    9762.6    6103.8    38.5   *  9694.7    8341.4    1353.3    14.0   77.8  57.7
 9   *119  240  15.70   1.57   78 * 15486.6    8761.3    6725.2    43.4   *  9416.4    7547.5    1869.0    19.8   80.5  62.7
10   *119  240  24.29   1.05   56 * 27196.9   18358.5    8838.4    32.5   * 15731.3   14260.9    1470.4     9.3   63.6  42.1
11   *119  240  24.29   1.05   67 * 26430.5   16158.2   10272.3    38.9   * 15199.9   12673.7    2526.2    16.6   68.0  48.8
12   *119  240  24.29   1.05   78 * 25797.8   14501.0   11296.8    43.8   * 14763.6   11467.5    3296.1    22.3   71.4  54.1
13   *119  240  24.29   1.31   56 * 29106.2   18792.2   10313.9    35.4   * 15731.3   13774.8    1956.5    12.4   67.8  49.3
14   *119  240  24.29   1.31   67 * 28286.0   16540.0   11746.0    41.5   * 15199.9   12241.7    2958.2    19.5   72.0  54.5
15   *119  240  24.29   1.31   78 * 27608.8   14843.6   12765.2    46.2   * 14763.6   11076.6    3687.0    25.0   74.9  60.6
16   *119  240  24.29   1.57   56 * 30768.0   19154.8   11613.2    37.7   * 15731.3   13389.3    2342.0    14.9   70.9  55.4
17   *119  240  24.29   1.57   67 * 29900.9   16859.1   13041.9    43.6   * 15199.9   11899.1    3300.8    21.7   74.8  61.6
18   *119  240  24.29   1.57   78 * 29185.2   15130.0   14055.2    48.2   * 14763.6   10766.6    3996.9    27.1   77.8  65.4
19   *119  240  31.06   1.05   56 * 38865.2   24974.9   13890.3    35.7   * 20267.1   17420.5    2846.6    14.0   61.1  44.6
20   *119  240  31.06   1.05   67 * 37770.0   21981.7   15788.3    41.8   * 19582.5   15481.7    4100.9    20.9   66.0  51.2
21   *119  240  31.06   1.05   78 * 36865.9   19727.3   17138.6    46.5   * 19020.4   14008.2    5012.2    26.4   69.4  55.4
22   *119  240  31.06   1.31   56 * 41593.7   25565.0   16028.7    38.5   * 20267.1   16826.7    3440.4    17.0   65.5  51.9
23   *119  240  31.06   1.31   67 * 40421.6   22501.1   17920.5    44.3   * 19582.5   14953.9    4628.6    23.6   70.1  58.4
24   *119  240  31.06   1.31   78 * 39454.0   20193.4   19260.6    48.8   * 19020.4   13530.7    5489.7    28.9   73.0  61.8
25   *119  240  31.06   1.57   56 * 43968.4   26058.2   17910.2    40.7   * 20267.1   16355.8    3911.3    19.3   68.8  58.0
26   *119  240  31.06   1.57   67 * 42729.4   22935.2   19794.2    46.3   * 19582.5   14535.5    5047.1    25.8   73.1  63.4
27   *119  240  31.06   1.57   78 * 41706.6   20583.0   21123.6    50.6   * 19020.4   13152.0    5868.3    30.9   76.1  65.0

                                                NOTE:  # IN  =POUNDS ENTERING
                                                       # OUT =POUNDS LEAVING
                                                       # REM =POUNDS REMOVED
                                                       %     =PERCENTAGE REMOVED FOR THAT UNIT
                                                       OVER.% REM=OVERALL EFFICIENCY COMPARING THE OUTPUT FOR
                                                                 THIS UNIT INPUT AT STATION # 2
                                                       O.O.R.=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                              RANGE OF THE ESTABLISHED OPERATION
                                                              MIN=15.70,MAX=31.06
```

```
             INPUT VECTORS                     O U T P U T  --  S E C O N D A R Y  T A N K  C H A R A C T E R I S T I C S
             *************                     ****************************************************************************
                                                             B O D                                SUSPENDED         SOLIDS
TRIAL*                                                                                                                        PLANT EFF
  #   *SS   BOD  FLOW   RECIRC  T  *  #   IN    # OUT     # REM     %    *  #   IN    # OUT     # REM     %   SLUDGE
       *                                                                                                                     BOD  S.S.  REMARK
  1  *119   240  15.70   1.05  56 * 9967.4    6118.0    3849.3    38.6 *  9469.0    6601.6    2867.4    30.3  10744. 80.2 56.2
  2  *119   240  15.70   1.05  67 * 8970.1    5579.2    3390.9    37.8 *  8471.8    5876.5    2595.3    30.6   9725. 82.3 61.2
  3  *119   240  15.70   1.05  78 * 8097.7    5133.4    2964.2    36.6 *  7723.9    5335.2    2388.8    30.9   8951. 83.5 65.3
  4  *119   240  15.70   1.31  56 * 8187.0    4535.7    3651.4    44.6 *  7388.3    4865.1    2523.2    34.2   9454. 84.4 63.6
  5  *119   240  15.70   1.31  67 * 7387.8    4136.0    3251.8    44.0 *  6589.1    4316.3    2272.9    34.5   8516. 85.9 68.1
  6  *119   240  15.70   1.31  78 * 6588.7    3780.1    2808.6    42.6 *  5989.8    3906.6    2083.2    34.8   7806. 87.4 71.3
  7  *119   240  15.70   1.57  56 * 6913.0    3529.4    3383.6    48.9 *  5996.8    3767.6    2229.2    37.2   8353. 87.2 69.0
  8  *119   240  15.70   1.57  67 * 6246.2    3215.9    3030.3    48.5 *  5330.1    3330.7    1999.3    37.5   7492. 88.6 73.2
  9  *119   240  15.70   1.57  78 * 5579.5    2937.6    2641.9    47.3 *  4830.0    3004.7    1825.3    37.8   6840. 89.6 76.5
 10  *119   240  24.29   1.05  56 *17156.0   11286.0    5870.0    34.2 * 13686.3   10619.7    3066.5    22.4  11490. 76.5 54.5
 11  *119   240  24.29   1.05  67 *15420.3   10630.0    4790.3    31.1 * 13300.0   10306.5    2993.5    22.5  11217. 77.7 56.2
 12  *119   240  24.29   1.05  78 *13877.6    9390.9    4486.7    32.3 * 10986.5    8439.[illegible]    2546.6    23.2   9542. 80.6 64.8
 13  *119   240  24.29   1.31  56 *14057.0    8351.3    5705.7    40.6 * 10658.6    7810.8    2847.8    26.7  10671. 81.1 62.7
 14  *119   240  24.29   1.31  67 *12356.9    7830.2    4526.7    36.6 * 10503.4    7691.8    2811.6    26.8  10535. 82.7 62.9
 15  *119   240  24.29   1.31  78 *11429.5    6995.4    4434.2    38.8 *  8649.4    6278.2    2371.1    27.4   8885. 84.5 70.8
 16  *119   240  24.29   1.57  56 *11984.3    6521.7    5462.5    45.6 *  8633.8    6036.0    2597.8    30.1   9734. 84.5 68.9
 17  *119   240  24.29   1.57  67 *10565.9    5894.0    4671.9    44.2 *  7731.2    5377.8    2353.4    30.4   8818. 86.4 72.8
 18  *119   240  24.29   1.57  78 * 9663.3    5466.8    4196.5    43.4 *  7086.4    4909.7    2176.7    30.7   8156. 87.4 75.2
 19  *119   240  31.06   1.05  56 *23416.9   15942.0    7475.0    31.9 * 16761.6   13811.3    2950.3    17.6  11055. 74.1 53.7
 20  *119   240  31.06   1.05  67 *20457.9   14358.1    6099.8    29.8 * 15035.3   12327.6    2707.7    18.0  10146. 76.5 58.7
 21  *119   240  31.06   1.05  78 *18978.1   13411.8    5566.3    29.3 * 13802.3   11272.5    2529.8    18.3   9479. 78.2 62.8
 22  *119   240  31.06   1.31  56 *19160.4   11783.2    7377.2    38.5 * 13036.9   10144.6    2892.3    22.2  10837. 79.2 62.2
 23  *119   240  31.06   1.31  67 *16788.9   10540.0    6248.8    37.2 * 11455.9    8861.9    2594.0    22.6   9720. 81.6 67.9
 24  *119   240  31.06   1.31  78 *15602.9   10194.5    5408.4    34.7 * 11455.3    8861.3    2594.0    22.6   9720. 82.4 67.6
 25  *119   240  31.06   1.57  56 *16313.5    9191.3    7122.2    43.7 * 10546.1    7828.5    2717.6    25.8  10183. 82.8 68.7
 26  *119   240  31.06   1.57  67 *14334.9    8276.0    6058.9    42.3 *  9391.8    6934.9    2456.9    26.2   9206. 84.7 72.5
 27  *119   240  31.06   1.57  78 *13180.6    8289.4    4891.2    37.1 * 10379.7    7699.2    2680.5    25.8  10044. 84.9 67.8

                                                 NOTE:  # IN  =POUNDS ENTERING
                                                        # OUT =POUNDS LEAVING
                                                        # REM =POUNDS REMOVED
                                                        %     =PERCENTAGE REMOVED FOR THAT UNIT
                                                        SLUDGE=GALLONS OF SLUDGE PRODUCED  ASSUMING 3.2% SOLIDS
                                                        PLANT EFF= OVERALL PLANT EFFICIENCY
                                                        O.O.R.=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                               RANGE OF THE ESTABLISHED OPERATION
                                                               MIN=15.70,MAX=31.06
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                        COMPUTER SIMULATION OF TRICKLING FILTER OPERATION

                  ALEXANDRIA SANITATION AUTHORITY HIGH RATE TRICKLING FILTER SYSTEM

                                   SET #  8 :  SS =178 MG/L
                                               BOD =240 MG/L

         INPUT VECTORS                 O U T P U T  --  S T R E A M  V E C T O R S
         *************                 ***********************************************

                                            *  STATION # 2    STATION # 3   STATION # 4   STATION # 5   STATION # 7   STATION # 8 *
TRIAL*                                                                                                                       
  #  *SS   BOD  FLOW    RECIRC   T  * FLOW    BOD SS   FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS * REMARK

  1  *178  240  15,70   1,05    56 *14,95   247 182   0,75  95  91 15,70 240 178 15,67 115  92 14,93  95  91 14,91  57  64*
  2  *178  240  15,70   1,05    67 *14,95   247 182   0,75  83  81 15,70 240 178 15,67 112  89 14,92  83  81 14,91  51  56*
  3  *178  240  15,70   1,05    78 *14,95   248 183   0,75  76  75 15,70 240 178 15,67 109  86 14,92  76  75 14,91  47  52*
  4  *178  240  15,70   1,31    56 *11,98   284 205   3,72  97  88 15,70 240 178 15,67 123  92 11,96  97  88 11,95  52  58*
  5  *178  240  15,70   1,31    67 *11,98   288 208   3,72  85  78 15,70 240 178 15,67 120  89 11,96  85  78 11,95  47  51*
  6  *178  240  15,70   1,31    78 *11,98   290 210   3,72  78  73 15,70 240 178 15,67 117  86 11,96  78  73 11,95  44  48*
  7  *178  240  15,70   1,57    56 *10,00   320 230   5,70  99  86 15,70 240 178 15,67 130  92  9,97  99  86  9,96  49  54*
  8  *178  240  15,70   1,57    67 *10,00   327 236   5,70  87  76 15,70 240 178 15,67 126  89  9,97  87  76  9,96  44  47*
  9  *178  240  15,70   1,57    78 *10,00   331 236   5,70  80  73 15,70 240 178 15,67 123  86  9,97  80  73  9,96  41  45*
 10  *178  240  24,29   1,05    56 *23,13   246 182   1,16 106  84 24,29 240 178 24,25 140  93 23,09 106  84 23,08  67  65*
 11  *178  240  24,29   1,05    67 *23,13   247 183   1,16  93  76 24,29 240 178 24,25 136  90 23,09  93  76 23,08  61  59*
 12  *178  240  24,29   1,05    78 *23,13   247 183   1,16  83  69 24,29 240 178 24,25 133  88 23,09  83  69 23,08  56  53*
 13  *178  240  24,29   1,31    56 *18,54   280 208   5,75 108  81 24,29 240 178 24,25 150  93 18,50 108  81 18,49  62  59*
 14  *178  240  24,29   1,31    67 *18,54   284 210   5,75  95  74 24,29 240 178 24,25 146  90 18,50  95  74 18,49  56  54*
 15  *178  240  24,29   1,31    78 *18,54   288 212   5,75  85  67 24,29 240 178 24,25 142  88 18,50  85  67 18,49  51  49*
 16  *178  240  24,29   1,57    56 *15,47   314 234   8,82 110  79 24,29 240 178 24,25 159  93 15,43 110  79 15,42  58  55*
 17  *178  240  24,29   1,57    67 *15,47   321 238   8,82  97  72 24,29 240 178 24,25 154  90 15,43  97  72 15,42  53  50*
 18  *178  240  24,29   1,57    78 *15,47   327 242   8,82  87  65 24,29 240 178 24,25 150  88 15,43  87  65 15,42  48  45*
 19  *178  240  31,06   1,05    56 *29,58   246 182   1,48 113  80 31,06 240 178 31,01 157  94 29,53 113  80 29,52  74  66*
 20  *178  240  31,06   1,05    67 *29,58   247 183   1,48  99  73 31,06 240 178 31,01 152  91 29,53  99  73 29,52  67  60*
 21  *178  240  31,06   1,05    78 *29,58   247 183   1,48  89  66 31,06 240 178 31,00 149  88 29,53  89  66 29,51  62  54*
 22  *178  240  31,06   1,31    56 *23,71   278 208   7,35 115  78 31,06 240 178 31,01 168  94 23,66 115  78 23,65  68  61*
 23  *178  240  31,06   1,31    67 *23,71   283 211   7,35 101  71 31,06 240 178 31,01 163  91 23,66 101  71 23,64  62  55*
 24  *178  240  31,06   1,31    78 *23,71   286 213   7,35  91  64 31,06 240 178 31,00 159  88 23,65  91  64 23,64  57  49*
 25  *178  240  31,06   1,57    56 *19,78   310 236  11,28 117  76 31,06 240 178 31,01 177  94 19,73 117  76 19,72  64  56*
 26  *178  240  31,06   1,57    67 *19,78   318 240  11,28 103  69 31,06 240 178 31,01 172  91 19,73 103  69 19,72  58  51*
 27  *178  240  31,06   1,57    78 *19,78   324 244  11,28  92  62 31,06 240 178 31,00 168  88 19,73  92  62 19,72  53  45*

                                   NOTE:  FLOWS ARE IN MGD
                                          BOD & SS ARE IN MG/L
                                          O.O.R.=MEANSFLOW THRU THE PLANT IS OUT OF THE
                                                 RANGE OF THE ESTABLISHED OPERATION
                                                 MIN=15,70,MAX=31,06
```

```
             INPUT VECTORS                 O U T P U T  --  P R I M A R Y   T A N K   C H A R A C T E R I S T I C S
             *************                 ************************************************************************
TRIAL*                                                    B O D                                  SUSPENDED        SOLIDS
  #  *SS   BOD  FLOW    RECIRC  T  *   #  IN     # OUT     # REM     %     *   #  IN    # OUT     # REM     %    SLUDGE   REMARK

  1  *178  240  15.70   1.05   56 * 31425.1    15096.8   16328.3   52.1  * 23307.0   12112.6   11194.4   48.3   26845.
  2  *178  240  15.70   1.05   67 * 31425.1    14671.3   16753.8   53.3  * 23307.0   11703.4   11603.5   50.0   27826.
  3  *178  240  15.70   1.05   78 * 31425.1    14320.1   17105.0   54.6  * 23307.0   11367.5   11939.5   51.7   28632.
  4  *178  240  15.70   1.31   56 * 31425.1    16156.6   15268.5   48.7  * 23307.0   12112.6   11194.4   48.3   26845.
  5  *178  240  15.70   1.31   67 * 31425.1    15701.3   15723.8   50.0  * 23307.0   11703.4   11603.5   50.0   27826.
  6  *178  240  15.70   1.31   78 * 31425.1    15325.5   16099.7   51.2  * 23307.0   11367.5   11939.5   51.7   28632.
  7  *178  240  15.70   1.57   56 * 31425.1    17079.1   14346.1   45.8  * 23307.0   12112.6   11194.4   48.3   26845.
  8  *178  240  15.70   1.57   67 * 31425.1    16597.8   14827.3   47.5  * 23307.0   11703.4   11603.5   50.0   27826.
  9  *178  240  15.70   1.57   78 * 31425.1    16200.5   15224.7   48.7  * 23307.0   11367.5   11939.5   51.7   28632.
 10  *178  240  24.29   1.05   56 * 48618.8    28450.5   20168.3   41.7  * 36059.0   18990.7   17068.3   47.8   40931.
 11  *178  240  24.29   1.05   67 * 48618.8    27648.8   20970.0   43.3  * 36059.0   18349.2   17709.7   49.4   42469.
 12  *178  240  24.29   1.05   78 * 48618.8    26986.9   21631.9   44.6  * 36059.0   17822.5   18236.5   50.6   43733.
 13  *178  240  24.29   1.31   56 * 48618.8    30447.9   18171.0   37.5  * 36059.0   18990.7   17068.3   47.8   40931.
 14  *178  240  24.29   1.31   67 * 48618.8    29589.8   19029.0   39.2  * 36059.0   18349.2   17709.7   49.4   42469.
 15  *178  240  24.29   1.31   78 * 48618.8    28881.5   19737.3   40.8  * 36059.0   17822.5   18236.5   50.6   43733.
 16  *178  240  24.29   1.57   56 * 48618.8    32186.3   16432.6   33.7  * 36059.0   18990.7   17068.3   47.8   40931.
 17  *178  240  24.29   1.57   67 * 48618.8    31279.3   17339.6   35.8  * 36059.0   18349.2   17709.7   49.4   42469.
 18  *178  240  24.29   1.57   78 * 48618.8    30530.5   18088.3   37.5  * 36059.0   17822.5   18236.5   50.6   43733.
 19  *178  240  31.06   1.05   56 * 62169.7    40656.8   21512.9   34.6  * 46109.2   24466.4   21642.8   47.2   51901.
 20  *178  240  31.06   1.05   67 * 62169.7    39511.1   22658.6   36.7  * 46109.2   23639.9   22469.2   48.9   53883.
 21  *178  240  31.06   1.05   78 * 62169.7    38565.3   23604.4   37.9  * 46109.2   22961.3   23147.9   50.6   55510.
 22  *178  240  31.06   1.31   56 * 62169.7    43511.0   18658.7   30.0  * 46109.2   24466.4   21642.8   47.2   51901.
 23  *178  240  31.06   1.31   67 * 62169.7    42284.9   19884.8   32.1  * 46109.2   23639.9   22469.2   48.9   53883.
 24  *178  240  31.06   1.31   78 * 62169.7    41272.7   20897.0   33.7  * 46109.2   22961.3   23147.9   50.6   55510.
 25  *178  240  31.06   1.57   56 * 62169.7    45995.2   16174.5   26.2  * 46109.2   24466.4   21642.8   47.2   51901.
 26  *178  240  31.06   1.57   67 * 62169.7    44699.1   17470.5   28.3  * 46109.2   23639.9   22469.2   48.9   53883.
 27  *178  240  31.06   1.57   78 * 62169.7    43629.1   18540.5   30.0  * 46109.2   22961.3   23147.9   50.6   55510.

                                    NOTE:  # IN  =POUNDS ENTERING
                                           # OUT =POUNDS LEAVING
                                           # REM =POUNDS REMOVED
                                           %     =PERCENTAGE REMOVED FOR THAT UNIT
                                           SLUDGE=GALLONS OF SLUDGE PRODUCED  ASSUMING 5.0% SOLIDS
                                           O.O.R.=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                  RANGE OF THE ESTABLISHED PLANT OPERATION
                                                  MIN=15.70,MAX=31.06
```

```
                  INPUT VECTORS                      O U T P U T  --  T R I C K L I N G   F I L T E R   C H A R A C T E R I S T I C S
                  *************                      ****************************************************************************
                                                                  B O D                          SUSPENDED        SOLIDS
TRIAL*                                                                                                                     OVERALL % REM
  #  *SS   BOD  FLOW   RECIRC  T  *  #  IN       # OUT     # REM      %     *  #  IN    # OUT     # REM      %     BOD    S.S. REMARK

  1  *178  240  15.70   1.05  56 * 15096.8    12553.4    2543.3    16.8   * 12112.6   12145.1    -32.5    -0.3   61.1   49.5
  2  *178  240  15.70   1.05  67 * 14671.3    11049.0    3622.3    24.7   * 11703.4   10793.5    910.0     7.8   66.0   54.9
  3  *178  240  15.70   1.05  78 * 14320.1     9915.9    4404.3    30.8   * 11367.5    9766.2   1601.2    14.1   69.8   59.6
  4  *178  240  15.70   1.31  56 * 16156.6    12850.0    3306.6    20.5   * 12112.6   11731.1    381.5     3.1   65.5   56.6
  5  *178  240  15.70   1.31  67 * 15701.3    11310.1    4391.3    28.0   * 11703.4   10425.5   1277.9    10.9   70.1   62.0
  6  *178  240  15.70   1.31  78 * 15325.5    10150.1    5175.3    33.8   * 11367.5    9433.3   1934.2    17.0   73.4   65.7
  7  *178  240  15.70   1.57  56 * 17079.1    13097.9    3981.1    23.3   * 12112.6   11402.8    709.8     5.9   68.8   62.2
  8  *178  240  15.70   1.57  67 * 16597.8    11528.3    5069.5    30.5   * 11703.4   10133.8   1569.6    13.4   73.1   67.4
  9  *178  240  15.70   1.57  78 * 16200.5    10346.0    5854.5    36.1   * 11367.5    9169.3   2198.1    19.3   76.1   70.3
 10  *178  240  24.29   1.05  56 * 28450.5    21678.5    6772.1    23.8   * 18990.7   17325.1   1665.6     8.8   56.5   53.3
 11  *178  240  24.29   1.05  67 * 27648.8    19080.5    8568.3    31.0   * 18349.2   15397.0   2952.3    16.1   61.9   58.5
 12  *178  240  24.29   1.05  78 * 26986.9    17123.7    9863.2    36.5   * 17822.5   13931.7   3890.8    21.8   66.0   62.8
 13  *178  240  24.29   1.31  56 * 30447.9    22190.6    8257.2    27.1   * 18990.7   16734.5   2256.2    11.9   61.1   60.6
 14  *178  240  24.29   1.31  67 * 29589.8    19531.3   10058.5    34.0   * 18349.2   14872.1   3477.1    18.9   66.2   65.2
 15  *178  240  24.29   1.31  78 * 28881.5    17528.3   11353.3    39.3   * 17822.5   13456.7   4365.8    24.5   70.1   68.9
 16  *178  240  24.29   1.57  56 * 32186.3    22618.8    9567.4    29.7   * 18990.7   16266.2   2724.5    14.3   64.6   65.8
 17  *178  240  24.29   1.57  67 * 31279.3    19908.2   11371.1    36.4   * 18349.2   14456.0   3893.3    21.2   69.5   70.2
 18  *178  240  24.29   1.57  78 * 30530.5    17866.5   12664.0    41.5   * 17822.5   13080.2   4742.3    26.6   73.1   73.6
 19  *178  240  31.06   1.05  56 * 40656.8    29491.4   11165.3    27.5   * 24466.4   21163.5   3302.8    13.5   53.7   55.5
 20  *178  240  31.06   1.05  67 * 39511.1    25957.2   13553.9    34.3   * 23639.9   18808.3   4831.6    20.4   59.5   60.7
 21  *178  240  31.06   1.05  78 * 38565.3    23295.1   15270.1    39.6   * 22961.3   17018.3   5943.0    25.9   63.6   64.5
 22  *178  240  31.06   1.31  56 * 43511.0    30188.2   13322.8    30.6   * 24466.4   20442.1   4024.3    16.4   58.3   62.0
 23  *178  240  31.06   1.31  67 * 42284.9    26570.5   15714.4    37.2   * 23639.9   18167.2   5472.8    23.2   64.0   66.8
 24  *178  240  31.06   1.31  78 * 41272.7    23845.6   17427.1    42.2   * 22961.3   16438.2   6523.1    28.4   67.8   70.4
 25  *178  240  31.06   1.57  56 * 45995.2    30770.6   15224.6    33.1   * 24466.4   19870.1   4596.3    18.8   61.9   67.8
 26  *178  240  31.06   1.57  67 * 44699.1    27083.2   17616.0    39.4   * 23639.9   17658.8   5981.1    25.3   67.3   71.7
 27  *178  240  31.06   1.57  78 * 43629.1    24305.6   19323.6    44.3   * 22961.3   15978.2   6983.2    30.4   71.3   75.0

                                          NOTE:  # IN  =POUNDS ENTERING
                                                 # OUT =POUNDS LEAVING
                                                 # REM =POUNDS REMOVED
                                                 %     =PERCENTAGE REMOVED FOR THAT UNIT
                                                 OVER.% REM=OVERALL EFFICIENCY COMPARING THE OUTPUT FOR
                                                         THIS UNIT INPUT AT STATION # 2
                                                 O.O.R.=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                       RANGE OF THE ESTABLISHED OPERATION
                                                       MIN=15.70,MAX=31.06
```

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                INPUT VECTORS              O U T P U T  --  S E C O N D A R Y   T A N K   C H A R A C T E R I S T I C S
                *************              ****************************************************************************
                                                          B O D                                      SUSPENDED        SOLIDS
TRIAL*                                                                                                                %  SLUDGE  PLANT EFF
 #  *SS    BOD  FLOW   RECIRC  T  *  #  IN    # OUT     # REM     %    *   #  IN      # OUT      # REM                         BOD  S.S.  REMARK
    *
 1  *178   240  15.70   1.05   56 *11825.5   7097.6    4727.9   40.0 * 11327.6    7960.6     3367.0    29.7  12616. 76.9 64.8
 2  *178   240  15.70   1.05   67 *10331.1   6372.6    3958.5   38.3 * 10082.1    7047.8     3034.3    30.1  11370. 79.4 69.2
 3  *178   240  15.70   1.05   78 * 9459.3   5937.4    3521.8   37.2 *  9334.8    6502.5     2832.3    30.3  10613. 81.0 71.6
 4  *178   240  15.70   1.31   56 * 9673.7   5236.7    4437.0   45.9 *  8776.1    5823.1     2953.0    33.6  11065. 81.7 71.7
 5  *178   240  15.70   1.31   67 * 8476.3   4700.2    3776.1   44.5 *  7778.2    5132.6     2645.6    34.0   9913. 83.7 75.5
 6  *178   240  15.70   1.31   78 * 7777.7   4402.2    3375.5   43.4 *  7279.1    4788.7     2490.4    34.2   9332. 84.8 77.1
 7  *178   240  15.70   1.57   56 * 8234.4   4096.2    4138.2   50.3 *  7153.1    4529.0     2624.1    36.7   9833. 84.7 76.5
 8  *178   240  15.70   1.57   67 * 7235.6   3676.8    3558.8   49.2 *  6320.8    3979.4     2341.3    37.0   8773. 86.5 80.1
 9  *178   240  15.70   1.57   78 * 6652.9   3482.7    3170.2   47.7 *  6070.8    3815.0     2255.8    37.2   8452. 87.6 80.9
10  *178   240  24.29   1.05   56 *20414.6  13048.1    7366.4   36.1 * 16177.6   12646.5     3531.1    21.8  13231. 72.8 64.3
11  *178   240  24.29   1.05   67 *17909.7  11814.1    6095.6   34.0 * 14635.9   11389.1     3246.8    22.2  12166. 75.3 67.8
12  *178   240  24.29   1.05   78 *15983.1  10795.2    5187.9   32.5 * 13287.1   10294.0     2993.2    22.5  11215. 77.3 71.0
13  *178   240  24.29   1.31   56 *16664.2   9607.0    7057.2   42.3 * 12498.2    9223.4     3274.8    26.2  12271. 77.9 71.6
14  *178   240  24.29   1.31   67 *14657.1   8742.2    5915.0   40.4 * 11417.1    8390.8     3026.3    26.5  11340. 80.3 74.3
15  *178   240  24.29   1.31   78 *13113.4   7988.5    5124.9   39.1 * 10336.4    7562.1     2774.3    26.8  10395. 82.3 76.9
16  *178   240  24.29   1.57   56 *14155.8   7501.7    6654.1   47.0 * 10166.5    7158.6     3007.9    29.6  11270. 81.5 76.5
17  *178   240  24.29   1.57   67 *12481.6   6827.4    5654.2   45.3 *  9264.7    6496.0     2768.7    29.9  10374. 83.5 79.0
18  *178   240  24.29   1.57   78 *11194.0   6238.3    4955.6   44.3 *  8363.3    5836.6     2526.7    30.2   9468. 85.3 81.4
19  *178   240  31.06   1.05   56 *27828.8  18379.2    9449.5   34.0 * 19701.8   16350.8     3350.9    17.0  12556. 69.9 63.7
20  *178   240  31.06   1.05   67 *24379.3  16686.7    7692.6   31.6 * 17976.7   14856.8     3119.8    17.4  11690. 72.9 67.2
21  *178   240  31.06   1.05   78 *21915.6  15272.5    6643.0   30.3 * 16252.0   13369.8     2882.2    17.7  10800. 74.9 70.5
22  *178   240  31.06   1.31   56 *22690.4  13584.8    9105.6   40.1 * 15390.0   12063.7     3326.3    21.6  12464. 75.5 70.7
23  *178   240  31.06   1.31   67 *19926.4  12335.2    7591.3   38.1 * 14007.7   10933.0     3074.7    21.9  11521. 78.1 73.9
24  *178   240  31.06   1.31   78 *17952.3  11287.5    6664.7   37.1 * 12625.8    9807.8     2818.0    22.3  10559. 80.1 77.0
25  *178   240  31.06   1.57   56 *19253.6  10598.3    8655.3   45.0 * 12506.6    9353.6     3153.0    25.2  11814. 79.4 76.3
26  *178   240  31.06   1.57   67 *16948.1   9623.6    7324.4   43.2 * 11353.6    8453.7     2899.8    25.5  10866. 81.8 78.7
27  *178   240  31.06   1.57   78 *15136.8   8760.4    6376.4   42.1 * 10200.9    7558.4     2642.5    25.9   9901. 83.6 81.6

                                      NOTE:  # IN  =POUNDS ENTERING
                                             # OUT =POUNDS LEAVING
                                             # REM =POUNDS REMOVED
                                             %     =PERCENTAGE REMOVED FOR THAT UNIT
                                             SLUDGE=GALLONS OF SLUDGE PRODUCED  ASSUMING 3.2% SOLIDS
                                             PLANT EFF= OVERALL PLANT EFFICIENCY
                                             O.O.R.=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                    RANGE OF THE ESTABLISHED OPERATION
                                                    MIN=15.70,MAX=31.06
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                              COMPUTER SIMULATION OF TRICKLING FILTER OPERATION

                        ALEXANDRIA SANITATION AUTHORITY HIGH RATE TRICKLING FILTER SYSTEM

                                           SET #  9 :  SS =278 MG/L
                                                       BOD =240 MG/L

         INPUT VECTORS                  O U T P U T  --  S T R E A M   V E C T O R S
         *************                  ***********************************************

                                        *  STATION # 2        STATION # 3   STATION # 4   STATION # 5   STATION # 7   STATION # 8 *
TRIAL*                                                                                                                            REMARK!
 #  *SS   BOD  FLOW   RECIRC  T  * FLOW    BOD SS      FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS  FLOW  BOD SS *

 1  *278  240  15,70   1,05   56 *14,95    246 286     0,75 114 114 15,70 240 278 15,65 121 114 14,90 114 114 14,89  67  80*
 2  *278  240  15,70   1,05   67 *14,95    246 286     0,75 100 101 15,70 240 278 15,65 118 110 14,90 100 101 14,89  60  71*
 3  *278  240  15,70   1,05   78 *14,95    247 287     0,75  90  91 15,70 240 278 15,65 115 107 14,90  90  91 14,89  55  63*
 4  *278  240  15,70   1,31   56 *11,98    278 330     3,72 117 110 15,70 240 278 15,65 130 114 11,93 117 110 11,92  62  73*
 5  *278  240  15,70   1,31   67 *11,98    282 333     3,72 103  98 15,70 240 278 15,65 126 110 11,93 103  98 11,92  56  65*
 6  *278  240  15,70   1,31   78 *11,98    285 336     3,72  92  88 15,70 240 278 15,65 123 107 11,93  92  88 11,92  51  58*
 7  *278  240  15,70   1,57   56 *10,00    308 375     5,70 119 107 15,70 240 278 15,65 137 114  9,95 119 107  9,94  58  68*
 8  *278  240  15,70   1,57   67 *10,00    316 302     5,70 105  95 15,70 240 278 15,65 133 110  9,95 105  95  9,94  52  60*
 9  *278  240  15,70   1,57   78 *10,00    323 387     5,70  94  86 15,70 240 278 15,65 130 107  9,95  94  86  9,94  48  54*
10  *278  240  24,29   1,05   56 *23,13    245 286     1,16 128 105 24,29 240 278 24,21 148 115 23,05 128 105 23,04  80  82*
11  *278  240  24,29   1,05   67 *23,13    246 287     1,16 112  93 24,29 240 278 24,21 143 111 23,05 112  93 23,04  72  73*
12  *278  240  24,29   1,05   78 *23,13    246 287     1,16 101  84 24,29 240 278 24,21 140 108 23,05 101  84 23,04  66  65*
13  *278  240  24,29   1,31   56 *18,54    273 332     5,75 131 101 24,29 240 278 24,21 158 115 18,46 131 101 18,45  74  75*
14  *278  240  24,29   1,31   67 *18,54    278 336     5,75 115  90 24,29 240 278 24,21 154 111 18,46 115  90 18,45  66  66*
15  *278  240  24,29   1,31   78 *18,54    282 339     5,75 103  81 24,29 240 278 24,21 150 108 18,46 103  81 18,45  60  59*
16  *278  240  24,29   1,57   56 *15,47    300 380     8,82 133  98 24,29 240 278 24,21 167 115 15,39 133  98 15,38  69  69*
17  *278  240  24,29   1,57   67 *15,47    310 386     8,82 117  87 24,29 240 278 24,21 162 111 15,39 117  87 15,38  62  61*
18  *278  240  24,29   1,57   78 *15,47    316 391     8,82 105  79 24,29 240 278 24,21 158 108 15,39 105  79 15,38  57  55*
19  *278  240  31,06   1,05   56 *29,58    245 286     1,48 136 100 31,06 240 278 30,96 165 116 29,48 136 100 29,47  88  83*
20  *278  240  31,06   1,05   67 *29,58    246 287     1,48 119  89 31,06 240 278 30,96 160 112 29,48 119  89 29,46  79  74*
21  *278  240  31,06   1,05   78 *29,58    246 287     1,48 107  80 31,06 240 278 30,96 157 109 29,48 107  80 29,46  72  66*
22  *278  240  31,06   1,31   56 *23,71    271 334     7,35 139  97 31,06 240 278 30,96 177 116 25,61 139  97 23,59  81  76*
23  *278  240  31,06   1,31   67 *23,71    276 337     7,35 122  86 31,06 240 278 30,96 172 112 23,61 122  86 23,59  73  67*
24  *278  240  31,06   1,31   78 *23,71    280 339     7,35 110  78 31,06 240 278 30,96 168 109 23,61 110  78 23,59  67  61*
25  *278  240  31,06   1,57   56 *19,78    295 382    11,28 142  94 31,06 240 278 30,96 187 116 19,68 142  94 19,67  76  70*
26  *278  240  31,06   1,57   67 *19,78    305 389    11,28 125  83 31,06 240 278 30,96 181 112 19,68 125  83 19,67  68  62*
27  *278  240  31,06   1,57   78 *19,78    312 393    11,28 112  76 31,06 240 278 30,96 177 109 19,68 112  76 19,67  63  56*

                                           NOTE:  FLOWS ARE IN MGD
                                                  BOD & SS ARE IN MG/L
                                                  O.O.R.=MEANSFLOW THRU THE PLANT IS OUT OF THE
                                                         RANGE OF THE ESTABLISHED OPERATION
                                                         MIN=15,70,MAX=31,06
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                 INPUT VECTORS                   O U T P U T  --  P R I M A R Y   T A N K   C H A R A C T E R I S T I C S
                 *************                   ********************************************************************
                                                               B O D                                   SUSPENDED        SOLIDS
TRIAL*                                                         # OUT      # REM      %      *  #. IN    # OUT     # REM      %     SLUDGE   REMARK
  #   *SS   BOD   FLOW    RECIRC   T  *  #  IN

  1  *278  240  15.70    1.05    56 * 31425.1    15869.2    15555.9    49.6  * 36400.8    14920.5   21480.3   59.0   51511.
  2  *278  240  15.70    1.05    67 * 31425.1    15422.0    16003.1    50.8  * 36400.8    14416.5   21984.2   60.4   52720.
  3  *278  240  15.70    1.05    78 * 31425.1    15052.8    16372.3    52.1  * 36400.8    14002.7   22398.1   61.5   53712.
  4  *278  240  15.70    1.31    56 * 31425.1    16983.2    14441.9    45.8  * 36400.8    14920.5   21480.3   59.0   51511.
  5  *278  240  15.70    1.31    67 * 31425.1    16504.7    14920.4    47.5  * 36400.8    14416.5   21984.2   60.4   52720.
  6  *278  240  15.70    1.31    78 * 31425.1    16109.6    15315.5    48.7  * 36400.8    14002.7   22398.1   61.5   53712.
  7  *278  240  15.70    1.57    56 * 31425.1    17952.9    13472.2    42.9  * 36400.8    14920.5   21480.3   59.0   51511.
  8  *278  240  15.70    1.57    67 * 31425.1    17447.0    13978.1    44.6  * 36400.8    14416.5   21984.2   60.4   52720.
  9  *278  240  15.70    1.57    78 * 31425.1    17029.3    14395.8    45.8  * 36400.8    14002.7   22398.1   61.5   53712.
 10  *278  240  24.29    1.05    56 * 48618.8    29906.2    18712.7    38.3  * 56316.8    23393.1   32923.7   58.6   78954.
 11  *278  240  24.29    1.05    67 * 48618.8    29063.4    19555.4    40.4  * 56316.8    22603.0   33713.9   60.1   80849.
 12  *278  240  24.29    1.05    78 * 48618.8    28367.7    20251.1    41.7  * 56316.8    21954.1   34362.7   61.2   82405.
 13  *278  240  24.29    1.31    56 * 48618.8    32005.7    16613.2    34.2  * 56316.8    23393.1   32923.7   58.6   78954.
 14  *278  240  24.29    1.31    67 * 48618.8    31103.8    17515.1    35.8  * 56316.8    22603.0   33713.9   60.1   80849.
 15  *278  240  24.29    1.31    78 * 48618.8    30359.2    18259.6    37.5  * 56316.8    21954.1   34362.7   61.2   82405.
 16  *278  240  24.29    1.57    56 * 48618.8    33833.0    14785.8    30.4  * 56316.8    23393.1   32923.7   58.6   78954.
 17  *278  240  24.29    1.57    67 * 48618.8    32879.6    15739.2    32.5  * 56316.8    22603.0   33713.9   60.1   80849.
 18  *278  240  24.29    1.57    78 * 48618.8    32092.6    16526.3    34.2  * 56316.8    21954.1   34362.7   61.2   82405.
 19  *278  240  31.06    1.05    56 * 62169.7    42737.0    19432.7    31.3  * 72013.2    30138.1   41875.1   58.3  100420.
 20  *278  240  31.06    1.05    67 * 62169.7    41532.6    20637.0    33.3  * 72013.2    29120.1   42893.1   59.7  102861.
 21  *278  240  31.06    1.05    78 * 62169.7    40538.4    21631.2    34.6  * 72013.2    28284.2   43729.0   60.8  104866.
 22  *278  240  31.06    1.31    56 * 62169.7    45737.2    16432.4    26.2  * 72013.2    30138.1   41875.1   58.3  100420.
 23  *278  240  31.06    1.31    67 * 62169.7    44448.3    17721.3    28.3  * 72013.2    29120.1   42893.1   59.7  102861.
 24  *278  240  31.06    1.31    78 * 62169.7    43384.4    18785.3    30.0  * 72013.2    28284.2   43729.0   60.8  104866.
 25  *278  240  31.06    1.57    56 * 62169.7    48348.6    13821.1    22.1  * 72013.2    30138.1   41875.1   58.3  100420.
 26  *278  240  31.06    1.57    67 * 62169.7    46986.1    15183.6    24.6  * 72013.2    29120.1   42893.1   59.7  102861.
 27  *278  240  31.06    1.57    78 * 62169.7    45861.4    16308.3    26.2  * 72013.2    28284.2   43729.0   60.8  104866.

                                         NOTE:  # IN  =POUNDS ENTERING
                                                # OUT =POUNDS LEAVING
                                                # REM =POUNDS REMOVED
                                                %     =PERCENTAGE REMOVED FOR THAT UNIT
                                                SLUDGE=GALLONS OF SLUDGE PRODUCED  ASSUMING 5.0% SOLIDS
                                                O.O.R.=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                       RANGE OF THE ESTABLISHED PLANT OPERATION
                                                       MIN=15.70,MAX=31.06
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                                                          O U T P U T  --  T R I C K L I N G   F I L T E R   C H A R A C T E R I S T I C S
                    INPUT VECTORS                         ***************************************************************************************
                    *************                                      B O D                                     SUSPENDED        SOLIDS
TRIAL*                                                                                                                                       OVERALL  % REM
 #   *SS   BOD  FLOW    RECIRC   T  *   #  IN       # OUT       # REM       %      *   #  IN      # OUT       # REM       %     BOD      S.S. REMARK

 1   *278  240  15.70    1.05    56 * 15869.2     15097.6       771.5      4.9    * 14920.5     15072.1     -151.6     -1.0    53.3     59.8
 2   *278  240  15.70    1.05    67 * 15422.0     13288.5      2133.5     13.8    * 14416.5     13394.9     1021.7      7.1    58.9     64.3
 3   *278  240  15.70    1.05    78 * 15052.8     11925.8      3127.0     20.8    * 14002.7     12120.2     1882.5     13.4    63.2     67.9
 4   *278  240  15.70    1.31    56 * 16983.2     15454.3      1528.9      9.0    * 14920.5     14558.3      362.2      2.4    57.6     66.4
 5   *278  240  15.70    1.31    67 * 16504.7     13602.4      2902.2     17.6    * 14416.5     12938.3     1478.3     10.3    63.1     70.3
 6   *278  240  15.70    1.31    78 * 16109.6     12207.5      3902.0     24.2    * 14002.7     11707.0     2295.7     16.4    67.4     73.5
 7   *278  240  15.70    1.57    56 * 17952.9     15752.5      2200.4     12.3    * 14920.5     14150.9      769.6      5.2    61.0     71.2
 8   *278  240  15.70    1.57    67 * 17447.0     13864.9      3582.1     20.5    * 14416.5     12576.2     1840.3     12.8    66.5     74.9
 9   *278  240  15.70    1.57    78 * 17029.3     12443.1      4586.3     26.9    * 14002.7     11379.4     2623.3     18.7    70.6     77.5
10   *278  240  24.29    1.05    56 * 29906.2     26072.0      3834.2     12.8    * 23393.1     21500.5     1892.6      8.1    47.3     62.9
11   *278  240  24.29    1.05    67 * 29063.4     22947.7      6115.8     21.0    * 22603.0     19107.9     3495.1     15.5    54.1     67.2
12   *278  240  24.29    1.05    78 * 28367.7     20594.5      7773.2     27.4    * 21954.1     17289.5     4664.6     21.2    58.5     70.4
13   *278  240  24.29    1.31    56 * 32005.7     26688.0      5317.7     16.6    * 23393.1     20767.6     2625.5     11.2    51.6     69.3
14   *278  240  24.29    1.31    67 * 31103.8     23489.8      7613.9     24.5    * 22603.0     18456.5     4146.4     18.3    58.3     72.9
15   *278  240  24.29    1.31    78 * 30359.2     21081.1      9278.1     30.6    * 21954.1     16700.2     5254.0     23.9    63.1     75.8
16   *278  240  24.29    1.57    56 * 33833.0     27202.9      6630.2     19.6    * 23393.1     20186.4     3206.7     13.7    55.3     73.9
17   *278  240  24.29    1.57    67 * 32879.6     23943.1      8936.6     27.2    * 22603.0     17940.0     4662.9     20.6    61.9     77.2
18   *278  240  24.29    1.57    78 * 32092.6     21487.8     10604.8     33.0    * 21954.1     16232.8     5721.3     26.1    66.5     79.5
19   *278  240  31.06    1.05    56 * 42737.0     35468.2      7268.8     17.0    * 30138.1     26263.9     3874.2     12.9    44.1     64.7
20   *278  240  31.06    1.05    67 * 41532.6     31218.1     10314.5     24.8    * 29120.1     23341.3     5778.8     19.8    51.2     68.6
21   *278  240  31.06    1.05    78 * 40538.4     28016.8     12521.6     30.9    * 28284.2     21120.1     7164.1     25.3    56.1     71.8
22   *278  240  31.06    1.31    56 * 45737.2     36306.2      9431.0     20.6    * 30138.1     25368.6     4769.5     15.8    48.3     70.7
23   *278  240  31.06    1.31    67 * 44448.3     31955.6     12492.7     28.1    * 29120.1     22545.6     6574.5     22.6    55.4     74.2
24   *278  240  31.06    1.31    78 * 43384.4     28678.8     14705.6     33.9    * 28284.2     20400.1     7884.1     27.9    60.4     76.7
25   *278  240  31.06    1.57    56 * 48348.6     37006.8     11341.8     23.5    * 30138.1     24658.7     5479.4     18.2    51.5     75.1
26   *278  240  31.06    1.57    67 * 46986.1     32572.2     14413.9     30.7    * 29120.1     21914.7     7205.4     24.7    58.7     78.4
27   *278  240  31.06    1.57    78 * 45861.4     29232.1     16629.3     36.3    * 28284.2     19829.3     8454.9     29.9    63.8     80.7

                                                  NOTE:  # IN  =POUNDS ENTERING
                                                         # OUT =POUNDS LEAVING
                                                         # REM =POUNDS REMOVED
                                                         %     =PERCENTAGE REMOVED FOR THAT UNIT
                                                         OVER.% REM=OVERALL EFFICIENCY COMPARING THE OUTPUT FOR
                                                                  THIS UNIT INPUT AT STATION # 2
                                                         O.O.R.=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                               RANGE OF THE ESTABLISHED OPERATION
                                                               MIN=15.70,MAX=31.06
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                INPUT VECTORS                 O U T P U T  --  S E C O N D A R Y   T A N K   C H A R A C T E R I S T I C S
                *************                 **************************************************************************
                                                           B O D                                   SUSPENDED          SOLIDS
TRIAL*                                                                                                               %  SLUDGE  PLANT EFF
  #   *SS   BOD  FLOW    RECIRC  T  *  #  IN     # OUT     # REM     %    *   #  IN    # OUT     # REM                    BOD  S.S.   REMARK
      *
  1   *278  240  15.70    1.05  56 *14167.2    8414.8    5752.4    40.6 * 14167.2  10054.6    4112.5    29.0  15410.  72.8 72.0
  2   *278  240  15.70    1.05  67 *12426.3    7554.8    4871.5    39.2 * 12550.6   8858.2    3692.4    29.4  13835.  75.6 75.2
  3   *278  240  15.70    1.05  78 *11182.9    6908.5    4274.5    38.2 * 11307.2   7942.7    3364.5    29.8  12607.  77.7 78.0
  4   *278  240  15.70    1.31  56 *11644.2    6214.2    5430.0    46.6 * 10947.5   7334.2    3613.3    33.0  13539.  77.7 77.9
  5   *278  240  15.70    1.31  67 *10249.8    5600.5    4649.4    45.4 *  9752.3   6499.0    3253.2    33.4  12190.  80.1 80.5
  6   *278  240  15.70    1.31  78 * 9154.4    5096.8    4057.7    44.3 *  8756.4   5806.7    2949.7    33.7  11052.  82.1 82.7
  7   *278  240  15.70    1.57  56 * 9873.5    4841.5    5032.0    51.0 *  8877.8   5673.7    3204.2    36.1  12006.  81.2 81.9
  8   *278  240  15.70    1.57  67 * 8710.8    4361.7    4349.1    49.9 *  7881.2   5009.4    2871.8    36.4  10761.  83.5 84.3
  9   *278  240  15.70    1.57  78 * 7797.5    3986.3    3811.2    48.9 *  7133.9   4513.8    2620.1    36.7   9818.  85.1 86.0
 10   *278  240  24.29    1.05  56 *24611.0   15500.5    9110.5    37.0 * 20188.7  15936.6    4252.1    21.1  15933.  67.3 71.3
 11   *278  240  24.29    1.05  67 *21532.9   13898.9    7633.9    35.5 * 17880.0  14036.0    3843.9    21.5  14403.  70.7 74.6
 12   *278  240  24.29    1.05  78 *19416.7   12733.8    6682.9    34.4 * 16148.5  12618.0    3530.5    21.9  13229.  73.2 77.4
 13   *278  240  24.29    1.31  56 *20171.6   11418.3    8753.3    43.4 * 15552.1  11587.0    3965.2    25.5  14858.  72.9 77.4
 14   *278  240  24.29    1.31  67 *17706.1   10278.1    7427.9    42.0 * 13856.9  10269.6    3587.3    25.9  13442.  76.3 80.4
 15   *278  240  24.29    1.31  78 *15857.1    9373.8    6483.3    40.9 * 12470.2   9197.5    3272.7    26.2  12263.  78.7 82.6
 16   *278  240  24.29    1.57  56 *17073.5    8879.9    8193.6    48.0 * 12580.5   8940.2    3640.3    28.9  13640.  77.0 81.8
 17   *278  240  24.29    1.57  67 *15017.7    7988.7    7029.0    46.8 * 11167.0   7892.6    3274.4    29.3  12269.  80.0 84.2
 18   *278  240  24.29    1.57  78 *13476.1    7318.1    6158.0    45.7 * 10139.1   7134.5    3004.6    29.6  11258.  82.0 85.9
 19   *278  240  31.06    1.05  56 *33438.0   21800.7   11637.3    34.8 * 24586.8  20604.8    3982.0    16.2  14920.  64.1 71.0
 20   *278  240  31.06    1.05  67 *29255.8   19585.8    9670.1    33.1 * 21880.4  18239.3    3641.1    16.6  13643.  67.9 74.2
 21   *278  240  31.06    1.05  78 *26303.9   17885.8    8418.1    32.0 * 19666.4  16314.1    3352.3    17.0  12561.  70.7 77.0
 22   *278  240  31.06    1.31  56 *27369.5   16103.1   11266.4    41.2 * 19099.6  15113.0    3986.6    20.9  14938.  70.1 77.2
 23   *278  240  31.06    1.31  67 *24019.7   14464.9    9554.8    39.8 * 16931.9  13324.2    3607.7    21.3  13518.  73.6 80.1
 24   *278  240  31.06    1.31  78 *21655.3   13272.9    8382.4    38.7 * 15355.6  12029.9    3325.7    21.7  12461.  76.1 82.0
 25   *278  240  31.06    1.57  56 *23310.2   12552.4   10757.8    46.2 * 15430.7  11645.5    3785.2    24.5  14183.  74.2 81.7
 26   *278  240  31.06    1.57  67 *20517.0   11271.7    9245.2    45.1 * 13623.3  10223.0    3400.3    25.0  12741.  77.7 84.1
 27   *278  240  31.06    1.57  78 *18381.3   10352.4    8029.0    43.7 * 12473.1   9322.2    3150.9    25.3  11806.  79.8 85.8

                                        NOTE:  # IN  =POUNDS ENTERING
                                               # OUT =POUNDS LEAVING
                                               # REM =POUNDS REMOVED
                                               %     =PERCENTAGE REMOVED FOR THAT UNIT
                                               SLUDGE=GALLONS OF SLUDGE PRODUCED  ASSUMING 3.2% SOLIDS
                                               PLANT EFF= OVERALL PLANT EFFICIENCY
                                               O.O.R.=MEANS FLOW THRU THE PLANT IS OUT OF THE
                                                      RANGE OF THE ESTABLISHED OPERATION
                                                      MIN=15.70,MAX=31.06
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