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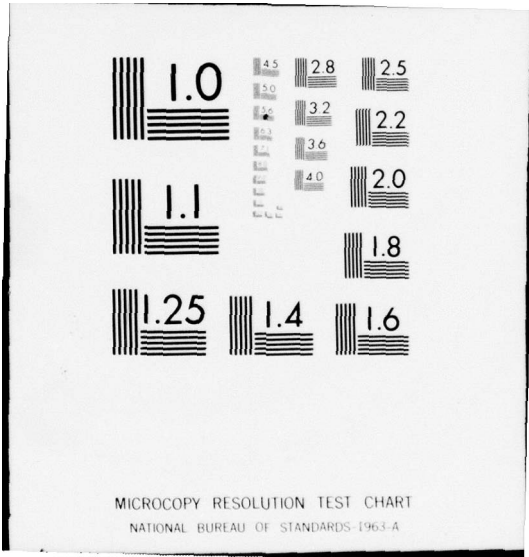
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A SYSTEMS ANALYSIS OF WATER QUALITY SURVEY DESIGN

FINAL REPORT

AUGUST 1975

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The site modeling program models the manufacturing processes which contribute pollutants to the system, models the sewer system, and models the treatment system including acid or caustic neutralization, settling ponds, and domestic treatment. The inputs to the model are the production levels of the manufacturing processes and the outputs are the predicted pollutant measurement values at each possible measure point in the system.

The resource matching program accepts data defining proposed measurements and matches these against the available time, manpower, and equipment. The output lists the pollutant to be measured at each measure point, the total commitment of time for each analyst and for each piece of equipment. Note is made of any overcommitment of manpower or equipment.

The model refinement or updating program accepts measurements taken during a preliminary survey or during a regular survey and computes suggested new parameters for the process models.

The indicator model program evaluates the performance of sanitary treatment facilities.

The program uses design data, data from the operating log and/or data generated during the survey and computes key operational characteristics. Comparing these with desirable values as cited in design books and manuals will give the survey planner insight into the operation of the system and suggest the need for more survey measurements or the need for changes in operation.

A system was developed for automatic instrumentation of pH, conductivity, and other parameters which use strip chart recordings. Interface hardware was selected and purchased and interface software was developed for direct connection to a digital computer.

A data handling system was developed for use during and after the survey. A PDP8-OS/8 and peripheral equipment was purchased. Software was developed to perform data handling functions and to direct the user in application of the software. The program accepts raw data from the analytical chemist and performs data conversions, transcriptions, and data logging functions. Output is available in several forms as may be needed for various reports during and at the end of the survey.

Recommendations are: the survey planner should obtain sufficient data in a preliminary survey to model and analyze the site; measurements should be automated to the maximum extent possible; data handling should be delegated to the computer when the operations are well defined and repetitive. The programs, software and hardware included here will assist the survey planner in following these recommendations and design a more effective survey.

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ABSTRACT

This is the final report of a three year project titled, "A Systems Analysis of Water Quality Survey Design."

In this project a study was made of water quality surveys conducted by the United States Army Environmental Hygiene Agency (AEHA). Mainly data and reports from studies of Army Ammunition Plants (AAP) were used.

The focus of this project was the development of computer aided procedures which would assure efficient use of manpower and equipment and assure that the measurements taken give a reasonable representation of the system. Planning the survey, conducting the survey and reporting on the survey were included in the study.

The site modeling program models the manufacturing processes which contribute pollutants to the system, models the sewer system, and models the treatment system including acid or caustic neutralization, settling ponds, and domestic treatment. The inputs to the model are the production levels of the manufacturing processes and the outputs are the predicted pollutant measurement values at each possible measure point in the system.

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Recommendations are: the survey planner should obtain sufficient data in a preliminary survey to model and analyze the site; measurements should be automated to the maximum extent possible; data handling should be delegated to the computer when the operations are well defined and repetitive. The programs, software and hardware included here will assist the survey planner in following these recommendations and design a more effective survey.

I. Introduction

This research addresses the problem of improving the design of short-term (15 days) water quality surveys. These surveys are primarily concerned with monitoring for industrial wastes generated at Army-owned and, sometimes, contractor-operated facilities. Most of the data used was from munitions facilities.

In general terms a water quality survey involves a survey team going to the site (e.g. an ammunition plant) and over a period of several days collecting water samples. These samples are collected at predetermined time intervals at predetermined points in the site sewer. The frequency of sampling and points for sampling are part of a survey plan or design determined after a preliminary site visit. The samples are analyzed to determine the level of pertinent pollutants in the samples. Some of the analyses are done on site in portable laboratory vans and some of the analyses are performed in a central laboratory facility. This latter requires sample preparation and shipping. A survey report is prepared. The report clearly defines the sampling and analysis procedures used and lists survey results with tables and curves. Thus, the report identifies any time and location variation in pollutant levels measured. Also, any potential pollution problem and its cause should be detected.

A good survey design is one which yields data which accurately describes the system state with a minimum of redundant data. To paraphrase the previous statement, a good survey design is one which yields a maximum of useful information within the limitation of the available time, personnel, and equipment.

In a review of reports of past surveys, it was noted that some of the pollutants measured at some of the measure points were at levels too low to be significant or remained unchanged throughout the survey period. If modeling and preliminary analysis indicated one of the above cases to apply to a planned

survey, analysis for that particular pollutant on one or two samples would be sufficient to verify the preliminary analysis and much of the chemists time could be saved or put to better use. *Modeling and preliminary analysis can* also be used to trace any pollutant back to its source and this clearly defines a cause-effect relationship. A good survey design should not allot time for measurement of insignificant parameters and the results should point out causes for presence of significant pollutants.

Efficient use of time, personnel, and equipment is part of a good survey plan. For each sample collected several chemical analyses are performed to determine the level of pertinent pollutants. In general each data point involves a chemical analysis and not merely a meter reading. Tests for different pollutants may require different equipment, different amounts of time, and different abilities for the analyst. A good survey design should include a correlation between the number of samples, the number of analyses on each sample, and the time, personnel and equipment available for the survey.

Good data management should be a corollary to a good survey plan or design. As a general rule, any data manipulation that is well defined and highly repetitive should be delegated to the digital computer. When hardware is available, analysis should be automated and interfaced with the digital computer. When automation is not practical, raw analysis data should be fed to the computer by the analytical chemist and the computer should be programmed to perform conversions, transcriptions or logging. Preparation of data for reports, plotting curves, and setting up tables are valid computer operations. Reports are needed during and at the end of a survey. The computer should be programmed to generate these reports or appropriate output for these reports.

The design of water quality surveys was investigated by an interdisciplinary team using systems analysis techniques. The team included faculty and graduate student researchers with expertise in environmental systems, environmental

chemistry, computer programming, computer hardware and systems analysis. As the research progressed, six objectives evolved. Work on these objectives included:

1. A method was developed for computer modeling of the site to be surveyed. The various manufacturing processes of the site form the pollutant sources. Each process model has as its input the production level and as its output the effluent it discharges into the sewer systems. The effluent is defined in terms of flow rate and a parameter* measure number for each pertinent pollutant. The sewer system into which the processes discharge their effluent is modeled such that for any branch of the sewer system the contribution of each source is determined and hence to total flow and each pollutant parameter for that branch. The survey planner can thus specify the production level of each process on the site and determine the flow and pollutant parameters for each branch of the sewer system. The site model also allows for caustic or acid neutralization, settling ponds and domestic treatment within the sewer system. By specifying the production levels that may occur for each site process, the survey planner is better informed in deciding what should be measured, where it should be measured and how often it should be measured.

2. A procedure was defined for modeling the measurement resources. Also a program was developed which utilizes the site model and the measurement resources model and determines the commitment of resources required for a measurement plan proposed by the survey planner. The resource model lists personnel, equipment, and time required to measure each parameter for each method available

*The term parameter measure number or just parameter is used here since some pollutants are measured in terms of concentrations such as milligrams per liter while others such as pH and turbidity each have their own units.

The output of the program lists the method of measurement of each parameter to be measured at each point where it is to be measured. Equipment used is also listed. Total time demand on personnel and equipment is given and this is compared with time available for personnel and equipment. Non-feasible conditions are noted. By iteration through several plans the survey planner can arrive at a "best" survey, a plan which yields a maximum of useful information for the available time, personnel, and equipment.

In choosing a survey plan the planner can determine which pollutants will be measured at which points in several ways.

a. The program logic selects the minimum number of measure points required to detect all of the pollutant arriving at the outfall. Low concentrations may preclude measurement at the outfall.

b. The program can be made to select as a measure point any source which contributes more than X% to the output mass of a particular parameter.

c. Any parameter at any point can be manually flagged as a measure point.

3. A program was developed which will use the site model data and survey results and prepare data for verifying or updating the site model. Experience in the three years of the study showed that good dependable process data was elusive. Further, some variance was noted in the same processes at different sites and in different seasons. Over a period of time, use of this program will result in more dependable process models. With confidence in the process models, the site model can be used to extrapolate and determine pollutant conditions for operating levels that exist at times when measurements are not taken.

4. A program was developed for sanitary treatment facilities (called the indicator model) which will calculate certain parameters, generally termed process variables or operating characteristics, that indicate the operational state of the system. These calculated values can then be compared with the desirable values as cited in design books or manuals.

A comparison will give the engineer insight into the operation of the system such that problem areas and possible causes of these problems are more readily apparent.

5. The feasibility of using automated measurement equipment was investigated. Direct measurement probes and interface (hardware and software) with the computer were investigated. Equipment was purchased and software was developed for pH and conductivity measurements. A digitizer was purchased and interfaced with the computer for digitization of strip chart recordings. There is limited automatic measuring equipment available for water quality analysis.

6. A data handling system was developed. A Digital Equipment Corporation PDP-8 computer system with OS/8 operating system software and peripheral equations was purchased. Software was developed to perform the data handling function and direct the user in application of the software. The program accepts raw data from the analytical chemist and performs data conversions, transcriptions, and data logging functions. Maximum, minimum, mean, variance, and standard deviations are computed. Ordering, classifying and storing operations are performed. At the request of the user, output is available in several forms as may be appropriate for the various reports needed during the survey and at the end of the survey. These forms include tables of data and plotted curves.

The philosophy and structure of the models, programs, and software is described in subsequent sections in the body of this final report. Appendices to this report include users' manuals, programmers' manuals, program listings, and software tapes. The manuals give the details of procedures, data required, and options available in using programs, models and software. The appendices include:

- A. The Survey Planning Program
 - a. program listing with example results (Appendix I)
 - b. user's manual (Appendix II)
 - c. programmer's manual (Appendix III)

The card decks are not included in the appendix but were presented to AEHA.

The decks include:

Deck 1. Contains MAIN and subroutines which will permit modeling of plant processes and sewer systems. The output includes the pollutant level at each possible measure point in the system for each pollutant in the study. The program allows consideration of acid or caustic neutralization, settling ponds, and domestic sewage treatment. Process production levels can be varied for sensitivity analysis.

Deck 2. Contains all of Deck 1 but also includes subroutines which will permit modeling of measurement resources and subroutines which determine the commitment of resources for a measurement plan proposed by the survey planner. By iteration the planner can arrive at a best plan for available resources.

Deck 3. Contains all of Deck 1 but also includes a subroutine CORRCT which compares site model data and survey results and prepares data for verifying the model or updating the process models.

B. Domestic Treatment Evaluation (INDICATOR MODEL)

- a. program listing (Appendix IV)
- b. user's manual (Appendix IV)
- c. programmers' manual (Appendix IV)

This program computes key operational characteristics which can be compared to desirable values for domestic treatment systems.

C. Automated Instrumentation

- a. user's manual (Appendix V)
- b. software to interface with computer (delivered to AEHA)
- c. programmers' manual (Appendix VI)

D. Data Handling

- a. user's manual (Appendix VII)
- b. software (delivered to AEHA)
- c. programmers' manual (Appendix VIII)

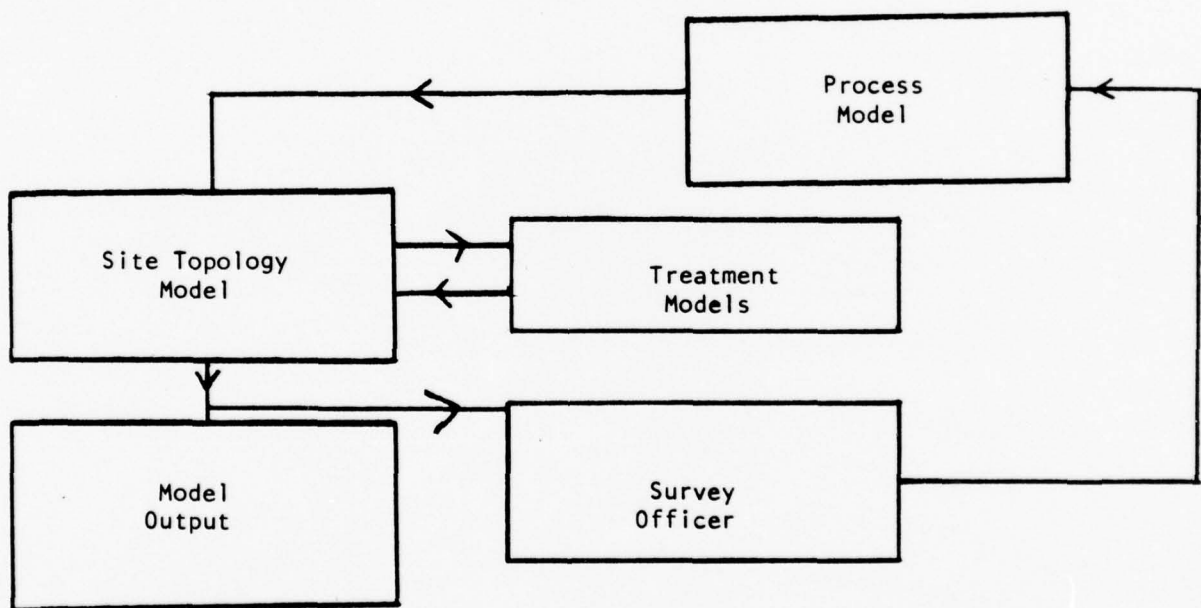
The software developed is essentially interactive, i.e. it prints messages which tell the user what is required next with minimum use of the manual. This system consists of a PDP8-0S/8 and software developed for accepting raw measurement data, for preparing data for reports, and for generating reports.

Recommendations as a result of these studies are that the survey planner should obtain sufficient data in a preliminary survey to model and analyze the site, that measurements should be automated to the maximum extent possible with commercially available equipment, and that data handling should be delegated to the computer at all points in the survey where the operations on data are well defined and repetitive. If the survey planner has a more complete picture of the site through modeling, redundant or meaningless measurements could be eliminated and more useful data could be obtained in the limited time available. In automating measurements and in delegating repetitive tasks to the computer, efficiency is improved. Further, requiring creative personnel to perform repetitive tasks can be counter-productive.

II. SURVEY PLANNING PROGRAMS

A. Site Modeling and Simulation

The purpose of site modeling and simulation in survey planning is to give the survey planner a detailed and accurate picture of the plant site so that he will be better informed when deciding what is to be measured and where the sample points should be chosen. The preliminary survey or site visit should give sufficient information to model the plant and should give the survey planner information on levels of production of various parts of the plant expected during the survey period. Modeling and simulation should give a reasonable estimate of the quantities to be measured.



SITE MODEL COMPONENTS

Figure 1

The components of the plant site model are shown in Figure 1. The components are: the process model which represents the plant operation; the treatment model which represents the treatments that take place within the plant site; the topology model which models the plant site sewer system and with the process and treatment data determines the state of the effluent in each branch of the sewer system (this is output); the survey officer who observes the system states and makes appropriate changes in the plant process levels to represent expected plant production schedules.

The following sections describe these component models in detail.

A. 1.0 Process Model:

This model is designed to define a manufacturing plant in terms of the pollutants produced by the manufacturing operations as a function of production levels of the various plant components. In order that the model be applicable to more than one plant, plants are subdivided on the basis of objectives and then further subdivided into processes required by these objectives. A given plant may have one or several objectives. Examples of objectives are: continuous TNT; TNT (batch); paint stripping of artillery shells. The components representing the plant then are these processes required by a plant objective. The processes are manufacturing operations which are definable in terms of production level and resultant pollutants. These processes may be components for one or several plant objectives and may occur in one or several plants. A plant process model is obtained by assembling the appropriate component process models. The input to the plant model is the production level of each of the processes making up the plant model. The output is an ordered listing of the types and levels of pollutants generated by producing products at that level. Also listed are the points

in the effluent drain system at which the pollutants enter. Any time variation in pollutant flow requires a new listing, a listing for each state. The modeling program PROCES is written so that the user inputs to the program only: the number of processes at the site; the process codes for all processes at the site (partial list given in Table II, complete list in user's manual); the production level for each process. "Process" models have been constructed for eight plant "objectives". These objectives are: Continuous TNT; Nitrocellulose (batch); Continuous Nitroglycerine; Single-Base Power; "Detrex" Preparation of Forgings; Paint Stripping of Artillery Shells; Motor Pool Wash Racks; Troop Installation (sanitary). All of the process models are identified in a list in Table I of the user's manual in the Appendix. The process models are given in the Appendix in the Program Listing.

The pollution potential of an effluent is measured in a number of ways. One type of measurement is to determine the concentration of a particular element or compound. An example of this type of measurement would be the measure of sulfates in milligrams per liter. Another type of measurement measures a characteristic of the system not necessarily related to only one chemical compound or element. Examples of this type of measurement are conductivity, color, and pH. To speak in general terms of the numbers that define the level of pollution potential, whether they are of one or the other of the above types, the term, "pollution parameter" will be used.

Figure II is an example of a computer program subroutine model of a process. All of the other processes are given in the appendix in the Program Listing. Statement 0001 gives the subroutine name. Statement 0002 is the dimension statement. Statement 0003 is:

1. pH
2. COD
3. CONDUCTIVITY
4. TOC
5. AMMONIA (NH₃) - N
6. DISSOLVED SOLIDS
7. NITRITE/NITRATE
8. TOTAL N(KJELDAHL)
9. TOTAL SOLIDS
10. SUSPENDED SOLIDS
11. TOTAL HANDNESS
12. SULFATES
13. MBAS
14. SULFITES
15. CHLORIDES
16. VOL. SUSP. SOLIDS
17. SODIUM
18. TOTAL PHOSPHATES
19. TNT
20. CALCIUM
21. COLOR
22. ALKALINITY
23. TURBIDITY
24. ACIDITY
25. BOD

MASTER LIST OF PARAMETERS

Table 1

```
0001 SUBROUTINE STNT (FLOW,SPLIST,CAP,JM,MSORS,MPARM)
0002 DIMENSION FLOW (MSORS),SPLIST(MSORS,MPARM),CAP (MSORS)
0003 FLOW(JM)=0.01*CAP(JM)*0.10
0004 SPLIST(JM,1)=1.5
0005 SPLIST(JM,3)=40000
0006 SPLIST(JM,4)=40
0007 SPLIST(JM,7)=1000
0008 SPLIST(JM,8)=8
0009 SPLIST(JM,9)=20000
0010 SPLIST(JM,10)=10
0011 SPLIST(JM,12)=2500
0012 SPLIST(JM,15)=1500
0013 SPLIST(JM,16)=5.0
0014 SPLIST(JM,18)=0.5
0015 SPLIST(JM,19)=10.0
0016 SPLIST(JM,20)=20
0017 SPLIST(JM,22)=0.0
0018 SPLIST(JM,23)=5.0
0019 SPLIST(JM,24)=5000
0020 RETURN
0021 END
```

EXAMPLE PROCESS MODEL

Figure 11

$FLOW(JM)=0.01*CAP(JM)*0.10$

This statement computes the effluent flow from process numbered (JM) in million gallons per day (MGD) for a given operating level, CAP(JM) in % capacity. The 0.01 premultiplier changes the % to a decimal fraction and the 0.10 postmultiplier is the MGD of the process at 100% capacity.

The remaining lines 0004 through 0019 give the pollutant parameters necessary to define this process. These parameters must be identified by a number assigned in a master list given in Table I. For example, SPLIST (JM,3) = 4000 gives the conductivity of the effluent for the process numbered JM. Three is the parameter number for conductivity from the master list.

Further, each process is identified by a mnemonic from a master list. A partial list is given in Table II. A complete list is in the User's Manual of the Appendix. The mnemonic for calling this subroutine is PTNT and the subroutine name is STNT.

The processes are numbered in the order in which they are read in by the process model. The ordering or the numbering is arbitrary except that it must be consistent with the numbering used in the TOP subroutine modeling the sewer system. This data is read in the START subroutine. It is by this numbering that the modeling designates where a process discharges into the sewer system.

The plant process modeling in review is as follows: During the preliminary survey all processes which make up the plant operation are identified in terms of the proper mnemonic from the master list. The expected operating capacity in % of full load is noted for each process. The mnemonic and capacity are placed on a data card for read in by the PROCES subroutine.

CORRESPONDING
SUBROUTINES

MNEMONIC - DESCRIPTION

PAPC - AOP Compression	SAPC
PAOP - AOP - Flow 3	SAOP
PSAC - Sulfuric Acid Concentrator	SSAC
PNAC - Nitric Acid Concentrator	SNAC
PBDN - Blowdown at BAAP	SBDN
PBIX - Ion Exchange at BAAP	SBIX
PCOW - Cooling Water - Flow 10	SCOW
PNBP - Nitration and Boiling Operations	SNBP
PBPP - Beater and Poaching Operation	SBPP
PBEX - Benzene Extraction	SBEX
PNCS - Nitrocellulose Into Ball Power	SNCS
PNGS - Ball Power with Nitroglycerin	SNGS
PPND - Pond at Head of Sewer	SPND
PAPP - AOP - Flow 4	SAPP
PSWG - Sewer Influent - Flow into STP Process	SSWG
PCWZ - AAP - Cooling Water - Flow 11	SCWZ
PPAS - Purification Acid Scrubber	SPAS
PPCU - Purification Clean-Up	SPCU
PPCW - Purification Cooling Water	SPCW
PFSW - Finishing Scrubber Water	SFSW

(Partial List)

PROCESSES AND MNEMONICS

(SOURCES)

Table 11

The process cards are read in the order defined later in the discussion of the TOP subroutine.

As the subroutine PROCES reads in the process data cards it forms a plant model in terms of a SPLIST matrix. The SPLIST matrix has as its rows the different processes present and as its columns the parameter values, the parameters in order as defined by the master list of Table II and the processes in the order read in. An abbreviated SPLIST matrix format for five processes and four pollutants is given in Figure III.

	PH	COD	CONDUCTIVITY	TOC	Pollutant Names in Columns
PPND	6.0	20.0	0.0	11.0	
PAPC	6.2	20.0	0.0	11.0	
PAOP	6.2	20.0	0.0	11.0	Pollutant Parameters
PAPP	6.2	20.0	0.0	11.0	
PNAC	2.5	25.0	0.0	22.0	

Process Model Names in Rows.

EXAMPLE SPLIST MATRIX

Figure III

An important feature of the PROCES subroutine is that it will accept data which will alter one or more parameters for any process present. If the user feels that at a particular plant site a different parameter value would give a better model, the parameter value can be changed. Further in a more extreme case all new parameter values can be read in for a given process if existing data and the judgement of the user warrant the change.

The procedure for making these changes is given in the user's manual. Clearly this latter capability can be used to include a process in a survey planning when the process is not in the process library.

A. 2.0 Site-Topology Model:

The site-topology model has as its body a codified listing of the details of the physical layout of the plant site sewer system and a program which computes the flow and pollution parameter values for each branch of the system.

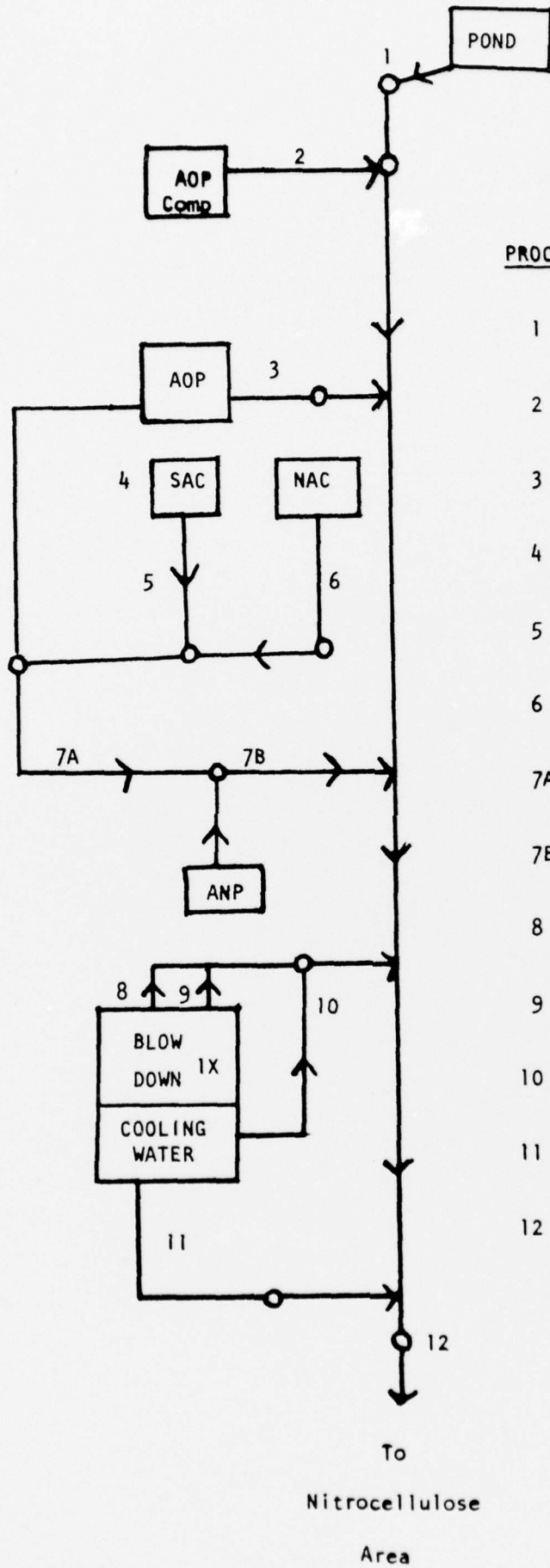
The details of the physical layout of the plant site sewer system includes:

1. Identification of all processes (sources of pollution) and the location at which they discharge into the sewer system.
2. Identification of all manholes, weirs or other possible measure points.
3. Identification of all processes effluents which flow through each of the possible measure points.

When the system is large it is recommended that the recording and coding of the physical layout data be done in three steps as follows:

1. During the preliminary survey, construct a map showing the processes, the treatments, the sewer systems, the manholes or other measure points, and the flow directions. Figure IV shows a part of Badger AAP and illustrates the data that should be recorded. The blocks show processes and treatments, the lines with arrows show the sewer lines and flow directions, and the small circles show the possible measure points.

2. The essential information from the site map is then included in a linear graph and the items are ordered or numbered. In the linear graph each branch (line) represents a possible measure point. The processes (pollutant sources) and treatments are shown also. The graph shows each possible measure point and the effluents which flow through these points. The source numbers are assigned arbitrarily (must run consecutively starting from 1). However, once assigned, the same numbering must be used in the process model, the site-topology model and other parts of the program. The linear graph branches



PROCESS

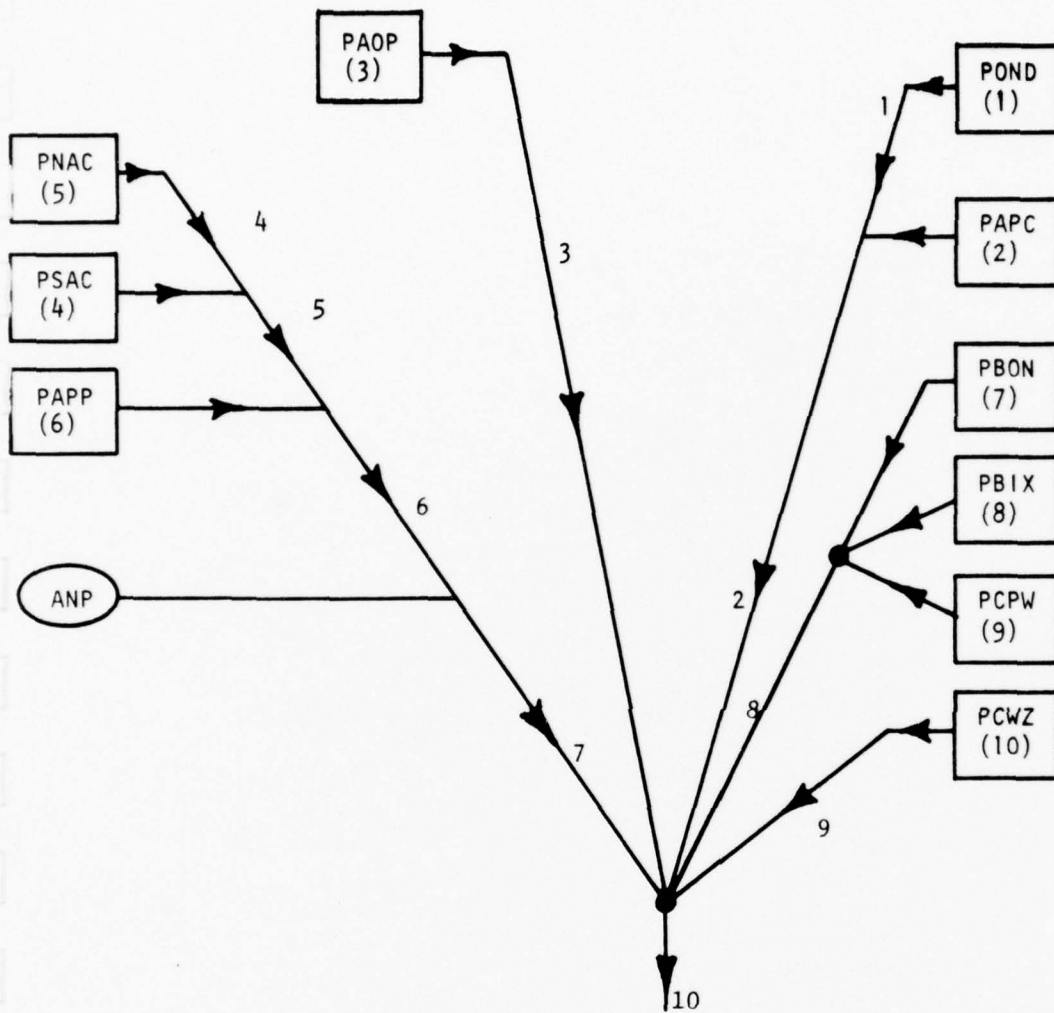
DESCRIPTION

<u>PROCESS</u>	<u>DESCRIPTION</u>
1	overflow from pond
2	AOP Compression house
3	AOP (cooling water)
4	AOP (process Water)
5	sulfuric acid concentrator
6	nitric acid concentrator
7A	Combined flow (4, 5, 6)
7B	acid neutralization plant
8	automatic boiler blowdown
9	ion exchange
10	boiler
11	compressors, fans pumps
12	combined processes effluent

TOPOLOGY
BADGER AAP

Figure IV

To
Nitrocellulose
Area



CODED LINEAR GRAPH

OF FIGURE IV

FIGURE V

are numbered with the following restrictions:

- a. The numbering must start at 1 and run consecutively.
- b. The numbering must be such that in tracing from any branch to the outfall, only higher numbered branches will be encountered.
- c. Thus, the outfall branch must have the highest number. Figure V illustrates with the linear graph for Figure IV.

3. A convenient way of tabulating the topological data for entering into a computer program is to put the information into a matrix. A matrix is constructed with a column, j , for each branch of the system and a row, i , for each process of the system. The entries for the i th row are obtained by starting at the i th process on the linear graph and tracing a path (with the flow) through the branches to the outfall. If the path does not include the j th branch the $i j$ entry is zero. If the path does include the j th branch, an appropriate number is entered in the $i j$ position. That appropriate number depends upon whether or not the flow undergoes treatment in that branch and specifically which treatment. If the flow of source i passes through branch j and no treatment occurs at branch j , then the $i j$ entry is 1. If the flow of source i passes through branch j and the composite flow of branch j is treated at branch j , then the $i j$ entry is 2, 3 or 4 depending on the type of treatment as follows:

Acid or caustic neutralization	2
settling pond	3
domestic sewage treatment	4

The matrix for the linear graph of Figure V is shown in Figure VI.

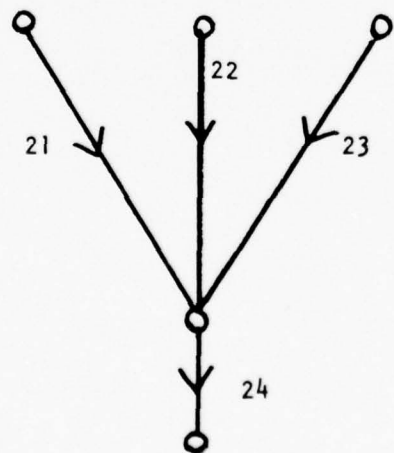
If the sewer system is in separate parts and hence has multiple outfalls, the outfall elements of the separate parts are connected together and a fictitious new outfall element is included in the linear graph. In the input

	1	2	3	4	5	6	7	8	9	10
POND (1)	1	1								1
PAPC (2)		1								1
PAOP (3)			1							1
PSAC (4)					1	1	2			1
PNAC (5)				1	1	1	2			1
PAPP (6)						1	2			1
PBDN (7)								1		1
PBIX (8)								1		1
PCON (9)								1		1
PCWZ (10)									1	1

TOPOLOGY MATRIX OF FIGURE V

Figure VI

data, a data item designated *NTOP* gives the program the information necessary to handle this situation. Figure VII illustrates the addition of the fictitious outfall.



21 - outfall of Part 1
 22 - outfall of Part 2
 23 - outfall of Part 3
 24 - fictitious outfall

MULTIPLE OUTFALLS

Figure VII

The operation of the program which computes the flow and pollutant parameter values is illustrated in the following example.

The output data of the process models are the inputs to the topology model. The format used for the input data is in vector form illustrated by

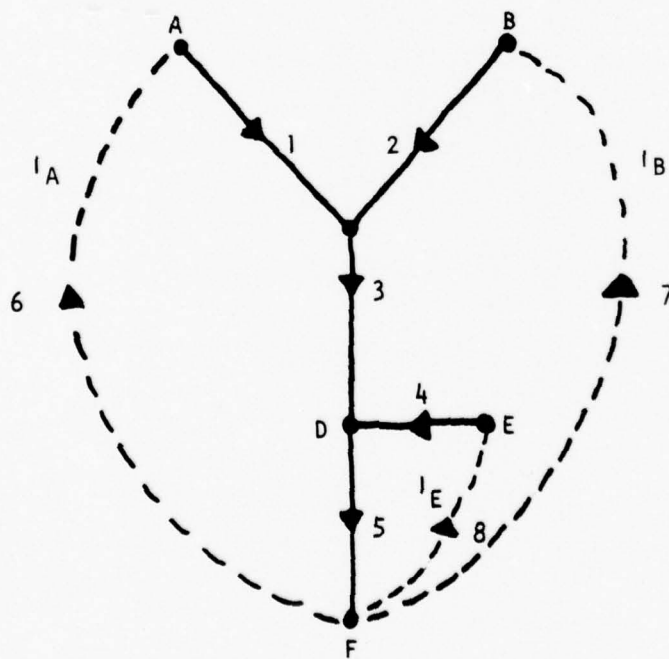
$$I = I_i (V_i, P_1, P_2 \dots)$$

Where I_i is input at point i in system

V_i is volume flow rate of input

P_j is measurement level of pollutant parameter for the j^{th} parameter.

The contribution of each input to each branch (measure point) can be determined by well-known network topology theory. A simple example using the system of Figure VIII will illustrate:



TOPOLOGY OF A SMALL SYSTEM

Figure VIII

Let the given tree graph (solid lines) show the branches with vertices lettered and the elements numbered. Consider the case where the effluent waste I_A , I_B , and I_E are entering the system at A, B, and E, respectively. The dashed lines represent sources.

Trace circuits in the diagram of Figure VIII such that one and only one source element is included in each circuit. Continue until all sources have been included. The circuit information is tabulated in matrix form where the columns correspond to the system elements and the rows correspond to the sources.

$$B_f = \begin{matrix} A \\ B \\ E \end{matrix} \begin{bmatrix} 1 & 0 & 1 & 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 \end{bmatrix} = [B U]$$

Also, let the source matrix of elements 6, 7, and 8 be

$$I_c = \begin{bmatrix} I_A \\ I_B \\ I_E \end{bmatrix}$$

Then one can determine the contribution of each source at each section of the system by:

$$B_f^T I_c = \begin{matrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \end{matrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 1 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 1 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I_A \\ I_B \\ I_E \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \\ I_5 \\ I_6 \\ I_7 \\ I_8 \end{bmatrix} = \begin{bmatrix} I_A \\ I_B \\ I_A + I_B \\ I_E \\ I_A + I_B + I_E \\ I_A \\ I_B \\ I_E \end{bmatrix}$$

The (+) in the expressions $I_A + I_B$ and $I_A + I_B + I_E$ is interpreted to mean "the combination of." This combination procedure used here will be a direct sum for the flow rates and a flow weighted combination for pollutant parameter levels. The following example illustrates this:

Consider $I_A (V_A, P_{I_A})$ and $I_B (V_B, P_{I_B})$ and $I_C = I_A + I_B$

where $V_A = 1,000$ gal/hr

$V_B = 500$ gal/hr

$$P_{I_A} = 50 \text{ mg/liter of sulfate}$$

$$P_{I_B} = 75 \text{ mg/liter of sulfate}$$

$$\text{mg sulfate/hr of A} = 50 \times 1,000 \times K$$

$$\text{mg sulfate/hr of B} = 75 \times 500 \times K$$

K converts gal to liters

$$V_C = V_A + V_B = 1,000 + 500$$

$$P_{I_C} = \frac{50 \times 1,000K + 75 \times 500K}{V_C \times K} = 58.4 \text{ mg/liters}$$

$$\begin{aligned} \text{thus } I_C (V_C, P_{I_C}) &= I_A (1000, 50) + I_B (500, 75) \\ &= I_C (1500, 58.4) \end{aligned}$$

It should be emphasized that the so-called "flow weighting" defined in the above example is a first order modeling. It should give reasonably accurate representation of combinations when considering such mass quantities as milligrams per liter of sulfates. However, for pH and when treatments take place more detailed calculations are performed.

The pH resulting from the mixing of the flows from several sources is calculated assuming that the alkalinity and the capacity factor (CT) of the combined flow are conservative, i.e. can be calculated by the above flow weighting procedures and that the combined pH can be calculated from the alkalinity and capacity factor of the combined flow. The equations and procedures used follows:

Given the alkalinity (ALK) and pH of each of the incoming flows, $[H^+]$ is computed for each flow by

$$[H^+] = 10^{-\text{pH}}, \text{ the H-ion concentration.}$$

$$\alpha_1 = \left(\frac{[H^+]}{K_1} + 1 + \frac{K_2}{[H^+]} \right)^{-1}$$

$$\alpha_2 = \left(\frac{[H^+]^2}{K_1 K_2} + \frac{[H^+]}{K_2} + 1 \right)^{-1}$$

$$K_1 = 4.446 \times 10^{-7} \quad K_2 = 4.688 \times 10^{-11}$$

The capacity factor is:

$$CT = [ALK - \frac{10^{-14}}{[H^+]} + H^+] / (\alpha_1 + 2\alpha_2).$$

Now with ALK, $[H^+]$, and CT given for each incoming flow, the combined flow values are computed, ALK_T , CT_T and $[H^+]_T$.

$$ALK_T = \frac{ALK_1 \times F_1 + ALK_2 \times F_2 + \dots}{F_1 + F_2}$$

$$CT_T = \frac{CT_1 \times F_1 + CT_2 \times F_2 + \dots}{F_1 + F_2 + \dots}$$

These values of ALK_T and CT_T are correct for ALK and CT conservative.

A first estimate of $[H^+]_T$ is also found by

$$[H^+]_T = \frac{[H^+]_1 \times F_1 + [H^+]_2 \times F_2 + \dots}{F_1 + F_2 + \dots}$$

where F_i are the individual source flows

$[H^+]_T$ is then found using ALK_T and CT_T in the formula

$$ALK = CT (\alpha_1 + 2\alpha_2) + \frac{10^{-14}}{[H^+]} - H^+$$

but α_1 and α_2 are functions of H^+ giving

$$ALK = CT \left[\frac{K_1 \times [H^+] + 2 \times K_1 \times K_2}{[H^+]^2 + K_1 \times [H^+] + K_1 K_2} \right] + \frac{10^{-14} - [H^+]^2}{[H^+]}$$

The CT_T and the first approximation of $[H^+]$ are used to calculate an ALK. By iteration with increments or decrements on $[H^+]$ the calculation is continued until an $[H^+]$ is found which gives ALK_T . This $[H^+]$ is the value taken to determine the combined flow pH.

The TOP subroutine computes the flow and pollution parameter values for each branch of the system. It uses the above illustrated flow weighting and pH calculations for each branch where no treatment is performed. In branches where treatment takes place, TOP calls in the appropriate subroutine which modifies the branch parameters properly for the particular treatment which takes place. The treatments and subroutines available in this study are: NEUTRA, acid or caustic neutralization; SETTLE, clarifier or settling pond; DOME, domestic or sanitary treatment.

The NEUTRA model allows consideration of acid neutralization using $Ca(OH)_2$, $CaCO_3$, Na_2CO_3 , or $NaOH$. Also, caustic neutralization is permitted using H_2SO_4 , HCl , HNO_3 , or CO_2 . The basic relations and equations that determined the model are given in the following paragraphs.

A. 2.1 NEUTRA MODEL(I) Analytical Determinations(A) Alkalinity

(1) $[\text{CO}_3^{-2} - \text{Alk}] = \text{Phenolphthalein Alkalinity (eq/l)}$

(2) $[\text{Alk}] = \text{Methyl Orange Alkalinity (eq/l)}$

(B) Acidity

(1) $[\text{H}^+ - \text{ACY}] = \text{Methyl Orange Acidity (eq/l)}$

(2) $[\text{CO}_2 - \text{ACY}] = \text{Phenolphthalein Acidity (eq/l)}$

(3) $[\text{ACY}] = \text{Titration to pure CO}_3 = (\text{eq/l})$

(Note: [ACY] is not routinely determined analytically, but is obtained by calculation.)

(II) Basic Capacity Equations

(A) $[\text{ALK}] = C_T (\alpha_1 + 2\alpha_2) + (10^{-14}/[\text{H}^+] - [\text{H}^+])$

(B) $[\text{ALK}] = C_T (2\alpha_0 + \alpha_1) + [\text{H}^+] - (10^{-14}/[\text{H}^+])$

where,

$$\alpha_0 = \left(1 + \frac{K_1}{[\text{H}^+]} + \frac{K_1 K_2}{[\text{H}^+]^2} \right)^{-1}$$

$$\alpha_1 = \left(\frac{[\text{H}^+]}{K_1} + 1 + \frac{K_2}{[\text{H}^+]} \right)^{-1}$$

$$\alpha_2 = \left(\frac{[\text{H}^+]^2}{K_1 K_2} + \frac{[\text{H}^+]}{K_2} + 1 \right)^{-1}$$

$$[\text{H}^+] = (10)^{-\text{pH}}$$

where,

$$K_1 = 4.446 \times 10^{-7} @ 25^\circ\text{C}$$

$$K_2 = 4.688 \times 10^{-11} @ 25^\circ\text{C}$$

$$K_1 K_2 = 2.0843 \times 10^{-17} @ 25^\circ\text{C}$$

111. Alkalinity/Acidity Relationships

- A. $[\text{ALK}] + [\text{H-ACY}] = 0$
- B. $[\text{ACY}] + [\text{OH} - \text{ALK}] = 0$
- C. $[\text{CO}_3 - \text{ALK}] + [\text{CO}_2 - \text{ACY}] = 0$
- D. $[\text{ALK}] + [\text{CO}_2 - \text{ACY}] = C_T$
- E. $[\text{ALK}] + [\text{ACY}] + 2 C_T$
- F. $[\text{ALK}] - [\text{CO}_3 - \text{ALK}] = C_T$
- G. $[\text{CO}_2 - \text{ACY}] - [\text{H-ACY}] = C_T$

where, $[\text{OH} - \text{ALK}] = \text{titration to pure } \text{CO}_3 = (\text{eq}/\ell)$

IV. Acid Neutralization (H_2SO_4 , HCl , HNO_3)/Using $\text{Ca}(\text{OH})_2$

(A) Calculate $[\text{ACY}]$ in

- (1) Analytically determined $[\text{H-ACY}]$ & $[\text{CO}_2 - \text{ACY}]$ & $(\text{pH})_{in}$
- (2) Calculate $(C_T)_{in}$ using Equation 111.G
- (3) Calculate $[\text{ACY}]_{in}$ using Equation 11.B, $(C_T)_{in}$, and $(\text{pH})_{in}$

(B) Stoichiometric Equations

- (1) $\text{H}_2\text{SO}_4 + \text{Ca}(\text{OH})_2 \rightarrow \text{CaSO}_4 + 2\text{H}_2\text{O}$
- (2) $2\text{HCl} + \text{Ca}(\text{OH})_2 \rightarrow \text{CaCl}_2 + 2\text{H}_2\text{O}$
- (3) $2\text{HNO}_3 + \text{Ca}(\text{OH})_2 \rightarrow \text{Ca}(\text{NO}_3)_2 + 2\text{H}_2\text{O}$

Note: CaCl_2 & $\text{Ca}(\text{NO}_3)_2$ are very soluble while CaSO_4 is relatively insoluble.

(C) Calculate $[\text{Ca}(\text{OH})_2]_{\text{added}}$

(1) During neutralization with $\text{Ca}(\text{OH})_2$

$$(\text{C}_T)_{\text{out}} = (\text{C}_T)_{\text{in}}$$

(2) Assuming neutralization reaction is carried to

pH = 7 ($[\text{H}^+] = 10^{-7}$), then using Equation

11.B, $[\text{H}^+] = 10^{-7}$, and $(\text{C}_T)_{\text{out}}$, calculate $[\text{ACY}]_{\text{out}}$

(3) $[\text{Ca}(\text{OH})_2]_{\text{added}} = ([\text{ACY}]_{\text{in}} - [\text{ACY}]_{\text{out}})/2$ (moles/liter)

(D) Analytically Determine $[\text{SO}_4^{+}]_{\text{in}}$

$$(1) \begin{array}{l} [\text{SO}_4] = 1.04616 \times 10^{-5} * [\text{SO}_4]_{\text{in}} \\ \text{Moles/liter} \qquad \qquad \qquad \text{mg/l} \end{array}$$

(E) Calculate $[\text{Ca}]_{\text{added}}$ in Moles/Liter

$$(1) \begin{array}{l} [\text{Ca}]_{\text{added}} = [\text{Ca}(\text{OH})_2]_{\text{added}} \quad \text{Eqn. IV.C.3} \\ \text{moles/liter} \qquad \qquad \qquad \text{moles/liter} \end{array}$$

(F) Calculate $[\text{Ca}]_{\text{total in}}$

$$(1) \begin{array}{l} [\text{Ca}]_{\text{Total in}} = [\text{Ca}] + [\text{Ca}]_{\text{added}} \\ \text{Analytical (moles/l)} \quad \text{Eqn. IV.E.1} \end{array}$$

(H) IF $SOLYPROD > 1.23 \times 10^{-4}$ then have precipitation of $CaSO_4$

$$(1) [CaSO_4]_{ppt} = \text{Quantity of } CaSO_4 \text{ precipitated (moles/l) then } ([Ca]_{total \text{ in}} - [CaSO_4]_{ppt})([SO_4]_{in} - [CaSO_4]_{ppt}) = 1.32 \times 10^{-4}$$

(2) Solve for $[CaSO_4]_{ppt}$ (moles/l)

$$[CaSO_4]_{ppt} = \frac{+([Ca]_{total \text{ in}} + [SO_4]_{in} - ([Ca]_{total \text{ in}} + [SO_4]_{in})^{2-4}}{2} \frac{([Ca]_{total \text{ in}} * [SO_4]_{in} - 1.32 \times 10^{-4})}{}$$

$$(3) [SS]_{out} = [SS]_{in} + [CaSO_4]_{ppt} * 1.36 \times 10^5$$

(mg/l) (mg/l)

$$(4) [TDS]_{out} = [TDS]_{in} + [Ca(OH)_2]_{added} * 74 \times 10^3 - [CaSO_4]_{ppt} * 1.36 \times 10^5$$

(mg/l)

$$(5) [COND]_{out} = 1.786 ([TDS]_{out} - 8.8)$$

(micromho's/cm) (mg/l)

$$(6) [TS]_{out} = [TDS]_{out} + [SS]_{out} \text{ or}$$

$$[TS]_{out} = [TS]_{in} + [Ca(OH)_2]_{added} * 74 \times 10^3$$

(mg/l)

$$(7) (pH)_{out} = 7.0$$

$$(8) [ALK]_{out} = 2(C_T)_{out} - [ACY]_{out}$$

(eg/l)

$$(9) [Ca]_{out} = ([Ca]_{total \text{ in}} - [CaSO_4]_{ppt}) * 40 \times 10^3$$

(10) No Change:

TKN	TNT
COD	Ammonia
TOC	Nitrates
MBAS	Nitrates
Sulfites	Color
Chlorides	Orthophosphate
Sodium	

$$(11) \text{[SO}_4\text{]}_{\text{out}} = \text{[SO}_4^+\text{]}_{\text{in}} - \text{[CaSO}_4\text{]}_{\text{ppt}} * 96 \times 10^3$$

(12) Total Hardness (TH)

$$\text{[Mg (mg/l as CaCO}_3\text{)]}_{\text{in}} = \text{[TH (mg/l as CaCO}_3\text{)]}_{\text{in}}$$

$$- \text{[Ca (mg/l as CaCO}_3\text{)]}_{\text{in}}$$

$$\text{[Mg]}_{\text{out}} = \text{[Mg]}_{\text{in}}$$

$$\text{[TH (mg/l as CaCO}_3\text{)]}_{\text{out}} = \text{[Ca (mg/l as CaCO}_3\text{)]}_{\text{out}}$$

$$+ \text{[Mg (mg/l as CaCO}_3\text{)]}_{\text{in}}$$

(1) IF SOLYPROD < 1.32 X 10⁻⁴, then you have no precipitation of CaSO₄

$$(1) [SS]_{out} = [SS]_{in}$$

$$(2) [TDS]_{out} = [TDS]_{in} + [Ca(OH)_2]_{added} * 74 * 10^3$$

$$(3) [TS]_{out} = [SS]_{out} + [TDS]_{out}$$

$$\text{or } [TS]_{out} = [TS]_{in} + [Ca(OH)_2]_{added} * 74 * 10^3$$

(mg/l)

$$(4) [COND]_{out} = 1.786 ([TDS]_{out} - 8.8)$$

$$(5) (pH)_{out} = 7.0$$

$$(6) [ALK]_{out} = 2(C_T)_{out} - [ACY]_{out}$$

$$(7) [Ca]_{out} = [Ca]_{in} + [Ca]_{added} * 40 * 10^3$$

$$(8) [SO_4^{=}] = [SO_4^{=}]_{in}$$

(9) No Change: Same as IV.H.10

(10) Same formula as IV.H.12

V Acid Neutralization (H_2SO_4 , HCl , HNO_3)/Using $CaCO_3$

(A) Calculate $[ACY]_{in}$

- (1) Same as IV.A.1
- (2) Same as IV.A.2
- (3) Same as IV.A.3

(B) Stoichiometric Equations

- (1) $H_2SO_4 + CaCO_3 \rightarrow CaSO_4 + H_2CO_3$
- (2) $2 HCl + CaCO_3 \rightarrow CaCl_2 + H_2CO_3$
- (3) $2 HNO_3 + CaCO_3 \rightarrow Ca(NO_3)_2 + H_2CO_3$

Note: $CaCl_2$ & $Ca(NO_3)_2$ are very soluble while $CaSO_4$ is relatively insoluble

(C) Calculate $[CaCO_3]_{added}$

- (1) During neutralization with $CaCO_3$

$$[ACY]_{out} = [ACY]_{in}$$

- (2) Assuming neutralization reaction is carried to $pH = 7$ ($[H^+] = 10^{-7}$), then using Equation II.B,

$$[H^+] = 10^{-7}, \text{ and } [ACY]_{out}, \text{ calculate } (C_T)_{out}$$

- (3) $[CaCO_3]_{added} = (C_T)_{out} - (C_T)_{in}$ (moles/liter)

(D) Analytically Determine $[SO_4]_{in}^*$

(1) Same as IV.D.1.

(E) Calculate [Ca] added in moles/liter

(1) $[Ca] = [CaCO_3]_{added}$ Eqn. V.C.3
 moles/l moles/l

(F) Calculate $[Ca^{++}]_{total}$ in

(1) Same as IV.F.1

(G) Calculate Solyprod

(1) Same as IV.G.1.

(H) If Solyprod $> 1.32 \times 10^{-4}$, then have precipitation of $CaSO_4$

(1) Same as IV.H.1

(2) Same as IV.H.2

(3) Same as IV.H.3

(4) $[TDS]_{out} = [TDS]_{in} + [CaCO_3]_{added} * 10^5 - [CaSO_4]_{ppt} * 1.36 * 10^5$

(5) Same as IV.H.5

(6) $[TS]_{out} = [TDS]_{out} + [SS]_{out}$

or

$[TS]_{out} = [TS]_{in} + [CaCO_3]_{added} * 10^5$

- (7) $(\text{PH})_{\text{out}} = 7.0$
- (8) Same as IV.H.8
- (9) Same as IV.H.9
- (10) Same as IV.H.10
- (11) Same as IV.H.11
- (12) Same as IV.H.12
- (1) If $\text{Solyprod} < 1.32 \times 10^{-4}$, then have no precipitation of CaSO_4

(1) Same as IV.1.1

$$(2) [\text{TDS}]_{\text{out}} = [\text{TDS}]_{\text{in}} + [\text{CaCO}_3]_{\text{added}} * 10^5$$

$$(3) [\text{TS}]_{\text{out}} = [\text{TDS}]_{\text{out}} + [\text{SS}]_{\text{out}}$$

or

$$[\text{TS}]_{\text{out}} = [\text{TS}]_{\text{in}} + [\text{CaCO}_3]_{\text{added}} * 10^5$$

(4) Same as IV.1.4

(5) Same as IV.1.5

(6) Same as IV.1.6

(7) Same as IV.1.7

(8) Same as IV.1.8

(9) Same as IV.1.9

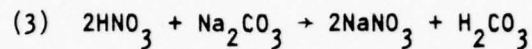
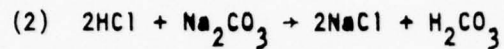
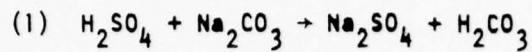
(10) Same as IV.1.10

V. Acid Neutralization (H_2SO_4 , HCl , HNO_3)/Using Na_2CO_3

(a) Calculate $[\text{ACY}]_{\text{in}}$

Same as IV.4

(b) Stoichiometric Equations



NOTE: Na_2SO_4 , NaCl , & NaNO_3 are very soluble.

(C) Calculate $[\text{Na}_2\text{CO}_3]_{\text{added}}$

(1) Same as V.C.1

(2) Same as V.C.2

$$(3) [\text{Na}_2\text{CO}_3]_{\text{added}} = (C_T)_{\text{out}} - (C_T)_{\text{in}} \quad (\text{moles/l})$$

$$(D) [\text{SS}]_{\text{out}} = [\text{SS}]_{\text{in}}$$

$$(E) [\text{TDS}]_{\text{out}} = [\text{TDS}]_{\text{in}} + [\text{Na}_2\text{CO}_3]_{\text{added}} * 1.06 * 10^5$$

$$(F) [\text{TS}]_{\text{out}} = [\text{TDS}]_{\text{out}} + [\text{SS}]_{\text{out}}$$

$$\text{or } [\text{TS}]_{\text{out}} = [\text{TS}]_{\text{in}} + [\text{Na}_2\text{CO}_3]_{\text{added}} * 1.06 * 10^5$$

$$(G) [\text{COND}]_{\text{out}} = 1.786 ([\text{TDS}]_{\text{out}} - 8.8)$$

$$(H) (\text{PH})_{\text{out}} = 7.0$$

$$(I) [\text{ALK}]_{\text{out}} = 2(C_T)_{\text{out}} - [\text{ACY}]_{\text{out}}$$

$$(J) [\text{Na}^+]_{\text{out}} = [\text{Na}^+]_{\text{in}} + 2([\text{Na}_2\text{CO}_3]_{\text{added}}) * 23 * 10^3$$

(K) NO CHANGE:

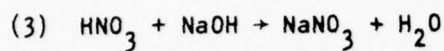
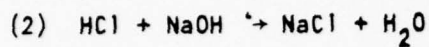
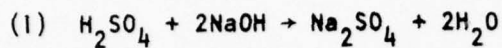
Same as IV.H.10

minus Na

plus SO_4 & CaVII. Acid Neutralization (H_2SO_4 , HCl , HNO_3)/Using NaOH(A) Calculate $[\text{ACY}]_{\text{in}}$

Same as IV.A

(B) Stoichiometric Equations

(C) Calculate $[\text{NaOH}]_{\text{added}}$

(1) Same as IV.C.1

(2) Same as IV.C.2

(3) $[\text{NaOH}]_{\text{added}} = [\text{ACY}]_{\text{in}} - [\text{ACY}]_{\text{out}}$

(eq/l = moles/l)

(D) $[\text{SS}]_{\text{out}} = [\text{SS}]_{\text{in}}$

(E) $[\text{TDS}]_{\text{out}} = [\text{TDS}]_{\text{in}} + [\text{NaOH}]_{\text{added}} * 40 \times 10^3$

(F) $[\text{TS}]_{\text{out}} = [\text{TDS}]_{\text{out}} + [\text{SS}]_{\text{out}}$

or $[\text{TS}]_{\text{out}} = [\text{TS}]_{\text{in}} + [\text{NaOH}]_{\text{added}} * 40 \times 10^3$

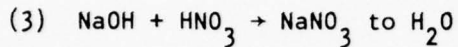
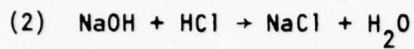
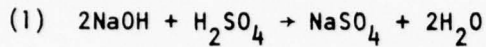
(G) $[\text{COND}]_{\text{out}} = 1.786 ([\text{TDS}]_{\text{out}} - 8.8)$

(H) $(\text{PH})_{\text{out}} = 7.0$

(I) $[\text{ALK}]_{\text{out}} = 2(\text{C}_T)_{\text{out}} - [\text{ACY}]_{\text{out}}$

(J) $[\text{Na}]_{\text{out}} = [\text{Na}]_{\text{in}} + [\text{NaOH}]_{\text{added}} * 23 \times 10^3$

(K) No Change: Same as VI.KVIII. Caustic Neutralization (NaOH)/Using H_2SO_4 , HCl, or HNO_3 (A) Calculate $(\text{C}_T)_{\text{in}}$ (1) Analytically determine $[\text{ALK}]_{\text{in}}$ and $(\text{PH})_{\text{in}}$ (2) Calculate $(\text{C}_T)_{\text{in}}$ in Using Eqn. 11.A

(B) Stoichiometric Equation(C) Calculate $[\text{H}_2\text{SO}_4]_{\text{added}}$, $([\text{HCl}]_{\text{added}}$ or $[\text{HNO}_3]_{\text{added}}$)(1) During neutralization with either H_2SO_4 , HCl , or HNO_3 , $(C_T)_{\text{out}} = (C_T)_{\text{in}}$ (2) Assuming neutralization reaction is carried to $\text{pH} = 7$ ($[\text{H}^+] = 10^{-7}$), then using Eqn. 11.A, $[\text{H}^+] = 10^{-7}$, and $(C_T)_{\text{out}}$, calculate $[\text{ALK}]_{\text{out}}$ (3) If neutralizer is H_2SO_4 , then $[\text{H}_2\text{SO}_4]_{\text{added}} = ([\text{ALK}]_{\text{in}} - [\text{ALK}]_{\text{out}})/2$ (moles/l)(4) If neutralizer is either HCl or HNO_3 , then $[\text{HCl}]_{\text{added}} = ([\text{ALK}]_{\text{in}} - [\text{ALK}]_{\text{out}})$, $[\text{HNO}_3]_{\text{added}} = ([\text{ALK}]_{\text{in}} - [\text{ALK}]_{\text{out}})$ (D) $[\text{SS}]_{\text{out}} = [\text{SS}]_{\text{in}}$ (for H_2SO_4 , HCl & HNO_3)(E) $(\text{pH})_{\text{out}} = 7.0$ (for H_2SO_4 , HCl & HNO_3)(F) $[\text{ACY}]_{\text{out}} = 2(C_T)_{\text{out}} - (\text{ALK})_{\text{out}}$ (for H_2SO_4 , HCl & HNO_3)(G) $[\text{COND}]_{\text{out}} = 1,786 ([\text{TDS}]_{\text{out}} - 8.8)$ (H) If H_2SO_4 is neutralizing agent

(1) $[\text{TDS}]_{\text{out}} = [\text{TDS}]_{\text{in}} + [\text{H}_2\text{SO}_4]_{\text{added}} * 98 * 10^3$

(2) $[\text{TS}]_{\text{out}} = [\text{SS}]_{\text{out}} + [\text{TDS}]_{\text{out}}$

(3) $[\text{SO}_4^{2-}]_{\text{out}} = [\text{SO}_4^{2-}]_{\text{in}} + [\text{H}_2\text{SO}_4]_{\text{added}} * 96 * 10^3$

(4) No Change: Sulfites TNT Nitrites
 TKN TOC Chlorides Ammonia Orthophosphates
 COD MBAS Sodium Nitrates Ca

(I) If HCl is neutralizing agent

(1) $[TDS]_{out} = [TDS]_{in} + [HCl]_{added} * 36.5 \times 10^3$

(2) $[TS]_{out} = [SS]_{out} + [TDS]_{out}$

or $[TS]_{out} = [TS]_{in} + [HCl]_{added} * 36.5 \times 10^3$

(3) $[Cl]_{out} = [Cl]_{in} + [HCl]_{added} * 35.5 \times 10^3$

(4) No Change:

TKN	Sodium	Orthophosphate
COD	TNT	Ca
TOC	Ammonia	
MBAS	Nitrates	
Sulfites	Nitrites	
Sulfates	Color	

(J) If HNO₃ is neutralizing agent

(1) $[TDS]_{out} = [TDS]_{in} + [HNO_3]_{added} * 63 \times 10^3$

(2) $[TS]_{out} = [SS]_{out} + [TDS]_{out}$

or $[TS]_{out} = [TS]_{in} + [HNO_3]_{added} * 63 \times 10^3$

(3) $[NO_3]_{out} = [NO_3] + [HNO_3]_{added} * 62 \times 10^3$

(4) No Change: Sodium Nitrites

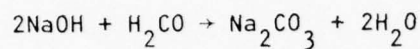
TKN	MBAS	TNT	Color
COD	Sulfite	Ammonia	Orthophosphates
TOC	Chloride	Sulfates	Ca

IX. Caustic Neutralization (NaOH)/Using CO₂

(A) Calculate $(C_T)_{in}$

Same as VIII.A

(B) Stoichiometric Equation



(C) Calculate $[\text{CO}_2]_{added}$

(1) During neutralization with CO₂,

$$[\text{ALK}]_{out} = [\text{ALK}]_{in}$$

(2) Assuming neutralization reaction is carried to pH = 7,

then using Eqn. II.A, $[\text{H}^+] = 10^{-7}$ and $[\text{ALK}]_{out}$, calculate

$$(C_T)_{out}$$

(3) $[\text{CO}_2]_{added} = (C_T)_{out} - (C_T)_{in}$ (moles/l)

(D) $[\text{SS}]_{out} = [\text{SS}]_{in}$

(E) $(\text{pH})_{out} = 7.0$

(F) $[\text{ACY}]_{out} = 2(C_T)_{out} - [\text{ALK}]_{out}$

(G) $[\text{COND}]_{out} = 1.786 ([\text{TDS}]_{out} - 8.8)$

(H) $[\text{TDS}]_{out} = [\text{TDS}]_{in} + [\text{CO}_2]_{added} * 44 * 10^3$

(I) $[\text{TS}]_{out} = [\text{TDS}]_{out} + [\text{SS}]_{out}$

or $[\text{TS}]_{out} = [\text{TS}]_{in} + [\text{CO}_2]_{added} * 44 * 10^3$

(J) No Change:

TKN	TNT
COD	Ammonia
TOC	Nitrates
MBAS	Nitrites
Sulfites	Sulfates
Chlorides	Color
Sodium	Orthophosphates
	Calcium

A.2.2. SETTLING MODEL

The SETTLE model takes into account of settling ponds or clarifiers. A removal factor RF is computed based on pond area and flow rate. This removal factor is applied to parameters involving settleable solids according to the following formulas.

Settle Model(A) Basic Removal Equation

$$[\text{CONC}]_{\text{out}} = [\text{CONC}]_{\text{in}} \frac{(1 - 0.82 \exp [-Q_i / 2780A])}{(1 - 0.00205 \exp [-Q_i / 2780A])}$$

Removal Factor

"

RF

or, $[\text{CONC}]_{\text{out}} = [\text{CONC}]_{\text{in}} * \text{RF}$

where,

Q_i = flow in million gallons/day (MGD)

A = surface area of clarifiers (acres)

(B) Suspended Solids (SS)

$$[\text{SS}]_{\text{out}} = [\text{SS}]_{\text{in}} * \text{RF}$$

(C) Volatile Suspended Solids (VSS)

$$[\text{VSS}]_{\text{out}} = [\text{VSS}]_{\text{in}} * \text{RF}$$

(D) Turbidity (T)

$$[\text{T}]_{\text{out}} = [\text{T}]_{\text{in}} * \text{RF}$$

(E) Chemical Oxygen Demand (COD)

$$[\text{COD}]_{\text{out}} = 0.3 [\text{COD}]_{\text{in}} + 0.7 [\text{COD}]_{\text{in}} * \text{RF}$$

(F) Total Organic Carbon (TOC)

$$[\text{TOC}]_{\text{out}} = 0.3 [\text{TOC}]_{\text{in}} + 0.7 [\text{TOC}]_{\text{in}} * \text{RF}$$

(G) Total Kjeldahl Nitrogen (TKN/N)

$$[\text{TKN/N}]_{\text{out}} = [\text{NH}_3/\text{N}]_{\text{in}} + ([\text{TKN/N}]_{\text{in}} - [\text{NH}_3/\text{N}]_{\text{in}}) * \text{RF}$$

where,

$$[\text{NH}_3/\text{N}] = \text{ammonia nitrogen}$$

(H) Total Solids (TS)

$$[\text{TS}]_{\text{out}} = [\text{TDS}]_{\text{in}} + [\text{SS}]_{\text{in}} * \text{RF}$$

where,

$$[\text{TDS}] = \text{total dissolved solids}$$

(I) Conductivity (COND)

$$[\text{COND}]_{\text{out}} = 1.786 * ([\text{TDS}]_{\text{in}} - 8.8)$$

(J) No Change:

- (1) pH
- (2) Total Dissolved Solids
- (3) MBAS
- (4) Sulfites
- (5) Chlorides
- (6) Sodium
- (7) TNT
- (8) Alkalinity
- (9) Acidity
- (10) Ammonia
- (11) Nitrates
- (12) Nitrates
- (13) Color
- (14) Orthophosphate

A. 2.3 DOME MODEL

Domestic or sanitary type treatment processes are simulated by the DOME subroutine. Two major types of domestic treatment systems are included in DOME. They are the trickling filter and activated sludge systems. While each of these systems may be employed in many different modifications or configurations, DOME is equipped to handle only a few.

DOME is suited for single stage filters only. Three different recycle configurations can be simulated: no recycle; recycle from the filter effluent; or recycle from the secondary clarifier effluent. Recycle configuration is controlled by input of the appropriate values of R2, R3, and R4; the trickling filter recycle terms in DOME. Recycle from the filter effluent is R2; recycle from the secondary clarifier is R3; and recycle to the filter is R4. Obviously, if R4 is zero, R2 and R3 must be zero and DOME will simulate a no recycle system. For a system with recycle from the filter effluent, R3 is zero and R2 is equal to R4. For recycle from the secondary clarifier effluent, R2 is zero and R3 is equal to R4.

Activated sludge systems simulated by DOME include the conventional or plug flow type and the complete mix type (which includes extended aeration.) Contact-stabilization, step-aeration, or other such modifications of the activated sludge process are not simulated by DOME. The net yield term supplied to the program by the user must be determined for the actual system being simulated. Calculation of the net yield term can be done as follows:

$$Y_n = \frac{(F_w) (SS_w) + (F) (SS_o)}{F(BOD_i + BOD_o)}$$

Y_n = Net yield (lbs. SS produced/lb. BOD used)

F_w = Volume of sludge wasted (MGD)

SS_w = Suspended solids concentration of waste sludge (mg/l)

F = Plant influent flow (MGD)

SS_o = Plant effluent suspended solids (mg/l)

BOD_i = Plant influent BOD (mg/l)

BOD_o = Plant effluent BOD (mg/l)

Information necessary for this calculation can be obtained from the plant's operating logs or measured during the preliminary survey.

Process Equations for Subroutine DOME

A listing of the mathematical expressions used in the formulation of the DOME subroutine follows:

Primary Clarifier

$$RF = \frac{1.0 - 0.82 \exp(-Q/2780A)}{1.0 - 0.00205 \exp(-Q/2780A)}$$

RF = Removal factor

Q = Plant flow (MGD)

A = Primary clarifier surface area (acres) AREAP

$$TSS_{out} = TSS_{in} * RF$$

$$BOD_{out} = 0.3BOD_{in} + 0.7BOD_{in} * RF$$

Assumes BOD, COD and
TOC are 70% particulate

$$COD_{out} = 0.3COD_{in} + 0.7COD_{in} * RF$$

$$TOC_{out} = 0.3TOC_{in} + 0.7TOC_{in} * RF$$

$$VSS_{out} = VSS_{in} * RF$$

$$Turb_{out} = Turb_{in} * RF$$

$$TKN_{out} = Ammonia_{in} + (TKN_{in} - Ammonia_{in}) * RF$$

Trickling FilterBOD reduction

$$E = \frac{1.0}{1.0 + 0.0085 \left[\frac{W}{VF} \right]^{\frac{1}{2}}}$$

E = Decimal BOD removal

W = BOD loading (lbs/day) to filter (not including recycle)

V = Volume of filter (acre-ft)

F = Recirculation factor = $\frac{1.0 + R}{1.0 + 0.1R}$

R = recirculation ratio

$$= \frac{\text{recycle flow}}{\text{plant flow}}$$

A temperature correction has been incorporated in the BOD reduction.

$$E_T = E_{20} (1.038)^{T-20}$$

E_T = Filter BOD removal at temperature T

E_{20} = Filter BOD removal at 20 °C, as above

T = Temperature of wastewater (°C)

$$\text{BOD}_{\text{out}} = \text{BOD}_{\text{in}} * E_T$$

$$\text{SS}_{\text{out}} = \text{SS}_{\text{in}} + \frac{\text{lbs. solids produced}}{8.34 (\text{plant flow} + \text{recycle flow})}$$

$$\text{lbs. solids produced} = 0.2 (\text{lbs BOD}_{\text{in}} - \text{lbs BOD}_{\text{out}})$$

Nitrification

$$E = \text{EXP}(-KD/Q^n)$$

E = Decimal reduction in $\text{NH}_3\text{-N}$ concentration

K = Reaction constant related to the specific surface of the media

D = Depth of filter (ft)

Q = Hydraulic loading rate (MGAD)

n = Constant related to the specific surface and configuration of packing of the media

= 2.36 1" rock media

= 3.80 2½" rock media

$$K_{20} = K \text{ at } 20^\circ \text{C} = \begin{matrix} 0.23 \text{ 1" rock media} \\ 0.13 \text{ 2½" rock media} \end{matrix}$$

$$K = K_{20} (1.07)^{T-20} \text{ where T is wastewater temperature } (^\circ\text{C})$$

$$\text{Ammonia}_{\text{out}} = \text{Ammonia}_{\text{in}} * E$$

$$\text{Nitrate}_{\text{out}} = \text{Nitrate}_{\text{in}} + \text{Ammonia}_{\text{in}} - \text{Ammonia}_{\text{out}}$$

$$\text{TKN}_{\text{out}} = \text{TKN}_{\text{in}} - \text{Ammonia}_{\text{in}} + \text{Ammonia}_{\text{out}}$$

Trickling filter secondary clarifier

The formulation for the trickling filter secondary clarifier is the same as that for the primary clarifier. The exception being that only suspended solids removal is considered.

Aeration basin

BOD reduction

$$\text{BOD}_{\text{out}} = \text{BOD}_{\text{in}} - \frac{(\text{MLSS}) (\text{Vol})}{(Y_n) (\text{Theta}) (F)}$$

MLSS = Mixed liquor suspended solids

Vol = Aeration basin volume (MG)

Y_n = Net yield = lb. SS produced/lb. BOD used in aeration

F^n = Plant flow + recycle flow (MGD)

Theta = Sludge retention time or sludge age

$$= \frac{1.0}{Y_n (\text{PLI})} \quad \text{where PLI} = \frac{(\text{BOD}_{\text{in}}) (\text{Plant flow})}{(\text{MLSS}) (\text{Vol})}$$

Nitrification

A double "halving" or Balzano type iteration is performed on the effluent concentrations of ammonia and the nitrifying bacteria, Nitrosomonas, until the governing system equations are satisfied:

$$S_i = S_o + \frac{K_r S_o X_o D_t}{Y (K_s + S_o)}$$

$$X_i = X_o - \frac{K_r S_o X_o D_t}{K_s + S_o}$$

S_i = Ammonia in

S_o = Ammonia out

K_r = Synthesis rate constant

Y = Yield coefficient

K_s = Saturation coefficient

X_i = Nitrosomonas in

X_o = Nitrosomonas out

D_t = Detention time (Vol/Flow)

A detailed explanation and justification of assumptions may be found in "A Generalized Computer Model for Steady-State Performance of the Activated Sludge Process", Water Pollution Control Research Report, by Robert Smith and Richard G. Eilers, FWPCA (Washington, 1969).

Activated sludge secondary clarifier

$$SSF = \frac{(SS_i)(F)(3.785)}{(24)(A)}$$

SSF = Solids surface feed (kg SS/m²/hr)
 F = Plant flow plus recycle flow (MGD)
 SS_i = Mixed liquor suspended solids (mg/l)
 SS_{out}ⁱ = 4.5 + 8.6 (SSF)

A. 3.0 Use of Plant Site Model:

The plant site can be modeled and various operating conditions simulated using a card deck containing the following subroutines:

MAIN: sets the system dimensions and calls appropriate subroutines;
 PROCES, START, TOP.

PROCES: defined in previous discussion. This program reads in process mnemonics for processes present at the particular site being studied.

Appropriate process data is called out of process library. Process data can be altered to better represent a particular site.

Process Library: described in previous discussion.

START: Reads in; the number of processes (sources), the number of branches, the number of parameters and the number of outfalls in this site study. Also reads in the numbers of the particular pollutants in the current study (NPLIST). Reads in branch names. Branches are named for convenient interpretation of output data. Calls CHK1.

CHK1: Reads in the number of non competing parameters (used in RM); reads in the names of all of the pollutants in the master list, for each the number of measurement methods available and the sampling frequency. This program also prints out the input information available at this point. In particular this includes the process data and the topology matrix.

TOP: This program was described in detail in previous paragraphs but essentially it does the following: reads in treatment data; takes process data and site topology data and calculates the flow and pollutant parameters for each branch of the system. The effects of treatments are included in the calculation; calls the treatment subroutine NEUTRA, SETTLE, and DOME; call CHK2 to output results.

NEUTRA: This subroutine is called by TOP if acid or caustic neutralization is required in any branch.

SETTLE: This subroutine is called by TOP if a settling pond or clarifier is required in any branch.

DOME: This subroutine is called by TOP if domestic or sanitary treatment is required.

CHK2: This program essentially writes out the results of the TOP calculations, i.e., the system simulation.

FLAG: This subroutine is not used in system simulation but in system planning with RM. However, it is called by TOP.

B. Resource Matching

After the survey planner has modeled the plant site and gone through several simulations for plant operating levels probable during the survey period, he needs to determine: at which of the branches should he take his samples; for which parameter should each sample be analyzed; for the proposed number of samples and parameters what equipment, time, and personnel are required or conversely for the available time, equipment, and personnel how many samples and parameters can be considered. This is the survey planning operation.

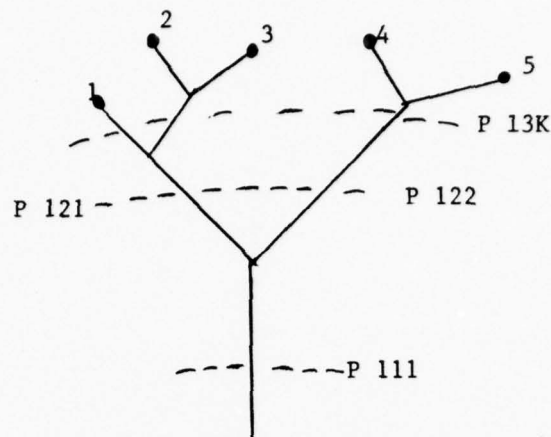
This survey planning is accomplished using the "site modeling and simulation" program discussed in the previous section of this report and the resource matching (RM) program and its subroutines.

Data is prepared for the RM program by TOP, LEVEL, and FLAG subroutines. As described in the previous section, the TOP subroutine determines the flow and the parameter value for each pollutant at each possible measure point in the system. The LEVEL subroutine rearranges TOP output data properly for use in RM.

B.1.0 LEVEL Subroutine:

RM considers measure points in subsets or "levels". These "levels" are defined such that if a pollutant, say sulfates, is measured at all points in a "level" then all the sulfates in the system have been detected. The following paragraphs explain the level designation.

The three dimensional space P_{ijk} is required to designate the pollutants at all points throughout the site. Note the following system topology and pollutant P_1 illustrated in Figure IX.


 $K = 1, 2, 3$

OUTFALL
Level Designations

Figure IX

Pollutant sources are at points 1, 2, 3, 4, 5. Whatever the source, if P_1 is measured at the outfall, one sample point detects all of P_1 . However, if P_1 is measured at level 2, two sample points are required to detect all of P_1 . Thus, pollutant P is designated as

$$P_{ijk}$$

where i is for the i th pollutant

j is for the j th level

k is for the measure point at the j th level.

One needs to consider the pollutant vectors in subsets to insure that all of a particular pollutant has been detected. For example, for pollutant P_1 the sets are

$$P_{111}$$

or

$$P_{121} + P_{122}$$

or

$$P_{131} + P_{132} + P_{133}$$

In reading pollutants into a computer for the matching program the pollutants will have a name and number designation, a measurement level, a measurement point and an approximate measure number (concentration, pH, other). For example, if sulfate is the number 5 pollutant, sulfate at the fourth measure point on the third level may be $P(5, 3, 4) = 50 \text{ mg/l}$.

The resource matching program is supplied with the predicted plant site state from the site-topology model. That is, a predicted number is given for P_{ijk} for each parameter i , for each level j , and for each point k at each level.

For the sewer network defined by the $A(I,J)$ matrix, the LEVEL subroutine generates the sets of points that form levels.

B.2.0 FLAG Subroutine:

The points where samples are to be collected and the parameters for which the samples are to be analyzed are determined by the RM logic or by the survey planner using the FLAG subroutine.

The RM logic assigns the outfall as the measure point for all parameters unless it is forced to seek a higher level because of low concentrations at the outfall or unless it is forced to seek a higher level because of violation of a constraint. When a constraint is violated, the RM logic seeks new methods and/or new levels. At whatever level measurements are to be taken for a given parameter, all points at that level must be measured.

However, as a result of system modeling and simulation of expected plant operating conditions the survey planner may wish to take additional measurements to obtain further useful information. By the use of the FLAG subroutine the survey can cause RM to consider (flag) additional measure points for each parameter.

The RM logic assigns resources to these flagged points before making assignments through its own logic. A flag designates a particular pollutant to be measured at a particular measure point. Three types of flagging procedures are available:

1. Automatic flagging
2. Manual flagging of sources
3. Manual flagging of branches

For automatic flagging the program computes the total mass of any pollutant discharged at the outfall and the total mass for that pollutant from each process (source). The program will then automatically flag any source which contributes more than X (decimal fraction) to the total at the outfall. The source is flagged for this parameter only. The survey officer specifies the flagging level X for each parameter.

The FLAG subroutine also permits manual flagging in two parts. The first part allows the user to select specific processes (sources) and parameters he wishes to flag. The second part allows specific branches and parameters to be flagged. In both cases the process (branch) numbers and corresponding parameter numbers are read in by FLAG. FLAG also outputs the names of the parameters and their flagging levels, and the names of the processes, branches and parameters selected by the user.

B.3.0 Other RM Data Required

The resources available for conducting the survey are in the form of the Measurements Resources Model, Sampler Data and Flow Measurement Data.

The measurement resources model consists of lists of measurement methods applicable for each pollutant. There are up to three methods listed for each pollutant in the master list. Different methods for a given pollutant may involve an entirely different technique (such as Specific Ion Electrode or 132C Phenate for Ammonia measurement) or may involve the same technique performed by a different class of analyst.

For each method for each pollutant, defining characteristics are tabulated in matrix form for ready access by a computer program. These defining characteristics are: method name, minimum acceptable concentration, equipment or preparation process name, equipment or preparation time per sample, van space required, analysts time required for each of four classes of analyst, cost per sample, sample volume per sample, at which lab analysis is done. The measurement Resources Model is illustrated in Figure X.

The RM program is also supplied with: the number of measure methods available for each parameter; the sampling frequency for each parameter; the names of the pieces of equipment in all resource models and time constraint on each; constraints other than on pieces of equipment.

B.4.0 Resource Matching Model Logic:

The function of the resource matching model is to take the predicted plant site state, the available resources and the constraints and to determine a feasible survey plan. The plan will include measure points selected by the RM logic and points flagged by the survey planner.

The predicted plant site state is supplied by the TOP subroutine (plant site model) and consists of flow and pollutant parameter values for each branch (possible measure point) of the system. The plant site state is determined for a specific set of processes and operating levels chosen by the survey planner as conditions one might expect to occur during the survey period.

The available resource data is supplied by the resource models. For each pollutant parameter to be measured on the survey, there are one to three measurement methods defined in the resource model part of the program. This model lists the equipment, personnel, and time required for a given measurement.

PARAMETER NAME AMMONIA (NH3)-N NUMBER OF METHODS AVAILABLE FOR ANALYSIS 2

METHOD 1 NAME SPEC. ION ELECTRODE MINIMUM ACCEPTABLE CONCENTRATION 0.0500

<u>EQUIPMENT NAME</u>	<u>CODE #</u>	<u>EQ. TIME PER SAMPLE</u>	<u>VAN SPACE</u>	<u>AVG. ANALYSTS TIME/SAMPLE</u>	<u>MISCELLANEOUS</u>
EXPD SCALE PH MET	1	2.00	10.00	0.0 Class 1	0.0 COST SAMPLE
SPEC ION ELECTRODE	2	2.00	0.0	0.0 Class 2	10.0 SET UP TIME
	0	0.0	0.0	8.0 Class 3	1.00 WHERE ANALYSIS DONE
	0	0.0	0.0	0.0 Class 4	24.00 TIME CONSTRAINT

METHOD 2 NAME 132C PHENATE MINIMUM ACCEPTABLE CONCENTRATION 0.0500

<u>EQUIPMENT NAME</u>	<u>CODE #</u>	<u>EQ. TIME PER SAMPLE</u>	<u>VAN SPACE</u>	<u>AVG. ANALYSTS TIME/SAMPLE</u>	<u>MISCELLANEOUS</u>
VIS SPECTROPHOT	3	0.50	10.00	0.0 Class 1	0.0 COST SAMPLE
	0	0.0	0.0	2.50 Class 2	10.0 SET UP TIME
	0	0.0	0.0	10.00 Class 3	1.00 WHERE ANALYSIS DONE
	0	0.0	0.0	0.0 Class 4	24.00 TIME CONSTRAINT

MEASUREMENT RESOURCE

Figure X

Other resource data was discussed in the previous section of this report and is illustrated in Figure X.

The constraints are generally in the form of limited time available for use of a given piece of equipment or class of analyst. Limits on available space and cost can also be included.

The survey plan determined by the resource matching model includes: specification of a measurement method for each parameter; specification of the measure points for each parameter; specification of resources used by measurement of each parameter; a listing of the total commitment for the survey period of each piece of equipment and each class of analyst; a listing of the constraint violations.

A feasible survey plan is feasible in the sense that limits on equipment and personnel time available have not been exceeded. If no feasible alternatives are available, the program will specify a non-feasible survey plan and note the constraints violated.

The survey planner can generate alternative feasible and non-feasible survey plans by altering priorities in measurement methods, priorities in the order of assigning resources to parameters, or by varying constraints on time, equipment or personnel. Also, different sets of measure points may be flagged by the survey planner.

Alternative solutions are possible because different measurement methods have different requirements. The characteristics of the measurement methods which afford a basis for trade off are:

1. Different measurement methods may require different minimum pollutant concentration.
2. Different measurement methods may require different amounts of time expenditure by technicians and by equipment.
3. Different methods require different pieces of equipment, and there are time and space constraints on personnel and equipment.

The programmer's manual in the appendix includes a flow chart or block diagram of the resource matching logic. The following paragraphs describe that logic in general terms.

The resource matching program is supplied with a predicted plant site state from the site-topology model (TOP). That is, a predicted number is given for P_{ijk} for each parameter i , for each level j , for each point k at that level. Also, for each parameter to be measured on a survey, one to three measure methods are defined by a measure matrix $P_{im\ell}$. That is, methods M1, M2, M3 for each pollutant i . As part of the method definition, the minimum parameter value is given. For any lower number, the method loses credibility.

The first step in the resource matching logic is the generation of a set of matrices which will list all feasible measurement method matrices (feasible in terms of minimum parameter value) for each P_{ijk} . Every number P_{ijk} is compared with the minimum parameter value in each appropriate measure method matrix $P_{im\ell}$. If the P_{ijk} number is equal to or greater than the required minimum, the $P_{im\ell}$ is saved or stored as $P_{ijk\ell}$. This is a feasible measure method matrix for parameter i , level j , point k , method ℓ . Each matrix is of the form of the previously defined method matrix $P_{im\ell}$ illustrated in Figure X. The complete set of matrices contains all feasible methods for each parameter at each measure point in the system. The resource matching model will next determine a feasible survey schedule. The schedule is the assignment of measure point or points for each parameter and a measure method for each parameter at those points. The schedule is feasible if the total commitment of time and equipment does not exceed availability limits.

It is reasonable to assume that for any system there are many feasible surveillance schedules.

The survey officer may choose a best schedule in terms of: value in dollars, technician time, space required, time used on automated equipment, or total survey time.

The feasible solutions are determined by assigning a measurement method to each pollutant at the outfall or at the lowest level at which a P_{ijkl} exists for that pollutant. This is started with some arbitrary P_1 . As each additional pollutant is added an account of the commitment of resources is kept. The limits or constraints on the resources are known. When any constraint is encountered the program first seeks an alternate measurement method at the same topological level. If the alternate method is found and does not violate the same or any new constraints the next pollutant is considered. If no alternative measurement method is found at the same level, then a new level is tried. If no alternative is found at new levels, then the previously considered pollutant is tried for an alternative method. If the alternative exists P_{j-1} is replaced by P_j and the next pollutant is considered. If P_{j-1} does not afford a solution then P_{j-2} is considered and so forth. If no feasible alternative exists the program returns to the P_j entered with the violation. The assignment continues with the violation noted. Alternative solutions are generated by selecting alternative sequences for considering measurement methods or for considering the different pollutant parameters.

The systems analysis of the survey design will reduce the time required for survey planning. Also, the systems approach will allow consideration of many alternative plans, with each of these plans more precisely defined quantitatively. It is reasonable to expect that a computerized system analysis will be used to seek alternatives during the survey, as well as during planning.

B.5.0 Output Data:

Some of the output of the RM program is a reiteration of the input data. Other output data is essentially the survey design and is discussed in the following paragraphs. Sample output data is given in the appendix under Program Listing and in the User's manual.

Each branch of the system is listed and along with each parameter that is to be measured at that branch. Also for each branch the sampling procedure is defined in terms of the number of samples taken at that point, the sampling method, and the total technician time required for those samples.

Next, for each parameter in the study, the points where this parameter is to be measured are listed. At each point, the measurement method and the expected value are given along with the total number of samples.

Items of equipment used, total time used for this parameter, and any equipment time constraint are noted for each parameter. In addition, the total time commitment for this parameter for each of four classes of analysts is listed along with time constraints encountered.

Next the survey commitments are summarized in terms of the demand on each piece of equipment and each class of analyst.

For each item of equipment used the program lists: the number of parameters using this item; the total time used; was constraint violated; the amount of the violation; space required.

For each class of analyst the program lists: the total time commitment; was constraint violated; the amount of the violation.

Data on van space utilization and cost can be read out if proper data is input.

B.6.0. Subroutines Required for RM

MAIN and all of the subroutines required in Site Modeling and Simulation are required in Resource Matching (RM). In addition the following subroutines are required.

LEVEL arranges TOP output for use in RM.

FLAG allows survey planner to specify for RM measure points in addition to those selected by RM logic.

RM reads in and prints out resource information, allocates resources and calls subroutines when needed to relieve violations, and prints out resource allocation information.

CONCK determines feasible measure methods and allocates resources to flagged points.

TO zeros out temporary allocations for equipment times.

EQCHEC determines if any equipment time violations occur.

VSCHEC checks for van space constraint violations.

CNCHEC checks for analyst time constraint violation.

ADD adds current allocations of equipment time, analysts' times, van space and costs.

SET stores the array of methods used at a branch in a level for a given parameter.

PIEQCH searches past assignments to attempt to relieve constraint violations.

SUBT subtracts current allocations.

INFORM prints out branch names and parameters to be measured at that branch.

SAMPLE allocates analyst type 1 time required for taking samples and measuring flow.

PRPAR outputs parameter measurement information.

USECT totals usage equipment.

TICHAN converts minutes to hours and minutes.

C. MODEL VERIFICATION AND/OR UPDATING
(Subroutine CORRCT)

C.1.0. INTRODUCTION

The CORRCT subroutine accepts site measurement data, compares it with model predicted measurement data and computes and prints out suggested new values for the parameters of the process models.

The subroutine CORRCT is used in conjunction with the program subroutines which make up the site model. They are MAIN, PROCES, START, TOP, NEUTRA, SETTLE, and DOME.

The site model package with CORRCT has two objectives. First, the process models can be updated or improved using preliminary survey data. While the best data available were used in constructing the process models, there was considerable variation in data for a given process from one plant site to another or from one season to another. Better process model values may be obtained with CORRCT using measurements from judiciously selected grab samples taken on a preliminary survey. The output of CORRCT lists new values for certain process parameters. If the survey officer wishes, he may enter these new values into the process models using procedures outlined in the discussion of the PROCES subroutine.

A second use of site model package with CORRCT would be verification of the model. After the survey, measurements are available for obtaining max, min, average or other expected values for each parameter at each branch for known levels of production. These values can be entered into the site model package with CORRCT to determine values for process model parameters which can be used to verify the

model or refine the model as appropriate. With confidence in the site model, one can now use it to predict levels of potential pollutants for production levels other than those which occurred during the survey. This should give added significance to the survey report.

Ideally, if measurements are to be made to verify the process models, the measure points should be chosen such that each process will be determined uniquely by the measurements. However, if the survey officer who determines the measure point does not visualize the system in terms of the same processes as are used in the process model, measurements may not uniquely determine process parameters. The program is designed to accept such non-unique measurement data and uniquely determine processes, where possible, and make approximations on other processes informing the user if the determination is non-unique.

The measure points for uniquely determining all processes can be identified by referring to the linear graph of the system (Figure 1 for example) which displays all processes and all possible measure points. On the linear graph, identify all of the vertices (junctions) nearest to the processes. If at a vertex there are N branches incident to a vertex, then measurements must be taken or implied at $N - 1$ of those branches. By taking $N - 1$ measurements, the N th measurement is implied. Note that one of the $N - 1$ measurements at vertex A may be implied by measurements at vertex B or other vertices.

C.2.0. INPUT DATA AND OUTPUT DATA

After the decisions are made which determine where measurements are to be made, this information is supplied to the CORRCT subroutine in the form of the MESUR(I) matrix. The MESUR(I) matrix contains a

"0" for each branch where measurements are not taken and a "1" for each branch where measurements are taken.

It may not be appropriate or even possible to check every parameter in a process model. The subroutine CORRCT only applies to conservative parameter (i.e. only those measured in terms of mass, mg/l). The program allows the user to select the one, two or several (up to 20) parameters to be included in each model verification. The parameters to be considered in a particular study are identified by their numbers in the master list of Table II. The flows must be included in any branch where other parameters are considered.

The number of parameters and the parameter numbers are supplied to CORRCT for each branch where measurements are taken using BPLIST (IB,N), where IB is the branch number and N is the parameter number. The first number N for each branch is the number of parameters considered in that branch. The subsequent numbers N are the parameter numbers for that branch.

The next inputs to CORRCT are the measured parameter values YM(IB,N). For each branch IB the first value, for N = 1, must be the flow. The remaining YM(IB,N) input for a branch are the measured values of the parameters listed in BPLIST(IB,N).

The subroutine CORRCT output lists each source (process) by number, notes if the determination is unique or estimated, and gives the old parameter and the new parameter for each parameter verified. If the determination is unique, the branch where the defining measurement was taken is listed.

C.3.0. SUBROUTINE LOGIC

The logic of the program is outlined in this and the following paragraphs. The program scans each branch of the system starting with branch number one. It determines how many sources (processes) contribute to this branch and specifically which sources. The program also notes if any of the contributing sources were treated on or before reaching their branch. If only one source contributes to this branch and it is not treated, then the branch measurements are taken as the suggested new values for the source (process) parameters. If only one source contributes to this branch and it is treated, then the effect of the treatment on each parameter is determined using the original model. The branch measurements are modified by these factors to give the suggested new values for the source (process) parameters.

If more than one source contributes to a branch, the program determines if all but one has previously determined uniquely. If all but one has, then the suggested new parameter values are obtained by subtracting known source values from the measurements to give a new uniquely determined source. These subtractions are done in terms of mass and not concentrations.

If more than one source contributes to a branch and more than one of these sources has not been previously uniquely determined, then these undetermined sources can only be estimated. For each undetermined source J contributing to branch I the percent contribution for parameter K is determined from the original model. The branch measurements are modified by this % to give estimated new values for the source parameter

K. These percentages are determined in terms of mass and not concentrations.

Due to the treatment there may be some nonlineraties and therefore some errors in the uniquely determined sources. If refinement is desired, the suggested new values could be assigned to the processes and in several iterations these errors could be eliminated.

Errors in the estimates for the non unique sources could have many causes. Attempted improvements through interative solutions may not be fruitful. If better results are desired, the best course would be to re-assess the selection of measurement points.

III INDICATOR MODEL

A. INTRODUCTION

The indicator model is used to calculate certain parameters, generally termed process variables or operating characteristics, that indicate the operational state of the system. These calculated values can then be compared with the desirable values as cited in design books or manuals*. A comparison will give the engineer insight into the operation of the system such that problem areas and possible causes of these problems are more readily apparent. It can also indicate whether inadequate plant performance is due to design deficiencies or poor operational practices.

An example should suffice to illustrate this more clearly. If a plant's effluent suspended solids concentration is too high, the first thing the engineer might suspect is the secondary clarifier. Solids removal efficiency calculated by the model will indicate if the secondary clarifier is performing poorly. If the secondary does appear to be performing poorly, operating characteristics such as surface settling rate and solids loading rate, calculated by the model, can be compared to those suggested in the literature as above. If the clarifier is failing due to a hydraulic overload, the comparison of the surface settling rate to suggested values should indicate this. If the operational characteristics of the secondary clarifier compare favorably with those in the literature, but it still appears to be failing, an investigation of the operational characteristics of the other unit processes might be

*
Wastewater Engineering, Metcalf and Eddy, Inc., McGraw Hill Book Company, N. Y., N. Y., (1972)

Process Design Manual for Upgrading Existing Wastewater Treatment Plant, U. S. EPA, Office of Technology Transfer, (Washington 1974)

Environmental Systems Engineering, L. G. Rich, McGraw Hill Book Company, N. Y., N. Y., (1973)

helpful. Should the process loading intensity fo the aeration basin not compare favorably with cited values, a poorly settling sludge might be the cause of the secondary clarifier's failure.

A.1.0 OPERATIONAL CHARACTERISTICS

Like the treatment system model, the indicator model is applicable to trickling filter and activated sludge type treatment plants. Operational characteristics calculated by the model are as follows:

Primary Clarifier

Detention time (hrs.)
Surface settling rate (GPD/ft²)
Weir overflow rate (GPD/ft)
Solids loading rate (lb SS/ft² -day)
Solids removal efficiency (%)

Trickling Filter

Hydraulic loading (MGAD)
Organic loading (lb BOD/day/acre-ft)
Recirculation ratio
BOD removal efficiency (%)

Aeration Basin

Detention time (hrs)
Volumetric loading (lb BOD/day/1000 ft³)
Process loading intensity (lb BOD/day/lb MLSS)
Sludge age or retention time (days)
Diffused aeration
 Volumetric air supply (CFM/1000 ft³)
 Organic air supply (ft³/lb BOD)
Mechanical aeration
 Volumetric power supply (HP/1000 ft³)
 Organic oxygen supply (lb oxygen/lb BOD)
BOD removal efficiency (%)

Secondary Clarifier

Detention time (hrs)

Surface settling rate (GPD/ft²)

Weir overflow rate (GPD/ft)

Solids loading rate (lb SS/day/ft²)

Solids removal efficiency (%)

Overall Plant

BOD removal efficiency (%)

Solids removal efficiency (%)

A.2.0 MATHEMATICAL RELATIONSHIPS

Each of the operational characteristics calculated by the model is represented by a mathematical expression. Many of these expressions are evaluated at both average and peak flow conditions. This is done by using either the average or peak flow term in the expression. However, this may not always be completely accurate, as the BOD and suspended solids concentrations also vary. Such error may be overcome, if desired, by substituting the peak values of these parameters (BOD, flow, etc.) for the average values and running the model a second time. Average values of the operational characteristics calculated on the second run will then represent the peak values. Following is a listing of the relationships

Primary Clarifier

Detention time:

$$DT = \frac{V}{1000 F/24}$$

V = clarifier volume (1000 gal)

F = plant flow (MGD)

Surface settling rate:

$$SSR = \frac{F * 10^6}{A}$$

F = plant flow (MGD)

A = clarifier surface area (ft²)

Weir overflow rate:

$$\text{WOR} = \frac{F * 10^6}{L}$$

F = plant flow (MGD)

L = weir length (ft)

Solids loading:

$$\text{SL} = \frac{(\text{SS}) (F) (8.34)}{A}$$

SS = influent suspended solids (mg/l)

F = plant flow (MGD)

A = clarifier surface area (ft²)

Solids removal efficiency:

$$\text{SRE} = \frac{\text{SSI} - \text{SSO}}{\text{SSI}} * 100.$$

SSI = plant influent suspended solids (mg/l)

SSO = primary effluent suspended solids (mg/l)

Trickling Filter

Hydraulic loading:

$$\text{HL} = \frac{F + R}{A}$$

F = plant flow (MGD)

R = recycle flow to filter (MGD)

A = filter surface area (acres)

Organic loading:

$$\text{OL} = \frac{(F) (\text{BOD}) (8.34)}{V}$$

F = plant flow (MGD)

BOD = primary effluent BOD (mg/l)

V = filter volume (acre-ft)

Recirculation ratio:

$$\text{RR} = \frac{R}{F}$$

F = plant flow (MGD)

R = recycle flow to filter (MGD)

BOD removal efficiency:

$$E = \frac{BOD_i - BOD_o}{BOD_i} * 100$$

BOD_i = primary effluent BOD (mg/l)
 BOD_o = plant effluent BOD (mg/l)

Aeration Basin

Detention time:

$$DT = \frac{24V}{(F+R)1000}$$

V = aeration basin volume (1000 gal)
 F = plant flow (MGD)
 R = recycle flow (MGD)

Volumetric loading:

$$VL = \frac{(BOD) (F) (8.34) (7.481)}{V}$$

BOD = primary effluent BOD (mg/l)
 F = plant flow (MGD)
 V = aeration basin volume (1000 gal)

Process loading intensity:

$$PLI = \frac{(BOD) (F) (8.34) (1000)}{(MLSS) (V) (8.34)}$$

BOD = primary effluent BID (mg/l)
 F = plant flow (MGD)
 MLSS = mixed liquor suspended solids (mg/l)
 V = aeration basin volume (1000 gal)

Sludge age:

$$SA = \frac{(MLSS) (0.001V) (8.34)}{(F_w) (RSS) (8.34) + (F-F_w) (SS) (8.34)}$$

MLSS = mixed liquor suspended solids (mg/l)
 V = aeration basin volume (1000 gal)
 F_w = waste sludge flow rate (MGD)
 RSS = return sludge suspended solids (mg/l)
 F = plant flow (MGD)
 SS = plant effluent suspended solids (mg/l)

A basic assumption made in the sludge age formulation is that sludge wasting is from the sludge recycle line. If the wasting is from the aeration basin, the actual waste sludge flow rate must be adjusted before input to the model.

$$F_i = \frac{(F_a) (MLSS)}{RSS}$$

F_i = input waste sludge flow (GPD)
 F_a = actual waste sludge flow (GPD)
 MLSS = mixed liquor suspended solids (mg/l)
 RSS = return sludge suspended solids (mg/l)

Volumetric air supply:

$$VAS = \frac{(AV) (1000) (7.481)}{(24) (60) (V)}$$

AV = volume of air delivered (1000 ft³/day)
 V = aeration basin volume (1000 gal)

Organic air supply:

$$OAS = \frac{(AV) (1000)}{(BOD) (F) (8.34)}$$

AV = volume of air delivered (1000 ft³/day)
 BOD = primary effluent BOD (mg/l)
 F = plant flow (MGD)

Volumetric power supply:

$$VPS = \frac{7.481 \text{ HP}}{V}$$

HP = total aerator horsepower (HP)
 V = aeration basin volume (1000 gal)

Organic oxygen supply:

$$OAS = \frac{(N) (HP) (HR)}{(BOD) (F) (8.34)}$$

N = oxygen transfer rate (lb O₂/HP-hr)
 HP = total aerator horsepower (HP)
 HR = hours of aerator operation (hr/day)
 BOD = primary effluent BOD (mg/l)
 F = plant flow (MGD)

$$N = (2.5) \frac{CS-C}{9.17} (1.024)^{T-20} (.08)$$

CS = D.O. saturation in aeration basin (mg/l)
 C = D.O. conc. in aeration basin (mg/L)
 T = plant effluent temperature (°C)

A basic assumption made in the organic oxygen supply formulation is that the mechanical aerators employed are rated at 2.5 lb O₂/HP-hr under standard conditions as defined in [1]. Also assumed is an alpha value for the wastewater of 0.8. If the engineer has the actual values of these parameters for the system being investigated, the model should be changed accordingly.

[1] Wastewater Engineering, Metcalf and Eddy, Inc., McGraw-Hill Book Company, N.Y., N.Y., (1972).

BOD removal efficiency:

$$E = \frac{BOD_i - BOD_o}{BOD_o} * 100.$$

BOD_i = primary effluent BOD (mg/l)

BOD_o = plant effluent BOD (mg/l)

Secondary Clarifier

For the secondary clarifier, the flow to the clarifier depends on whether it is part of a trickling filter or activated sludge type system. For the trickling filter system, the flow to the clarifier is equal to the plant flow plus the recycle to the filter minus the recycle from the filter effluent. For the activated sludge system, the flow to the clarifier is equal to the plant flow plus the recycle sludge flow.

Detention time:

$$DT = \frac{V}{1000 F/24}$$

V = clarifier volume (1000 gal)

F = flow to clarifier (MGD)

Surface settling rate:

$$SSR = \frac{F * 10^6}{A}$$

F = flow to clarifier (MGD)

A = clarifier surface area (ft²)

Weir overflow rate:

$$WOR = \frac{F * 10^6}{L}$$

F = flow to clarifier (MGD)

L = weir length (ft)

Solids loading rate:

$$SL = \frac{(SS) (F) (8.34)}{A}$$

SS = aeration basin or trickling filter effluent suspended solids (mg/l)

F = flow to clarifier (MGD)

Solids removal efficiency:

$$E = \frac{SSI - SSO}{SSO} * 100$$

SSI = aeration basin or trickling filter
effluent suspended solids (mg/l)

SSO = plant effluent suspended solids (mg/l)

A.3.0 Data Input

The indicator model is designed to use data that is available prior to a survey's implementation and also the data generated by the survey. Design data needed should, of course, always be available. Operational data required will be available from the daily and monthly operation logs as required by Technical Manual 5-665, and then from the data generated by the survey. (If the value of any parameter is not available, it should be replaced by -1.0 in the appropriate columns for the data input.) Following is a listing of the data input necessary to implement the indicator model.

Trickling Filter Type Plant

Card 1

Column 1: Plant type; 1 for trickling filter type plant.

Columns 2-41: Name of installation e.g. Fort Ord, CA
(Should be centered)

Card 2 - Primary Clarifier

Columns 1-8: Total volume (1000 gal)
(2 clarifiers @ 4000 gal ea. = 8.0)

Columns 9-16: Total surface area (Ft²)
(2 clarifiers @ 200 Ft² ea. = 400.)

Columns 17-24: Total weir length (Ft)
(2 clarifiers @ 500 Ft ea. = 1000.)

Columns 25-32: Design flow rate (MGD)

Columns 33-40: Design detention time (Hrs)
If not readily available, calculate

$$DT = \frac{\text{Total Vol (1000 gal)} \times 0.024}{\text{Design flow (MGD)}}$$

Columns 41-48: Design surface settling rate (GPD/Ft²)
If not readily available, calculate

$$SSR = \frac{\text{Design flow (MGD)} \times 10^6}{\text{Total surface area (Ft}^2\text{)}}$$

Columns 49-56: Design weir overflow rate (GPD/Ft)
If not readily available, calculate

$$WOR = \frac{\text{Design Flow (MGD)} \times 10^6}{\text{Total weir length (Ft)}}$$

Card 3 - Trickling Filter

Columns 1-8: Design flow rate (MGD)

Columns 9-16: Design organic loading (Lb BOD/Acre-Ft Day)

Columns 17-24: Total volume (Acre-Ft)
(2 filters @ 3 acre-ft ea. = 6.)

Columns 25-32: Total area (Acres)
(2 filters @ .75 acres ea. = 1.5)

Columns 33-40: Total design recycle per day (MG)
If not readily available, calculate

$$R = \text{Design percent recycle} \times 100. \times \text{Design flow (MGD)}$$

Card 4 - Secondary Clarifier

Columns 1-8: Total volume (1000 Gal)
(2 clarifiers @ 4000 gal ea. = 8.0)

Columns 9-16: Total surface area (Ft²)
(2 clarifiers @ 200 Ft² ea. = 400.)

Columns 17-24: Total weir length (Ft)
(2 clarifiers @ 500 Ft ea. = 1000.)

Columns 25-32: Design flow rate (MGD)

Columns 33-40: Design detention time (Hrs)
If not readily available, calculate

$$DT = \frac{\text{Total Vol (1000 gal)} \times 0.024}{\text{Design flow (MGD)}}$$

Columns 41-48: Design surface settling rate (GPD/Ft²)
If not readily available, calculate

$$SSR = \frac{\text{Design flow (MGD)} \times 10^6}{\text{Total surface area (Ft}^2\text{)}}$$

Columns 49-56: Design weir overflow rate (GPD/Ft)
If not readily available, calculate

$$\text{WOR} = \frac{\text{Design flow (MGD)} \times 10^6}{\text{Total weir length (Ft)}}$$

Columns 57-64: Design solids loading (lb SS/Ft²-Day)

Card 5 - General Operations

Columns 1-8: Peak flow (influent) (MGD)

Columns 9-16: Total daily flow (influent) (MG)

Columns 17-24: BOD (influent) (mg/l)

Columns 25-32: Suspended solids (influent) (mg/l)

Columns 33-40: BOD (effluent) (mg/l)

Columns 41-48: Suspended solids (effluent) (mg/l)

Card 6 - Process Operations

Columns 1-8: Primary clarifier effluent BOD (mg/l)

Columns 9-16: Primary effluent suspended solids (mg/l)

Columns 17-24: Trickling filter effluent BOD (mg/l)

Columns 25-32: Filter effluent suspended solids (mg/l)

Columns 33-40: Total recycle to filter (MGD)

Columns 41-48: Total recycle from filter effluent (MGD)

Columns 49-56: Recycle from secondary clarifier (MGD)

Activated Sludge Type Plant

Card 1

Column 1: Plant type; 2 for activated sludge type plant.

Columns 2-41: Same as for trickling filter type plant.

Card 2 - Primary Clarifier

Same as for trickling filter type plant.

Card 3 - Aeration Tanks

Columns 1-8: Total tank volume (1000 Gal)
(2 tanks @ 50,000 gal ea. = 100.)

Columns 9-16: Design flow rate (MGD)

Columns 17-24: Design detention time (Hrs)
If not readily available, calculate

$$DT = \frac{\text{Total Vol (1000 Gal)} \times 0.024}{\text{Design flow (MGD)}}$$

Columns 25-32: Design organic loading (Lb BOD/1000 Gal)

Columns 33-40: Design mixed liquor volatile suspended solids (mg/l)

Columns 41-48: Number of aerators or compressors

Columns 49-56: Total aerator or compressor horsepower
(2 aerators @ 50 HP ea. = 100.)

Card 4 - Secondary Clarifier

Same as for trickling filter type plant.

Card 5 - General Operations

Same as for trickling filter type plant with the exception of:

Columns 49-56: Average temperature of plant effluent (°C)

Columns 57-64: D.O. saturation in aeration basin (mg/l)

Card 6 - Process Operations

Columns 1-8: Primary clarifier effluent BOD (mg/l)

Columns 9-16: Primary effluent suspended solids (mg/l)

Columns 17-24: Mixed liquor suspended solids (mg/l)

Columns 25-32: Volume of air delivered (1000 ft³/day)

Columns 33-40: Average Mech. aerator operating time (hrs/day)
This should be computed by multiplying the time of operation of each aerator by its horsepower and summing to get the total. This horsepower-hour total should then be divided by the total aerator horsepower.

Columns 41-48: Recycle sludge volume (MGD)

Columns 49-56: Recycle sludge suspended solids (mg/l)

Columns 57-64: Wasted sludge volume (GPD)

Columns 65-72: Average aeration basin dissolved oxygen (mg/l)

IV. AUTOMATED INSTRUMENTATION

A Fisher Scientific Accumet Model 520 Digital pH/Ion meter, a Yellow Springs Model 33 S-C-T meter, A Talos 514B graphic tablet, and a Digital Equipment Corporation RT02-BA data entry terminal were interfaced to the data handling system via a Digital Equipment Corporation PDM-70 programmable data mover. Figure XI is a block diagram of the automated instrumentation showing the inter-connection of these devices. Each of these devices can operate in a stand-alone mode independent of the data handling system or under the control of the data handling system. The Automated Instrument Users' Manual and the Automated Instrument System Programmer's Manual have been written to provide a detailed description of the operation of this system. These Manuals are Appendix V and VI of this report. The presentation which follows is intended to provide an overview of the automated instrumentation.

The Talos digitizer provides the capability to the Army personnel of automating the data reduction of field strip chart recordings. By placing a strip chart on a 14 inch by 14 inch active area on the Talos digitizer surface, the user through either a four button cursor or a stylus may determine the x-y coordinates of any point on this graph to an accuracy of .01 inches. The x-y coordinates of this point are displayed on a front panel display and can be transferred to the data handling system via the PDM-70 by pressing a cursor button or touching the point with the stylus. Some status information such as the cursor push button is also interfaced to the PDM-70. The data handling system can then be programmed with the appropriate data reduction algorithm to arrive at the result. The interface between the Talos digitizer and the PDM-70 was fabricated at Clemson University.

The Fisher Scientific pH/Ion meter provides a 5 digit display on the front panel of the meter and is interfaced to the PDM-70.

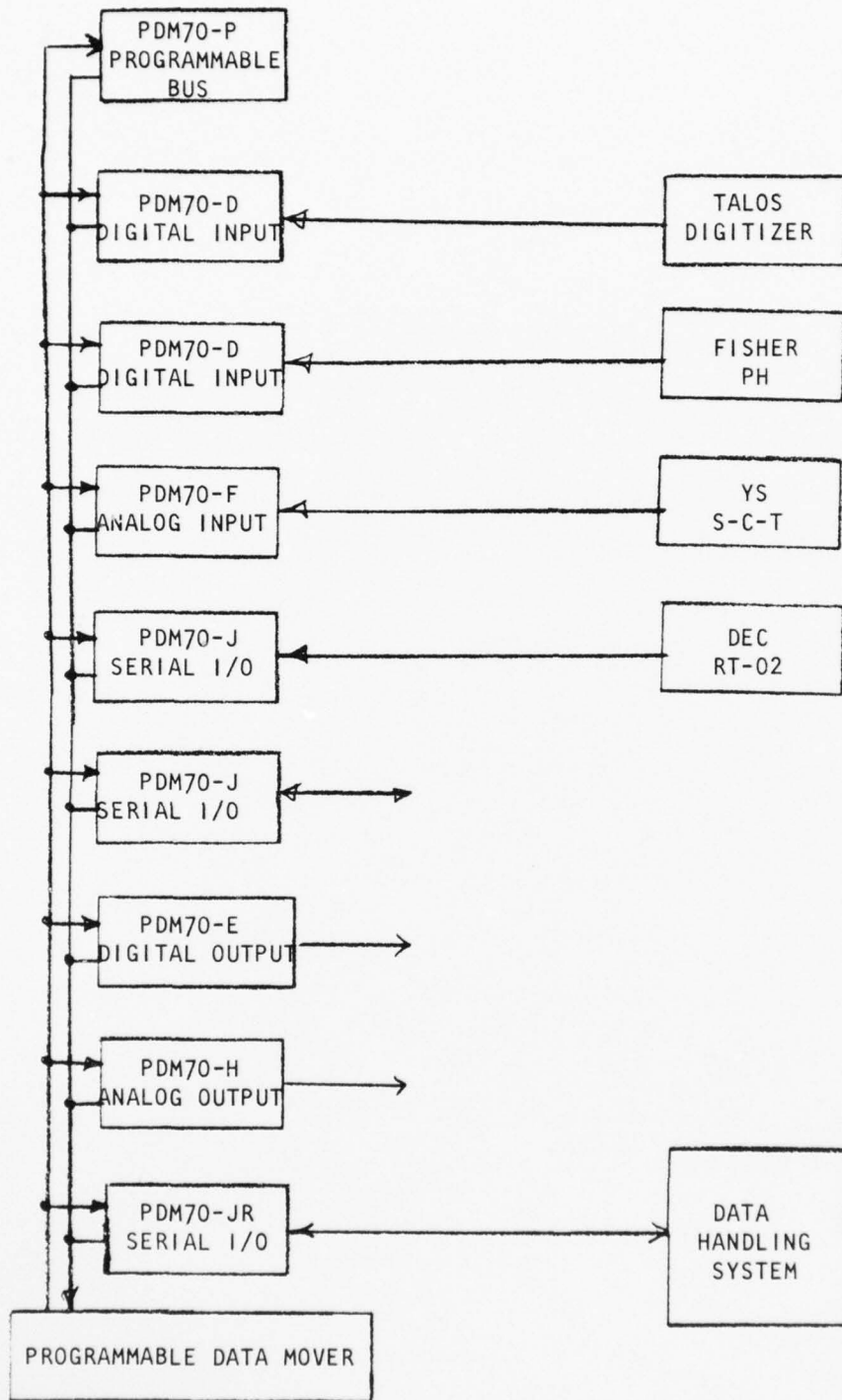


FIGURE XI - BLOCK DIAGRAM OF THE AUTOMATED INSTRUMENTATION

The interface between the PDM-70 and the pH meter was implemented at Clemson University and contains a button with a light for data transfer. The measurement value being displayed on the front panel display along with the front panel switch settings and over range indicator is transferred to the PDM-70 by pressing the lighted button on the PDM-70 interface.

The Yellow Springs S-C-T meter was slightly modified to permit the meter to give two analog outputs. One output is proportional to the S-C-T meter reading while the other output is coded to give the front panel switch settings. These analog outputs are interfaced to the PDM-70 with a meter reading being transferred whenever a lighted button associated with the PDM-70/S-C-T interface is pressed by the user. This interface was fabricated at Clemson University.

Each measurement handled by the data handling system must have an ID and a measurement value. The DEC RT-02-BA provides the user of the automated instrumentation the ability to enter the ID information via the keyboard for each of the samples whose value is being measured by either the interfaced pH and specific conductivity instrumentation. The DEC RT-02-BA also has a 32 character alphanumeric display and provides the user with messages from the data handling system.

The PDM-70 programmable data mover provides a communications link and formatting facilities for concentrating and transferring data between a selected source and destination. The data may be in an analog, parallel BCD or binary, and serial format. The PDM-70 can be operated as a stand-alone unit or under the control of a host computer. Integration into a computer-based system is easily accomplished through a standard asynchronous serial interface on the computer.

The PDM-70 system accomodates both source and destination modules. Any source module under the control of the PDM-70 can communicate with any or all destination modules. Source modules present in the system are as follows:

- 2 PDM70-D Eight digit BCD input
- 1 PDM70-F Four channel analog input
- 1 PDM70-JR Serial I/O module
- 2 PDM70-J Serial I/O module

The destination modules present in the system are as follows:

- 1 PDP70-E Eight digit BCD output
- 1 PDP70-H Two channel analog output
- 2 PDM70-J Serial I/O module
- 1 PDM70-JR Serial I/O module

Communication or information transfer from a selected source to the selected destination modules is controlled by the stored program being executed by the PDM-70. This program is normally entered via a PDM70-JR serial I/O module with a connected Teletype or remote computer. The programming commands are a sequence of ASCII characters.

A user function for OS/8 BASIC has been provided to allow any BASIC program to remotely program the PDM-70 and to transfer data between the BASIC program and the PDM-70. In addition, the data entry software for the data handling system supports the automated instrumentation.

The OS/8 BASIC program WTHDL.BA is provided for handling the Talos digitizer data. This program receives x-y coordinate information from the digitizer on-line, converts these coordinates from the digitizer units to the units of the strip chart recording, and places these converted coordinates in a file. The program provides the user with the capability to edit the data received from the digitizer and the data within the data files created by this program. These data files can be accessed by any OS/8 BASIC program.

V. DATA HANDLING

A data handling system has been implemented to automate the handling of field data during a water quality survey. Figure XII is a block diagram of the data handling system showing the inter-connection of the system components. Table III lists the subsystem components which comprise this system. Each measurement handled by the system is represented by 6 primary ID tags, 5 secondary ID tags, and a measurement value with each tag being a variable length character string. Functions performed by the system include data entry, report generation, file management, analysis, and sorts. The data entry function is capable of accepting one or more raw measurement values for each measurement and then perform the appropriate data reduction to arrive at a final measurement value. The Data Handling System Users' Manual and System Programmer's Manual have been written to provide a detailed description of the operation of this system. The presentation which follows is intended to provide an overview of the data handling system.

The data handling system may be located at a fixed remote site and/or may be found on-site. A remote site would require a voice grade telephone line data link with the field survey whenever communications between the data handling equipment at the field site and the data handling system are occurring. Occasional assistance at the data handling system site will be required to perform functions such as to mount magnetic tapes and to start the data handling system.

The data handling system may be viewed as a collection of programs which operate within the supervision of the OS/8 executive on a DEC PDP-8/E minicomputer. The OS/8 is a software system which is supported by a large variety of hardware configurations with a DEC PDP-8/E CPU.

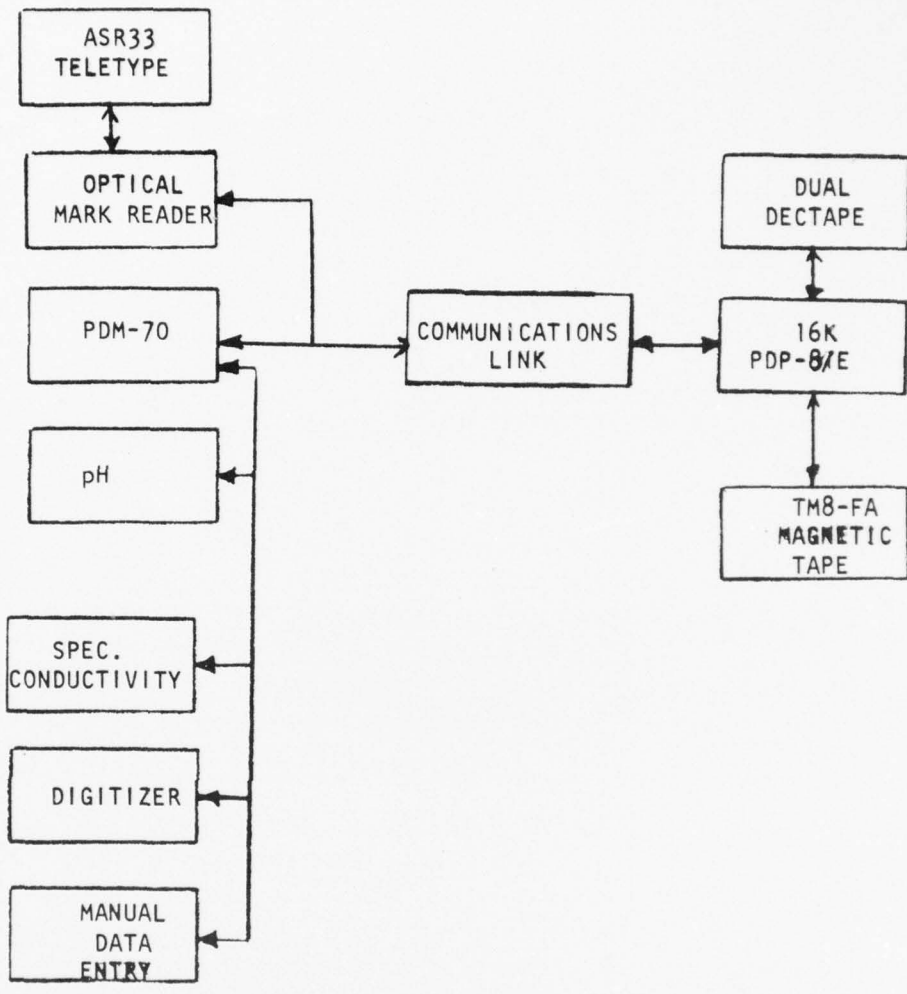


FIGURE XII BLOCK DIAGRAM OF DATA HANDLING SYSTEM

ID1 ID2 ID3 ID4 ID5 ID6 ID7 ID8 ID9 ID10 ID11 Value

FIGURE XIII MEASUREMENT FORMAT

AD-A036 521

CLEMSON UNIV S C COLL OF ENGINEERING
A SYSTEMS ANALYSIS OF WATER QUALITY SURVEY DESIGN. (U)
AUG 75 L C WILCOX, T L DRAKE, R W GILCHRIST

F/G 13/2

DADA17-72-C-2152

UNCLASSIFIED

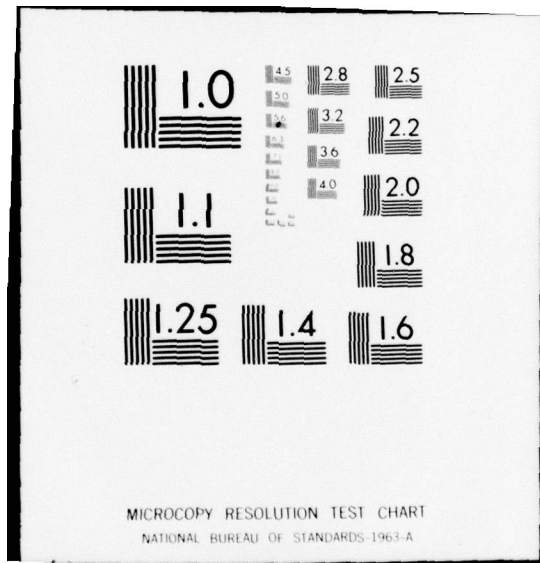
NL

2 of 2
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END

DATE
FILMED
3-77



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

A. OS/8 Minicomputer System

PDP-8/E-AE DEC 8K Minicomputer with Asynchronous Serial Interface
 TD8-EM Dual DECTape Transports with Control
 MR8-EC OS/8 ROM for TD8-EM
 KL8-EJ Serial Interface for Mark Reader
 ASR-33 Teletype

B. Hewlett-Packard 7260A Optical Mark Reader

C. DEC PDM-70 Programmable Data Mover System

PDM70-C Mounting Box with Power Supply
 PDM70-P Programmable Bus Control
 PDM70-D Eight Digit BCD Input (Digitizer)
 PDM70-D Eight Digit BCD Input (pH)
 PDM70-E Eight Digit BCD Output
 PDM70-F Four Channel Analog Input (Conductivity)
 PDM70-J Serial Interface (Manual Data Entry)
 PDM70-J Serial Interface (Optical Reader)
 PDM70-JR Serial Interface (OS/8 System)
 PDM70-H Two Channel Analog Output

D. Automated Data Entry Equipment

Fisher Scientific Accumet Model 520 Digital pH/Ion Meter with Accessories
 Yellow Springs Model 33 S-C-T Meter with Accessories
 DEC RT02-BA Data Entry Terminal
 Talos Systems 514B Graphic Tablet with BCD and Four Positions Cursor Options

E. DEC TM8-FA 7-Track Industry Compatible Magnetic Tape

F. Other

3 - Omnitec 701-B Originate Couplers
 DEC KL8-M Modern Control Interface
 DEC BE8-A Omnibus Expansion (TM8-FA)

TABLE III DATA HANDLING SYSTEM SUBSYSTEM COMPONENTS

Each of these programs operate in conjunction with data files found on the mini-computer's mass storage devices. Because of core requirements, a particular data handling operation is often implemented by chaining several of these programs together. Special user programs can be readily implemented using languages such as BASIC, FORTRAN II, and FORTRAN IV, to analyze the information found within the data base created by the data handling system software.

All measurements are represented by 6 primary ID tags, 5 secondary ID tags, and a measurement value with each ID tag being a variable length character string. The primary ID tags uniquely identify which measurement while the secondary ID tags give information about the measurement. Figures XIII, XIV, and XV respectively show the measurement format, primary ID tag assignments, and secondary ID tag assignments. More than one quality ID may be used to describe each measurement with commas separating these tags. The first example measurement in Figure XVI indicates that conductivity was measured on day 1 of the survey at sample point C1 with this measurement being the second discrete measuring during period 2. The water sample was turbid, light color, and hot in appearance. The analysis was performed by Drake using method 1 to yield a value of 700 and the analysis yielded an accurate result.

Data and commands are usually entered into the system on-line via either the Teletype keyboard, a Hewlett-Packard optical mark reader, the Talos graphic digitizer, the DEC manual data entry station, Yellow Springs S-C-T meter, or Fisher pH/Ion meter. The digitizer, manual data entry station, specific conductivity instrumentation, and pH instrumentation are interfaced to the system via the DEC PDM-70 programmable data mover. Then data when received is extensively checked to insure that only valid data is entered into the data files with numerous error messages being generated to identify data entry errors. The system is capable of accepting one or more raw measurement values for each measurement on input and then perform the appropriate data reduction

to arrive at a final measurement value. The particular data reduction algorithm selected is determined by the ID tags associated with the measurement. Commands are provided for the user to enter constants relative to each data reduction algorithm and to select one of several input options. When the optical mark reader is used on input, a special mark card is designed for each application. This card has fields for command information, ID information, and value entry. The use of mark cards permits users of the system to enter data on a card with any combination of pencil marks and punches. Mark sense cards provide an effective low cost data entry method especially when this data is being entered on-line by several system users. A unique translate table is provided for each column to translate each character received from this reader into the appropriate character string. The resulting character string which results from each card or sequence of cards becomes the measurement input accepted by the system.

The file management software gives the user of the system the capability of adding, deleting, or changing measurements within a specified data file. In addition the system can transfer files between devices, merge and delete files, and list, zero, and compress directories on the mass storage devices.

An important system function is the capability to generate reports of selected data on a designated output device using a wide variety of formats. Report generation is accomplished in three job steps which are report specification, sort, and report preparation. The general report format is determined by the order in which the measurements have been sorted and is shown in Figure XVII. Note that each page of the report shows a tabulation of measurement values with three primary ID tags being held constant. The comment ID tag, ID6, when nonzero qualifies each measurement value with a symbol to indicate that the actual measurement is less than, greater than, or approximately equal to the value shown.

ID1 = Day ID
ID2 = Point ID
ID3 = Period ID
ID4 = Parameter ID
ID5 = Discrete ID
ID6 = Comment ID

FIGURE XIV PRIMARY ID TAG ASSIGNMENTS

ID7 = Quality ID
Turbid (T)
Clear (CL)
Light Color (LC)
Intense Color (IC)
Hot (H)
Cold (C)
Greasy (G)
Nonhomogeneous (NH)
Imperfect Preservation (IP)
Questional Stability (QS)

ID8 = Accuracy ID
Accurate Result (AR)
10% (10%)
Order of Magnitude (OM)
Inaccurate Results (IR)

ID9 = Chemist ID

ID10 = Method ID

ID11 = Unused

FIGURE XV SECONDARY ID TAG ASSIGNMENTS

1 C1 2 COND 2 T,LC,H AR DRAKE M1 700
10 S1 3 PH DRAKE 7.4
2 15 1 TOC 25 BROWN 200

FIGURE XVI EXAMPLES OF MEASUREMENTS

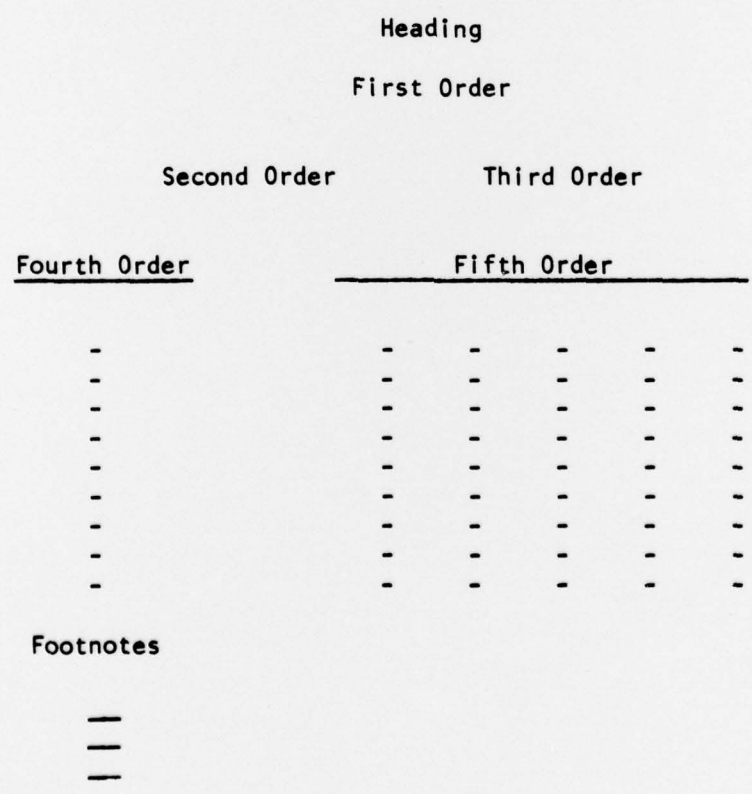


FIGURE XVII REPORT FORMAT

The report specification step, implemented with OS/8 BASIC, creates the file INFO:INFO.IN based on information received from the operator of the system. This file contained one record for each report requested during the report specification step. Each record contains information such as report format (order of sort), options (report or print-plot), ID tag lists, and segment size (number of columns). The order in which the ID tags appear within the lists determine the order they appear in the report.

At the completion of the report generation step, the sort software, implemented with PAL8, is automatically loaded by the system. The specified data file is searched sequentially to locate and retrieve those measurements which satisfy the ID lists within the file INFO.IN. These measurements are placed within a core buffer. The measurements within this buffer are sorted according to a specified order, order of the ID tags within the ID list, and segmentation size and then places these measurements within a designated temporary file. A temporary file is created for each report. Measurements with duplicate ID tags are detected and placed within a duplicate data file.

The sort step generally utilizes only the primary ID tags while sorting the measurements. The secondary ID tags are either ignored or result in footnotes on the reports generated.

The report preparation step, implemented with OS/8 BASIC, utilizes the file INFO.IN, the system definition file SYSDEF.AR, and the temporary data files to produce on the output device the designated reports. The system definition file is used to convert the internal ID tag formats to an external format required by the report. As each ID tag has several external representations, the particular representation depends upon the usage within the report. For example, a 24 character external representation is used to label a row of the

report while a 6 character representation labels columns. The system definition file specifies the number of digits following the decimal point to use when printing each numerical value based on the ID4 tag. Also found are specifications regarding margins, footnotes, and header information.

The report preparation step was specifically designed to prepare each page of the report in a format which can be reproduced directly in a final report. Each page is generally printed on a 8 1/2 x 11 page with standard margins.

The system has a DEC TM8-FA 7-track industry compatible magnetic tape unit to provide data transfer capability between this system and the Army UNIVAC 1108. The subroutine NTRAN(FORTRAN callable) provides FORTRAN V programs written for the Army UNIVAC 1108 with the capability for reading and writing magnetic tapes compatible with the OS/8 system. The subroutine NTRAN is well documented in the UNIVAC FORTRAN V Library Programmer Reference Manual (UP-7876). The OS/8 magnetic tape format, required by NTRAN, is found in the System Programmer's Manual for the data handling system.

The performance of the system is now highly dependent on the 10 character-per-second (cps) printer rate of the Teletype. This data rate requires the system to be committed for large blocks of time to the printing of reports, messages, and plots. The replacement of the Teletype with a Digital Equipment Corporation LA36 terminal is recommended and would increase the printing rate to 30 cps and provide a 132 print positions per line. The rental of a 30 cps terminal during the third year from Western Union Data Services Company demonstrated the performance improvements which can be obtained.

The addition of the second hard copy device such as the DEC LA36 terminal would permit one hard copy device at the field site and the other hard copy device to be at the OS/8 site. The use of two hard copy devices would also

permit operation of the OS/8 system from either location.

Several system tables are used by the system software to define a particular data handling application to the system. The system definition file (SYSDEF.AR) provides information which includes lists of valid ID tags, upper and lower limits for measurement values, data formats, and various heading and column information used during report generation. The translation table file (TRNTBL.AR) contains the translation tables for the mark sense cards. The method file (METHOD.AR) specifies for each parameter the particular data conversion algorithm within the function file (FNCTN.AR) to use on input.

Version III of the data handling system was successfully demonstrated by handling survey data generated by the USAEHA during the Letterkenny Army Depot survey in August 1974. This version of the system did not include any of the third year improvements. The system accepted raw measurement data for each parameter from the chemist and performed the necessary data reduction to arrive at a final measurement value. The various calibration curves used by the system were determined from calibration data entered into the system on a daily basis. Data validation was accomplished by having the system provide each chemist during data entry with a report showing calibration data, raw measurement data, and the computed final measurement result. The system was used an average of approximately two hours each day for all data handling functions during the survey.

Version IV of the data handling system satisfies the third year contract objectives and differs from the version III of the system. Version IV includes the following improvements not found in version III:

1. new measurement format (secondary ID tags)
2. new mark card format
3. improved data reduction for the chemists

4. interfaced pH and specific conductivity instrumentation
5. improved software
6. industry compatible magnetic tape
7. 8K core expansion to 16K
8. interfaced graphic digitizer
9. interfaced manual data entry station

This version of the system satisfies the data handling objectives established on September 12, 1974 in a conference between the Army and Clemson University personnel. This version of the system has not been evaluated in a field environment.

The two DEC tape units provide all the file storage for the data handling software. As most of the software both access and update the data base found within several files, the execution speed of this software is highly dependent on the average access time of these two DEC tape units. The addition of a disk to the system would significantly increase the execution speed of the software by substantially reducing the time required to access the disk data files. However, the speed of the current system configuration adequately handled the Letterkenny Depot data handling demonstration.

