Analyses of the Water and Wastewater Systems at Florida Technological University

Spring 1972

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ANALYSES OF THE WATER AND WASTEWATER SYSTEMS
AT FLORIDA TECHNOLOGICAL UNIVERSITY

BY
FRED J. JENSEN

A Research Report Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Science in Environmental Systems Management

FLORIDA TECHNOLOGICAL UNIVERSITY
June 1972
ACKNOWLEDGEMENT

I am grateful to the Professors and the Staff of Florida Technological University who have assisted me in obtaining knowledge and data necessary for the preparation of this Research Report.

I am especially grateful to Dr. Yousef A. Yousef who has provided me with much assistance, motivation and inspiration during and prior to the preparation of this paper. He has spent much time and effort in my behalf.

I also wish to acknowledge the support and assistance received from:

Dr. Robert D. Doering
Professor Christian S. Bauer
Professor Justin A. Myrick
Mr. D. S. Abbott and Staff
Mr. R.N. Peruf and Staff
Mr. F.E. Clayton and Staff.

I am also very appreciative of the RETRO program which afforded me the opportunity to further my education in this very important field, and to all those who directly or indirectly provided me with assistance in preparing this report and obtaining my Master of Science Degree.
PREFACE

In searching for a subject to meet the M.S. Degree Research Report requirements, I had several objectives in mind. I wanted (1) a project with relevancy in the environmental field which would broaden my understanding of the environmental systems which I have studied, (2) a subject which would allow me to apply some of the Principles which I have learned in Operations Research, and (3) a project which had good practical application. With these objectives in mind, I reviewed the suggested topics presented by the Faculty and selected the FTU Water and Wastewater System Analyses topic which was recommended by Dr. Y. A. Yousef.

After selecting the topic I became very interested in the application of Management Information Systems (MIS) and discussed with Mr. C.S. Bauer, the possibility of utilizing such a program to evaluate the data which I had accumulated. He concurred that this would be a good application of a MIS and encouraged my use of it. He provided me with a basic MIS program which he and his IEMS 496-13 class of 1971 had developed. To meet the requirements of this study it was necessary to add some programs and make modifications to the basic programs which provided me with an extensive involvement in computer programming and MIS operations. The application and use of the MIS has become an important part of this research paper.

I have learned much in analyzing the FTU Water and Wastewater Systems and in applying the Management Information System.
It appears that a continuation of these studies with an increase of scope to encompass electrical and other mechanical utilities would be desirable. It would also appear that this study could have practical value in the management of the present utility systems and that FTU might elect to continue this or a similar MIS program as a part of the utilities operations. This type study should also have potential application for analyzing municipal and government operated facilities.
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- Maximum wastewater flow
- Minimum wastewater flow
- Five day BOD
- BOD removal efficiency
- BOD of the pond
- Wastewater solids (ppm)
- Dissolved oxygen
- Per capita wastewater collection
- Multiple parameter plots

Wastewater Treatment Costs

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- Maximum water consumption versus population
- Wastewater versus population
- Raw wastewater BOD (Five day) versus population
- Wastewater solids versus population
- Total solids versus five day BOD
- Total solids of the effluent versus fixed solids of the wastewater

V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary
Conclusions
Recommendations

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CHAPTER I

METHODS OF ANALYSIS

1.1 INTRODUCTION

It is the objective of this research report to analyze both quantitatively and qualitatively three years (1969 - 1971) of data related to the FTU Water and Wastewater Systems and to utilize a computerized Management Information System (MIS) in the analyses.

The MIS used in this study accepts raw data as recorded by the FTU Water and Sewage Plant personnel and converts these data into useful information that can be used to evaluate and improve operational performance. This study will also help evaluate future requirements and adequacy of current water and wastewater systems. A Management Information System is a "network reaching into all parts of the firm. . . it is the connective tissue which backs all other systems." (1) For the purpose of this report, the MIS is a network which reaches into areas of the FTU Water and Wastewater Systems and provides management with readily discernable information from which performance decisions can be formulated to improve the systems operation.

As in most utility operations a vast store of recorded performance data was available for analysis. Data were categorized and manipulated by the computer into meaningful information. This information will be used throughout the text of this report. Cost
evaluations have also been made to compare the cost effectiveness of the Water and Wastewater utility operations at FTU with those of typical industrial or municipal facilities.

The categories of data tabulated and used in this study follows.

1. Year and Month of data input
2. Potable water treated--million gallons per month (MGM)
3. Average daily water consumption--thousands of gallons per day (TGPD)
4. Maximum daily water consumption-- TGPD
5. Minimum daily water consumption-- TGPD
6. Monthly chlorine usage in water treatment-- pounds
7. Average residual chlorine measured-- parts per million (ppm)
8. Water consumption--gallons per capita per day (GPCD)
9. Student population
10. Total population
11. Average wastewater treated--TGPD
12. Maximum wastewater treated--gallons per minute (GPM)
13. Minimum wastewater treated-- GPM
14. Wastewater influent 5 day BOD--ppm
15. Wastewater effluent--5-day BOD--ppm
16. Percent BOD removal--efficiency--percent
17. Polishing pond--5-day BOD--ppm
18. Total wastewater solids in influent--ppm
19. Fixed solids in wastewater influent--ppm
20. Total solids in effluent--ppm
21. Fixed solids in effluent--ppm
22. Dissolved oxygen (D.O.) in wastewater influent--ppm
23. D.O. in wastewater effluent--ppm
24. D.O. in polishing pond--ppm
25. Average wastewater treated.

The methods used in this research report has proven to be a very practical approach for analyzing data and providing useful information for water and wastewater parameters and for relating system requirements to system capacities in a form that can be readily understood and from which management decisions can be made for operational improvements. Many Utility and Operations organizations are continually recording operational data which often lies dormant within a file and when not converted to useful information is wasted. The use of an MIS such as the one used in this report could provide Operating Management with an excellent means for monitoring and analyzing their performance effectively.

1.2 MANAGEMENT INFORMATION SYSTEM

1.2.1 GENERAL DESCRIPTION

The Management Information System (MIS) utilized in this research project uses the 1130 computer, the connected typewriter, the 1403 printer and the card reader. The MIS accepts 25 categories (parameters) of raw data for the 36-month period beginning January, 1969 and ending December, 1971 (as recorded by the utility operators) and calculates, tabulates, correlates, plots and provides a visual readout of pertinent information which can be used by management as a basis for decisions and controls to improve the performance of their
operations. It was necessary to reduce the number of categories of
data from 25 to 15 and consequently to make 2 computer runs to accom-
plish the total readout since the 1130 is too small to meet
the requirements of as large a program as was undertaken in this study
without the above described modifications.

1.2.2 THE MIS PROGRAMS AND RELATED ANALYSES
DESCRIPTIONS

The MIS used in this study consists of a monitor program,
seven subroutine programs, and a disk storage program. All of the
above are stored in disk memory and are called up and utilized as
required. Pages Al through Al4 of Appendix A are listings of these
programs.

The monitor program is the interface between the management
information system stored in computer memory, and the user of the
system. The monitor program informs the user of what information is
available in the system, attains selection of desired information,
calls up the information required and controls the overall system
proceedings through direct communications with the user. The monitor
program calls up a subroutine to provide the desired data processing
and to output the required information after which control is returned
to the monitor program, which then requests the user to indicate what
he would like to do next and reminds him of his options. The process
continues until the user terminates the program. Pages B1 through B6
of Appendix B are copies of actual communications which include some
of the information developed in this study.
The following MIS subroutine descriptions briefly define the functions of the subroutines. Subroutine names as used by the computer are in parenthesis.

(1) Dump (Dump) - This subroutine provides categorized listings of data. It prints the title of the data category and follows this with a listing of the required data. Data can be dumped by specific year and month or the total 36 months by 25 categories of data can be dumped in one listing. Examples of output data from this program are shown in Appendix C. Tables C1 through C4.

(2) Update (Updat) - This subroutine provides a means of revising or updating data that is already stored in memory without going through the formal punch card, delete, add procedure. It calls up the data categories by month and year from disk memory, erases the existing value, and allows on the spot correction.

(3) Trend (Trend) - This subroutine determines the best fit straight line equation which describes the input data relative to time. The method used in determining the equation of the best fit or trend line utilizes an inverted matrix multiplication procedure which results in a least squares best fit straight line (2). The Trend equations are provided for predicting future values. The subroutine does this by accepting the months in the future for which the prediction is required and calculating the predicted value. Examples of outputs of the Trend equation are contained in Appendix B.

(4) Regression (Regrs) - The regression subroutine compares corresponding data from a dependent and independent variable and determines the best fit straight line regression equation for the
relationship. It utilizes the same basic procedure as the Trend program (2).

This subroutine also contains a subprogram for calculating the Linear Correlation Coefficients relative to the dependent and independent variables.

Through the regression analysis and the determination of the corresponding linear correlation coefficient it is possible to obtain a better understanding of the interrelationships between the assumed dependent and independent variables. Examples of the output regression analysis are contained in Appendix B.

(5) Plot (Plot) - This subroutine plots a graph or curve of the data input. Several plot programs were used in this analysis. For most of the plots, the X axis is the time scale and the Y axis is the variable data scale. The Y axis is divided into one hundred equal increments, with the minimum ordinate value equal to the minimum datum value and the maximum ordinate value equal to the maximum datum value of the variable being plotted. These values plus the median value are identified on the plots. This is a very convenient method of plotting and provides convenient readouts of the maximum and minimum values. Plots for all data categories are included in Appendix C, Figures C1 through C33.

Trend lines were plotted on the variable versus time curves by inputing the equation of the line from the trend analysis into the plot program. These are the "B" values plotted on the curves. The equation of the trend line is delineated on the plot.
Regression lines were plotted on the variable versus population curves using the same procedure as for the Trend lines.

To provide comparisons of several system parameters on the same curve, multiple plots of several parameters were plotted on the same curve.

(6) Statistics (STATS) - This subroutine calculates the mean and standard deviations for the requested data category.

(7) Finish - Finish is a means for terminating the program. Selecting this option terminates the program and writes "End of FTUWW MIS Exercise."

1.3 POSSIBLE SYSTEM ENLARGEMENT

It would be possible to add other parameters such as costs which would plot or readout costs per 1000 gallons treated water or wastewater per month or to add other subroutines which would provide management with a continuous, objective analysis of system operational performance. This system could be expanded and improved upon to include all utilities, facility information, PM reporting, historical data compilations, etc. This appears to be a potentially valuable tool for Maintenance and Operations Management and an excellent use of a small amount of computer time.
CHAPTER II

POTABLE WATER ANALYSES

2.1 Introduction

This section describes the FTU water system from both a quantitative and qualitative viewpoint. The performance data used in this section of the report were obtained from the records of the Water and Sewage Treatment Section of the Physical Plant Department. Equipment cost data were obtained from the Physical Plant and Planning Departments.

2.2 Water Treatment System

Figure 2-1 is a schematic diagram of the water treatment system at FTU. Raw well water for all uses is provided from three wells located on Campus. Each well is 550 feet deep. Wells No. 1 and No. 2 are equipped with Peerless 500 GPM pumps powered by 15 HP (U.S. Motor) motors. Well No. 3 has a Peerless 600 GPM pump and is also powered by a 15 HP (U.S. Motor) motor. These pumps are capable of delivering a total of 1600 GPM.

Water is provided from the three deep well pumps to an Aerator for the removal of Hydrogen Sulfide and carbon dioxide and for re-oxygenation of the water. From the Aerator, water is pumped by either or both of two (Worthington) 30 HP, 600 GPM lift pumps to a 200,000 gallon elevated storage tank or to the Campus load as required. Either of these two pumps are capable of pumping 600 GPM. These pumps are the
Fig. 2-1--. Schematic Diagram of FTU Water Treatment System.

1. Deep Well Pumps
2. Aerator
3. Lift Pumps
4. Chlorinator
5. Water Tower
6. Valves
7. Check Valve
present limiting factors of system capacity. Chlorine is added as a function of demand by either of two chlorine 3 HP booster pumps which are located prior to the elevated tanks.

The tower is 150 feet high. It provides surge and emergency storage, and a uniform pressure of approximately 60 psi to the Campus facilities. Pumping to the tower is controlled by pressure switches which control the operations of the lift pumps. When the pressure drops below 57 psig, the first lift pump is started. If the pressure continues to drop, a second pump is started and both pumps continue to operate until the requirement becomes satisfied. At approximately 61 psig the pumps are automatically shut down by their respective pressure control switches. Figure 2-2 is a reproduction of a typical lift pump flow recording. During the daylight period from 7 AM until 4 PM it is not unusual for both pumps to be utilized to maintain the tower level and satisfy water demands. From this sample chart it appears that one pump is required approximately 80% of the time. The darkened area at the top of the recording pattern is a result of flow fluctuations from pumping against a fluctuating head. Controls are so installed that pump utilization can be alternated and thus usage balanced between the two pumps.

The treated water is used for drinking, washing, cleaning, toiletry, swimming pools, cooking, irrigation, air conditioning, heating, etc.

Water is distributed to Campus facilities via a 10" cast iron main with 6" cast iron take offs normally used to provide water to the
Fig. 2-2--.Water Lift Pump Flow Diagram--Hundreds of Gallons Per Minute
various facilities. Meters for measuring water consumption are located at most facilities.

2.3 RAW WATER CHARACTERISTICS

Well water is obtained from the Ocala Aquifer which is a part of the Florida aquifer. Flow of the subsurface aquifer water is generally Northeast from watershed areas West of Orlando (3).

A comparison of raw water quality to drinking water standards as established by the Public Health Service (4) is contained in Table 2-1. The Public Health Service is primarily concerned with those properties of water which can be considered unpleasant or injurious to health. These standards limit many water supply impurities such as arsenic, radioactivity, copper, manganese and cyanide which if present in sufficient quantity would be injurious to health (5). These impurities are below the detectable limits in the FTU water supply (6). All the properties of the raw water are within the regulated or desirable limits as indicated in Table 2-1 except turbidity which has a recorded value of 6-8 JTUs as compared to the recommended level of 5 (7). Turbidity should not result from impurities which cause offense to the senses of sight, taste or smell (7). The pH of the water supply is slightly alkaline and varies from 7.6 to 7.8.

From the total solids and fixed solids categories it is apparent that some volatile solids are prevalent within the raw water. Ground water also absorbs methane, hydrogen sulfide, and carbon dioxide, all of which are gases resulting from anaerobic decomposition
# TABLE 2-1

**FTU POTABLE WATER QUALITY CHARACTERISTICS**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Raw Water</th>
<th>Public Health Standards (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Hardness, as Ca CO₃</td>
<td>132-152 ppm</td>
<td>N.A.</td>
</tr>
<tr>
<td>Calcium Hardness, as Ca CO₃</td>
<td>104-134 ppm</td>
<td>N.A.</td>
</tr>
<tr>
<td>Alkalinity, as Ca CO₃</td>
<td>136-150 ppm</td>
<td>N.A.</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>4- 14 ppm</td>
<td>N.A.</td>
</tr>
<tr>
<td>Phosphate</td>
<td>0.4- 4 ppm</td>
<td>N.A.</td>
</tr>
<tr>
<td>Total Solids</td>
<td>145-168 ppm</td>
<td>Less than 500 ppm</td>
</tr>
<tr>
<td>Fixed Solids</td>
<td>81-135 ppm</td>
<td>N.A.</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>6.0 ppm</td>
<td>N.A.</td>
</tr>
<tr>
<td>Fluorides</td>
<td>0.27-0.4 ppm</td>
<td>Less than 1.0 ppm</td>
</tr>
<tr>
<td>Chlorides</td>
<td>15- 26 ppm</td>
<td>Less than 250 ppm</td>
</tr>
<tr>
<td>Sulphate</td>
<td>10- 12 ppm</td>
<td>Less than 250 ppm</td>
</tr>
<tr>
<td>Iron</td>
<td>0.10-0.29 ppm</td>
<td>Less than 0.3 ppm</td>
</tr>
<tr>
<td>Turbidity</td>
<td>6-8 JTU</td>
<td>Less than 5 JTU</td>
</tr>
<tr>
<td>pH</td>
<td>7.6-7.8 (units)</td>
<td>N.A.</td>
</tr>
<tr>
<td>Hydrogen Sulfide</td>
<td>.3 ppm</td>
<td>N.A.</td>
</tr>
</tbody>
</table>
which accumulate in the ground when plants die, crop stubble rots, leaves fall and organic wastes are destroyed by bacteria, molds or other micro-organisms (8).

In summary, the raw water is a good source of drinking water. It has a medium hardness level and is all bicarbonate hardness. The only treatment performed is aeration to remove the hydrogen sulfide and carbon dioxide, improve odor, and increase the dissolved oxygen level, plus chlorination to disinfect the water and oxidize foreign materials.

2.4 MIS POTABLE WATER ANALYSES

Graphical and tabulated information of the important factors related to the consumption, production and treatment of potable water at FTU is presented in Table C1 and Figure C1 through C9 of Appendix C. Figures C1 through C9 are plots of various water parameters as related to time. The relationships of water parameters to population and other parameters are discussed in Chapter IV.

Table C1 is the output of the MIS Dump Program. This output consists of a categorized readout of the accumulated data for the water related factors which were included in this analysis.

2.4.1 WATER TREATED

Average water treated and consequently consumed over the period of January 1969 through December 1971 is illustrated in Figure C1. From this figure it is evident that the maximum of the monthly average usage occurs in May and June of each year when irrigation is at a peak. The maximum water produced was 22.3 million gallons in the month of
May 1971. This production is equivalent to 738 thousand gallons per day or approximately 510 gallons per minute. The Trend Line indicates a steady increase of 0.294 million gallons per month. The maximum values are increasing at a higher rate as can be seen by drawing a straight line through the peak values of the curve. The slope of the peak value line is approximately 5.68 million gallons per year as compared to 3.53 MG per year increase in the average monthly consumption. By extending the Trend line or using the Trend Equation it is possible to forecast future potable water demand. The projected (Trend line) water requirement for January 1974 is 29.32 million gallons per month. The maximum value for this year is projected to be 37.5 million gallons per month. This value is equal to an average value of 838 gpm. A velocity in the 10-inch cast iron main of 3.25 feet per second and a loss of head of 4.5 feet per 1000 feet will occur under these projected conditions. These values were obtained using the Hazen Williams Nomograph with C=120.

2.4.2 AVERAGE DAILY WATER CONSUMPTION

The information contained in Figure C2 is essentially the same as discussed in the paragraph 2.4.1 except that the data base has been changed from millions of gallons per month to thousands of gallons per day.

2.4.3 MAXIMUM DAILY WATER CONSUMPTION

The maximum daily flows in thousands of gallons per day (as recorded within the month) are indicated in Figure C3. The Trend Line representing these data follows the equation B=408 + 15.9 T.
The maximum maximum daily water usage as indicated in Figure C3 occurs in May and June with minimum maximum daily requirements occurring in late summer or early fall. The exception to this is the reduced requirement of December 1971. It is understandable that the peak demands occur during May since this is the month of high irrigation requirements and full enrollment.

The three yearly peaks of the maximum daily flow appears to follow a straight line which increase more rapidly than does the plot of the Trend equation. The equation for a continuation of the peak curve would approximate \( B = 1320 + 24.2 \, T \) where \( T \) is months in the future from January 1972, and \( B \) is thousands of gallons per day. Using this equation the forecasted value for peak daily requirements in January 1974 would be 1,930 thousand gallons per day. This is equivalent to 1,340 gpm, a velocity in the 10-inch line of 5.5 feet per second and a loss of head of 13 feet per 1000 feet. This peak is greater than the 1200 GPM lift pump capacity and indicates a trend towards system overload within two years. These values were found for the above flow using a Hazen Williams Nomograph of \( C=120 \). This value would exceed the installed lift pump capacity and would require the continuous use of all the well pumps.

From the pump demand charts, it also appears that the maximum hourly rates will approximately double the daily rate and thus exceed the design capacity in the next two years. Automatic, remote or manual valving could be used during periods of peak demand to reduce or eliminate irrigation until the demand subsides. Raw water irrigation could also be provided, however, a cost benefit analysis should be made to
determine the most economical method to meet the forecasted demands.

2.4.4 Figure C4, MINIMUM DAILY WATER CONSUMED

The Trend Line of Figure C4 illustrates that the minimum daily requirements for water have been increasing at a rate of 8.5 thousand gallons per month or 102 TGPD per year. The equation of this line is \( B = 137.1 + 0.45 T \).

The minimum of the minimum daily rate over the three year period under study is 19 thousand gallons per day. This occurred in August 1969. The maximum of the minimum daily usage occurred in April of 1971. This value was 496 thousand gallons per day. The only unusual values associated with this plot occur in November and December 1971 when unusually low readings of 250 and 196 thousand gallons per day were recorded respectively. The November reading occurred during the Thanksgiving Holidays and the December reading during the Christmas Holidays when on-campus population was at a minimum.

2.4.5 CHLORINE USED FOR WATER TREATMENT

It can be seen that water treated (Figures C1 and C2) and the monthly chlorine requirements (Figure C9) are closely related. From the Trend equations it can be determined that 719 pounds of chlorine are used for 18.8 million gallons of water per month or approximately 38 pounds of chlorine are used for every million gallons of water. This chlorine dosage is equivalent to 4.5 ppm and results in a mean chlorine residual 1.4 ppm. The chlorine usage for the months
of December 1971 and November 1971 show only a slight decrease and are essentially on the Trend Line, whereas water used for these two months indicate a heavier decline.

2.4.6 RESIDUAL CHLORINE (ppm)

Residual chlorine (Figure C6) appears to follow a narrow band probability curve with a tendency toward reduced residual with increasing time. The mean of the chlorine residual data is 1.40 and it has a standard deviation of 0.25. All data values except the value for March 1969 fall within the range of .90 to 1.90. It can be seen that the Trend Line is almost parallel to the time axis. There is a probability of 95.4% that the measured residual chlorine will fall within the range of .90 to 1.90. The mean value of 1.4 meets the residual chlorine requirements for potable water and assures complete disinfection of the water. Bacteriological samples taken in accordance with Public Health Standards (9) confirm the effectiveness of the chlorination.

2.4.7 WATER CONSUMPTION

A comparison of Figure C7 and Figure C9 illustrates that as population increases the per capita daily consumption decreases. Water consumption shows a decrease from 186 gallons per capita per day in January 1969 to 112 GPCD in December 1971. This is due to the fact that irrigation and facilities air conditioning water requirements are more dependent upon climatic conditions than on population. Thus as the population increases with these loads remaining almost
fixed (not affected by population) it can be seen that the per capita demand will decrease as indicated.

Average air conditioning requirements are approximately equal to 1500 gallons per hour or 36,000 gallons per day. Irrigation requirements are estimated to average approximately 150,000 gallons per day. This is equivalent to 3,000 gallons per acre of irrigated land per day.

2.4.8 STUDENT AND TOTAL POPULATION

A population growth rate equivalent to a 117 personnel per month or 1400 per year has been experienced by FTU during the period of this study. The population figures used in this study which are charted in Figures C8 and C9, student population and total population, respectively, were obtained from the historical records of the Registrar's Office. The two curves are closely related. The only difference between them is that the FTU Faculty and Staff are included in the total population.

Populations predicted for December 1973 using the Trend Lines are 7316 students and 8394 total population. From the figures it can be seen that approximately 600 capita should be added to attain the peak population which occurs during the fall quarter and extends through December.

2.5 WATER COSTS

A very important operational performance parameter of water production and distribution is the cost per 1000 gallons. To arrive at the cost it is necessary to include all costs (capital and
operational) and to relate these costs to a common cost per 1000 gallon basis. Cost values are approximate. Operating costs were established from estimates by the operating personnel. Capital costs are mostly actual costs as provided by the Planning Office where these costs could be separated from other non-related contracts and estimated where it was not possible to segregate the specific capital cost. A life of 25 years is assumed for the capital equipment with a salvage value at the end of the 25 years equal to 20 percent of the initial investment and interest rates of six percent per annum.

Capital Costs: Initial Worth

<table>
<thead>
<tr>
<th>Description</th>
<th>Initial Worth</th>
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</thead>
<tbody>
<tr>
<td>Water Mains, Wells, Tanks</td>
<td>$133,200.00</td>
</tr>
<tr>
<td>Foundations</td>
<td>15,000.00</td>
</tr>
<tr>
<td>Lift Pumps</td>
<td>2,400.00</td>
</tr>
<tr>
<td>Aeration Unit &amp; Chlorinator</td>
<td>30,600.00</td>
</tr>
<tr>
<td><strong>Total Capital Costs</strong></td>
<td><strong>$181,200.00</strong></td>
</tr>
<tr>
<td>Salvage Value ([$36,240.00])</td>
<td>8,444.00</td>
</tr>
<tr>
<td><strong>Net Initial Capital Costs</strong></td>
<td><strong>$172,756.00</strong></td>
</tr>
</tbody>
</table>

Monthly Capital Recovery Costs

- 6 Percent Interest: $1,126.00

Monthly Costs:

- Labor 80 man hrs/wk at 4.25 per man hour: $1,470.00 per month
- Chemical Costs: 167.00 per month
- Maintenance Costs: 150.00 per month
- Electrical Power Costs: 864.00 per month
- Capital Recovery Costs: 1,126.00 per month

**Total Monthly Costs**: $3,777.00
Monthly Water Production 18.97 million gallons

Cost per 1000 gallons $0.199

This cost is essentially equal to the minimum price of $0.20 per 1000 gallons for which the water could be obtained commercially (10).
CHAPTER III

WASTEWATER ANALYSES

3.1 INTRODUCTION

This portion of the report describes and analyzes the FTU wastewater treatment system which includes the analyses of fifteen categories of wastewater treatment data.

A three year span of recorded data related to the FTU wastewater treatment operations was used in this analysis. Operations data was obtained primarily from records of the Water and Sewage Plant Section of the Physical Plant Department. Equipment specifications, cost data and related information were obtained from records and personnel of the Physical Plant Department.

3.2 WASTEWATER COLLECTION

The wastewater collection facilities consist of a complete underground collection system with an 18 inch diameter main and submains sized at 12 inches, 10 inches, eight inches and six inches. Slopes vary throughout the area as a function of topography. The slope on the main 18 inch feeder averages about .0012 ft/ft. There is over a mile of 18 inch underground wastewater (main) sewer piping installed.
Fig. 3-1.--Wastewater Flow Diagram--Gallons Per Minute.
Figure 3-1 is a typical chart of the flow to the sewage treatment plant. Wastewater collected shows separate peaks that result from water consumption between classes which end at ten minutes before the hour and start on the hour.

3.3 TREATMENT PLANT

The treatment plant is designed to aerobically process 0.5 million gallons of effluent per day. The treatment plant consists of a grit chamber, comminutor, wet well, lift station, 63,000 gallon contact tank, two 45,000 gallon clarifiers, a 62,000 gallon digester and a 30,000 gallon digester, a 130,000 gallon reaeration tank, a chlorinator tank and a lagoon (polishing pond). Figure 3-2 is a schematic diagram showing the related process flows and layout of the FTU Wastewater Treatment Plant.

Sewage is received at the grit chamber via the 18 inch sewer main. At this point it is screened and the flow is measured by a flow meter which records in GPM and provides a cumulative flow reading. A comminutor grinds up large items and the wastewater proceeds to the wet well from which a low lift sewage pump station pumps the wastewater to the contact tank. Here the wastewater is aerated and mixed with activated return sludge which results in an effective formation of flocs. This process requires a retention time of only one and a half to three hours (11). The effluent is then processed to a clarifier where separation of suspended solids
<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>63000 GALLON CONTACT TANK</td>
</tr>
<tr>
<td>2</td>
<td>45000 GALLON FINAL CLARIFIERS (a &amp; b)</td>
</tr>
<tr>
<td>3</td>
<td>62000 GALLON DIGESTOR #2</td>
</tr>
<tr>
<td>4</td>
<td>30000 GALLON DIGESTOR #1</td>
</tr>
<tr>
<td>5</td>
<td>130000 GALLON REAERATOR</td>
</tr>
<tr>
<td>6</td>
<td>5000 GALLON CHLORINATOR</td>
</tr>
<tr>
<td>7</td>
<td>POLISHING POND</td>
</tr>
<tr>
<td>8</td>
<td>IRRIGATION PUMP</td>
</tr>
<tr>
<td>9</td>
<td>SLUDGE PUMP</td>
</tr>
<tr>
<td>10</td>
<td>AIR BLOWERS</td>
</tr>
<tr>
<td>11</td>
<td>SEWAGE LIFT PUMPS</td>
</tr>
<tr>
<td>12</td>
<td>WET WELL</td>
</tr>
<tr>
<td>13</td>
<td>CHLORINE SUPPLY</td>
</tr>
<tr>
<td>14</td>
<td>SCREEN AND COMMINUTOR</td>
</tr>
</tbody>
</table>

Fig. 3-2.--FTU Wastewater Treatment Plant.
from a clear supernatent occurs. The sludge from the clarifier is pumped to an aeration tank where it is reaerated and returned as activated sludge to the contact tank and wasted sludge is removed to an aerobic sludge digester for further treatment. The secondary effluent from the clarifiers is chlorinated at the chlorinator tank and pumped into the lagoon for further treatment and to reduce nitrates and phosphates which are presumably utilized by the lagoon plants. It is also spread upon the land by "land spreading techniques" where it is further purified by the plants and percolation through the soil.

The present method of operation does not utilize the large reaeration tank or the number two clarifier. As loads increase it will become necessary to use these to meet the demands of BOD removal.

Since the reaeration tank has a volume of 130,000 gallons which is almost equivalent to the effective daily wastewater flow of 135,000 gallons (average Trend Line value) it appears possible that the system could be semi-automated using the reaeration tank as a holding preaeration tank and treating a uniform flow through the balance of the system as presently configured.

3.4 MIS WASTEWATER AND WASTEWATER TREATMENT ANALYSES

To adequately evaluate the wastewater treatment at FTU, 15 categories of related information were developed from a three year span of recorded data of the FTU wastewater treatment operations.
The wastewater related information categories as output from the MIS are displayed as graphical presentations in Appendix C, Figures C10 through C24 and are discussed below.

3.4.1 AVERAGE QUANTITY OF WASTEWATER PROCESSED

The average quantity of wastewater processed is related to population, fixture leakage, overflow at the swimming pools, cafeteria wastes, operational wastes, and ground water seepage. Figure C10 is a plot of the average monthly wastewater processed in thousands of gallons per day. Wastewater collected increased from 46,600 GPD in 1969 to 132,000 GPD in December 1971. The effect of population can be seen by comparing the general trends of this curve with the total population curve of Figure C9 and the multiple plot, Figure C25. Wastewater has increased by a factor of 307% during the 36 month period while population has increased by 412% during the same period. The total wastewater load is equal to the populations spent water (unused domestic water returned to the sewer) plus operational wastewater and infiltration. There is a continuous flow of approximately 30 gallons per minute from the swimming pool overflow and the cafeteria drain. Prior to and during the 1971 Christmas holidays many leaking fixtures were repaired eliminating an additional continuous wastewater inflow of approximately 30 GPM. Thirty gallons per minute is equivalent to 43,200 gallons per day. This is 32% of the December 1971 Trend Line (effective value) processed wastewater value and approximately equal to the January 1969
value. The Trend Line equation \( B = 76.6 + 5.69 \, T \) can be used to forecast future average daily flows. The minimum average daily flow occurred in September of all three years.

3.4.2 MAXIMUM WASTEWATER FLOW

The maximum wastewater flow in gallons per minute is recorded directly from a meter at the wastewater treatment plant. The maximum value can be used to determine the maximum flow through the mains. Figure C11, a plot of the maximum values, shows that in October, 1971, the flow reached a maximum of 375 gallons per minute. Assuming a minimum velocity for full flow is 2.00 feet per second, a design full flow of 3.8 cubic feet per second or 1690 GPM was calculated for the 18 inch main with the slope equal to the actual slope of .00125 ft/ft and a roughness coefficient of \( n = .013 \). The current average maximum velocity is calculated to be 1.5 feet per second as compared to 2.0 feet per second for full flow, and the average maximum depth is 4.8 inches. (12) Assuming a line is drawn through the last two peak values of Figure C11 parallel to the Trend Line, the equation of this line from December 1971 on would be \( y = 375 + 5.69 \, T \). Letting \( y = 1690 \, \text{GPD} \) (full flow value) and solving for \( T \) yields, \( T = 235 \) months or about 20 years at the present maximum flow growth rate before the 18 inch pipe would attain full flow. This does not allow for infiltration. At the present there is no indication of infiltration into the sewage system. As the system ages and the pipes move, infiltration from ground water could increase to a value of 50,000 GPD per mile of under-
ground pipe which would be approximately 100,000 gallons per day or 70 GPM for the two miles of sewers. This would reduce the time to 19 years before the 18 inch main pipe line would reach full flow. From these calculations it is evident that dense particulate matter could settle from the sewage flow and eventually block the line. The Trend Line maximum flow value increased from 76 GPM in January of 1969 to 275 GPM in December of 1971. This flow is equivalent to approximately 0.4 MGD.

Figure 3-1 is a reproduction of a typical daily flow meter recording which indicates the times of maximum and minimum flows and the cyclic pattern of the water flow. The difference between the maximum and minimum values on this recording is primarily population related flow. The minimum is primarily all operational, infiltration or leakage flow. The maximum flow occurs between 7:00 AM and 5:00 PM and the minimum flow extends from about 1:00 AM to 6:00 AM.

3.4.3 MINIMUM WASTEWATER FLOW

The minimum wastewater flow is an important consideration in wastewater collection system design especially in the distribution mains since too low a flow could result in insufficient or non-cleaning action and eventually plugging the pipes.

In Figure C12 it can be observed that minimum flows of five GPM have prevailed on three occasions and that the minimum has been 30 GPM or lower 28 times in the 36 month period. A 30 GPM flow in the 18 inch main is obviously not sufficient for self-cleaning and conse-
quently settling should occur. This minimum flow rate coupled with a large line, small slope and low maximum flows provide conditions which make it very possible that the 18 inch main could become plugged.

3.4.4 FIVE DAY BOD

The BOD of the raw influent and treated effluent are important considerations in the operation of a wastewater treatment facility since these are the measurements of the input and output load concentrations. Figure C13 and C14 are plots of the five day BOD of the raw influent and the treated effluent respectively.

It can be seen from Figure C13 that the BOD of the influent normally falls within a band width of 100 ppm and 268 ppm. The Trend Line ($B = 158 + 1.97 T$) indicates a gradual increase in BOD from an initial value of 154 ppm to 223 ppm. This increase in BOD can be attributed to increased population and will be discussed in more detail in the regression analysis of Chapter IV.

The BOD of the effluent also shows an increasing trend, ($B = 1.99 + .149 T$), and as indicated in Figure C13. This is understandable since as the raw sewage increases in BOD the effluent will also increase if the plant efficiency remains constant or decreases. The BOD increase as indicated by the Trend Line is from 2.13 ppm to 7.35 ppm.

The minimum BOD of the effluent was 0.2 ppm in February 1969 and a maximum value of 10.6 ppm was reached in October 1971.
3.4.5 BOD REMOVAL EFFICIENCY

BOD removal is one of prime concern of all wastewater treatment facilities. Recent regulations have established that all treatment plants will be required to attain a removal efficiency of 90 percent or better by 1973 (13). The FTU Wastewater treatment plant more than meets these efficiencies. Figure C15 indicates that the overall efficiency of the FTU Wastewater Plant is operating above 95 percent. The percent BOD removal of Figure C15 has a minimum value of 93.5 and a maximum value of 99.8. The Trend Line shows a slight decrease in operating efficiency (Percent BOD removal) with time. This is understandable since as plant loads increase the tendency is toward decreased efficiency. The best fit (Trend) line \(B = 98.4 - 0.056 \cdot T\) indicates the BOD removal decreased from 98.4 percent in January 1969 to 96.3 percent in December 1972.

As loads continue to increase, variations in present operational methods will be required to meet the regulation requirements. The mean efficiency of BOD removal, Figure C15, is 97.28 percent and has a standard deviation of 1.8005. That is, more than 95 percent of the time the percentage of BOD removal is greater than 93.68 percent.

3.4.6 BOD OF THE POND

The Polishing Pond has shown a continually increasing trend of BOD as can be seen in Figure C16 and from the Trend Equation \(B = 4.77 + 0.162 \cdot T\). It can be seen from comparing C16 with Figure C14 that the Trend Line BOD values of the effluent have increased by 345 percent, and the BOD of the Pond has only increased by 220 percent. The plot
of the 36 months of data in Figure C16 represent a standard distribution with a mean of 7.07 ppm and a standard deviation of 3.5 ppm. Seventy-five percent of the values of the plot fall between four and twelve ppm. Excluding 1969 which was a year of low BOD the plot appears to oscillate about a 7.5 ppm mean.

3.4.7 WASTEWATER SOLIDS (ppm)

Wastewater solids are of both a fixed and volatile nature. These solids can be in a suspended or dissolved form. Fixed solids consist of salts, phosphates, nitrates, and other minerals. Volatile solids are primarily organic and undergo biodegradation in the wastewater treatment process. The approximate build-up of dissolved solids through one municipal use may be as high as 250 ppm. (14) Treatment plant effluents, normally contain 20 ppm phosphate and 15 ppm nitrate. (15) The effluent at FTU for the recorded period, July 1971 through December 1971, contained a mean phosphate level of 14.2 ppm and nitrates of 5.7 ppm. It would be expected that the values of these nutrients would be lower than those from the normal municipality since laundry soaps, nitrates, etc. are not as extensively used at the University.

The total solids dissolved and suspended, fixed and volatile, in the raw sewage are plotted in Figure C17. From the Trend Line, \( B = 429 + 5.7 \, T \), of this figure it can be seen that there has been a gradual increase in the total solids of 145 percent over the three year period. This agrees very closely with the BOD increase of
148 percent (Figure C13) over the same period. Since November of 1969 the solids have fluctuated between a minimum of 210 and a maximum of 850 and have a mean value of 552. The solids in the potable water have a mean value (Table 2-1) of approximately 155 ppm thus total solids have increased by an average value of approximately 400 ppm during one pass through the University.

The fixed solids levels have increased from a value of 145 to 244 ppm during the three year period as indicated by the best fit Trend Line of Figure C18. This is an increase of 171 percent which is greater than the total solid percentage increase.

The total solids in the effluent as measured over the span of this study are graphically illustrated in Figure C19. The total solids in the effluent are almost identical to the fixed solids in the influent as can be shown from the equations representing the best fit of Figures C18 and C19, \( B = 142 + 2.82 \cdot T \) and \( B = 140 + 2.93 \cdot T \) respectively. The total solids in the effluent varied from a minimum of 67 to a maximum of 345 ppm. They have a mean of 193.9 ppm and a standard deviation of 62.9 ppm.

The fixed solids in the wastewater effluent over the study period are illustrated in Figure C20. This figure indicates that the effective fixed solids have increased from a value of 112 mg/l to 211 mg/l which is an increase of 182 percent and consistent with the previously described solids change rates. By comparing the Trend Line of Figure C20 with that of Figure C18 it is evident that there has been an almost constant reduction of fixed solids during
the treatment process. In January 1969 the reduced fixed solids value was 30.5 ppm, in December 1971, this value was 33.3 ppm. This could happen due to changes in bicarbonate alkalinity between influent and effluent of the plant as a result of biological treatment.

3.4.8 DISSOLVED OXYGEN

The dissolved oxygen of the raw wastewater as it arrives at the wastewater treatment plant has decreased from an initial value of 1.73 ppm to 1.21 ppm during the 36 month period as indicated by the Trend Line of Figure C21, \( B = 1.75 - 0.015 T \). These values are consistent with the increased BOD of Figure C13 and increased total solids C17 indicating a greater aerobic demand for oxygen as a result of increased BOD during the trip to the treatment plant.

The treatment plant does a good job of reaerating the water as it is processed through the treatment facility, as can be seen from Figure C22. The effluent has been aerated to a dissolved oxygen level having a mean value of 6.66 and a standard deviation of 1.23. This is still below the saturation level of 8.2 at 25°C (77°F) (16).

From the available information it can be seen that the dissolved oxygen level of the pond has shown a decline in the effective value of dissolved oxygen of 38 percent as indicated in Figure C23. It is assumed that this reduction is primarily due to the increased BOD of the effluent introduced into the pond which has increased by a factor of 372 percent during the period of this study.
3.4.9 PER CAPITA WASTEWATER COLLECTION

The per capita daily utilization of water which when spent has been returned through the wastewater system has decreased from 30.0 gallons per capita per day to 25.3 gallons per capita per day as indicated by the Trend Line, \( B = 30.0 - 0.13 T \), of Figure C24. The plot is cyclic and very consistent in the monthly occurrence of the maximum and minimum values. The maximum values occur during the hot summer months of July, August and September and the minimum values are prevalent in October, November and December. In addition to the climatic and operational related requirements associated with these periods are also the times of minimum and maximum annual student populations respectively. The values plotted on this curve were obtained by dividing the average wastewater collected for a three month period (quarter) by the student population for this quarter. The mean in gallons per capita of wastewater collected is 27.57 and has a standard deviation of 7.99.

3.4.10 MULTIPLE PARAMETER PLOTS

Figures C25, C26 and C27 are multiple plots of three parameters per curve as related to the same time axis. The A, B, and C values of the plots correspond to the respective minimum, median and maximum values indicated on the plot. From these plots a visual indication of the interrelationships is obtainable. A more analytical approach is used in the regression analysis of Part IV.
3.5 WASTEWATER TREATMENT COSTS

Initially it was not planned for FTU to have a wastewater treatment plant. Generated wastewater was to be piped to a proposed treatment plant to be located about a mile north of the FTU campus. This plant did not materialize and thus it became necessary for FTU to provide its own treatment facilities. These facilities were installed for an initial capital expenditure of $353,049.00. Values used in this analysis were obtained from Personnel of the Physical Plant Department.

Since wastewater treatment costs are an important part of good operations, the following cost evaluation has been prepared. It is assumed that the plant will have an effective life of 25 years (17) with a salvage value of 20 percent of the initial investment.

Capital Recovery Costs ....................... 2,194.00 per month (6 percent Interest)
*Operating Labor 200 hrs/week.................. 3,660.00 per month (three shift continuous + lab)
Maintenance costs............................. 500.00 per month
Chemicals........................................ 125.00 per month
Power............................................. 252.00 per month

Total Monthly Costs........... $6,731.00
Wastewater Treated........... 135,000 gallons per day
4.05 million gallons per month (MGD)

*Present Cost per 1000 gallons treated........ $1.496

*These figures do not allow for the non water treatment work (other activities) performed by these personnel.
Full capacity costs per 1000 gallons treated would be $0.448 which is equal to $6,731.00 divided by the 15,000,000 gallons per month rating of the plant. The present cost is larger than that of a large volume municipal plant which processes over five MGD or up to 100 MGD. It should be noted that although continuous (24 hour, seven day) manning is provided at the plant that the personnel are quite often engaged in other activities such as building pump houses, installing pipe lines, maintenance of facilities, etc., and consequently, the estimated cost of 1.496 per 1000 gallons is high. The rated capacity costs of $0.448 per 1000 gallons is more reasonable and compares favorably with most municipalities.

It appears possible to semi-automate the plant using the 130,000 gallon aeration tank as a holding tank to regulate and provide uniform flow rates and adjusting second, third and weekend shift flow rates to a uniform level. The large aeration tank would contain inflow fluctuations and act as a system holding tank where aeration and consequently biodegradation would take place. From an operation of this type much valuable information could be obtained towards improved treatment facility operations and automation techniques. This would most likely reduce the operating costs and allow the operating personnel to devote more effort to facility improvements, preventive maintenance, etc.
CHAPTER IV

REGRESSION ANALYSES OF RELATED PARAMETERS

4.1 INTRODUCTION

There are many interesting relationships between the parameters of water and wastewater and the total population served. Dependent variables such as water consumption, wastewater, five day BOD, and total solids were compared to the independent variable, population, and a best fit straight line equation was developed by the computer, using the least squares technique. Correlation factors were also calculated for the related regression analysis. The equation used for this calculation is (18)

\[
\text{Linear Correlation} = r = \frac{\Sigma xy}{\left(\Sigma x^2\right)^{\frac{1}{2}} \left(\Sigma y^2\right)^{\frac{1}{2}}}
\]

\[x = X - \bar{X} \text{ where } X = \text{DATUM Value}\]
\[y = Y - \bar{Y} \text{ where } Y = \text{Corresponding DATUM Value}\]

The correlation factor is used to determine if the correlations between the independent and dependent variable is significant and is tested as follows:

If, \[-\frac{2.58}{(n-1)^{\frac{1}{2}}} > r > \frac{2.58}{(n-1)^{\frac{1}{2}}}\]

then it can be said with a probability of 99 percent that the correlation is significant. Correlation factors vary from 0 to ±1. The
best correlation possible is ±1 which means that all points fall on a straight line. If the correlation coefficient is zero, when ef- fectively comparing two regression lines, this would indicate the lines are at right angles (19). The actual linear relationship is a func-
tion of the correlation coefficient squared, i.e., a .80 correlation is only .64 as good as 1.0 correlation.

Table 4.1 is a summary of the most important linear regression analysis equations and linear correlation coefficients of this analysis. Sample readouts are contained in Appendix B, and plots of six selected parameters versus population are included in Figures C28, through C33.

4.1.1 WATER CONSUMPTION VERSUS POPULATION

Average water consumption is related to population as indicated in Figure C28 by the regression equation \( y = 277 + 0.051 \cdot x \) where \( y \) is in thousands of gallons per day and \( x \) is the population. By using this equation it is apparent that \( y = 277 \) TGPD when the population \( x = 0 \) and that the average water increases by 51 gallons per day for each unit increase in population. The correlation coefficient calculated for this relationship is .59 which indicates that there is a proba-
bility greater than 99 percent that a correlation exists. It is assumed that this correlation is also indicative of a good fit.

4.1.2 MAXIMUM WATER CONSUMPTION VERSUS POPULATION

The regression analysis relates maximum water consumption to population as plotted in Figure C29 and by the corresponding regres-


<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Dependent Variable</th>
<th>Linear Regression Equation</th>
<th>Linear Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>Average Water Used (TGPD)</td>
<td>( y = 277 + 0.051(x) )</td>
<td>0.590</td>
</tr>
<tr>
<td>Population</td>
<td>Maximum Water Used (TGPD)</td>
<td>( y = 456 + 0.071(x) )</td>
<td>0.505</td>
</tr>
<tr>
<td>Population</td>
<td>Average Wastewater (TGPD)</td>
<td>( y = 23.35 + 0.019(x) )</td>
<td>0.8599</td>
</tr>
<tr>
<td>Population</td>
<td>Max Wastewater (TGPD)</td>
<td>( y = 82.16 + 0.027(x) )</td>
<td>0.55</td>
</tr>
<tr>
<td>Population</td>
<td>Water Consumption GPCD</td>
<td>( y = 248.6 - 0.028(x) )</td>
<td>-0.813</td>
</tr>
<tr>
<td>Population</td>
<td>Wastewater 5-Day BOD</td>
<td>( y = 119 + 0.020(x) )</td>
<td>0.535</td>
</tr>
<tr>
<td>Population</td>
<td>Effluent 5-Day BOD</td>
<td>( y = 1.1 + 0.010(x) )</td>
<td>0.537</td>
</tr>
<tr>
<td>Population</td>
<td>Wastewater Total Solids</td>
<td>( y = 340 + 0.056(x) )</td>
<td>0.527</td>
</tr>
<tr>
<td>Population</td>
<td>Wastewater Fixed Solids</td>
<td>( y = 144 + 0.014(x) )</td>
<td>0.369</td>
</tr>
<tr>
<td>Avg Water Used (TGPD)</td>
<td>Avg Wastewater (TGPD)</td>
<td>( y = 13.19 + 0.168(x) )</td>
<td>0.656</td>
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<td>Fixed Solids Wastewater</td>
<td>Total Solids Effluent</td>
<td>( y = -5.4 + 1.02(x) )</td>
<td>0.997</td>
</tr>
<tr>
<td>5-Day BOD</td>
<td>Total Solids</td>
<td>( y = 145 + 2.07(x) )</td>
<td>0.72</td>
</tr>
<tr>
<td>5-Day BOD</td>
<td>Suspended Solids</td>
<td>( y = 58.3 + 0.45(x) )</td>
<td>0.362</td>
</tr>
</tbody>
</table>
sion line \( y = 456.3 + 0.071\cdot x \). From this equation it is evident that with zero population, the maximum water requirements are 456 thousands gallons per day and that a maximum of 71 gallons per day is required for each capita served. The 71 GPCD value is equal to 433 thousand gallons per day with a population of 6113 and is 141.5 percent of the average daily requirement. The present maximum requirement, using the regression equation and a population of 6113, is 889 thousand gallons per day. This is equivalent to 617 gpm or approximately 51.5 percent of the rated capacity of 1200 gpm. The linear correlation coefficient for this equation is 0.505.

4.1.3 WASTEWATER VERSUS POPULATION

The average wastewater collected is closely related to population. This is understandable since wastewater is not affected by seasonal variations and operational requirements as water is. From Figure C30 the relationship is quite apparent. The regression analysis indicates that the wastewater \( y \), in thousands of gallons per day is equal to \( 23.35 + 0.019\cdot x \) where \( x \) is the value of the population.

Figure C30 is a plot of the relationship between average wastewater and population and has the regression line superimposed as a function of population. The correlation coefficient of the straight line relationship is .8599.

From this analysis it can be stated that a minimum value of \( y = 23.35 \) thousands of gallons of wastewater would be collected daily when the population is zero and that for every per capita increase in
population an increase of 19 gallons per day of wastewater is collected.

The relationship of maximum wastewater to population is shown in Figure C31. The equation for the regression line of this analysis is \( y = 86.162 + 0.027 \cdot x \). The correlation coefficient is 0.55.

### 4.1.4 RAW WASTEWATER BOD (FIVE DAY) VERSUS POPULATION

The regression equation of Raw Wastewater BOD versus population indicates that the BOD of the wastewater has increased as a function of population. The equation is \( y = 119 + 0.020 \cdot x \) which indicates a minimum BOD of 119 ppm at zero population and an increase of 20 ppm per 1000 persons. Figure C32 is a plot of this relationship. The correlation coefficient between five day BOD and population is 0.535. With a population of 6113 the population load is 114 mg/l and the five day BOD is 233 ppm.

### 4.1.5 WASTEWATER SOLIDS VERSUS POPULATION

The wastewater solids consist of both fixed and volatile solids. The regression equation for this comparison is \( y = 340 + 0.056 \cdot x \) where \( y \) is the total solids and \( x \) is the population. Figure C33 is a plot of wastewater solids as related to population and has the regression line superimposed as a function of population. The linear regression equation for this relationship is \( y = 340 + 0.056 \cdot x \) and has a linear correlation coefficient of 0.527.
4.1.6 TOTAL SOLIDS VERSUS FIVE DAY BOD

The linear regression equation of this relationship is
\[ y = 5.4 + 1.02 \cdot x. \]
The correlation coefficient is .841 which is a strong correlation. It may be possible to use this relationship for operational control of the plant since it is faster to measure solids than BOD. This method would have the disadvantage of being much more laborious than measuring BOD and subject to significant errors.

4.1.7 TOTAL SOLIDS OF THE EFFLUENT VERSUS FIXED SOLIDS OF THE WASTEWATER

The linear regression equation of this relationship is
\[ y = -5.4 + 1.02 \cdot x. \] It is not possible to have negative solids in the effluent, however, the negative constant is small in comparison to the mean fixed solids level of 201. This may occur due to the projection of straight line regression analysis. The linear correlation relationship is .997 which indicates that an almost perfect correlation exists. This is understandable since the effluent contains predominantly fixed solids which are equal to the fixed solids of the wastewater minus the almost constant reduction of approximately 30 ppm fixed solids as explained in section 3.4.7.
CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 SUMMARY

Data were collected and analyzed for a period of three years (1969-1971). The information derived from the data describes quantities and qualities of water and wastewater important to operational effectiveness. These data were analyzed using a management information system (MIS). The analysis provided such information as future trends, plots of single and multiple system parameters as they relate to time, regression analysis of independent and dependent variables, tables of data and time specified data outputs. This useful information provides: (1) a means for forecasting future operational requirements for such items as water, chlorine, sewage treatment; (2) a visual readout of maximum loads, cycling conditions, minimums, and other visual indicators from which improved operational and treatment techniques can be formulated such as irrigation programs and system automation; (3) a comparison of present capacity to rated capacity; (4) a basis for computing operating costs; (5) chemical feed requirements; (6) effects of population on consumption rates and production rates; (7) an effective visual readout of performance efficiencies such as percent BOD removal; (8) BOD load and concentration changes; (9) a basis for determining why some system parameters behave as they do such as the BOD increase within the polishing pond, BOD increase
of the effluent, and (10) variations in statistical information related to changing or fluctuating inputs.

5.2 CONCLUSIONS

Some of the most important conclusions that were derived as a result of this study are delineated below. Details pertaining to these conclusions are contained in the body of the report.

1. The MIS computer program, used to analyze operational data of the FTU water and wastewater systems, proved to be an effective method for evaluating future requirements and adequacy of current water and wastewater systems.

2. The FTU water system is characterized by:
   A. A good source of water of moderate hardness and slightly alkaline. The alkalinity is all bicarbonate.
   B. The water system capacity is limited to the 1200 GPM (72,000 gallons per hour) capacity of the lift pumps plus the 200,000 gallon elevated reserve tank. A maximum daily requirement of 1,164,000 gallons per day or 820 gpm has already been experienced. Based on the maximum daily requirements which increases at a rate of 15,900 gallons/month, the system capacity (both pumps running continually) will be reached by the end of 1975.
C. Water consumption in gallons per capita per day decreases with increasing population. The monthly average water treated varied between 186 GPCD in January, 1969 and 112 GPCD in December, 1971.

D. The average three year chlorine dosage of potable water is 30 pounds per million gallons or 3.6 mg/1. The mean chlorine residual is 1.4 mg/1 and there is a calculated demand of 2.2 mg/1.

E. The average water consumption increases with time at a rate of 319 gallons per day. In the year 1980 it is expected to reach 851,600 gallons per month or 28,290 gallons per day.

3. A steady increase in student population of approximately 1,260 students per year and a total population increase of approximately 1,400 persons per year has been established for the period of study.

4. The FTU wastewater system is characterized by:

A. The flow rate through the 18 inch sewer main is insufficient for self-cleaning and it is possible that blockage will occur if remedial action is not taken. This line will not reach full flow for approximately 20 years.

B. The wastewater treatment plant is presently operating below its rated capacity of 500,000 gallons per day.
The maximum monthly average flow is 141,000 gallons per day. However, peak flows of 375 gpm have been recorded which, if continuous, would be equal to 540,000 gallons per day which exceeds the rating of the plant.

C. The operation of the wastewater systems at FTU is maintained at a 97.3 percent five day BOD removal with a standard deviation of 1.3 percent which exceeds the 90 percent level required by Florida Department of Pollution Control.

D. The five day BOD in the influent increases with increasing population.

E. The monthly average wastewater collected varied between 30 and 25.3 GPCD over the study period.

5. The ratio between wastewater collected and water treated varied between 16 percent and 22.5 percent during the period of study.

6. Several important dependent relationships exist between some of the parameters and between parameters and population. Most notable of these are:

A. There is a strong straight line correlation between population and average wastewater. The regression equation is \( y = 23.35 + 0.019 \cdot x \) and the correlation coefficient is 0.8599.
B. The regression equation of total solids in the effluent as a function of fixed solids in the wastewater is \( y = -5.4 + 1.02 \cdot x \) and has a correlation coefficient of .997.

5.3 **RECOMMENDATIONS**

It is recommended that: (1) A Management Information System be used to provide operating management with a continuing monthly or quarterly information report, similar to what has been developed here; (2) The Management Information System be increased in scope to include electrical, heating, ventilating and air conditioning information; (3) A study be made and consideration given to semi-automation of the sewage treatment facility as a model or state of the art plant; (4) A lift station be installed at the head of the 18 inch main to collect wastewater and to discharge it at a flow and subsequent velocity that would assure self-cleaning of the main; (5) that further studies be made to determine the effectiveness of the pond, nutrient concentrations and effects; the reason for the increased concentration of BOD, etc.; (6) The various trends of increased and decreased performance be utilized in improving the operation of an already efficient system.
LIST OF REFERENCES


10. Water Rates for the City of Maitland, Water Department, Public Works, City of Maitland.

11. Florida State Board of Health, Bureau of Sanitary Engineering Division of Wastewater. No Date. Florida Experience in Small Activated Sludge Plants. Appendix VIII.


13. Florida Department of Pollution Control. Rules of The Department of Pollution Control Supplement#11.Chapter 17-3.04.


17. Joint Committee of the American Society of Civil Engineers and Water Pollution Control Federation. 1969. Sewage Treatment Plant Design. p. 3.


DIMENSION FTUWW(25,36)
DEFINE FILE 200(8,320,U,NREC)
NR = 2
NP = 5
READ DATA BASE INTO CORE AREA...
WRITE(NP,1)
1 FORMAT(1H1,' ECHO PRINT OF FTUWW AS READ IN...',//)
DO 2 I=1,25
READ(NR,3) (FTUWW(I,J),J=1,36)
WRITE(NP,4) (FTUWW(I,J),J=1,36)
2 WRITE(NP,4) FORMAT(10F8.2)
3 WRITE(NP,6) FORMAT(1H1,' ECHO PRINT OF FTUWW AS READ FROM DISK...',//)
DO 7 I=1,25
WRITE(NP,4) (FTUWW(I,J),J=1,36)
 CALL EXIT
END

FEATURES SUPPORTED
ICCS

CORE REQUIREMENTS FOR
COMMON 0 VARIABLES 1820 PROGRAM 272

END OF-compilation
// XEC 1
#FILES(200, JENWW)
COMMON FTUWW(15,36), ITTLE(15,30)
DEFINE FILE 200(8,320,U,NREC)
IBLK=5184
IRED=13632
LL=1
LO=6
WRITE(5,300)

300 FORMAT(1HI)
DO 1 I = 1, 15
   READ(2,100) (ITTLE(I,J),J=1,30)
1   WRITE(5,200) (ITTLE(I,J),J=1,30)
WRITE(5,300)
100 FORMAT(30A2)

200 FORMAT(20X,30A2)
WRITE(LL,201)

201 FORMAT(/10X,'THIS IS AN ANALYSIS(MIS) OF THE FTU WATER AND',/10X
1\'WASTE WATER SYSTEMS FOR THE PERIOD JAN 1969 THRU DEC 1971',/10X
210X,'THERE ARE 8 CATEGORIES OF WATER DATA, 15 CATEGORIES OF',/10X
310X\'WASTE WATER DATA AND TWO RELATED POPULATION CATEGORIES.',/10X
410X\'THIS INFORMATION IS DELINEATED BELOW.',/)
WRITE(1,52)

52 FORMAT(/10X,'THE FOLLOWING INFO CATEGORIES ARE AVAILABLE BY ',/10X
1\'YEAR AND MONTH FROM JAN 1969 THRU DEC 1971',/)
   DO 53 I=1,15
      WRITE(5,54) I, (ITTLE(I,J),J=1,30)
54 FORMAT(1X,I2,2X,30A2)
   WRITE(LL,207) IBLK, IRED

207 FORMAT(A1/20X,'1. DUMP-SELECTED LISTINGS OF THE DATA BASE',/20X
120X,'2. TREND-INDICATES TREND OF CATEGORIES',/20X
320X,'3. PLOT-PLOTS CATEGORIES VERSUS TIME',/20X
420X,'4. REGRS-COMPARES VARIABLES AND INDICATES REGRESSION LINE',/20X
520X,'5. STATS-CALCULATES MEAN AND STANDARD DEVIATIONS',/20X
620X,'6. FINISH-TERMINATES MIS PROCESSING',/20X)
   WRITE(LL,208) IBLK, IRED

208 FORMAT(A1/20X,'SELECT AN OPTION...ENTER IN I1 FORMAT',A1//)
   READ(LL,101) N

101 FORMAT(I1)
   IF(N-0) 20,20,19
   IF(N=6) 19,15,20
21 NREC=1
   READ(200,NREC) FTUWW
   GO TO (10,11,12,13,14,15),N
10 CALL DUMP
   GO TO 22
11 CALL TREND
   GO TO 22
12 CALL PLOT
   GO TO 22
13 CALL REGRS
   GO TO 22
14 CALL STATS
   GO TO 22
15 WRITE(5,300)
   WRITE(LL,203)
   WRITE(5,300)
203 FORMAT(/20X, ('***********END OF FTUWW MIS EXERCISE****',/))
301 CALL EXIT
20 CALL(LL,204)
204 FORMAT(5X, 'INVALID OPTION CODE---TRY AGAIN.',/)  
GO TO 2  
END  

UNREFERENCED STATEMENTS  
301  

FEATURES SUPPORTED  
ONE WORD INTEGERS  
10CS  

CORE REQUIREMENTS FOR  
COMMON 1530 VARIABLES 18 PROGRAM 706  

END OF COMPILATION  
// DUP  
*STORE WS UA MONIT  
CART ID 0001 DB ADDR 4010 DB CNT 002D  
// FOR  
** SUBROUTINE DUMP..  
* LIST SOURCE PROGRAM  
* ONE WORD INTEGERS
SUBROUTINE DUMP

COMMON FTUWW(15,36), ITTLE(15,30)
WRITE(1,60)

999 WRITE(1, 10)
10 FORMAT(' ARE YOU REQUESTING DATA FOR ALL YEARS? , / ,
* IF ALL ENTER 1. IF NOT ENTER 0. ')
READ(6, 11)
11 FORMAT(11)
IF(N) 4 1, 12, 13
41 WRITE(1, 40)
GO TO 999
13 WRITE(5, 14)
14 FORMAT('RAW DATA FOLLOWS. ', '/ ')
DO 7 I = 1, 15
7 WRITE(5, 15)( ITTLE(I, J), J = 1, 30), (FTUWW(I, K), K = 1, 36)
WRITE(5, 60)
60 FORMAT(1H1)
GOTO 35
12 WRITE(1, 16)
16 FORMAT(' ENTER MONTH AND YEAR FOR WHICH DATA IS REQUESTED. ' , / ,
1 USE I2, I2 FORMAT; ... I.E... O3 70. ', '/ ')
READ(6, 17) IMNTH, IYEAR
17 FORMAT(12, I2)
K = (IYEAR-69)*12 + IMNTH
IF(1-K) 99, 99, 20
99 IF(36-K) 20, 22, 22
20 WRITE (1, 30)
30 FORMAT(' INVALID YEAR. DATA COVERS 1969-1971. ' , / )
GO TO 12
22 WRITE(5, 14)
DO 3 I = 1, 15
3 WRITE(5, 18)( ITTLE(I, J), J = 1, 30), FTUWW(I, K)
18 FORMAT(1X, 30A2, ' , F8.2)
35 WRITE(1, 36)
36 FORMAT(' IS ADDITIONAL DATA REQUIRED? ', /
* IF YES ENTER 1. IF NO ENTER 0. ')
1 READ(6, 11) I
IF (I) 39, 38, 999
39 WRITE(1, 40)
40 FORMAT(' INVALID ENTRY. ')
GO TO 35
38 RETURN
END

FEATURES SUPPORTED
ONE WORD INTEGERS

CORE REQUIREMENTS FOR DUMP
COMMON 1530 VARIABLES 8 PROGRAM 418

RELATIVE ENTRY POINT ADDRESS IS 00D9 (HEX)

END OF COMPILATION

// DUP

*STORE WS UA DUMP
SUBROUTINE TREND

DIMENSION Y(36),X(36,2),XT(2,36),XTX(2,2),XTY(36),BETA(2)

COMMON FTUWW(15,36),ITLLE(15,30)

M=36
L=36

WRITE(1,101)

101 FORMAT(5X,'ENTER NUMBER OF DATA CATEGORY REQUESTED IN 12 FORMAT')

READ(6,102)M

102 FORMAT(I2)

IF (M.1)103,103,104

104 IF(M.1=15)105,105,103

105 IF(M.1=1)103,103,106

WRITE(1,110)

103 WRITE(1,110)

110 FORMAT(5X,'YOU MUST ENTER A VALUE BETWEEN 2 AND 8')

GO TO 120

WRITE(1,111) (ITTLE(M,J),J=1,30)

111 FORMAT(5X,30A2)

NOTE ...INPUT DATA IS SCALED FROM 1,2,... TO 36

DO 100 I=1,36

X(I,1)=1.0

X(I,2)=I

100 Y(I)=FTUWW(M,I)

N=36
M=2

DO 4 I=1,N

DO 4 J=1,M

4 XT(J,I)=X(I,J)

DO5I=1,M

DO5J=1,M

5 XTX(I,J)=XTX(I,J)+XT(I,K)*X(K,J)

DET = (XTX(1,1)*XTX(2,2))-(XTX(2,1)*XTX(1,2))

A(1,1) = XTX(2,2)/DET

A(1,2) = -XTX(1,2)/DET

A(2,1) = -XTX(2,1)/DET

A(2,2) = XTX(1,1)/DET

DO 17 I=1,2

DO 17 J=1,2

17 XTX(I,J)=A(I,J)

C

************************************************************

N=36

DO6I=1,M

6 XTY(I)=0.0

DO7I=1,M

DO7J=1,N

7 XTY(I)=XTY(I)+XT(I,J)*Y(J)

DO8I=1,M

8 BETA(I)=0.0

DO 999 I=1,M

999 BETA(I)=BETA(I)+XTX(I,J)*XTY(J)

WRITE(1,10) (BETA(I),I=1,M)

10 FORMAT(1X,'EQUATION IS Y = ',E20.5,' + ',E20.5,'*(MONTHS)')

WRITE(1,112)

112 FORMAT(' ENTER 00 TO RETURN TO MONITOR...',/,' TO PREDICT A DATA

VALUE IN THE FUTURE, ENTER THE NUMBER OF MONTHS IN THE FUTURE')
SUBROUTINE TREND

2',/,'IN I2 FORMAT..IE..07..',/)
READ(6,502)IMO
502 FORMAT(I2)
X1=IMO+36
VALUE = BETA(1) + BETA(2)*X1
WRITE(1,500) IMO,VALUE
500 FORMAT('PREDICTED VALUE OF DATA ITEM FOR',I2,'IS' ,E20.5,/
WRITE(1,601)
601 FORMAT(1X,'IF YOU WANT THE EQUATION OF ANOTHER INFORMATION',/,,1X,
1CATEGORY, ENTER 01 IN I2 FORMAT. IF NOT ENTER 00.',/)
READ(6,602)NM
602 FORMAT(I2)
IF (NM)103,603,900
603 CONTINUE
RETURN
END

FEATURES SUPPORTED
ONE WORD INTEGERS

CORE REQUIREMENTS FOR TREND
COMMON 1530 VARIABLES 474 PROGRAM 836

RELATIVE ENTRY POINT ADDRESS IS 02D6 (HEX)

END OF COMPILATION

// DUP
*STORE WS UA TREND
CART ID 0001 DB ADDR 4E1F DB CNT 0036

// FOR
*ONE WORD INTEGERS
** SUBROUTINE UPDAT... JENSEN
*LIST ALL
SUBROUTINE PLOT

DIMENSION X(36), Y(36), Y2(36), Y3(36), Y4(36), Y5(36)
COMMON FUWW(15,36),ittle(15,30)

WRITE(1,12)
1 INCLUDE ' ENTER DATA CATEGORY NUMBER OF INFORMATION YOU WISH TO
2 HAVE PLOTTED IN 12 FORMAT',/
READ(6,3)NCAT

3 FORMAT(12)
WRITE(1,31)
31 FORMAT(1X,' ENTER Y INTERCEPT AND SLOPE FROM TREND OR REGRESSION',
1/ , ' EQUATION IN F 8.3 FORMAT....IE..0273.000,0000.091',/
READ(6,32)A,B

32 FORMAT(F8.3,F8.3)
DO 20 I=1,36
J=I
X(I)=-174+174*(I)
Y(I)=FUWW(NCAT,J)
Y2(I)=A+B*J
Y3(I)=0.0
Y4(I)=0.0
Y5(I)=0.0
20 CONTINUE
K=1.
M=36
CALL ZPLOT(M,Y,Y2,Y3,Y4,Y5,X,K)
WRITE(5,30) (ittle(NCAT,L),L=1,30),A,B
30 FORMAT(//////,' THE PLOT ABOVE IS OF ','30A2,' AND B=',
1F8.3,'+',F8.3,'(X)',/
WRITE(1,10)
10 FORMAT(1X,'IF YOU WANT ANOTHER PLOT, ENTER 01 IN 12 FORMAT,
1 IF NOT, ENTER 00',)
READ(6,8)N
8 FORMAT(12)
IF(N)21,21,6
21 RETURN
END

FEATURES SUPPORTED
ONE WORD INTEGERS

CORE REQUIREMENTS FOR PLOT
COMMON 1530 VARIABLES 448 PROGRAM 354

RELATIVE ENTRY POINT ADDRESS IS 027E (HEX)

END OF COMPILATION

/ D UP

STORE WS UA PLOT
ART ID 0001 DB ADDR 4D58 DB CNT 0017

/ FOR

LIST SOURCE PROGRAM
ONE WORD INTEGERS
* SUBROUTINE ZPLOT
SUBROUTINE ZPLOT (M, AA, BB, CC, DD, EE, ZZ, KK)

DIMENSION X(100)
DIMENSION AA(2), BB(2), CC(2), DD(2), EE(2), ZZ(2)

DATA BL, A, B, C, D, E, DOT, DASH/' ', 'A', 'B', 'C', 'D', 'E', 'I', 'I' ./

FOLLOWING CARD SETS FORTRAN LOGICAL UNIT NUMBER FOR PRINTER...
J=5
AMIN = AA(1)
AMAX = AA(1)
BMAX = BB(1)
BMIN = BB(1)
CMAX = CC(1)
CMIN = CC(1)
DMAX = DD(1)
DMIN = DD(1)
EMAX = EE(1)
EMIN = EE(1)

DO 555 N=1,100

DO 35 I=1,M

IF (AA(I) - AMAX) 10,11,11

AMAX = AA(I)

10 IF (AA(I) - AMIN) 12,12,13

12 AMIN = AA(I)

13 IF (BB(I) - BMAX) 20,21,21

21 BMAX = BB(I)

20 IF (BB(I) - BMIN) 22,22,23

22 BMIN = BB(I)

23 IF (CC(I) - CMAX) 24,25,25

25 CMAX = CC(I)

24 IF (CC(I) - CMIN) 26,26,27

26 CMIN = CC(I)

27 IF (DD(I) - DMAX) 28,29,29

29 DMAX = DD(I)

28 IF (DD(I) - DMIN) 30,30,31

30 DMIN = DD(I)

31 IF (EE(I) - EMAX) 32,33,33

33 EMAX = EE(I)

32 IF (EE(I) - EMIN) 34,34,35

34 EMIN = EE(I)

35 CONTINUE

AWID = AMAX - AMIN

BWID = AMAX - AMIN

CWID = CMAX - CMIN

DWID = DMAX - DMIN

EWID = EMAX - EMIN

AUNIT = AWID / 100.

BUNIT = AUNIT

CUNIT = CWID / 100.

DUNIT = DWID / 100.

EUNIT = EWID / 100.

AMID = AWID / 2. + AMIN

BMID = BWID / 2. + BMIN

CMID = CWID / 2. + CMIN

DMID = DWID / 2. + DMIN

EMID = EWID / 2. + EMIN

NK = 1

DO 1000 L = 1,M

Z = L
SUBROUTINE ZPLOT

IF ((L/10) - (Z/10.)) 40, 41, 40

41 DO 223 LL = 1, 100

223 X(LL) = DASH

40 X(1) = DOT
X(25) = DOT
X(50) = DOT
X(75) = DOT
X(100) = DOT
IF (AUNIT) 90, 93, 90

90 KA = (AA(L) - AMIN) / AUNIT
IF (KA) 91, 91, 92

91 KA = 1

92 X(KA) = A

93 IF (BUNIT) 94, 97, 94

94 KB=(BB(L)-AMIN)/AUNIT
IF (KB) 95, 95, 96

95 KB = 1

96 X(KB) = B

97 IF (CUNIT) 98, 101, 98

98 KC = (CC(L) - CMIN) / CUNIT
IF (KC) 99, 99, 100

99 KC = 1

100 X(KC) = C

101 IF (DUNIT) 102, 105, 102

102 KD = (DD(L) - DMIN) / DUNIT
IF (KD) 103, 103, 104

103 KD = 1

104 X(KD) = D

105 IF (EUNIT) 106, 109, 106

106 KE = (EE(L) - EMIN) / EUNIT
IF (KE) 107, 107, 108

107 KE = 1

108 X(KE) = E

109 IF (NK - 1) 151, 152, 151

152 WRITE(J,111) A, AMIN, AMID, AMAX, B, BMIN, BMID, BMAX, C, CMIN, CMID,
CMAX, D, DMIN, DMID, DMAX, E, EMIN, EMID, EMAX

111 FORMAT ('1', T12, 'MINIMUM', T61, 'MEDIAN', T111, 'MAXIMUM',/
1 T2, 'SYMBOL', T12, 'VALUE', T61, 'VALUE', T111, 'VALUE',/
2 IX, 5(T5, I1A, T10, 1E12.5, T59, 1E12.5, T109, 1E12.5, /, 1X),
3 T 12, '++', T61, '+', T111, '+', '/', T12, 100(' -1'))

151 IF (KK) 155, 156, 155

156 WRITE (J,116) L,(X(MM),MM=1,100)

116 FORMAT (T5, I5, T12, 100A1)
GO TO 77

155 WRITE(J,117) ZZ(L), (X(MM), MM=1, 100)

117 FORMAT (T2, F8.2, T12, 100A1)

77 IF (((L/10) - (Z/10.)) 45, 46, 45

46 DO 47 KL = 1, 100

47 X(KL) = BL

45 IF(NK - 50) 153, 154, 154

154 NK = 0

153 NK = NK + 1
IF (AUNIT) 400, 401, 400

400 X(KA) = BL

401 IF (BUNIT) 402, 403, 402

402 X(KB) = BL

403 IF (CUNIT) 404, 405, 404

404 X(KC) = BL
SUBROUTINE ZPLOT

405 IF (DUNIT) 406, 407, 406
406 X(KD) = BL
407 IF (EUNIT) 408, 1000, 408
408 X(KE) = BL
1000 CONTINUE
   RETURN
END

FEATURES SUPPORTED
ONE WORD INTEGERS

CORE REQUIREMENTS FOR ZPLOT
COMMON 0 VARIABLES 290 PROGRAM 1068

RELATIVE ENTRY POINT ADDRESS IS 0180 (HEX)

END OF COMPILATION

// DUP

*STORE  WS  UA  ZPLOT
CART ID 0001 DB ADDR 406F DB CNT 004E

// FOR
** SUBROUTINE REGRS..
* LIST SOURCE PROGRAM
* ONE WORD INTEGERS
SUBROUTINE REGRS

DIMENSION Y(36), X(36,2), XT(2,36), XTX(2,2), XTY(36), BETA(2)
DIMENSION A(2,2), Z(36)
COMMON FTUWW(15,36), ITTLE(15,30)

900 WRITE(1,101)
101 FORMAT(5X, 'ENTER NUMBER OF DATA CATEGORIES REQUESTED IN 112,12 FORMAT')
120 READ(6,102) L1, M1
102 FORMAT(I2, I2)
105 IF(M1-15) 105, 105, 103
105 IF(M1-1) 103, 103, 114
114 IF(L1-1) 115, 115, 103
115 IF(L1-1) 103, 103, 106
103 WRITE(1,110)
110 FORMAT(5X, 'YOU MUST ENTER VALUES BETWEEN 2 AND 15')
GO TO 120
106 WRITE(1,111) (ITTLE(M1,J), J=1,30), (ITTLE(L1,K), K=1,30)
111 FORMAT(9X, 30A2, 2X, 'VERSUS', /, 9X, 30A2)
NOTE ... INPUT DATA IS SCALLED FROM 1,2,... TO 36

DO 100 I = 1,36
X(I,1) = 1.0
X(I,2) = FTUWW(L1, I)
100 Y(I) = FTUWW(M1, I)
N=36
M=2
DO 4 I=1,N
DO 4 J=1,M
4 XT(J,I) = X(I,J)
D05I = 1, M
D05J = 1, M
XTX(I,J) = 0.0
D05K = 1, N
5 XTX(I,J) = XTX(I,J) + XT(I,K)*X(K,J)
DET = (XTX(1,1)*XTX(2,2))-(XTX(2,1)*XTX(1,2))
A(1,1) = XTX(2,2)/DET
A(1,2) = -XTX(1,2)/DET
A(2,1) = -XTX(2,1)/DET
A(2,2) = XTX(1,1)/DET
DO 17 I = 1,2
D017 J = 1,2
17 XTX(I,J) = A(I,J)
C
***************************************************************************************
N=36
D06I = 1, M
6 XTY(I) = 0.0
D07I = 1, M
D07J = 1, N
7 XTY(I) = XTY(I) + XT(I,J)*Y(J)
D08I = 1, M
8 BETA(I) = 0.0
DO 999 I=1, M
D0 999 J=1, M
999 BETA(I) = BETA(I) + XTX(I,J)*XTY(J)
ZSUM=0.0
RSUM=0.0
QSUM=0.0
YSUM=0.0
DO 888 I=1,36
Z(I)=FTUWW(L1,I)
Y(I)=FTUWW(M1,I)
ZSUM=ZSUM+Z(I)
YSUM=YSUM+Y(I)
888 CONTINUE
YBAR=YSUM/36.
ZBAR=ZSUM/36.
DO777 I=1,36
Q=(Z(I)-ZBAR)
P=(Y(I)-YBAR)
QSUM=Q**2+QSUM
PSUM=P**2+PSUM
RSUM=RSUM+Q**P
777 CONTINUE
CF=RSUM/SQRT((QSUM)*(PSUM))
WRITE(1,10)(BETA(I),I=1,M),CF
10 FORMAT(1X,'EQUATION IS Y= ',E20.5,'+',E20.5,'*(X)',/,1X,'
1CORRELATION FACTOR = ',E20.5,/)
SUBROUTINE STATS

REAL MEAN
COMMON FTUWW(15,36), ITTLE(15,30)

4 WRITE(1,2)
2 FORMAT(1X,'ENTER DATA CATEGORY NUMBER BETWEEN 02 AND 25 OF',/
1 'INFORMATION FOR WHICH YOU DESIRE TO HAVE THE MEAN AND',/
2 'STANDARD DEVIATION CALCULATED. ENTER IN 12 FORMAT...IE..12...',/
READ(6,3)NCAT
3 FORMAT (12)
IF(NCAT-2)11,5,5
5 IF(15-NCAT)11,7,7
11 WRITE(1,6)
6 FORMAT('YOU SELECTED A WRONG CATEGORY, TRY AGAIN.',/
GO TO 4
7 SUM=0.0
DO 20 I=1,36
SUM=SUM+FTUWW(NCAT,I)
20 CONTINUE
MEAN=SUM/36.
WRITE (1,22)(ITTLE(NCAT,J),J=1,30),MEAN
22 FORMAT (4X,'A2',4X,'I',F8.2,/) CONTINUE
XSQ=0.
DO 21 I=1,36
XSQ=FTUWW(NCAT,I)**2+XSQ
21 CONTINUE
STDDV=SQRT((XSQ-(SUM*SUM/36))/35)
CONTINUE
WRITE (1,23)(ITTLE(NCAT,J),J=1,30),STDDV
23 FORMAT('THE STANDARD DEVIATION OF ',',30A2,2X,'IS',2X,F10.4,/) WRITE (1,10)
10 FORMAT(1X,'IF YOU WANT THE MEAN AND STANDARD DEVIATION FOR',/
1 'ANOTHER CATEGORY OF INFORMATION, ENTER 01 IN 12 FORMAT',/
2 'IF NOT ENTER 00',/) READ(6,8)N
8 FORMAT(I2)
IF(1-N)11,4,9
9 RETURN
END

FEATURES SUPPORTED
ONE WORD INTEGERS

CORE REQUIREMENTS FOR STATS
COMMON 1530 VARIABLES 18 PROGRAM 430

RELATIVE ENTRY POINT ADDRESS IS 00FB (HEX)

END OF COMPILATION

// DUP

#STORE WS UA STATS
CART ID 0001 DB ADDR 4E03 DB CNT 001C

// FOR
** SUBROUTINE TREND
* LIST. SOURCE PROGRAM
SUBROUTINE UPDAT

COMMON FTUWW(15,36), ITTLE(15,30)

C

FOLLOWING TWO CARDS DEFINE SYSTEM KEYBOARD AND TYPEWRITER...

NK = 1
NT = 6

100 WRITE(NK,1)
1  FORMAT(' ENTER DATA CATEGORY NUMBER IN I2 FORMAT...','/
READ(NT,2) IDATA
IF(1-IDATA)31,51,41
31 IF(15-IDATA)41,51,51
41 WRITE(NK,18)
18 FORMAT(' ERROR...DATA CATEGORIES ARE 01-25 ')
GO TO 100

51 CONTINUE
40 WRITE(NK,3)
3  FORMAT(' ENTER MONTH,YEAR DESIRED IN I2,I2 FORMAT...I.E. 03,69','/
READ (NT,4) IMNTH, IYEAR
4  FORMAT(I2,I2)
J=(IYEAR-69)*12+IMNTH
IF(1-J)17,17,15
17 IF(36-J)15,111,111
15 WRITE(NK,19)
19 FORMAT(' ERROR...DATA IS RESTRICTED TO 1969-1971 ONLY ')
GO TO 40

111 CONTINUE
C

READ DISK FOR DATA ITEM REQUIRED...
NREC = 1
READ(200'NREC) FTUWW
OUT = FTUWW(IDATA,IYEAR)
WRITE(NK,5)(ITTLE(IDATA,K),K=1,30),IMNTH,IYEAR,OUT
5  FORMAT(/,'VALUE OF',30A2,/, 'FOR THE DATE',I2,I2,' IS', F8.2, '/
WRITE(NK,6)
6  FORMAT(' TO REQUEST UPDATE OF LAST VALUE, ENTER 01','/
1   ' TO ACCESS ANOTHER DATA VALUE, ENTER 00','/
2   ' TO RETURN TO MONITOR, ENTER -1', '/
READ(NT,2) IWHAT
2  FORMAT(I2)
IF(IWHAT) 12,100,8
8 WRITE(NK,9)
9  FORMAT(' ENTER NEW VALUE IN F8.2 FORMAT','/
READ(NT,10) VALUE
10 FORMAT(F8.2)
FTUWW(IDATA,IYEAR) = VALUE
C

WRITE THE DISK UPDATE...
NREC = 1
WRITE(200'NREC) FTUWW
GO TO 100
12 RETURN
END

VARIABLE ALLOCATIONS
FTUWW(RC)=7FFE-7BC8 ITTLE(1C)=7BC7-7A06 OUT(R)=0000 VALUE(R)=C
IDATA(I )=0006 IMNTH(I )=0007 IYEAR(I )=0008 J(I )=C
IWHAT(I )=000C

STATEMENT ALLOCATIONS
1  =0018 18 =0031 3 =0045 4 =0063 19 =0066 5 =007F
100 =00F6 31 =0107 41 =010D 51 =0113 40 =0113 17 =012F
1 ARE YOU REQUESTING DATA FOR ALL YEARS?
   IF ALL ENTER 1. IF NOT ENTER 0.
1 IS ADDITIONAL-DATA REQUIRED?
   IF YES ENTER 1. IF NO ENTER 0.
1 ARE YOU REQUESTING DATA FOR ALL YEARS?
   IF ALL ENTER 1. IF NOT ENTER 0.
0 ENTER MONTH AND YEAR FOR WHICH DATA IS REQUESTED.
   USE 12,12 FORMAT,...1.E,...03 70.
1271 IS ADDITIONAL-DATA REQUIRED?
   IF YES ENTER 1. IF NO ENTER 0.
0

1. DUMP-SELECTED LISTINGS OF THE DATA BASE
2. TREND-INDICATES TREND OF CATEGORY
3. PLOT-PLOTS CATEGORY VERSUS TIME
4. REGRS-COMPARES VARIABLES AND INDICATES REGRESSION LINE
5. STATS-CALCULATES MEAN AND STANDARD DEVIATIONS
6. FINISH-TERMINATES M I S PROCESSING.

SELECT AN OPTION...ENTER IN 11 FORMAT.

2 ENTER NUMBER OF DATA CATEGORY REQUESTED IN 12 FORMAT
02 02 WATER-TREATED-MG-PER-MONTH
   EQUATION IS Y = 0.83773E 01 + 0.29424E 00*(MONTHS)
   ENTER 00 TO RETURN TO MONITOR...
   TO PREDICT A DATA VALUE IN THE FUTURE, ENTER THE NUMBER OF MONTHS IN THE FUTURE
   IN 12 FORMAT...1.E...07..
24 PREDICTED VALUE OF DATA ITEM FOR241S 0.26031E 02
   IF YOU WANT THE EQUATION OF ANOTHER INFORMATION
   CATEGORY, ENTER 01 IN 12 FORMAT. IF NOT ENTER 00.
03 ENTER NUMBER OF DATA CATEGORY REQUESTED IN 12 FORMAT
03 03 AVE DAILY WATER USED-TAPP
   EQUATION IS Y = 0.27768E 03 + 0.95724E 01*(MONTHS)
   ENTER 00 TO RETURN TO MONITOR...
   TO PREDICT A DATA VALUE IN THE FUTURE, ENTER THE NUMBER OF MONTHS IN THE FUTURE.
   IN 12 FORMAT...1.E...07..
24 PREDICTED VALUE OF DATA ITEM FOR241S 0.85203E 03
   IF YOU WANT THE EQUATION OF ANOTHER INFORMATION
   CATEGORY, ENTER 01 IN 12 FORMAT. IF NOT ENTER 00.
01 ENTER NUMBER OF DATA CATEGORY REQUESTED IN 12 FORMAT
04 MAX DAILY WATER USED-TGPD
EQUATION IS \( y = 0.40475 \times 10^{-3} + 0.15913 \times 10^{-2} \times \text{MONTHS} \)
ENTER 00 TO RETURN TO MONITOR.
TO PREDICT A DATA VALUE IN THE FUTURE, ENTER THE NUMBER OF MONTHS IN THE FUTURE
IN 12 FORMAT...IE...07..

24 PREDICTED VALUE OF DATA ITEM FOR 241S 0.13628E 04
IF YOU WANT THE EQUATION OF ANOTHER INFORMATION CATEGORY, ENTER 01 IN 12 FORMAT. IF NOT ENTER 00.

01 ENTER NUMBER OF DATA CATEGORY REQUESTED IN 12 FORMAT
05 MIN DAILY WATER USED-TGPD
EQUATION IS \( y = 0.13711 \times 10^{-3} + 0.84546 \times 10^{-2} \times \text{MONTHS} \)
ENTER 00 TO RETURN TO MONITOR.
TO PREDICT A DATA VALUE IN THE FUTURE, ENTER THE NUMBER OF MONTHS IN THE FUTURE
IN 12 FORMAT...IE...07..

24 PREDICTED VALUE OF DATA ITEM FOR 241S 0.64439E 03
IF YOU WANT THE EQUATION OF ANOTHER INFORMATION CATEGORY, ENTER 01 IN 12 FORMAT. IF NOT ENTER 00.

01 ENTER NUMBER OF DATA CATEGORY REQUESTED IN 12 FORMAT
06 LBS-OF-CL2/WATER-MONTHLY
EQUATION IS \( y = 0.12968 \times 10^{-3} + 0.16393 \times 10^{-2} \times \text{MONTHS} \)
ENTER 00 TO RETURN TO MONITOR.
TO PREDICT A DATA VALUE IN THE FUTURE, ENTER THE NUMBER OF MONTHS IN THE FUTURE
IN 12 FORMAT...IE...07..

24 PREDICTED VALUE OF DATA ITEM FOR 241S 0.11133E 04
IF YOU WANT THE EQUATION OF ANOTHER INFORMATION CATEGORY, ENTER 01 IN 12 FORMAT. IF NOT ENTER 00.

01 ENTER NUMBER OF DATA CATEGORY REQUESTED IN 12 FORMAT
07 AVE RESIDUAL CL2-PPM
EQUATION IS \( y = 0.15068 \times 10^{-3} - 0.40475 \times 10^{-2} \times \text{MONTHS} \)
ENTER 00 TO RETURN TO MONITOR.
TO PREDICT A DATA VALUE IN THE FUTURE, ENTER THE NUMBER OF MONTHS IN THE FUTURE
IN 12 FORMAT...IE...07..

24 PREDICTED VALUE OF DATA ITEM FOR 241S 0.12639E 01
IF YOU WANT THE EQUATION OF ANOTHER INFORMATION CATEGORY, ENTER 01 IN 12 FORMAT. IF NOT ENTER 00.

5
EQUATION IS \[ Y = 0.18571E \ 03 + -0.19921E \ 01 \times (M O N T H S) \]

ENTER 00 TO RETURN TO MONITOR...

TO PREDICT A DATA VALUE IN THE FUTURE, ENTER THE NUMBER OF MONTHS IN THE FUTURE IN 12 FORMAT... 1E... 07...

PREDICTED VALUE OF DATA ITEM FOR 241S 0.66186E 02

IF YOU WANT THE EQUATION OF ANOTHER INFORMATION CATEGORY, ENTER 01 IN 12 FORMAT. IF NOT ENTER 00.

01 ENTER NUMBER OF DATA CATEGORY REQUESTED IN 12 FORMAT

09 STUDENT POPULATION

EQUATION IS \[ Y = 0.10008E \ 04 + 0.99860E \ 02 \times (M O N T H S) \]

ENTER 00 TO RETURN TO MONITOR...

TO PREDICT A DATA VALUE IN THE FUTURE, ENTER THE NUMBER OF MONTHS IN THE FUTURE IN 12 FORMAT... 1E... 07...

PREDICTED VALUE OF DATA ITEM FOR 241S 0.70824E 04

IF YOU WANT THE EQUATION OF ANOTHER INFORMATION CATEGORY, ENTER 01 IN 12 FORMAT. IF NOT ENTER 00.

10 TOTAL POPULATION

EQUATION IS \[ Y = 0.14160E \ 04 + 0.11135E \ 03 \times (M O N T H S) \]

ENTER 00 TO RETURN TO MONITOR...

TO PREDICT A DATA VALUE IN THE FUTURE, ENTER THE NUMBER OF MONTHS IN THE FUTURE IN 12 FORMAT... 1E... 07...

PREDICTED VALUE OF DATA ITEM FOR 241S 0.81273E 04

IF YOU WANT THE EQUATION OF ANOTHER INFORMATION CATEGORY, ENTER 01 IN 12 FORMAT. IF NOT ENTER 00.

01 ENTER NUMBER OF DATA CATEGORY REQUESTED IN 12 FORMAT

11 AVE WASTE WATER (W.H.)-TGPD

EQUATION IS \[ Y = 0.44222E \ 02 + 0.24559E \ 01 \times (M O N T H S) \]

ENTER 00 TO RETURN TO MONITOR...

TO PREDICT A DATA VALUE IN THE FUTURE, ENTER THE NUMBER OF MONTHS IN THE FUTURE IN 12 FORMAT... 1E... 07...
01 ENTER NUMBER OF DATA CATEGORIES REQUESTED IN 12,12 FORMAT
00
0711 15 W.H. 5 DAY BOD-EEFlUENT VERSUS TOTAL POPULATION
EQUATION IS Y = 0.11016E+01* 0.10483E-02*X (X)
CORRELATION FACTOR = 0.70298E 04
ENTER 00 TO RETURN TO MONITOR...
TO PREDICT A DATA VALUE IN THE FUTURE, ENTER THE VALUE OF THE INDEPENDENT VARIABLE IN F8.3 FORMAT IE 6125.200
00
PREDICTED VALUE IS 10.536

IF YOU WANT THE EQUATION OF ANOTHER INFORMATION CATEGORY, ENTER 01 IN 12 FORMAT. IF NOT ENTER 00.
00
1. DUMP-SELECTED LISTINGS OF THE DATA BASE
2. TREND-INDICATES TREND OF CATEGORY
3. PLOT-PLOTS CATEGORY VERSUS TIME
4. REGRS-COMPARES VARIABLES AND INDICATES REGRESSION LINE
5. STATS-CALCULATES MEAN AND STANDARD DEVIATIONS
6. FINISH-TERMINATES MIS PROCESSING.

SELECT AN OPTION...ENTER IN 11 FORMAT
3
00
01 ENTER DATA CATEGORY NUMBER OF INFORMATION YOU WISH TO HAVE PLOTTED IN 12 FORMAT
02 ENTER Y INTERCEPT AND SLOPE FROM TREND OR REGRESSION EQUATION IN F8.3 FORMAT...IE..0273.000,0000.091
429.0000005.70
01 IF YOU WANT ANOTHER PLOT, ENTER 01 IN 12 FORMAT, IF NOT, ENTER 00
09 ENTER DATA CATEGORY NUMBER OF INFORMATION YOU WISH TO HAVE PLOTTED IN 12 FORMAT
09 ENTER Y INTERCEPT AND SLOPE FROM TREND OR REGRESSION EQUATION IN F8.3 FORMAT...IE..0273.000,0000.091
70.57005.69
01 IF YOU WANT ANOTHER PLOT, ENTER 01 IN 12 FORMAT, IF NOT, ENTER 00
09 ENTER DATA CATEGORY NUMBER OF INFORMATION YOU WISH TO HAVE PLOTTED IN 12 FORMAT
09 ENTER Y INTERCEPT AND SLOPE FROM TREND OR REGRESSION EQUATION IN F8.3 FORMAT...IE..0273.000,0000.091
0070.57005.69
01 IF YOU WANT ANOTHER PLOT, ENTER 01 IN 12 FORMAT, IF NOT, ENTER 00
00
1. DUMP-SELECTED LISTINGS OF THE DATA BASE
2. TREND-INDICATES TREND OF CATEGORY
5
1. DUMP-SELECTED LISTINGS OF THE DATA BASE.
2. TREND-INDICATES TREND OF CATEGORY.
3. PLOT-PLOTS CATEGORY VERSUS TIME.
4. REGRS-COMPARES VARIABLES AND INDICATES REGRESSION LINE.
5. STATS-CALCULATES MEAN AND STANDARD DEVIATIONS.
6. FINISH-TERMINATES M I S PROCESSING.

SELECT AN OPTION...ENTER IN 12 FORMAT.

1. ENTER NUMBER OF DATA CATEGORIES REQUESTED IN 12,12 FORMAT.

1517

17 5 DAY BOD-POND
15 W.W. 5 DAY BOD-EFFLUENT

EQUATION IS: Y = 0.66510E 01 + 0.66570E 00*(X)
CORRELATION FACTOR = 0.14647E -05

ENTER 00 TO RETURN TO MONITOR...
TO PREDICT A DATA VALUE IN THE FUTURE, ENTER THE VALUE OF THE INDEPENDENT VARIABLE
IN F8.3 FORMAT 1E - 6125.200

6125.
PREDICTED VALUE IS 4069.803

IF YOU WANT THE EQUATION OF ANOTHER INFORMATION
CATEGORY, ENTER 01 IN 12 FORMAT. IF NOT ENTER 00.

1106

1106

1106

06 LBS. OF CL2/WATER-MONTHLY
11 AVE HASTE WATER (W.W)-TPPD

EQUATION IS: Y = 0.13697E 03 + 0.36770E -01*(X)
CORRELATION FACTOR = 0.14987E -05

ENTER 00 TO RETURN TO MONITOR...
TO PREDICT A DATA VALUE IN THE FUTURE, ENTER THE VALUE OF THE INDEPENDENT VARIABLE
IN F8.3 FORMAT 1E - 6125.200

6125.
PREDICTED VALUE IS 5069.803

IF YOU WANT THE EQUATION OF ANOTHER INFORMATION
CATEGORY, ENTER 01 IN 12 FORMAT. IF NOT ENTER 00.

01

01

01

1115

1115

1115

15 W.W. 5 DAY BOD-EFFLUENT
11 AVE-HASTE WATER (W.W)-TPPD

EQUATION IS: Y = 0.10397E 03 + 0.36770E -01*(X)
CORRELATION FACTOR = 0.14987E -05

ENTER 00 TO RETURN TO MONITOR...
TO PREDICT A DATA VALUE IN THE FUTURE, ENTER THE VALUE OF THE INDEPENDENT VARIABLE
### APPENDIX C

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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Note: The table values are placeholders for demonstration purposes.
### Tested Data Follows.

**YEAR AND MONTH**

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**WATER TREATED-MG PER MONTH**

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**AVE DAILY WATER USED-TGPD**

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**MAX DAILY WATER USED-TGPD**

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**MIN DAILY WATER USED-TGPD**

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**LBS OF CL2/WATER-MONTHLY**

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**AVE RESIDUAL CL2-PPM**

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**WATER CONSUMPTION-GPCD**

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**STUDENT POPULATION**

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**TOTAL POPULATION**

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**TABLE C1--TABULATED DATA FROM MTS DUMP PROGRAM**
| TABLE C2—TABULATED DATA FROM MIS PUMP PROGRAM. |
REQUESTED DATA Follows.

<table>
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<tr>
<th>21 W.W. FIXED SOLIDS-EFFLUENT</th>
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<tr>
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<td>10.90</td>
<td>10.10</td>
<td>13.00</td>
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<table>
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<td>37.20</td>
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<td>22.00</td>
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</tbody>
</table>

TABLE C3--TABULATED DATA FROM MIS DUMP PROGRAM
REQUESTED DATA FOLLOWS.

| REQUESTED DATA | | |
|----------------|------------------|
| **01 YEAR AND MONTH** | **71.12** |
| **02 WATER TREATED-MG PER MONTH** | **12.00** |
| **03 AVE DAILY WATER USED-TGPD** | **386.00** |
| **04 MAX DAILY WATER USED-TGPD** | **616.00** |
| **05 MIN DAILY WATER USED-TGPD** | **196.00** |
| **06 LBS OF CL2/WATER-MONTLY** | **693.00** |
| **07 AVE RESIDUAL CL2-PPM** | **1.70** |
| **08 WATER CONSUMPTION-GPCD** | **59.00** |
| **09 STUDENT POPULATION** | **5417.00** |
| **10 TOTAL POPULATION** | **6113.00** |
| **11 AVE WASTE WATER (W.W)-TGPD** | **108.00** |
| **12 MAX W.W.-GPM** | **230.00** |
| **13 MIN W.W.-GPM** | **30.00** |
| **14 W.W. 5 DAY BOD-RAW-PPM** | **146.00** |
| **15 W.W. 5 DAY BOD-EFFLUENT** | **9.00** |
| **16 PERCENT REMOVAL-EFFCNCY** | **93.50** |
| **17 5 DAY BOD-POND** | **16.00** |
| **18 W.W. TOTAL SOLIDS-RAW** | **560.00** |
| **19 W.W. FIXED SOLIDS-RAW** | **222.00** |
| **20 W.W. TOTAL SOLIDS-EFFLUENT** | **222.00** |
| **21 W.W. FIXED SOLIDS-EFFLUENT** | **163.00** |
| **22 W.W./D.O./RAW-PPM** | **2.10** |
| **23 W.W./D.O./EFFLUENT-PPM** | **8.00** |
| **24 W.W./D.O./POND-PPM** | **9.00** |
| **25 SPENT WATER-GPCD** | **22.00** |

UNITS ARE INDICATED IN CATEGORY DESCRIPTION.

TABLE C4--SPECIFIC YEAR AND MONTH DUMP PROGRAM OUTPUT
<table>
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<td>A</td>
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</tr>
<tr>
<td>B</td>
<td>0.28725E 03</td>
</tr>
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<td>C</td>
<td>0.00000E 00</td>
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<td>E</td>
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**Figure C2 - Monthly Variations of Treated Water**

B = 277.6 + 9.57 T

Thousands of Gallons
<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUE</th>
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<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.4170E 03</td>
<td>0.7905E 03</td>
<td>0.1164E 04</td>
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<tr>
<td>B</td>
<td>0.4239E 03</td>
<td>0.9804E 03</td>
<td>0.0000E 00</td>
</tr>
<tr>
<td>C</td>
<td>0.0000E 00</td>
<td>0.0000E 00</td>
<td>0.0000E 00</td>
</tr>
<tr>
<td>D</td>
<td>0.0000E 00</td>
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<tr>
<td>E</td>
<td>0.0000E 00</td>
<td>0.0000E 00</td>
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</table>

---

**THOUSANDS OF GALLONS PER DAY**

- B = 408 + 15.9 T
THOUSANDS OF GALLONS PER DAY

---

**SYMBOL** | **MINIMUM** | **MEDIAN** | **MAXIMUM**
--- | --- | --- | ---
A | 0.19000E 02 | 0.25750E 03 | 0.49600E 03
B | 0.14555E 03 | 0.00000E 00 | 0.44130E 03
C | 0.00000E 00 | 0.00000E 00 | 0.00000E 00
D | 0.00000E 00 | 0.00000E 00 | 0.00000E 00
E | 0.00000E 00 | 0.00000E 00 | 0.00000E 00

---

B = 137.1 + 8.45 T
<table>
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<th>MINIMUM VALUE</th>
<th>MEDIAN VALUE</th>
<th>MAXIMUM VALUE</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>0.90000E+00</td>
<td>0.18999E+01</td>
<td>0.29000E+01</td>
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<td>B</td>
<td>0.13560E+01</td>
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</tr>
<tr>
<td>C</td>
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<td>0.00000E+00</td>
<td>0.00000E+00</td>
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<tr>
<td>D</td>
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\[ B = 1.50 - 0.004 \, T \]

PARTS PER MILLION
FIGURE C7 - MONTHLY VARIATIONS OF AVERAGE WATER CONSUMPTION PER CAPITA
FIGURE C8 - MONTHLY VARIATIONS OF STUDENT POPULATION
FIGURE C9 - MONTHLY VARIATIONS IN TOTAL POPULATION
**FIGURE C11 - MONTHLY VARIATIONS OF MAXIMUM WASTEWATER FLOW**

GALLONS PER MINUTE

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>A</td>
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<td>0.22250E 03</td>
</tr>
<tr>
<td>B</td>
<td>0.76759E 02</td>
<td>0.27541E 03</td>
</tr>
<tr>
<td>C</td>
<td>0.00000E 00</td>
<td>0.00000E 00</td>
</tr>
<tr>
<td>D</td>
<td>0.00000E 00</td>
<td>0.00000E 00</td>
</tr>
<tr>
<td>E</td>
<td>0.00000E 00</td>
<td>0.00000E 00</td>
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B = 76.6 + 5.69 T
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<th>VALUE</th>
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<tr>
<td>A</td>
<td>0.50000E+01</td>
<td>0.32500E+02</td>
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<td>0.60000E+02</td>
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<tr>
<td>B</td>
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<tr>
<td>C</td>
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<td>0.00000E+00</td>
<td>0.00000E+00</td>
<td>0.00000E+00</td>
</tr>
<tr>
<td>D</td>
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<td>0.00000E+00</td>
<td>0.00000E+00</td>
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<tr>
<td>E</td>
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GALLONS PER MINUTE

FIGURE C12 - MONTHLY VARIATIONS OF MINIMUM WASTEWATER FLOW
### Table:

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<td>0.36600E+03</td>
</tr>
<tr>
<td>B</td>
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<td>0.00000E+00</td>
<td>0.22275E+03</td>
</tr>
<tr>
<td>C</td>
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<td>0.00000E+00</td>
<td>0.00000E+00</td>
</tr>
<tr>
<td>D</td>
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<td>0.00000E+00</td>
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### Diagram:

Figure C13 - Monthly Variations of 5 Day BOD in Wastewater

*B = 151.8 + 1.97 T*

Parts per Million
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<th>MEASURED VALUE</th>
<th>EXTRAPOLATED VALUE</th>
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<tbody>
<tr>
<td>A</td>
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<td>0.53999E 01</td>
<td>0.10000E 02</td>
</tr>
<tr>
<td>B</td>
<td>0.21389E 01</td>
<td>0.00000E 00</td>
<td>0.73540E 01</td>
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<tr>
<td>C</td>
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<td>0.00000E 00</td>
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<td>D</td>
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<td>0.00000E 00</td>
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\[ B = 1.99 + 0.149 T \]
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<tbody>
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<td>0.96271E 02</td>
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<tr>
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<td>0.00000E 00</td>
<td>0.00000E 00</td>
</tr>
<tr>
<td>D</td>
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<td>0.00000E 00</td>
<td>0.00000E 00</td>
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<tr>
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PERCENT

**Figure 215** - Monthly Variations of Rod Removal Efficiency
<table>
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<th>MEDIAN VALUE</th>
<th>MAXIMUM VALUE</th>
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</thead>
<tbody>
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<td>0.19400E 02</td>
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<td>B</td>
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<td>0.00000E 00</td>
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<tr>
<td>C</td>
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<td>0.00000E 00</td>
<td>0.00000E 00</td>
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<td>0.00000E 00</td>
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</tbody>
</table>

\[ B = 4.77 + 0.162 \, T \]
PARTS PER MILLION

FIGURE C17 - MONTHLY VARIATIONS OF TOTAL SOLIDS IN THE WASTEWATER
FIGURE C18 - MONTHLY VARIATIONS OF FIXED SOLIDS IN THE WASTEWATER
Figure C19 - Monthly Variations of Total Solids in the Effluent
<table>
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<th>MEDIAN VALUE</th>
<th>MAXIMUM VALUE</th>
</tr>
</thead>
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</tr>
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<td>B</td>
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<td>0.20905E 03</td>
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<tr>
<td>C</td>
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<td>0.00000E 00</td>
</tr>
<tr>
<td>D</td>
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\[ B = 111.5 \pm 2.71 T \]

FIGURE C20 - MONTHLY VARIATIONS OF FIXED SOLIDS IN THE EFFLUENT
FIGURE C21 - MONTHLY VARIATIONS OF DISSOLVED OXYGEN IN WASTEWATER
PARTS PER MILLION

FIGURE C22 - MONTHLY VARIATIONS OF DISSOLVED OXYGEN IN THE EFFLUENT.
FIGURE C23 - MONTHLY VARIATIONS OF DISSOLVED OXYGEN IN THE POND
**Figure C24** - Monthly Variations of Per Capita Wastewater
THE PLOTS ABOVE ARE OF: A: TOTAL POPULATION
B: WATER TREATED-MG PER MONTH
C: AVE WASTE WATER (W.W)-TGPD

FIGURE 025 - MONTHLY VARIATION COMPARISON OF POPULATION, TGP
The plots above are of: A: TOTAL POPULATION  
B: WATER TREATED-MG PER MONTH  
C: AVE DAILY WATER USED-TGPD
<table>
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<th>VALUE</th>
<th>VALUE</th>
<th>VALUE</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
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<td>0.64250E+01</td>
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<td></td>
</tr>
<tr>
<td>B</td>
<td>0.79050E+03</td>
<td>0.11650E+04</td>
<td>0.00000E+00</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.19000E+02</td>
<td>0.25750E+03</td>
<td>0.00000E+03</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>0.30300E+00</td>
<td>0.00000E+00</td>
<td>0.00000E+00</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>0.00000E+00</td>
<td>0.00000E+00</td>
<td>0.00000E+00</td>
<td></td>
</tr>
</tbody>
</table>

The plots above are of:
- A: WATER TREATED-MG PER MONTH
- B: MAX DAILY WATER USED-TSPD
- C: MIN DAILY WATER USED-TSPD

FIGURE C27 - MONTHLY VARIATION COMPARISONS OF AVERAGE, MAXIMUM AND MINIMUM WATER CONSUMPTION
FIGURE C28 - VARIATIONS OF AVERAGE DAILY WATER CONSUMPTION AS RELATED TO POPULATION
<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>MINIMUM VALUE</th>
<th>MEDIAN VALUE</th>
<th>MAXIMUM VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.4170E 03</td>
<td>0.7905E 03</td>
<td>0.1164E 04</td>
</tr>
<tr>
<td>B</td>
<td>0.45639E 03</td>
<td></td>
<td>0.89126E 03</td>
</tr>
<tr>
<td>C</td>
<td>0.000000E 00</td>
<td>0.000000E 00</td>
<td>0.000000E 00</td>
</tr>
<tr>
<td>D</td>
<td>0.000000E 00</td>
<td>0.000000E 00</td>
<td>0.000000E 00</td>
</tr>
<tr>
<td>E</td>
<td>0.000000E 00</td>
<td>0.000000E 00</td>
<td>0.000000E 00</td>
</tr>
</tbody>
</table>

THOUSANDS OF GALLONS PER DAY

THE PLOT ABOVE IS OF A = MAX DAILY WATER USED-TGPD AND B = 456.390 + 0.671(X)

FIGURE C29 - VARIATIONS OF MAXIMUM DAILY WATER CONSUMPTION AS RELATED TO POPULATION
<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>MINIMUM VALUE</th>
<th>MEDIAN VALUE</th>
<th>MAXIMUM VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.10000E+02</td>
<td>0.75500E+02</td>
<td>0.14100E+03</td>
</tr>
<tr>
<td>B</td>
<td>0.23355E+02</td>
<td></td>
<td>0.13973E+03</td>
</tr>
<tr>
<td>C</td>
<td>0.00000E+00</td>
<td>0.00000E+00</td>
<td>0.00000E+00</td>
</tr>
<tr>
<td>L</td>
<td>0.00000E+00</td>
<td>0.00000E+00</td>
<td>0.00000E+00</td>
</tr>
</tbody>
</table>

THOUSANDS OF GALLONS PER DAY

THE PLOT ABOVE IS OF A = AVE WASTE WATER (T.GPD) AND B = 23.355 + 0.019(X)
The plot above is of $A = \text{MAX W.W. - GPM}$ and $B = 86.162 + 0.27X$.

**Figure C31 - Variations in Maximum Wastewater Flow as Related to Population**
<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>MINIMUM VALUE</th>
<th>MEDIAN VALUE</th>
<th>MAXIMUM VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.68200E+02</td>
<td>0.21710E+03</td>
<td>0.36600E+03</td>
</tr>
<tr>
<td>B</td>
<td>0.11966E+03</td>
<td>0.24217E+03</td>
<td>0.00000E+00</td>
</tr>
<tr>
<td>C</td>
<td>0.00000E+00</td>
<td>0.00000E+00</td>
<td>0.00000E+00</td>
</tr>
<tr>
<td>E</td>
<td>0.00000E+00</td>
<td>0.00000E+00</td>
<td>0.00000E+00</td>
</tr>
</tbody>
</table>

The plot above is of \( A = \text{W.W. 5 DAY BOD-Raw-PPM} \) and \( B = 119.68C + 0.620X \) for population in Hampshire.
<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>MINIMUM VALUE</th>
<th>MEDIAN VALUE</th>
<th>MAXIMUM VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.21000E+03</td>
<td>0.53000E+03</td>
<td>0.85000E+03</td>
</tr>
<tr>
<td>B</td>
<td>0.34000E+03</td>
<td></td>
<td>0.68300E+03</td>
</tr>
<tr>
<td>C</td>
<td>0.00000E+00</td>
<td>0.00000E+00</td>
<td>0.00000E+00</td>
</tr>
<tr>
<td>D</td>
<td>0.00000E+00</td>
<td>0.00000E+00</td>
<td>0.00000E+00</td>
</tr>
<tr>
<td>E</td>
<td>0.00000E+00</td>
<td>0.00000E+00</td>
<td>0.00000E+00</td>
</tr>
</tbody>
</table>

The plot above is of \( A = k \cdot \text{h} \cdot \text{TOTAL SOLIDS-RAh} \) and \( B = 340.000 + 0.056(x) \).

**Figure C33 - Variations of Total Solids in Wastewater as Related to Population**