Design and Implementation of a Microcomputer Based Laboratory and Operations Information System (LOIS) for Wastewater Treatment Plants

by

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(ABSTRACT)

The requirements for a wastewater treatment plant microcomputer based Laboratory and Operations Information System (LOIS) were considered. Emphasis was placed on combining data generated by the laboratory and the operations divisions of the Alexandria Sanitation Authority. Goals were established to meet the information needs of key decision makers within the Authority and external information consumers such as regulatory authorities and design engineers. Integration of laboratory analysis and plant operational data was of prime importance.

A series of related computer programs was developed to manage laboratory and operational data and calculate results derived from both sources. The programs stressed data integrity, flexible report generation, statistical and graphical data analysis, and ease of use. A program was developed to address laboratory quality control data

management and the production of quality control charts.

The computer programs were written in a generic fashion so as to be applicable to other water or wastewater treatment plants and to provide maximum flexibility for future expansion. Programs were developed in a modular fashion to allow greater ease of maintenance and revision in the future. Common subroutines were employed wherever possible. Some report generation subprograms were written specifically to the requirements of the Alexandria Sanitation Authority.

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I. Introduction

The purpose of this project was to develop a Laboratory and Operations Information System (LOIS) for the wastewater treatment plant operated by the Alexandria Sanitation Authority. The project will be described using the case history approach common in business school applications. Although the project was specific to the Alexandria Sanitation Authority (ASA) the intent was to create a program flexible enough to be applicable at facilities of various sizes in the water and wastewater treatment industries. The description of the process of system analysis for treatment plant operation and laboratory data integration should be universally applicable from small package plants to large advanced wastewater treatment (AWT) facilities.

A primary concern of the project was the integration of operational data generated in the field with data generated in the laboratory and the dissemination of the resultant information to meet the needs of a variety of information consumers. Information consumers include operators and shift supervisors, laboratory staff, plant management, regulatory agencies, design and consulting engineers and the public. Various information consumers require raw data packaged in different formats and have differing temporal perspectives. The operational staff requires a large range of data on as close to a "real-time" basis as is reasonably possible. State regulatory personnel require more limited effluent data on a monthly basis. Operations managers may wish to compare data by season over a period of years. Design engineers may require data summaries over a period of several years.

The ultimate goal of the Laboratory and Operations Information System is to provide accurate information in a wide range of standard formats as quickly as possible while maintaining the flexibility to meet virtually any information request related to laboratory and operations data or information generated from the union of the two sources of data. Vital to this goal is the ability to insure data integrity and the maintainability of the system software.

II. Literature Review

The development of computer based information systems is a relatively new phenomenon in the wastewater treatment field. The annual literature review issue of the Water Pollution Control Federation (WPCF) Journal is described as a "comprehensive summary of the information that has been published during the preceding calendar year on water pollution control topics" (1). The topic of microcomputer based management information systems was first addressed in the 1988 literature review issue (2).

Microcomputer use in wastewater treatment plants provided the foundations for a Laboratory and Operations Information System via four main development paths.

* The first path to LOIS systems was the development of Laboratory Information Management (LIM) systems. LIM systems were originally developed on mainframe and mini computers for large commercial and university laboratory operations.

* The second path was the development of plant operation computer control systems (CCS) for wastewater treatment facilities. CCS systems not only provided

plant operation monitoring and control functions, but often provided limited operational data management and reporting functions.

* The third path to the development of LOIS programs for treatment plants was the development of reasonably priced but powerful microcomputers. The combination of expansive growth of microcomputer power, concurrent with declines in microcomputer prices allowed the required hardware for a LOIS package to be within the financial reach of virtually all treatment facilities.

* The fourth path that led to LOIS systems was the development of software application programming philosophies and environments suitable for large scale system development on microcomputers.

The software path includes three separate topics that are essential precursors to LOIS programs.

* The first was the advancement of concepts of software and information engineering designed to create modular programs that are easier to read, update and maintain than their predecessors.

* The second software related advance of importance to LOIS programs was the "Human Factors" or "Human Engineering" school of computer programming that focused on the relationships between program development and user interaction and needs.

* The third software advance was the introduction of integrated programming environments, which greatly reduced program development times.

LIMS

Prior to the 1970's, computers were large and expensive. Mainframe computers were the most expensive models costing millions of dollars but were capable of supporting dozens of users simultaneously. Mainframes were often used by major businesses, universities and government agencies. Minicomputers cost less than mainframes by an order of magnitude but were still capable of supporting a dozen users at once. The distinction between mainframe and minicomputer was sometimes indistinct but was often based on word size. Minicomputers used a word size of thirty-two bits and any computer which used a larger word size was considered a mainframe computer. Generally, university and research laboratories had access to computers but extremely few wastewater treatment plant laboratories had any access to computers. These facilities often had to share access to mainframes on a time-sharing basis. During the 1970's, commercial laboratories and large utilities began to use computers in the minicomputer class with commercial software specifically developed for laboratories(3,4). These Laboratory Information Management Systems (LIMS) usually tracked samples in the laboratory for chain of custody and billing purposes; calculated results from raw benchsheet data and provided quality control functions. Direct data acquisition from laboratory instruments also became available. Commercial LIMS programs did not include the facilities for integration of laboratory data and operational information needed for wastewater treatment plant data management and reporting.

Cooper(5) published a text oriented toward statistical data manipulation programs for laboratories. He considered the computer of choice for such work in 1977 to be the Digital Electronics Corporation (DEC) PDP-11 minicomputer. Sloan (6) described the architecture of the PDP-11 as well as the pioneer microcomputer, the Intel 4 bit 4004 CPU. Annino and Driver(7) published a text on laboratory use of microcomputers in 1986. The authors considered direct data acquisition, numerical analysis and graphical representations for Apple II and IBM microcomputers.

Garrett and Ahmad(8) described a custom programmed LIM system designed for the City of Houston which serves 44 wastewater treatment plants and industries. While the system provided daily reports to each WWTP, it did not include plant operations data, such as flows, or calculations resulting from lab and operations data, such as loadings. This shortcoming typifies the difference between a LIM and a LOIS program. While LIM systems are designed with laboratory uses in mind, such as tracking samples and data within the laboratory, integration with external or operations data is not considered. LOIS programs integrate laboratory and operational data and provide a wide range of data reporting and analysis capabilities.

Computer Control Systems (CCS)

Before the appearance of microcomputers, a few large, predominantly new, wastewater treatment plants had access to mainframe or minicomputers systems. These systems were generally real-time plant operation and control systems. The integration of laboratory and operational data often did not receive top priority in a Computer Control System (CCS).

Harper and Ballotti(9) described real-time operation computer control systems (CCS) at several plants operated by Orange County, CA. The data from the operations computers were incorporated with the business computer system for Orange County. Primarily concerned with operation and business integration, laboratory and operation integration was not a primary focus. The authors did, however, develop a subjective list of benefits to be realized from the utilization of computers in utility operations:

* Unification of the wastewater facility information system.
* Re-enforcement of interdivision communications.
* Closing the gap between business management and plant operations.
* Imposition of an analytical discipline on decision makers.
* Enrichment of the work environment.
* Establishment of credibility factor with financial community.
* Attract and maintain top management talent.
* Make possible information processing independence.

It was left to a "dedicated and experienced user" to develop "improved and innovative applications"; possibly including laboratory and operational data integration.

Ballotti and Gillman (10) described the computer control system at the 210 million gallon per day (MGD) Southwest Philadelphia plant. The only mention of laboratory data was that "Lab data to be entered manually for historic storage and report processing...". This typifies the minimalistic approach to integration of laboratory and operational data taken by designers of computer control systems in the 1970's.

This approach was also evident in the initial design of the Computer Control System for the Upper Occoquan Sewage Authority (U.O.S.A.) plant in Centreville, VA. In 1979, Vandeventer (11) of Leeds & Northrup Co. described the type of system installed at U.O.S.A. He was particularly concerned with the operator interface and felt that "the plant's control system should be easy to use". Little attention was paid to integration of laboratory data with the computer control system. It was left to plant operation personnel to write application programs to generate reports from laboratory data. Space was allocated on the minicomputer's two hard disks for laboratory data and a manual data input program was installed by the manufacturer. No attempt was made to integrate laboratory and operational data until a microcomputer became available.

Computer Control Systems (CCS) were poor platforms for Laboratory-Operations Information Systems for several reasons. First, their primary purpose was operation of the plant in real-time. The operating systems designed for this purpose were not designed primarily for batch data base processing. CCS's often were developed while plants were on the drawing board. Laboratory and operations managers had little or no input into the issues of software development. The laboratory and operations data and sample schemes were abstractions at best. Development of data management programs after the system was in operation were hampered for several reasons. The combination of real time operating systems and specialized languages required comparatively sophisticated programmers. The design engineers were often not on the plant site and personnel costs were too great to bring them back for a LOIS type program development project. Experimentation with systems that were actively controlling the plant was a risky business. Mistakes which caused disruptions of plant operations were not well received in the field.

Recently, philosophy in plant control system strategies has shifted away from centralized computer control systems toward distributed process control systems. These systems are more likely to contain management information systems (MIS) which are responsible for "tasks such as long-term historical data storage and retrieval, process and statistical data analysis, maintenance management operations, etc." (12) The MIS subsystem of a distributed control system may be implemented on a general purpose microcomputer or minicomputer which is not directly involved in process control operations. The opportunity exists to integrate laboratory data with operational data more conveniently under a distributed processing arrangement than was generally possible on centralized computer control systems.

Hardware Development

The development of computer-based information systems at wastewater treatment plants has closely followed the development of microcomputers. The LOIS project would certainly not have been undertaken when the Alexandria Sanitation Authority (ASA) began operation in 1956 given the expense and inflexibility of the vacuum tube computers then available. The development of microcomputer based Laboratory-Operations Information Systems began shortly after the appearance of microcomputers such as the Apple II in the late 1970's. Kramer (13) described the uses of general purpose laboratory workstations in 1983. He specifically dealt with the Apple II and the extensions to the Apple Basic language which were developed for laboratory use which were called LabSoft. The 1982 introduction of the IBM PC (14) was a critical date in the acceptance of microcomputer technology. The next six years saw substantial gains in the capabilities of microcomputers and the software available for microcomputers. Competition, driven by low cost clones of IBM microcomputers, has driven prices down dramatically, placing computer technology well within the budget of wastewater treatment plants(15).

Microcomputers have now become powerful enough to perform all functions that would reasonably be required of a LOIS hardware platform. Dongarra and Martin(16) reviewed paths and pitfalls in computer benchmarking, noting that many factors influence actual computer throughput. Advances in microcomputer technology that have greatly increased real throughput include:

* Faster central processing units (CPU) with wider bus widths leading to increases in computational and Input/Output (I/O) speed.

* Increases in Random Access Memory (RAM) size from 4 or 16 Kilobytes (KB) to 640 KB standard memory, often with 1 or 2 Megabyte (MB) of additional memory available for use by disk cache or print spool software. The use of these programs can greatly increase real system throughput.

* The availability of relatively cheap, high capacity hard disk drives that greatly increased the available

on-line data storage capacity.

* high resolution graphics displays that allowed graphs to be added to statistical packages.

* math coprocessor chips that increased the speed of floating point calculations by a factor of ten or more.

Software Development

Software and Information Engineering

The life cycle of a computer program has been viewed as a series of tasks. Analysts with different backgrounds and interests have defined the tasks in different ways and placed emphasis on different portions of the cycle. Shelly and Cashman (17), in a standard, business-oriented COBOL text, labeled the tasks and estimated the percent of effort required for each task :

1. Review System and Program Specifications (10%)
2. Design the Program (20%)
3. Code the Program (20%)
4. Test and Debug (50%)

Engineers tend to view the process a little differently. The first high level computer language, developed for science and engineering in the late fifties, was FORTRAN (FORmula TRANslation). A 1961 IBM manual (18) described FORTRAN as being "not the natural language of a computer, nor is it the natural language of the engineer. Rather, it is a compromise between the two."

Anderson (19) defined the program development cycle in a FORTRAN text oriented toward scientists and engineers:

1. Define the problem
2. Analyze the input required
3. Analyze the output desired
4. Develop a solution algorithm (usually represented by a flow chart of the program)
5. Write the program
6. Test the program

The task lists of Shelly and Cashman and the task list of Anderson may be merged and condensed to the following list of tasks:

1. System Analysis (Problem Definition)
2. Design (Algorithm Development)
3. Program Development (Coding)
4. Test and Debug (Fixing Problems)

To this list a final item must be added :

5. Maintenance

Maintenance is the on-going process of keeping a program effective over time. This may involve modifications or enhancements needed to meet new conditions or to meet user requests; or changes to match new hardware or software environments in which the program must function. For a LOIS program, many conditions or changes might require modification of the program or the data file definition. Maintenance at a wastewater treatment plant would be required when:

* Changes to the plant National Pollution Discharge Elimination System (NPDES) or other permits are made.
* New unit processes are added to the treatment plant.
* New laboratory samples or tests are initiated.
* New calculation results are desired.
* Different hardware is obtained.
* Users request new or modified reports.
* A new operating system becomes available.

Often, maintenance is required to meet conditions which could not have been foreseen at the time of system analysis or design.

Hull and Day (20) presented the conventional approach to computer problem solving in 1970. The primary focus was placed on developing algorithms that performed mathematical functions. Little or no attention was given to whether or not the resulting code could be read by others or reasonably modified in the future.

The term spaghetti program was coined during the early days of computers when programs were hard wired on patch boards similar to old style telephone switchboards and a program bug was literally an insect shorting the wiring of vacuum tubes (21). The term was adapted to spaghetti code by an unknown sage to describe programs that resulted from numerous modifications and attachments to FORTRAN programs. Spaghetti code was readily associated with unconditional jump statements to new sections of code. In the FORTRAN and BASIC languages an unconditional jump is implemented by a GOTO statement that is not associated with any logical test. An unconditional jump was a standard way of adding enhancements to a program that required sequential line numbers. The flow of program control after several revisions would end up randomly jumping from sections of old code to new code and back to the old code. While unconditional jumps were the most notorious examples of unstructured program development, several other programming procedures were considered severely detrimental to program maintainability. Eventually the logic and flow of control of such programs became so convoluted that further enhancements or modification became impossible. A program that can no longer be maintained is essentially dead.

The credit for the origination of the concept of structured programming theory is given to Corrado Bohm and Guiseppe Jacopini (22) for a paper presented at the International Colloquim on Algebraic Linguistics and Automata Theory in Israel in 1964. Two years later, the Communications of the Association of Computing Machinery brought the paper to the attention of the computer scientists of the world. The paper demonstrated that any program logic could be represented by three basic control structures: the Linear-Sequence, the If-Then-Else and the Do-While loop structures. The linear-sequence control structure is the most elementary process for passing program control to each succeeding statement. The If-Then-Else control structure allows for branches in program execution to be made as a result of a logical test. The logical test often compares to values to determine equality or which is greater. The Do-While loop structure allows repetitive execution of a block of code as long as a logical test remains true or until a condition is met. The latter part of the 1960's saw continued development of the ideas of structured programming in academic circles. One of the more influential papers of the period was the 1968 paper by Dijkstra (23) that decried the use of the GOTO or unconditional jump statements. Structured programming became a code word for a variety of practices to insure more reliable code generation and a product that was more maintainable. Modular programming was designed to generate operable units of code that could be tested independently of the rest of the system. Top-down programming was intended to improve the readability of computer programs. The intent was that programs should read like a novel.

During the 1970's, business and government adopted structured programming techniques. The Department of Defense was so concerned with maintainability and the ability to create embedded applications in larger physical structures (airplanes, ships, etc.) that DOD developed a new language, ADA, noted for its maintainability and mechanisms for concurrent data processing (24, 25). Methodologies for team program development were instituted, such as the chief programmer method, the structured walk through and the program development library. The chief programmer method detailed the responsibilities of a team leader for the work of several programmers working on a single project. The structured walk through method involved a group effort to review the flow of logic in a programmer's work to insure adherence with the program specification and to find bugs before the program was implemented. Program development libraries served two functions: to keep a common set of subroutines used by all programmers working on a project and to keep a history of the program development, including copies of the code at each stage of development. Modular development was deemed necessary to insure the maintainability of large applications with thousands of lines of code. Emphasis was also placed on internal documentation and variable identification. Internal documentation refers to notes or remarks included with the source code to indicate the programmer's intent when the program code was written. Variable identification refers to the use of meaningful variable names, such as DAY_OF_WEEK, instead of the rather cryptic variable names usually found in FORTRAN programs, such as DOW. By the late 1970's virtually all text books on computer programming spoke in terms of structured design. Bohl (26) presented flow chart development in structured perspective. By 1981, Miller (27) was advancing the idea of structured design in the use of BASIC programs for science and engineering applications.

Structured methods were extended beyond program code development to the broader areas of system analysis; applying structured ideas to the analysis of information requirements within an organization. Where structured methodologies were applied to program development, coding, debugging and maintenance; the term software engineering was applied. Where structured methodologies were applied to the broader realm of organizational goals and procedures, with software systems serving strategic needs, the term information engineering was applied. Both methods stress that system level decisions are made before proceeding to more detailed, lower level design decisions. The process of continually breaking large systems down to component parts, which can be dealt with more easily, is referred to as functional decomposition. Design methodologies have been divided as to emphasis on data structures, information systems or procedural analysis (28).

Several distinct structured methodologies have been proposed (29,30,31,32,33,34). One of the most comprehensive methodologies is the Martin Information Engineering Methodology presented by James Martin and Carma McClure (35,36). The Martin approach seeks information unification and sharing among all systems in an organization. The method is divided into four major activities. The first is the creation of a high level model that includes goals, organizational entities and data. System user interviews are used to define and merge information on organization entities, data structures and requirements. The next major activity involves decomposition of the high level model to operational units and a detailed model of the data entities and processes in the organization. The third major activity involves the design of procedures and data structures needed to meet the goals of the organization. This third activity is normally the starting point of methods that emphasize software design. Data-structure diagrams, screen and report layouts, decomposition and action diagrams may be used in this step. The final stage of activity in the Martin Information Engineering Methodology is the actual development of the software system and code required to meet the system design specification. This step includes testing and verification activities.

Human Engineering

The term human engineering became important with the proliferation of personal computers outside the confines of corporate and university computer centers. Suddenly, a broad range of technical and business people were expected to interact directly with computers. The previous generation's method of communicating with computers consisted of using desk sized machines to mechanically punch holes in stiff paper Hollerith cards (often incorrectly referred to as IBM cards). Hollerith cards contained one line of code or data on each card. The order in which the cards were entered in the computer's card reader was usually critical. Dropping a deck of several hundred cards would often require hours of effort to establish again the proper order of the cards. This method of man-computer interface needed to be replaced before the computer could become widely used in society.

Human engineering was often used in relationship to microcomputer applications in a narrow sense to describe user interface schemes. Human engineering was often incorrectly used interchangeably with the term user-friendly. Most commentary centered on the relative advantages of program control via commands or menus. The early microprocessor programs were often command driven. The popular early word processor, WordStar (37), epitomized command driven programs. A typical keyboard command sequence to mark a block starting position was Ctrl-K-B (press the control key and K simultaneously, then press B). The keyboard command to end a block was Ctrl-K-K. This style of program control required a relatively long time to learn, especially if the commands were not mnemonic. The positive aspect of command driven interfaces was speed. Once learned, the command system could be operated from a standard keyboard without awkward hand reaches to remote function keys or mice. Menu driven programs present a series of menus from which the user selects a choice. The popular spreadsheet program Lotus 1-2-3 (38) presents a list of menu options across the top two lines of the screen whenever the "/" key is pressed. A menu system is generally considered much easier to learn. However menus systems can be slower to use than a command driven interface, especially if several layers of menu selections are required to reach frequently used commands (39). Some programs have been developed that allow menu selection for novice users and command drives for more seasoned operators. On-line help screens which describe the operations of either menus or commands were considered important to user friendliness. Frequently, the F1 function key is used by programs to call an index of help screens. Context-sensitive help moves directly to different help screens depending upon what operation was being performed when the help was requested. Context sensitive help was considered the last word on the subject of human engineering, as viewed in the narrow sense.

Later, the great debate shifted to the value of graphical user interfaces, as typified by the Apple Macintosh (40, 41), versus traditional character oriented interfaces. The Macintosh system was identified with the use of pointing devices, called mice, to make program selections from graphical images called icons. This system was originally lampooned by serious computer users. The idea of dragging a file name to a picture of a trash can to delete a file did not find immediate acceptance with users. The usefulness of mice for Computer Aided Design and Drafting (CADD) programs and desktop publishing programs helped build the acceptance of the pointing devices and graphical interfaces. The incorporation of a similar graphical interface in the Microsoft Windows (42) program and the new IBM / Microsoft Operating System / 2 (OS/2) (43) has increased the acceptance of the graphical interface. Often however, the debate between styles of interfaces has masked the deeper issues involved in human-computer interactions.

Ledgard (44, 45), in a series of article on Human Factors, held that the user interface was only one component of human engineering. Ledgard felt the entire program, including the underlying data structures, should be considered from the perspective of the end user of the system. If the analogies used in structuring the data did not make sense to the user, no elaborate interface would cover the basic flaw. His suggestions for software development were not a set of procedures to be followed as were being defined for structured programming. Rather Ledgard recommended a mind set to be employed during program development. This mind set included a willingness and an open mind to communicate with users. While not addressed directly in Martin's methodology (35,36), human engineering is implicit in the first stage of activity: interviews with system users. Feedback from system users should be incorporated in all phases of system development.

Kreutzer(46) suggests that future programming languages in the model development and system simulation fields will strongly rely on structured concepts. Model and simulation programs may be developed which utilize artificial intelligence techniques such as the expert system concept. Kreutzer suggests that these programs should be able to interact with current structured languages and data bases. The applicability of a LOIS data base to serve as a base for the development of expert systems or models was considered to be a step beyond the scope of this project, however.

Integrated Programming Environments

The third software advancement that facilitated the development of LOIS programs was the introduction of integrated programming environments. The traditional approach to program development involves the writing of code, testing and correcting errors (debugging). The next step depends upon whether an interpreted or a compiled language is used.

Interpreters read source code one line at a time, convert the source code lines to machine language and execute the desired function. This allows the programmer to quickly test code. The disadvantage is the slow performance of the system when instructions in loops or subroutines must be repeatedly converted.

The alternative, compiled languages, convert the entire program to machine language in compile and link steps. The resultant program is much faster (an order of magnitude or more) than an interpreted program. The extra compile/link steps involved with a compiled language can add an appreciable amount of time to the development cycle, however. Borland Inc. introduced the first integrated environment with Turbo Pascal (47). The integrated approach allows editing, running, debugging and compiling a program from within the same program environment. Programs can be written and tested much faster within such an environment, providing advantages generally associated only with interpreted languages. The execution speed of the resulting compiled program often rivals the fastest of the traditional compiled languages(48). The use of a fully integrated program development environment allows more rapid development and testing of system code and results in fast executable programs.

Computers in Treatment Plant Management

The 1986 publication by the Water Pollution Control Federation of a Manual of Practice dedicated to computerized wastewater applications (49) is one indication of the acceptance now afforded computers in the wastewater treatment industry. In the same year Glysson et al. (50) published Computerization in the Water and Wastewater Fields. Both texts cover a large number of topics from introduction of computer terminology to Computer Control

Systems (CCS).

The WPCF Manual of Practice, however, does not cover the full range of considerations required to implement a LOIS type system. The majority of the text deals with CCS type systems and only brief mention is made of personal computers. Information regarding integration of laboratory and operational data is relegated to two case histories. Personal computer software is covered in two pages.

Other authors have also related case studies of computer applications in the wastewater field. Shirreff (51) discussed the cost effectiveness of a computer based control system. While process control calculations were felt to be part of the CCS system, no specific plan for incorporating laboratory input was included. Marshall (52) presented computer aided training for operations in Philadelphia though no mention was made of incorporating laboratory analysis or data. VanZile and Long (53) described computer use in tracking industrial wastes but did not integrate the pretreatment program described with plant operations.

Part of the explanation for the shortage of published data on lab-information systems is that the people working in the field are bringing commercial products to market, not writing scholarly articles. Reviews of commercially published software for plant operations have appeared in

WPCF Operations Forum (54) and Pollution Engineering (55). These reviews do not appear to be comprehensive in that they do not contain software packages sold by consulting engineering firms and packaged with plant design services. Sales material published by vendors can provide some information regarding the functions provided by commercial products (56,57,58). Sales brochures, however, tend to brief in providing technical detail. Common functions provided by commercial LOIS type applications are:

* data entry,
* report generation,
* statistical and graphical analysis.

The degree of flexibility and expandability available in commercial programs is often difficult to ascertain. One function conspicuously absent from several packages is data export capabilities.

Quality Control and Assurance

The purpose of a LOIS program is to integrate laboratory and operational data and produce useful information. Laboratory quality control (QC) might be considered to be outside the realm of a LOIS program because it is normally considered to be a laboratory specific concern. The increasing importance attached to quality control, however, dictated that a control charting program be included in the LOIS software package. Standard Methods for the Examination of Water and Wastewater (59), Booth (60) and Kirchmer (61) have defined the elements of an acceptable laboratory quality control program.

The QC section of the LOIS program developed for the Alexandria Sanitation Authority focuses on providing statistical analysis and graphical representations (control charts) of precision, accuracy and user defined control tests generated by the laboratory. A control chart is used to follow the historical behavior of a process and to determine if the process is currently operating in the same, presumably acceptable, manner. A parameter is plotted for a period of time and the average and standard deviation are determined. The next data point generated is compared to the historical values. If the current data point exceeds the average plus or minus two standard deviations, a warning is issued and the process is deemed to require closer attention. If the current data point exceeds the average plus or minus three standard deviations, the process is deemed to be beyond the control limits. In the laboratory, this usually requires that the test be repeated and that the cause of the deviation be investigated. The LABQC module was intended to be one tool in the laboratory Quality Control and Assurance Program. A variety of reports were developed to track the performance of laboratory quality control tests, the most important and interesting of which were the control charts.

III. Alexandria Sanitation Authority

The Alexandria Sanitation Authority (ASA) wastewater treatment plant is located in southeast Alexandria, VA, near the intersection of US Rt. 1 and the Washington Beltway (I-95). The original plant began operations in 1956 as an 18 MGD trickling filter facility (62). The ASA plant serves the majority of the City of Alexandria and portions of Fairfax County. The plant was expanded in the late 1970's to meet the wastewater treatment needs of a growing population and upgraded to meet increasing concerns with water quality in the Potomac River. The current design capacity is 54 MGD, and recent average flows have been approximately 40 MGD (Figure 1).

The plant has preliminary treatment consisting of bar racks, lift pumps, mechanical screens, aerated grit chambers, parshall flumes and primary sedimentation. Rotating Biological Contactors (RBCs) are used for secondary treatment. Carbon columns are expected to be placed in service in 1990 to provide increased soluble biochemical oxygen demand (BOD) removal. Intermediate clarification will be employed when the carbon columns are made operational. Flocculation tanks with chemical addition precede the secondary (final) clarifiers. Dual media

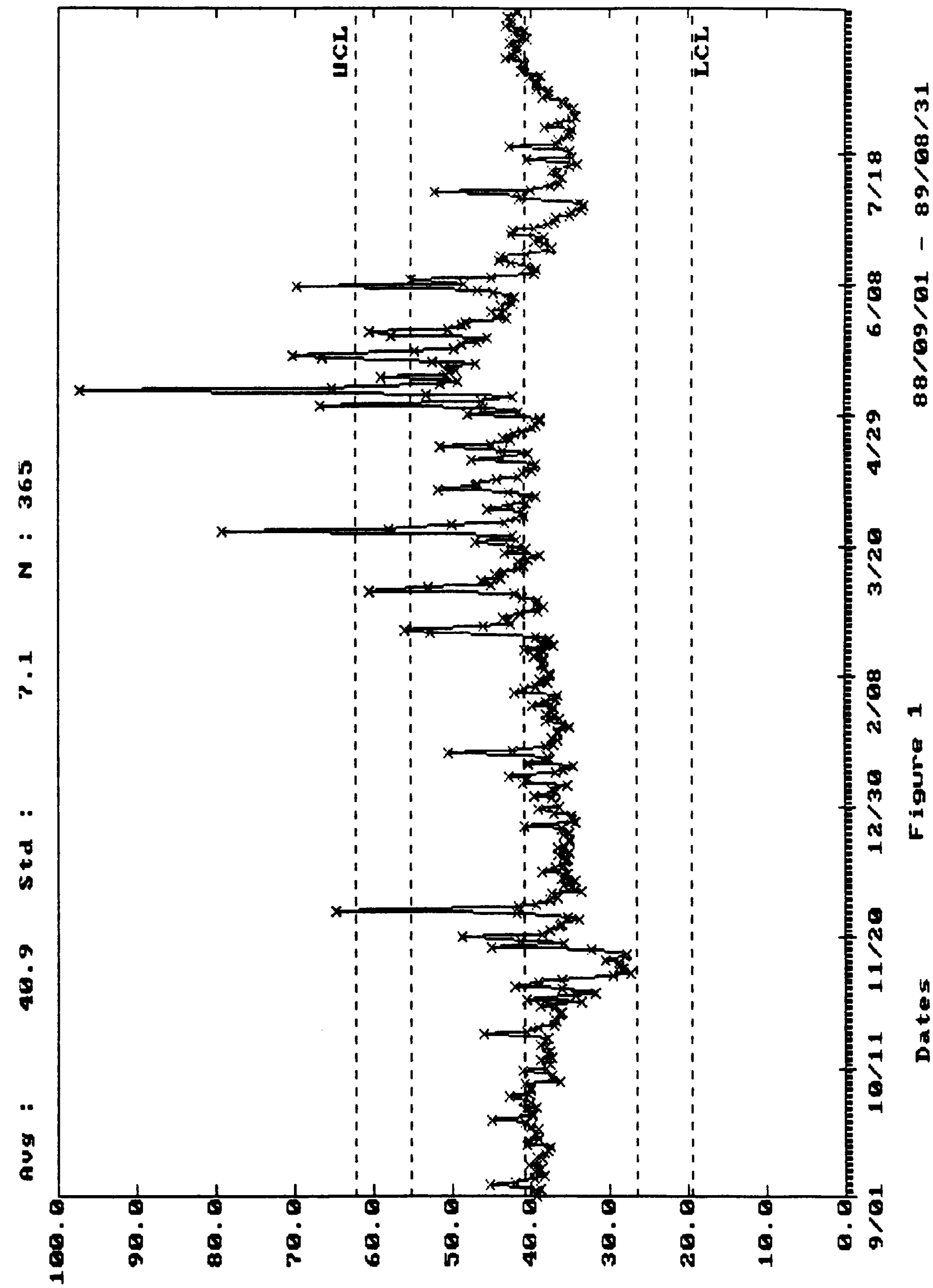

Avg : 40.9 Std : 7.1 N : 365
UCL
LCL
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
9/01
10/11
11/20
12/30
2/08
3/20
4/29
6/08
7/18
Dates
88/09/01 - 89/08/31

Figure 1

gravity filters remove floc that may be carried out of the secondary clarifiers. Chlorine is currently added to the filters. A combined chlorine contact and post aeration tank is the final unit process. At this time, ferric chloride is added to the primary tanks and alum is added to the secondary tanks for phosphorous removal. Design criteria are listed in the Operations and Maintenance Manual prepared by Greeley and Hansen(63). In general, the plant performs very well in terms of phosphorous and solids removal (measured as total suspended solids (TSS)), but is marginal with regard to BOD_5 removal.

The regulatory environment of the Alexandria Sanitation Authority is a very complex issue deserving separate treatment. The plant discharges to a minor tributary to a Virginia embayment of the Maryland-controlled Potomac River, which flows into the Chesapeake Bay. Final effluent standards have not yet been developed for the facility. Considering the number of bodies of water and political jurisdictions involved, the regulatory issues may not be resolved for some time. From the perspective of the LOIS project, it is necessary to make allowance for both the current NPDES parameters and those that may become permit parameters in the future. The parameters include both traditional pollutants such as BOD and TSS, currently controlled nutrients such as phosphorous and nutrients expected to be controlled in the future (nitrogen). The program should make ample allowance for the possibility that toxic substances may be regulated. Plant data that will be required for possible future design work must be made available. Flexibility to incorporate new unit process parameters must be built into the LOIS project.

Historically at the Alexandria Sanitation Authority, laboratory and operational data were kept via pen and ink systems similar to those described in MOP-11 (64) and the Sacramento Operations of Wastewater Treatment Plants (65) texts. Laboratory data were collected on bench sheets, then transferred to a daily data sheet. Operational data were collected on a series of log sheets. Both laboratory and operational data were then transferred to large spreadsheets, similar to those used in accounting. Loadings and process calculations were performed manually (later with the assistance of a hand held calculator) as were totals and averages for monthly and yearly reports. A weekly operations report was issued that contained only final effluent data. The data in the weekly report was six days old when it reached the operations personnel. The delay was imposed by the five day wait for BOD results and one day for data to be accumulated, typed and distributed.

The Authority staff recognized several deficiencies with this set of data handling procedures. First, it took an inordinate amount of time for managers to hand copy and manually process volumes of data. Second, the opportunity for error in a large number of manual transactions was too great. Third, very limited data were reaching the operations staff and not in a timely manner. Shift supervisors made frequent visits to the laboratory to get current data. Fourth, little time was left for in-depth analysis of the data. No time series or intra-parameter plotting of data was routinely done. Historic analysis was usually done on monthly average data as the daily data points were too cumbersome to handle. Because of the problems with the manual system, it was decided to proceed with the implementation of a microcomputer based laboratory operation information system. The initial expectation was that a computer information system would at least relieve a substantial amount of the tedium and potential for error involved with the manual calculations of loadings, detention time and similar calculations.

IV. Evaluation of Information Needs

Organizational Structure

The Alexandria Sanitation Authority is an independent authority created under Virginia law to accomplish a specific function: the treatment of wastewater generated by the City of Alexandria and immediately adjoining sections of the County of Fairfax. The organizational chart of the Authority is depicted in Figure 2. The Engineer-Director reports to the Board of Directors, an appointed, non-technical body. The Deputy Engineer-Director is the chief day-to-day operational officer. Both the Director of Operations and the Director of Maintenance report to the Deputy Engineer-Director. The direct supervisor of the laboratory, titled chemist, reports to the Director of Operations. Both the Mainstream and Sidestream Operations Managers report to the Director of Operations. Shift supervisors report to the operations managers. The staff engineer reports to the Deputy Engineer-Director but also provides technical support to Operations and Maintenance Divisions. The primary operational information needs of the Authority are concerned with the internal movement of information from the operations and laboratory departments to a central data base, the calculation of resultant data and the disbursement of that information both up and down the organizational structure. The persons considered key decision makers in the process control arena were determined to be the Deputy Engineer-Director, the Director of Operations, the two Process Managers, and the shift supervisors. The establishment of goals for the Laboratory Operations Information System focused on meeting the needs of these key decision makers first.

Information disbursements fall into three general categories. The first is information in the form of standard reports including daily operations reports, weekly laboratory and monthly NPDES reports. The second category is statistical and graphical presentation of LOIS data base information on demand. The third category of information disbursement is the export of data to other environments as required. Data export may be to a line printer, to a spreadsheet program or to a word processor for further manipulation.

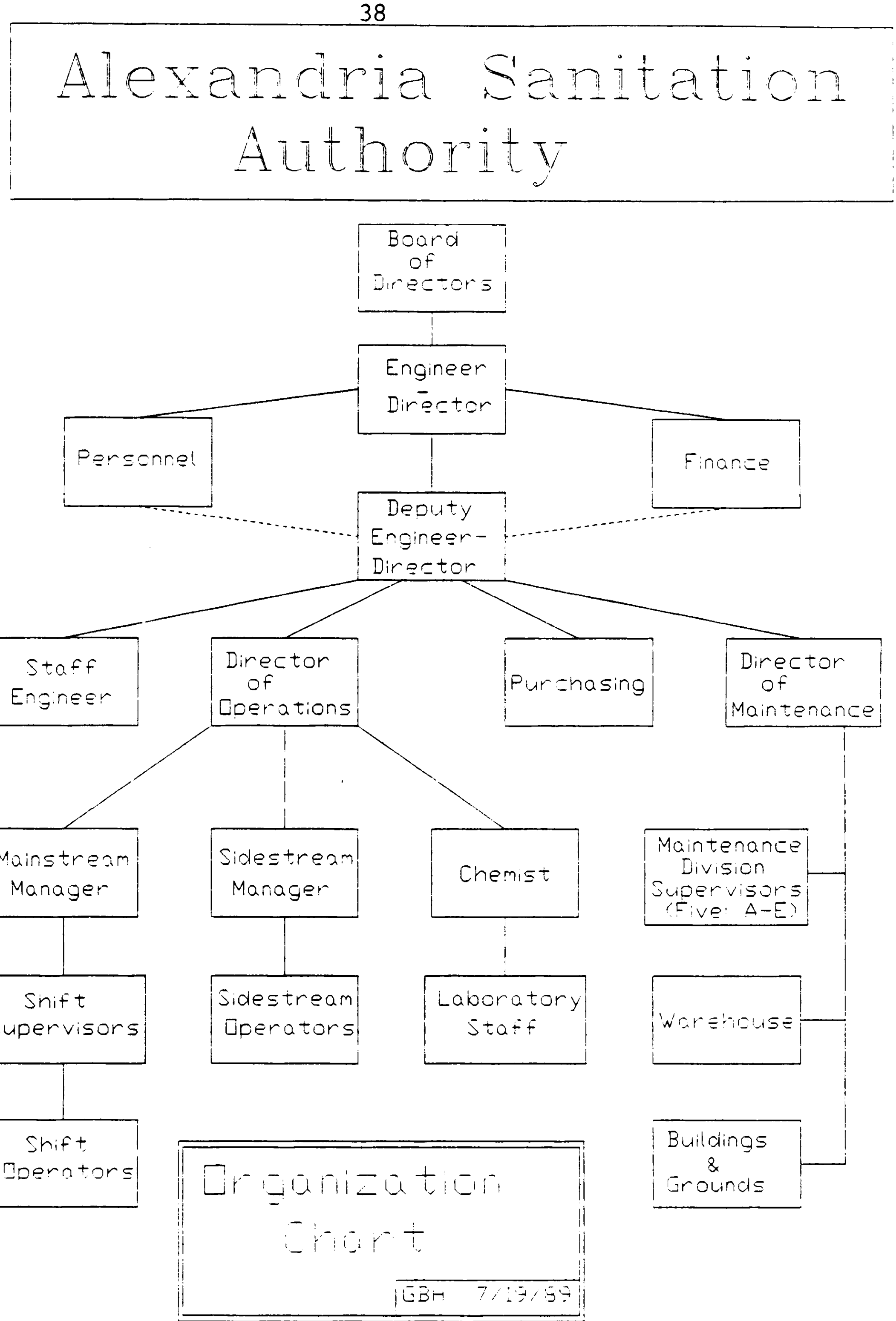

Alexandria Sanitation Authority
Board of Directors
Engineer Director
Personnel
Finance
Deputy Engineer-Director
Staff Engineer
Director of Operations
Purchasing
Director of Maintenance
Mainstream Manager
Sidestream Manager
Chemist
Maintenance Division Supervisors (Five: A-E)
Shift Supervisors
Sidestream Operators
Laboratory Staff
Warehouse
Shift Operators
Buildings & Grounds
Organization Chart
GBH 7/19/89

Figure 2

Information System Requirements

A series of needs interviews was conducted with information generators and users. The focus of the needs identified in interviews and during review of the historic information system were as follows:

1. Relieve the Deputy Engineer-Director of the task of data logging and performing repetitive calculations - such as loadings and detention times.
2. Provide data and calculated results to the key process decision makers (Deputy Engineer-Director, Director of Operations, Operations Managers and Shift Supervisors) as readily as data became available; to anticipate laboratory data when possible.
3. Provide shift supervisors and operators with process information on a timely basis.
4. Provide key decision makers both standard reports and flexible statistical analysis tools including graphical analysis tools.
5. Provide a tool for laboratory Quality Control data manipulation, both tabular reports and graphic presentation of control charts.
6. Provide data integrity and error detection methods. Considerable concern was expressed as to the accuracy of computer record keeping and the need for reasonability checking.

These were all considered first priority needs for data management. The first six needs were also internal needs of the Authority. External needs were identified as follows:

7. Provide the data for NPDES permit compilation.

8. Provide monthly reports for the various regulatory bodies (Virginia Water Control Board and Department of Health) and the engineers of record.

9. Provide a compilation of data for the annual report (a document that had been manually prepared since 1956).

10. Provide flexible summary and detail data compilation for external organizations either studying the Authority and its environmental impact (e.g. Washington Council of Governments etc.) or designing new facilities for the Authority.

11. Provide export facilities for data migration to other database formats that may be requested by other organizations.

The requirements for external studies and for long term trend analysis led to the conclusion that the data base must be structured to contain at least a five year rolling history of operations and results. A second point raised was that the Authority could have several new process units in the foreseeable future. A dechlorination facility was already mandated; the repair of the carbon columns was likely to be initiated and a nitrification or nitrogen removal facility might be required. These two considerations, the requirement for long term data storage and the flexibility to incorporate new process units, set the framework for the design of the LOIS database.

Identification of Data

The next step in the creation of the information model was the development of a system map identifying:

1. The unit processes employed by the Authority.
2. Sample locations within the plant.
3. Significant recycle flows.
4. The flow equation effective at each sample point.
5. Current and possible chemical addition points.

Figure 3 is the resultant system map of the Authority's wastewater treatment plant mainstream processes. Figure 4 represents the sidestream processes. Each sample point is identified on the system maps. Tables I and II list each sample point abbreviation used on the system maps. Many of the abbreviated acronyms, such as IST for Intermediate Settling Tanks, are in general use by operations and maintenance staff at the plant. The system map and list of abbreviations can serve as a useful tool to aid the orientation of new employees.

The treatment facility has a very flexible chemical addition design. Potential chemical addition points are marked on the system map by a diamond. At most points, coagulants such as alum or ferric chloride, coagulants aids such as polymer, chlorine or pH adjustment chemicals may be added. Potential chemical addition points that are currently in use are labeled with the chemical being fed and the diamond symbol has a cross connecting the points.

The development of the system map facilitates the determination of the flow components at each sample point. A flow equation was developed for each sample point. Several key issues were identified in the process of developing the system maps and flow equations. Most important, the RAW sample taken at the bar racks contained significant recycle flows from the thickeners and centrifuges. The thickener recycle flows by gravity to the Commonwealth interceptor and the centrifuge recycle flows to the Potomac interceptor before the interceptor flows mix. While the system maps provide an essential overview to the entire process, more detailed maps are often required. Figure 5 details the components of the RAW sample.

Another problem noted during the development of the system map was the sampling situation at the secondary settling tanks and filters. Although the system map shows one line from the settling tanks to the filters for simplicity, in fact there is no place where a satisfactory composite of secondary effluent may be taken. Each of the twelve settling tanks feeds primarily one filter, although an equalization manifold distributes some flow to or from adjoining tanks. This arrangement was designed to conserve space on the plant site. The lack of an appropriate secondary settling tank sample forces the secondary sedimentation and filtration process to be treated as one unit for purposes of calculating removal efficiencies.

The carbon column sample presents an analogous situation. There is no place where a composite of the effluent of all the carbon columns may be taken. Furthermore, sample facilities were not incorporated in the original design for individual columns whether they were operating in serial or in parallel mode. The individual column sample requirement is being addressed in the carbon column upgrade project though no practical method is available to crate a good composite effluent sample point.

A listing of the sample points, test parameters and potential calculations was circulated among the key process decision makers. They were asked to rank each parameter and sample point combination in order of importance and frequency of required analysis. Part of the effort was to judge the size requirements of the data base. Another aspect of the survey was to establish priorities for laboratory operations. The intent was to focus laboratory efforts on accurate evaluation of parameters important to the key decision makers and avoid wasted analysis of less critical parameters.

A preliminary estimate was made of the number and type of calculations the system must perform. A review was made of the manual calculations performed for the NPDES, monthly and annual reports. Key decision makers were polled regarding the calculated values that they would prefer to have available if the time to perform the calculations were not a constraint. Calculated parameters were grouped by process unit. The most prominent calculated values included on the initial list are presented in Table III.

Equations were developed for the initial list of desired calculated values. The flow equations for process units, including recycles, developed with information from the system maps were required for many of the calculations. The flow calculations for each process unit were placed at the beginning of the first calculated file. This insured that the flows would be calculated before any other calculations were performed which required the flows data.

A rolling average of the calculated value was deemed of greater value than a single day calculation for several parameters. The COD/BOD ratio exemplifies a parameter best treated on a rolling average basis. Daily values may fluctuate considerably, however, a rolling average reveals a significant seasonal trend. Because the monthly average BOD was often close to the regulatory limit, interest was expressed in predicting the current BOD, (which is not normally available for five days), based on the current COD value and the recent average of the COD/BOD ratio.

At this point, the first high-level review of the organization was conducted. Key organizational entities and relationships had been mapped. The data model of the plant was begun, though much detail work remained to be performed. Extensive system analysis should be conducted before any software system is initiated. Day (66) stated the matter clearly, "When you automate a mess, all you can get is an automated mess." He went on to explain that, "One of the greatest benefits of automation can be the review to determine feasibility. This review may result in the elimination or refinement of procedures used in performing certain functions." The initial review of operations, procedures and lines of communications is the most important step in the design and implementation of a computer software system. In information engineering, the all important first step is the development of a strategic system model of the organization and the organization's data requirements. The next steps in the design of an information system would involve the selection of software and hardware suitable for the implementation of the information model envisioned.

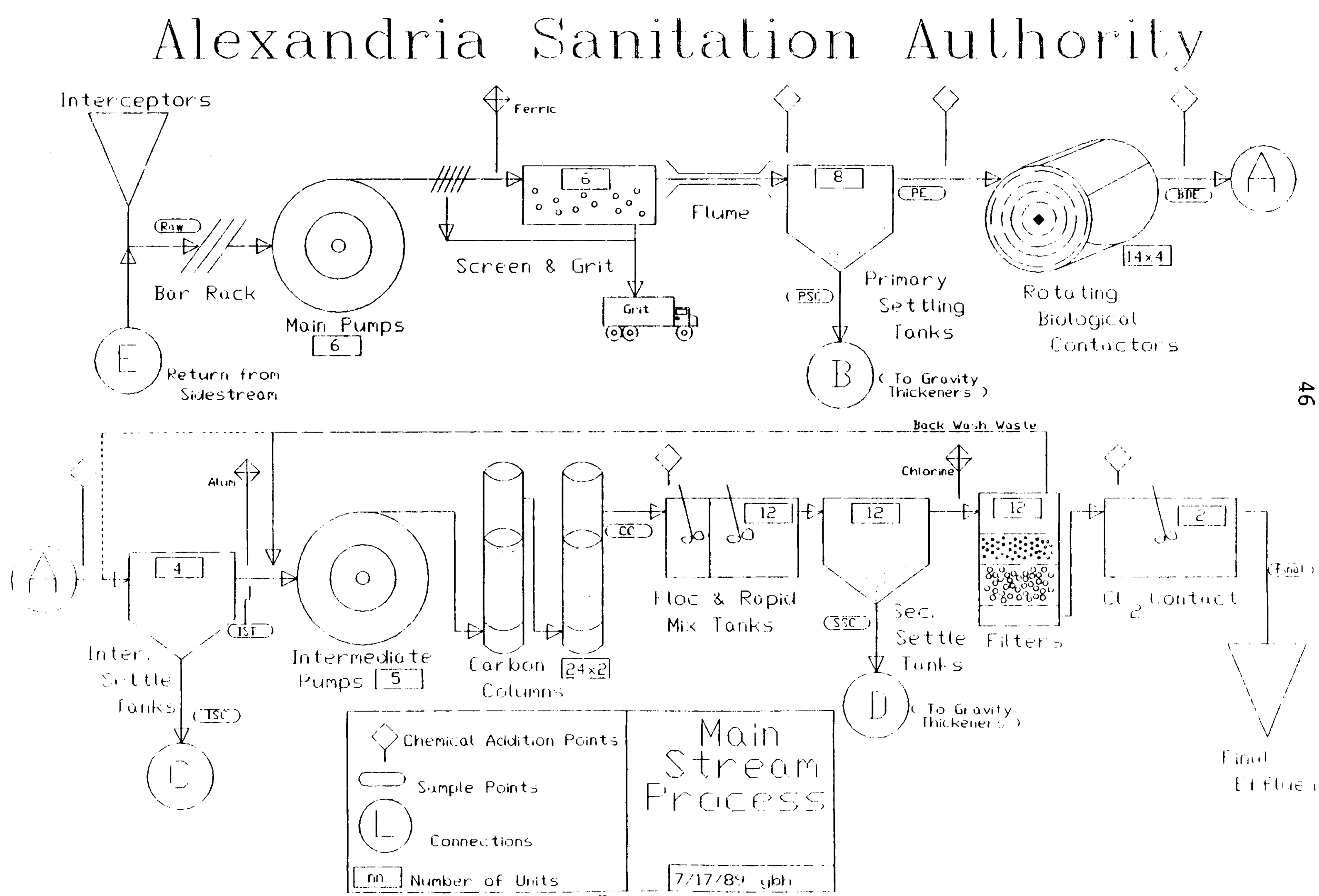

Alexandria Sanitation Authority
Interceptors
Raw
Bar Rack
Main Pumps
6
Return from Sidestream
E
Ferric
Screen & Grit
6
Grit
Flume
8
PE
PSC
Primary Settling Tanks
B
(To Gravity Thickeners)
14x4
Rotating Biological Contactors
BNE
A
Back Wash Waste
A
Alum
4
IST
Inter. Settle Tanks
TSC
C
Intermediate Pumps
5
Carbon Columns
24x2
CC
12
Floc & Rapid Mix Tanks
12
SSC
Sec. Settle Tanks
D
(To Gravity Thickeners)
Chlorine
12
Filters
2
Cl_2 Contact
Final
Final Effluent
Chemical Addition Points
Sample Points
L
Connections
nn
Number of Units
Main Stream Process
7/17/89 gbh

Figure 3

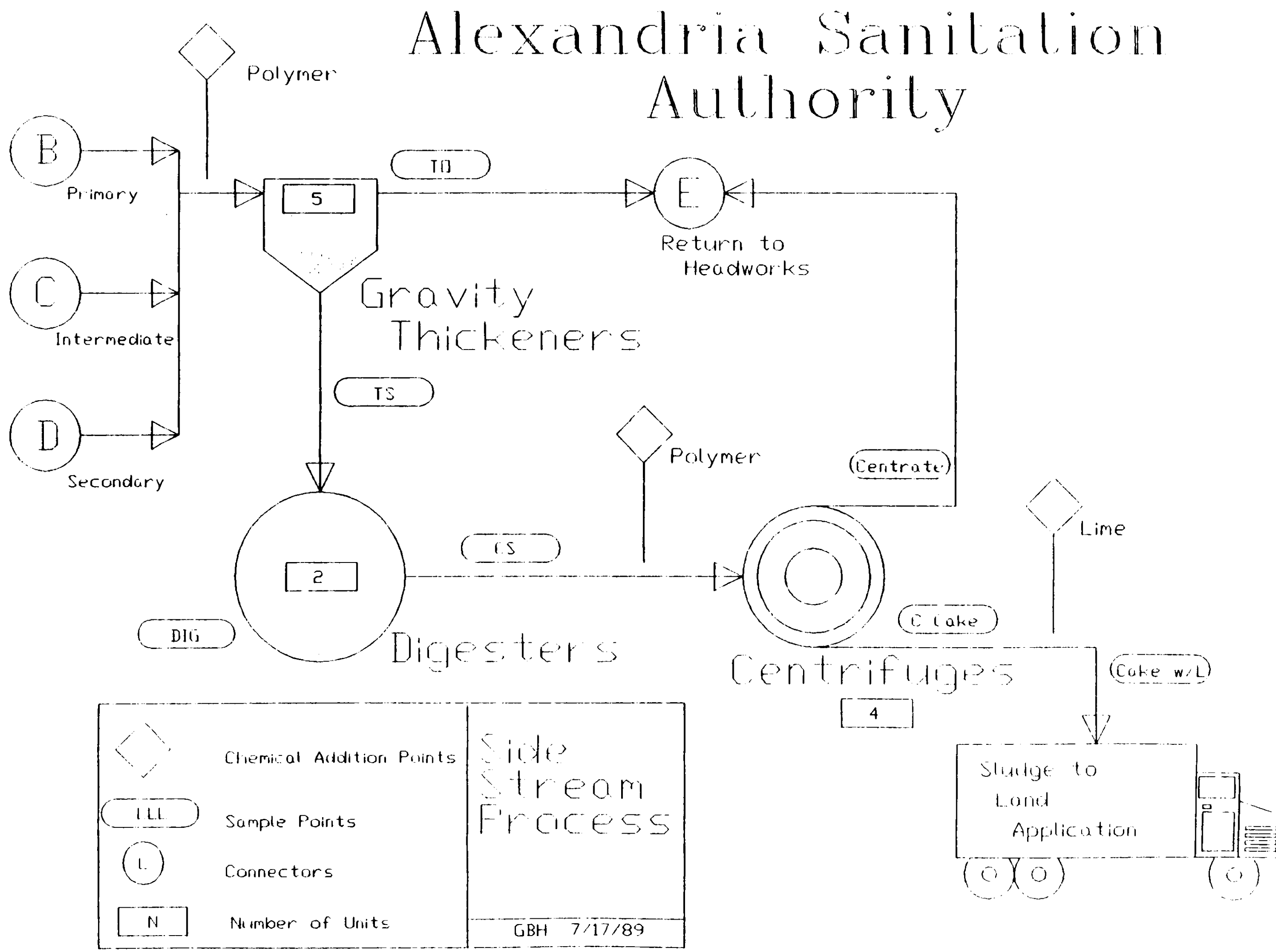

Alexandria Sanitation
Authority
Polymer
B
Primary
C
Intermediate
D
Secondary
5
TD
E
Return to
Headworks
Gravity
Thickeners
TS
Polymer
Centrate
2
DIG
Digesters
CS
C Cake
Centrifuges
4
Lime
Cake w/L
Sludge to
Land
Application
Chemical Addition Points
LLL
Sample Points
L
Connectors
N
Number of Units
Side
Stream
Process
GBH 7/17/89

Figure 4

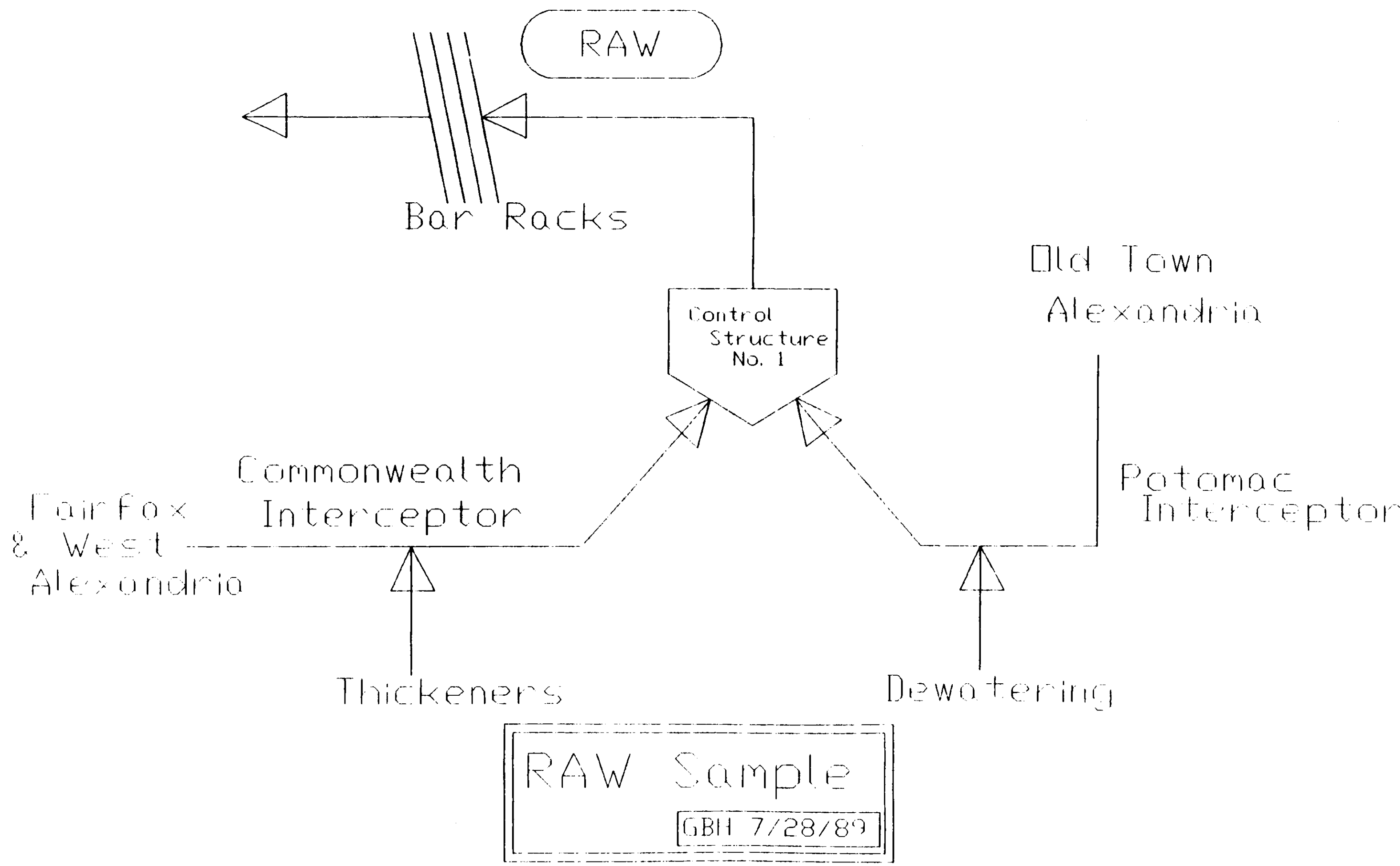

RAW
Bar Racks
Control Structure No. 1
Old Town Alexandria
Commonwealth Interceptor
Fairfax & West Alexandria
Potomac Interceptor
Thickeners
Dewatering
RAW Sample
GBH 7/28/89

Figure 5

Table I

Mainstream Samples

ID	Description	Type	Comment
RAW	Plant Influent /w Recycle	24 Hr. Composite Grab	See Fig 5 D.O., pH, Temp.
PE	Primary Effluent	24 Hr. Comp.	
BDE	BioDisk Effluent	24 Hr. Comp.	Also called RBC
IST	Intermediate Settling Tank Eff.	24 Hr. Comp.	Not in use now
CC	Carbon Column Eff.	24 Hr. Comp.	Not in use now Representative Composite may be difficult
FINAL	Final Effluent	24 Hr. Comp. 24 Grabs 1 Grab	 Cl Residual D.O., pH, Temp.

Table II

Sidestream Samples

ID	Description	Type	Comment
PSC	Primary Settled Sludge	24 Hr. Comp.	To Gravity Thickeners
ISC	Intermed. Settled Sludge	24 Hr. Comp.	Not in use now
SSC	Secondary Settled Sludge	24 Hr. Comp.	To Gravity Thickeners
TO	Thickener Overflow	24 Hr. Comp.	To Headworks
TS	Thickened Sludge	24 Hr. Comp.	To Digester
DIG1 DIG2	Digester 1 " 2	Grab	Alkalinity V. Acids, Temp.
CS	Centrifuge Feed	Comp.	During Cent. Operations
CE	Centrate	Comp.	To Headworks
C.Cake	Centrate Cake	Comp.	From Belt
L Cake	Centrate Cake	2/Truck	w/ Lime

Table III
Required Calculations

<u>MAINSTREAM :</u>

* Preliminary and Primary Treatment:
    - Mass of Screenings and Grit removed
    - Total Flow with and without recycle
    - Chemical Dose to the Primary Clarifiers
    - Primary Clarifier Detention Time
    - Mass Primary Sludge
* Rotating Biological Contactors
    - Hydraulic Loading (GPD / Sq Ft)
    - Detention Time (Minutes)
    - Organic Loading (Lb SBOD / K Sq Ft)
    - Per Cent SBOD removal
* Secondary Clarification
    - Chemical Dose
    - Detention Time
    - Mass Secondary Sludge
* Filters
    - Hydraulic Loading (GPD /Sq Ft)
    - Total Backwash Flow
* Chlorination
    - Feed Dosage
    - Detention Time
* Final Effluent
    - TSS, BOD and P Mass (Lb and KG)
    - COD / BOD Ratio
    - Expected BOD based on COD value
* Raw to Final
    - Total Mass Removals
    - Percentage Removals

<u>SIDESTREAM :</u>

* Thickeners
    - Overflow Solids Mass
    - Total Flow
* Digester
    - Feed Mass
    - Volatile Acid / Alkalinity Ratio
    - Retention Time (Rolling Average)
    - Percent Volatile Solids Reduction
    - Loading (Lb Vol. Solids / Cu Ft)
* Dewatering
    - Feed Mass
    - Sludge Mass (Wet and Dry Tons)
    - Lb Polymer / Dry Ton
    - Centrate Solids Mass

V. Design of Information System

Software Selection

Whether a commercial software package is determined to be most cost effective or an in-house programming effort is selected, the initial steps of need determination and system analysis are the same and should be carried out in detail. Commercially available software has the advantage of being ready to run with minimal start up time. The initial review of needs, however, should be even more thorough with commercial software in order to determine applicability. A drawback of commercial software compared to in-house development is the lack of inherent flexibility, especially after system operation has begun. Product literature was studied and several vendors provided demonstration or practice systems. While all the commercial packages were in some ways attractive, no system had all the features and flexibility desired in the LOIS project. In-house development is more flexible and adept at creating a dynamic system if the initial system analysis and review is carefully conducted and the program is structured so as to insure maintainablilty.

In-house development may follow several paths. One option is the use of standard business spreadsheets. MOP

SM-5 (49) details a case history of such an information system. The advantage of standard spreadsheet are simplicity, ease of use and flexibility. The disadvantage is the limitations of the package. Such systems are not designed to handle large data bases. Often, only one month's data can be reasonably manipulated at one time. As the data base grows, the speed of recalculations may deteriorate rapidly, making large data bases difficult to implement and maintain in a spreadsheet environment.

Another option, which alleviates the large data base problems associated with a spreadsheet package, is the use of data base programs for microcomputers, typified by the data base program dBASE III (67). Edgar F. Codd (68,69) described his ideal relational database model in 1970. Codd's model described data bases rigorously in terms of set theory. All information in the Codd model of a relational data base was to be expressed as tables. All manipulation of data base information was to produce other tables. Codd defined a rigorous standard to evaluate the logical organization and abilities of data base management systems. Seymour (70) indicated the shortcomings of current microcomputer data base managers, including dBASE III, compared to Codd's ideal model. Though not perfect, microcomputer based data base managers are capable of managing quantities of data limited only by hard disk size.

Data base managers, however, often lack the statistical and graphical functions which would be required in a LOIS package. The programming languages associated with data base programs have learning curves and development times approximately in line with general purpose languages.

The last option is the use of a general purpose programming language. Low level languages such as assembly or C were ruled out because of excessive development and maintenance time (71). High level languages such as Pascal or BASIC are more appropriate in the development of in-house applications programs where time of development is critical and software execution speed is not the limiting factor. Norton (14) strongly argued that programs should be developed at the highest level possible to aid maintainability and insure operation on current and future hardware platforms.

The two basic types of computer disk files are random access and sequential. Sequential files must be read starting at the beginning and write operations must occur at the end of the file as an append operation. Sequential data files are acceptable for relatively small files or files that must be read in their entirety with each access. Random access records, as the name implies, may have records read or written starting anywhere in the file. The size of the LOIS data base required the use of random access data files if a five year or more database was to be developed while maintaining adequate system performance. A compromise solution exists in the form of Indexed Sequential Access Method (ISAM) files which combine many of the attributes of random and sequential files access methods. ISAM files require the maintenance of index files to locate information within the main data files. If the relationship between the index file and the main data base file is corrupted for any reason, the information in the file may be difficult to recover. The design of the main LOIS data base files was predicated on the use of random access records with records arranged chronologically; a one to one relationship would exist between records and days. Data for a day would be located by means of a calendar that translates dates to record numbers.

Only two high level languages (BASIC (72) and PASCAL (47)) were considered for the LOIS project based on the availability of well established, integrated, microcomputer implementations of the languages. Pascal, however, was ruled out at the start of this project because it did not then support random access data files. The original BASIC language was developed in the late sixties for use as an educational tool for interactive programming in a time-sharing, university environment. The early microcomputer interpreters available on late seventies microcomputers were very limited. These early microcomputer renditions were often allocated only 4 kilobytes (K) of Read-Only-Memory (ROM). The space restrictions limited the length of variables to two characters, limited floating point accuracy, and were vested with line editors with very few features. Program space was limited to 64 K or the limits of machine Random Access Memory(RAM). Most damning, in the eyes of structured program advocates, was the lack of support for modular programming. BASIC line numbers limited modification or maintenance and led to the nearly random use of GOTO statements to redirect program execution to a free block of line numbers. BASIC did, however, have a wealth of functions that gave direct and easy (though not always fast) control of microcomputer resources. The ability to write directly to video memory or CPU ports made BASIC the favorite of a generation of computer hobbyists and experimenters.

The development of integrated programming environments which encompass program editing, syntax checking, debugging and compilation has made BASIC an attractive language for the development of large application programs(48,72,73,74). The new integrated compilers also introduced structured programming to BASIC. The introduction of line labels and the elimination of mandatory line numbers added a great deal of flexibility to program development and modification.

Multiline IF-THEN-ELSE and CASE structures eliminated the need for GOTO statements. The addition of subroutines that passed parameters and maintained local and global variables aided in the creation of modular programs. Inclusion of support for independent libraries moved the level of modularity of BASIC to the same level as C. The ability to compile separate modules and then link into one executable program allowed the creation of programs using all available memory. The normal limit for program size in the Microsoft Disk Operating System (DOS) is 640 Kb, though the use of Lotus-Intel-Microsoft (LIM) expanded memory and new operating systems is expanding the functional program area to several megabytes (75).

Two quality BASIC environments were available from established firms, Microsoft's QuickBASIC and Borland's Turbo BASIC (48,73,74). Both products are far advanced from previous interpreted implementations of BASIC, in that both provide integrated program editing, compilation and debugging. The execution speeds of stand alone programs developed with either language are an order of magnitude or more faster than their interpreted ancestors. The decision to use Microsoft QuickBASIC Version 4.0 was based on its superior support for modular programming and the development of large applications.

Hardware Selection

Alternatives to the IBM compatible family of microcomputers were never seriously considered for several reasons. The Authority already owned two IBM AT computers and had made a considerable investment in PC-DOS based applications. Both the finance and maintenance departments had committed to software packages that could not easily be transferred to other hardware platforms. The laboratory already used a common DOS based spreadsheet program for a variety of functions. In the general market; software, peripherals and clones were available at reasonable prices for the IBM extended family of microcomputers.

The selection of a microcomputer platform for the LOIS project took advantage of the improvements in technology and the reduction in prices that occurred in the past decade. A late 1970's microcomputer often came with 4 or 16 K of standard RAM memory. The 8 bit processors of the period were capable of addressing 64 K as a maximum without employing memory bank switching techniques. The Intel 8088 used in the original IBM PC is a 16 bit processor capable of addressing 1 megabyte(Mb) of RAM. The common operating system for the IBM and compatible class microcomputer is Microsoft's Disk Operating System (referred to as MS-DOS or PC-DOS or just DOS). While the Intel 8086 will address 1 Mb, DOS allows applications programs to address only 640 Kb.

The rest of the address space is reserved for system functions such as display memory. The 80286 CPU made popular by the IBM-AT and its many clones, can address 16 Mb of RAM. The additional memory capacity of the 80286 and 80386 has largely been unused by DOS. The Lotus/Intel/Microsoft expanded memory specification has been used to address additional RAM for all the Intel microprocessors (75). The use of expanded memory for disk cache and print spooler buffer space can greatly enhance the throughput of a microcomputer as disk access time and delays while printing reports or graphs are often the bottlenecks in system performance.

Floating point math coprocessors, most commonly of the Intel 8086 family, have greatly enhanced the ability of the microcomputer to deal effectively with statistical analysis of large databases and perform compute-intensive graphical applications with acceptable speed and accuracy (76,77). Top of the line graphical systems have become available for microcomputers that rival the resolution of minicomputer workstations. The evolution of microcomputer graphics interfaces has left several adequate options for LOIS programs in more reasonable price ranges (78).

Hard disk drives became standard equipment on microcomputers with the introduction of the IBM XT. Since the 10 Mb drive introduced with the XT, large improvements have been made in hard disk drive speed and capacity. Unfortunately, hard disks remain vulnerable to mechanical failure. Any system employing hard disk drives for mass storage must include provisions for data backup.

The Alexandria Sanitation Authority possessed two IBM AT computers when the LOIS project was begun. One AT was used exclusively by the finance department. The other was shared between the Maintenance Division, the Operations Division and the Laboratory. The Maintenance Division was the heaviest user due to implementation of a maintenance management program for preventive and corrective maintenance. It was decided a new microcomputer would be required for LOIS development and operations. The selection was based on compatibility, performance, suitablilty to the LOIS tasks and price. The selected system featured :

1. An AT class microcomputer from an established manufacturer with an 80286 CPU running at 10 MHz. The microcomputer selected represented several trade offs. The Authority did not wish to purchase a computer from an unknown vendor nor did it wish to spend more than necessary. The 10 MHz speed was 20 percent faster than IBM's then current offering yet within the operating range of most common peripheral equipment.
2. 640 K Standard Memory and 2 MB expanded memory

that can be used as expanded memory (LIM Memory). The expanded memory was expected to have three primary uses:

a. Provide disk cache memory to improve system performance by holding recently used data in memory with the expectation that it will be requested again. Under certain conditions, disk cache systems can greatly enhance hard disk performance. LOIS was expected to make heavy use of the hard disk during long term reports and statistical analysis.

b. Provide print buffer capacity. Printer speed is often the limiting factor in computer throughput.

c. Provide additional work space for spreadsheet or statistical packages for large sub-databases exported from LOIS.

3. A standard 40 Mb hard disk. Initial estimates of the size of the LOIS data base were put at approximately 5 Mb for data, 1 Mb for executable programs and 2 Mb for system development (source code and programming language). Other uses of the computer would, of course, utilize all remaining capacity.

4. An 80287 math coprocessor. LOIS was expected to perform a large number of floating point operations during database calculations, statistical and graphical analysis.

5. A high resolution color monitor and Enhanced Graphics Adapter providing 640 X 350 dot resolution in 16 colors. LOIS graphs require high resolution, but the requirement to contain costs ruled out more expensive combinations.

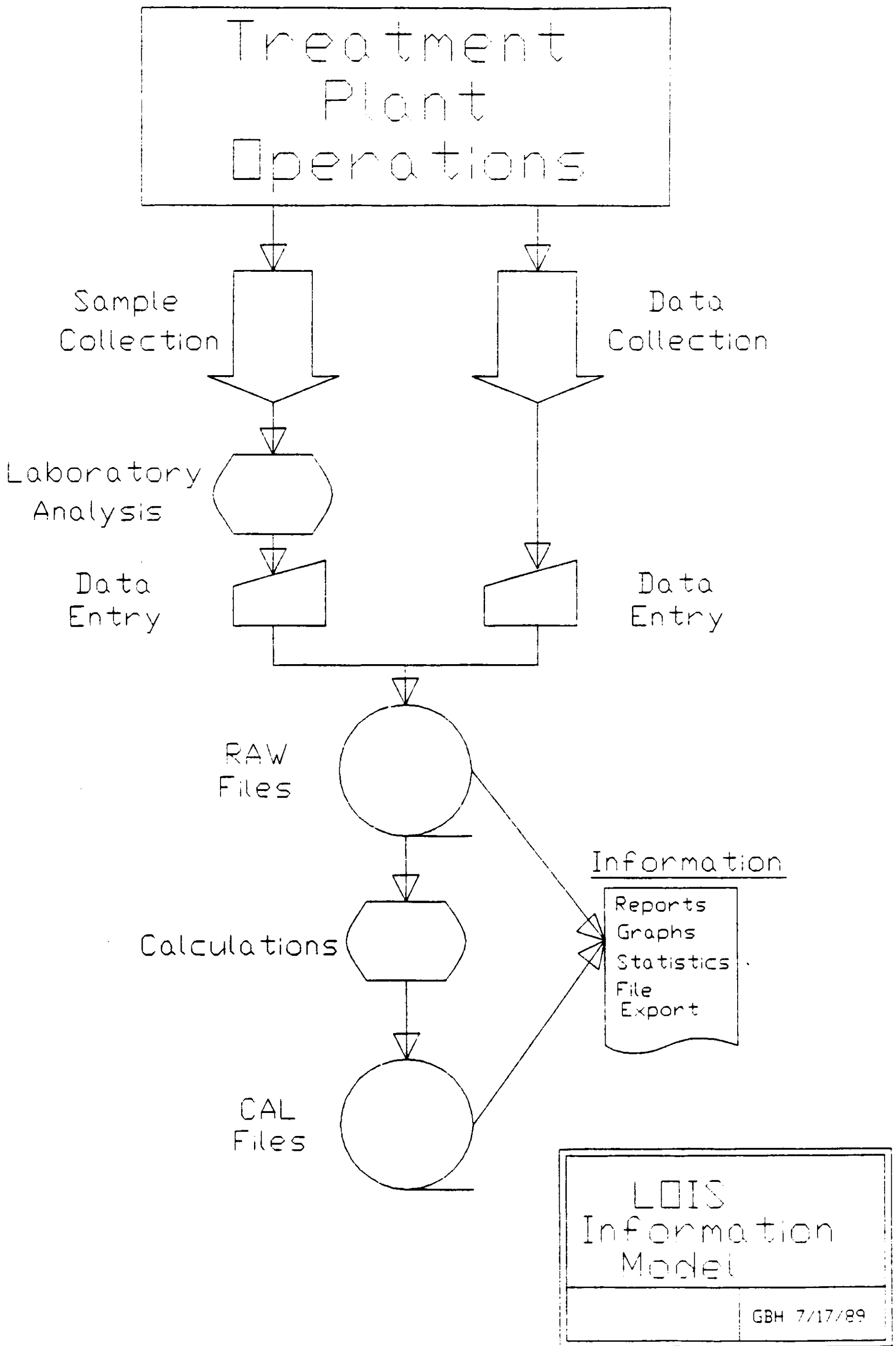
6. A dot matrix printer with 24 pin print head for near letter quality reports and a color printing option for production of color graphs.

The hardware package suited the needs of the LOIS project. While not being "state-of-the-art", the hardware package was composed of proven technology at a reasonable price.

Information Model

A proposed information model for the LOIS system was constructed. Figure 6 shows the system level representation of the LOIS project. The model of information flow is expressed in term of inputs, files created, processing procedures and output. Integration of laboratory and operational data and the development, storage and reporting of calculated results is a primary focus of the system. The inclusion of laboratory and operations comment files, adjustment files and the QC module were not included in the high level information model figure to avoid excessive clutter. Comments may be considered another form of raw data input. Statistical and graphical analysis and file export facilities may be considered another form of report for the functions of the high level system model.

The model shows inputs (arrows) from the plant operation in terms of operational data from the field and samples provided to the laboratory. Procedures (square boxes with rounded ends) are internal to the program (calculations, report generation) or external, performed by staff personnel (laboratory analysis, report review). The main portion of the LOIS data base, RAW and CAL data files (circles with tails), are shown on the high level data model. Three additional types of data files, Quality Control, ADJustment and COMment files, form the remainder of the LOIS database. Additional files define the database files and fields such as the LAbel and Limit (LAL) and calculation DEFinition (DEF) files. Several additional system definition files such as SETUP.TXT and Report Definition Files are essential parts of the LOIS package. These files are part of the system definition and are not normally changed on a daily basis.



Treatment Plant Operations
Sample Collection
Data Collection
Laboratory Analysis
Data Entry
Data Entry
RAW Files
Information
Reports
Graphs
Statistics
File Export
Calculations
CAL Files
LOIS Information Model
GBH 7/17/89

Figure 6

Data Integrity

An important feature of the system is error detection and correction. Figure 7 details the Data Input procedures followed during keyboard input to the LOIS database. The input process is the first and best opportunity to insure integrity of the LOIS data base. Efforts are made to insure that input is being made to the correct file and record and that reasonable data are being input. An opportunity to review and edit each record is presented to the user before the user may continue to the next file.

All RAW records are selected by choosing a file name and a date. The file name and date defines a physical record. Before input may continue, three checks are made. Date inputs are always checked to determine if the date selected (target) is a legal input, that being within the range of years that has been blocked out for the LOIS data base. The input routine also compares the target date with the current date as reported by the operating system of the computer. If the target date is in the future or more than seven days in the past, a warning is issued and the user has the opportunity to abort the input operation, select a new date or continue with the currently selected date. The current record is read to determine if data have already been entered in the target record. Normally, data are input to records which have been previously blocked out for the LOIS database by filling them with minus ones, the no data indicator. If any positive value is encountered while reading the record, a warning is issued on screen and the user is given the opportunity to abort the input operation. The record lock field (field thirty two) is also read and if the target record is locked, a warning is issued on the screen. The user is given no opportunity to continue the input operation in the case of a locked record. Program control is passed to the INEDIT module menu as soon as the enter key is pressed.

When input is allowed, the target file name and date are displayed on the screen at the start of record input. The associated LAbel and Limit (LAL) file is read for the list of field labels, units, limits and status of records contained in the file. The previous day's record is read to obtain comparative values for each field. Starting with the first field in the target record, the previous day's value, the field label and field unit are displayed. For each active field, a numeric value is requested. Reasonability limits (two high and two low limits - warning and control (unacceptable)) are applied to all inputs as they are entered to avoid keypunch errors. The warning and control limits are contained in a LAL file associated with each RAW file. While most transposition errors (an entry of 7.32

instead of 7.23) could not be trapped this way, an entry of 7023 would be prevented. After the data for each record are entered, the entire record is presented on screen for further review and editing. Just prior to the record being written to disk, the values of the thirty fields are summed and the result is entered in the thirty-first field. Thereafter, whenever the record is read for editing, report, graphical or statistical analysis, the thirty data fields are summed and the result is compared to the value in the check sum field. If the values do not match, the user is warned that a corrupt file condition may exist. When the record is complete, the user may choose to proceed to the next day (record) in the same RAW file or to proceed to the next RAW file and input data for the same day or to exit the data entry procedure.

The data input limit checks are only one of the mechanisms for insuring data integrity in the LOIS model. Figure 8 shows the other two primary data verification procedures as well as the establishment of values for the data input limit checks. Separate laboratory analysis of quality control samples may lead to the rejection of data entered in the LOIS database. An important component of the LOIS data integrity system is feedback from the review of reports by the key decision makers. The various types of reports generated by the LOIS system are presented in Figure

9. For the purposes of data integrity reviews, the standard reports types are most important. The laboratory daily report (Appendix A) is generated by the laboratory technician who inputs the day's data values. This report is reviewed by the chemist or the lead technician. The daily operations report (Appendix A) includes a list of all parameters, raw input and calculated data, that exceed the expected norms for that parameter. The limit checks on the daily operations reports cover all parameters for the report day and the two previous days. Often, laboratory or operations comments on the report explain the abnormal value. Review of the operations daily report by the key decision makers is an important source of data verification and correction. The weekly laboratory report (Appendix A) is reviewed by the chemist or lead technician for accuracy.

Alterations to the data base made within a short time frame, as a result of daily or weekly report reviews, are normally entered directly to the RAW files via the RAW file edit function. These changes are usually noted in the comment files. The RAW file edit function checks the target date versus the current system date. A warning is issued if the target date is more than ten days prior to the current date. Alterations of the earlier data should be made by way of the adjustment process. If the target record has been locked, the alteration must be made under the adjustment process.

Modifications made as a result of the preliminary monthly report (Appendix A) review process are noted via the adjustment procedure. This procedure makes the required changes in the RAW database and adds a record for each change made to the ADJustment file. The adjustment file record notes the parameter file and record changed, the old and new values, the date of the change and the person and reason for the change. The adjustment file is particularly important for logging and changes which may have been made after the monthly report has been finalized. Up until the production of the monthly report, all information in the LOIS database is used internally by the Authority. The monthly report, and associated permit report, is distributed to a variety of external users. All practical efforts are employed to insure that the information in the LOIS data base is correct and complete before the production of the final monthly report.

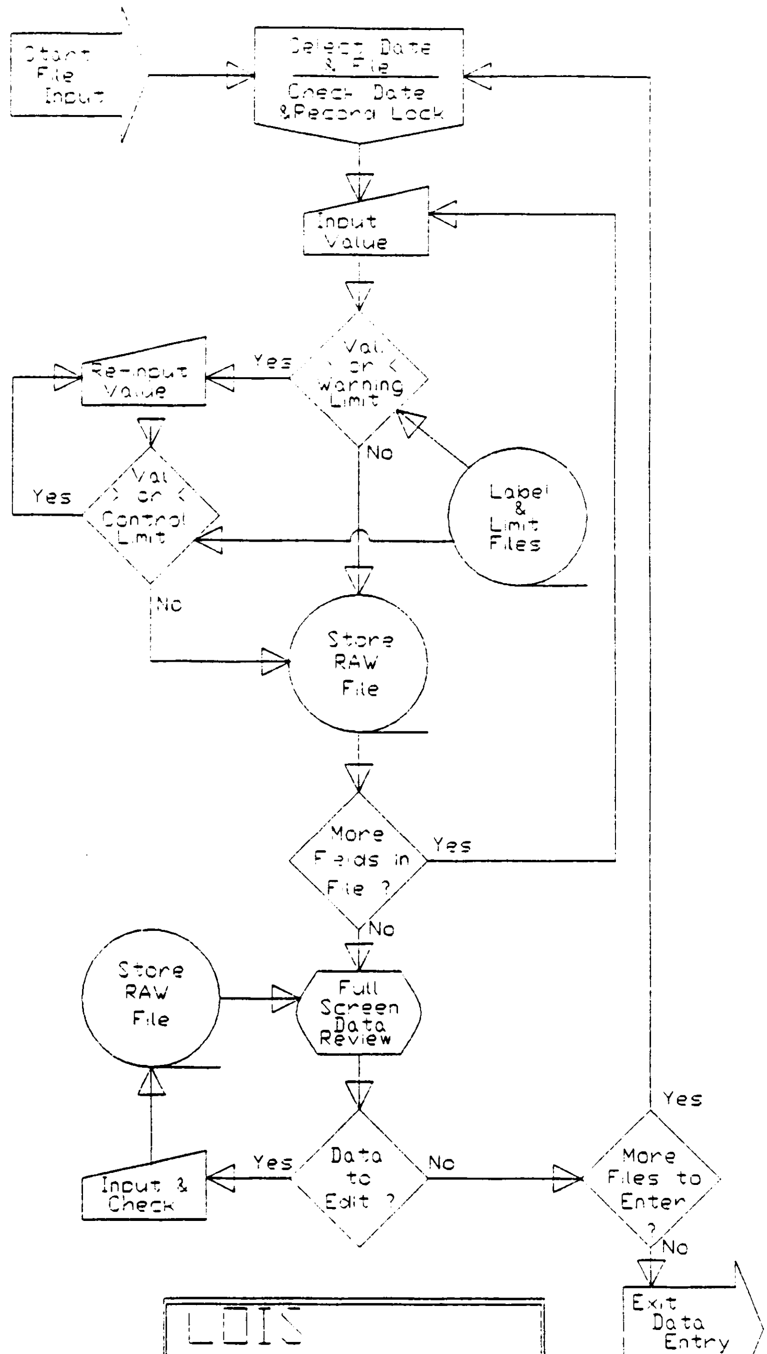

Start File Input
Select Date & File
Check Date & Record Lock
Input Value
Val. > or < Warning Limit
Yes
No
Re-input Value
Val > or < Control Limit
Yes
No
Label & Limit Files
Store RAW File
More Fields in File ?
Yes
No
Store RAW File
Full Screen Data Review
Data to Edit ?
Yes
No
Input & Check
More Files to Enter ?
Yes
No
Exit Data Entry
LOIS
Data Input
GBH 7/14/89

Figure 7

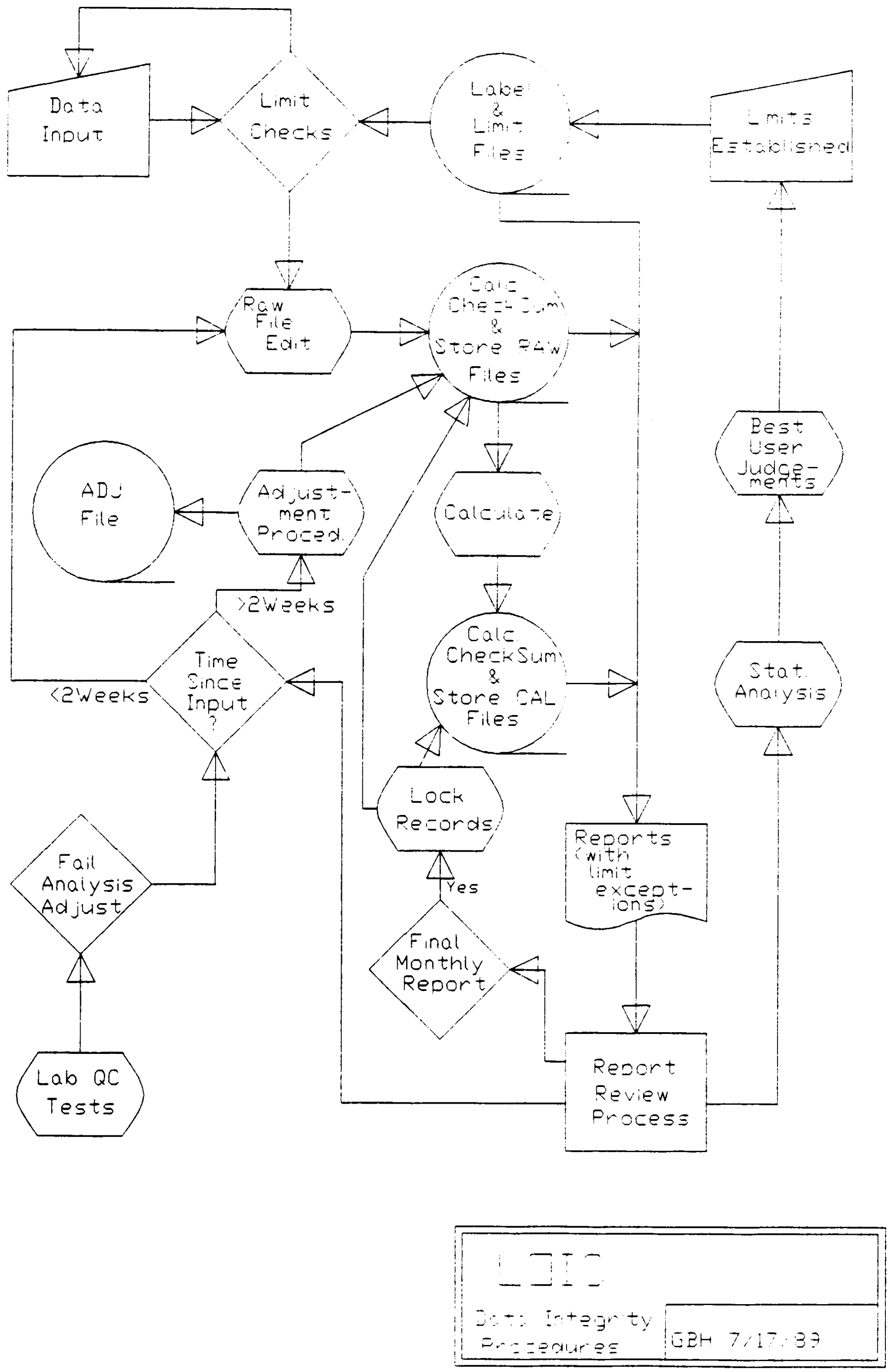
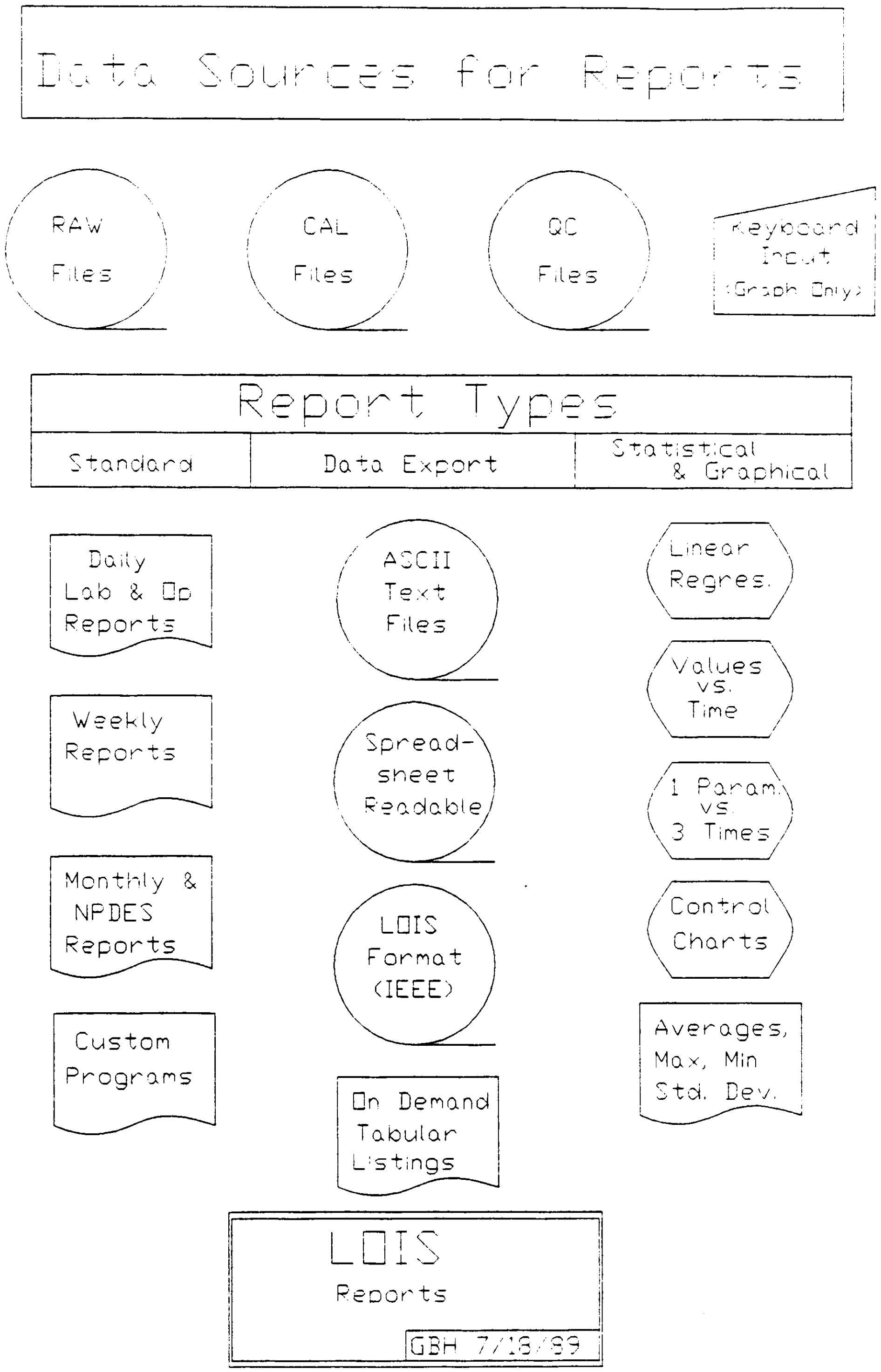

Data Input
Limit Checks
Label & Limit Files
Limits Established
Raw File Edit
Calc Check-Sum & Store RAW Files
Best User Judgements
ADJ File
Adjust-ment Proced.
Calculate
>2Weeks
Calc CheckSum & Store CAL Files
Time Since Input ?
<2Weeks
Stat. Analysis
Lock Records
Reports (with limit exceptions)
Fail Analysis Adjust
Yes
Final Monthly Report
Lab QC Tests
Report Review Process
Data Integrity Procedures
GBH 7/17/89

Figure 8



Data Sources for Reports
RAW Files
CAL Files
QC Files
Keyboard Input (Graph Only)
Report Types
Standard
Data Export
Statistical & Graphical
Daily Lab & Op Reports
Weekly Reports
Monthly & NPDES Reports
Custom Programs
ASCII Text Files
Spread-sheet Readable
LOIS Format (IEEE)
On Demand Tabular Listings
Linear Regres.
Values vs. Time
1 Param. vs. 3 Times
Control Charts
Averages, Max, Min Std. Dev.
LOIS Reports
GBH 7/18/89

Figure 9

Laboratory Quality Assurance

Laboratory quality assurance procedures and statistical analysis of duplicate, spikes and knowns help assure the quality of laboratory data. Figure 10 represents a more detailed view of the procedure for laboratory QC Model. An important aspect of the QC model is the determination of the current limits for a parameter during record input. The number of values used to determine the average, standard deviation and control limits may be varied for each file. This information is contained in the file definition file. During record input, previous records are examined. Only passing tests are used to determine the current control limits. The program determines the pass/fail status of each record before the record is written to the file. File maintenance utilities are required to update each record if records are entered out of order or edits are made to previous records which may change the status of following records. Utilities are also provided to archive QC data to separate historical files in order to maintain the size of QC files within manageable limits.

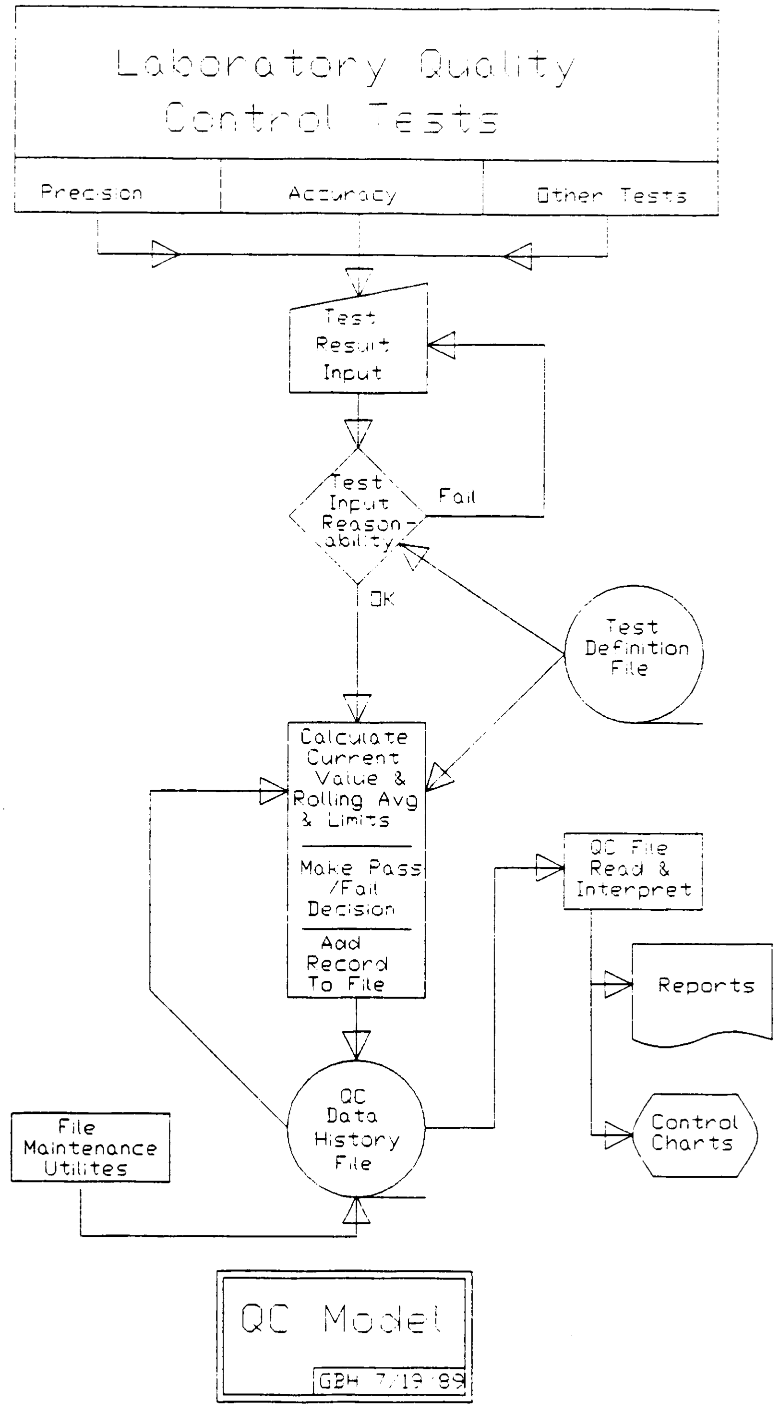

Laboratory Quality
Control Tests
Precision
Accuracy
Other Tests
Test
Result
Input
Test
Input
Reason-
ability
Fail
OK
Test
Definition
File
Calculate
Current
Value &
Rolling Avg
& Limits
Make Pass
/Fail
Decision
Add
Record
To File
QC File
Read &
Interpret
Reports
Control
Charts
File
Maintenance
Utilites
QC
Data
History
File
QC Model
GBH 7/19/89

Figure 10

System Modules

An alternative system module model of the LOIS program is presented in Figure 11. This model represents the main functions of the LOIS package grouped by program module. In the QuickBASIC environment, a module is an independent section of program code that can be compiled separately. Modules may be linked together to form larger programs or one program may transfer control to another program through the CHAIN command. LOIS is the main module and presents the main menu. All functions can be reached in a keystroke or two from the main menu and all other modules return control to the main menu. The report generation menu and standard report generation code is included in the LOIS module. File export and DOS functions are also included within the LOIS module. Four main program modules are accessed by LOIS via the BASIC CHAIN command:

1. INEDIT : Input and Editing of database files including RAW, CALculated, COMment, ADJustment and LAbel & Limit (LAL) files. The Calculation ENGine (CENG) subroutine performs calculations when called by INEDIT.

2. STATPACK : Performs graphical analysis of RAW, CALculated, QC , and external files. Graph types include: parameters (1-3) vs. time, one parameter vs.

multiple time periods (up to 3), linear and curve fitting of data (1-2 points) vs. an independent variable or vs time, and control charts (1 data point vs. time). The STATREV subroutine performs statistical analysis of RAW and CALculated file parameters when called by STATPACK.

3. SYSOP : SYStems OPerations controls the hardware environment (printer, display options, etc.) assigned in the SETUP.TXT file, and allows creation and modification of RAW, CALculated, and Report Definition files. DEFCALC (DEFine Calculation) and DEFREPT (DEFine REPorT) are subroutines called by SYSOP.

4. LABQC : The QC functions include data input, editing, and reporting of quality control files. LABQC includes a control chart graphics section similar to STATPACK. A QC file export section is also maintained.

All modules make use of common INCLUDE files at the beginning and end of the code to insure identical subroutine parameter declarations and error trapping procedures. All modules also use the services of the COMLOIS set of subroutines for commonly performed functions such as the julian calendar routines, menu presentation services and file read/write routines.

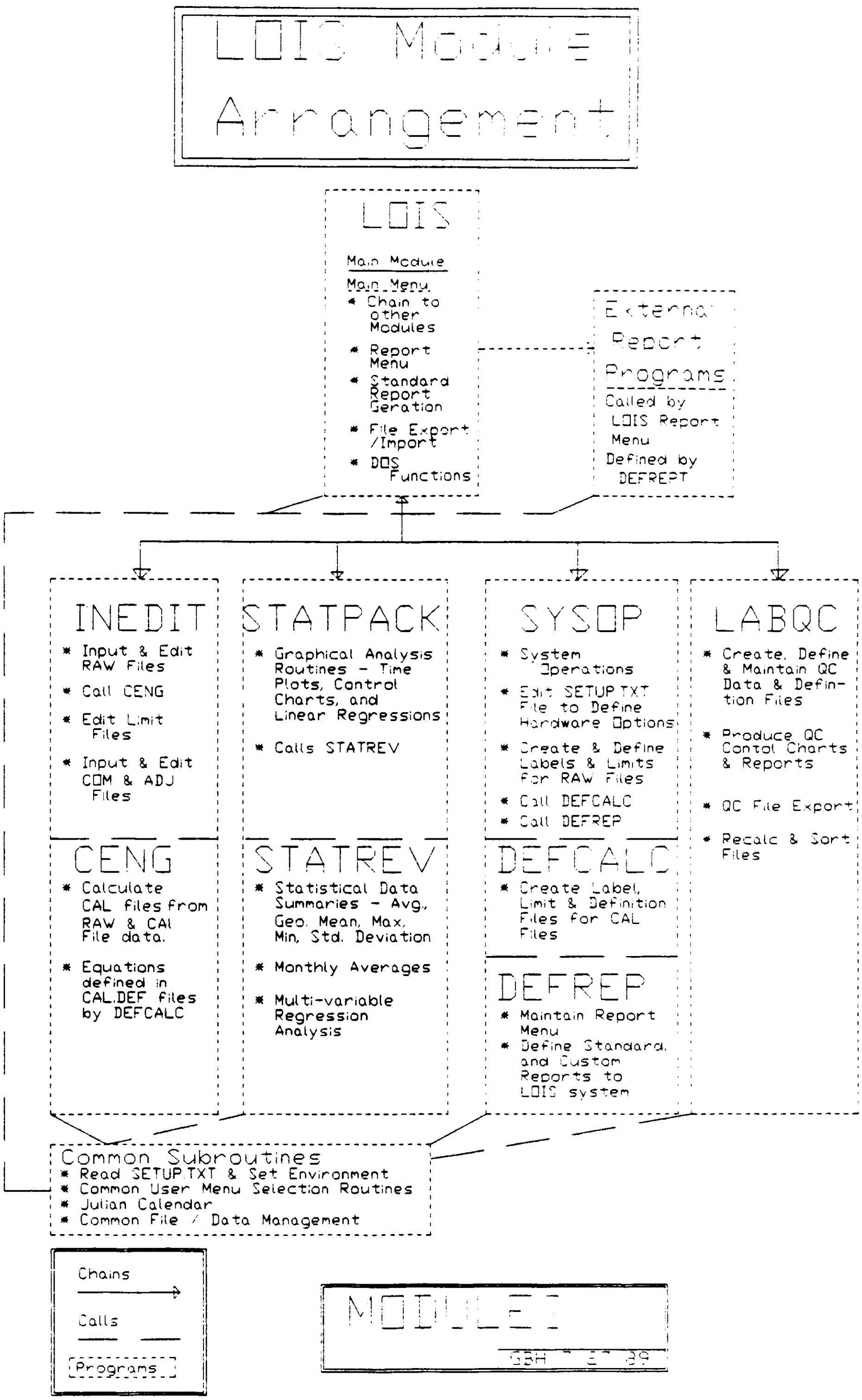

LOIS Module Arrangement
LOIS
Main Module
Main Menu
* Chain to other Modules
* Report Menu
* Standard Report Geration
* File Export /Import
* DOS Functions
External Report Programs
Called by LOIS Report Menu
Defined by DEFREPT
INEDIT
* Input & Edit RAW Files
* Call CENG
* Edit Limit Files
* Input & Edit COM & ADJ Files
STATPACK
* Graphical Analysis Routines - Time Plots, Control Charts, and Linear Regressions
* Calls STATREV
SYSOP
* System Operations
* Edit SETUP.TXT File to Define Hardware Options
* Create & Define Labels & Limits for RAW Files
* Call DEFCALC
* Call DEFREP
LABQC
* Create, Define & Maintain QC Data & Defin-tion Files
* Produce QC Contol Charts & Reports
* QC File Export
* Recalc & Sort Files
CENG
* Calculate CAL files from RAW & CAl File data.
* Equations defined in CAL.DEF files by DEFCALC
STATREV
* Statistical Data Summaries - Avg., Geo. Mean, Max, Min, Std. Deviation
* Monthly Averages
* Multi-variable Regression Analysis
DEFCALC
* Create Label, Limit & Definition Files for CAL Files
DEFREP
* Maintain Report Menu
* Define Standard and Custom Reports to LOIS system
Common Subroutines
* Read SETUP.TXT & Set Environment
* Common User Menu Selection Routines
* Julian Calendar
* Common File / Data Management
Chains
Calls
Programs
MODULES

Figure 11

Directory Specification and SETUP.TXT

The Disk Operating System (DOS) allows for the division of hard disks into groups of files referred to as directories. Each disk has at least one directory, referred to as the root directory. Floppy disks generally are not further divided. Hard disks normally are divided into a number of subdirectories for convenience. LOIS uses this directory arrangement in several ways.

The main LOIS programs (executable files) may be located in any disk or directory in the system. Among the several default values the SETUP.TXT file contains is the pointer to the directories that contain the active database and database definition files. The arrangement of the SETUP.TXT file is listed in Table IV.

The SETUP.TXT file is read as soon as the LOIS program starts. The contents are loaded into the SET$() string array and are declared common to all subprograms and modules that are called through CHAIN commands. The SETUP.TXT program allows for rapid adjustment to different computer hardware in terms of printers and graphics adapters. The contents of SETUP.TXT can be changed via the SYSOP module or with a common text editor.

This arrangement allows great flexibility in program design and testing. The currently active and tested executable program's executive files reside in a directory called \LOIS. The source code and development work area is located in a subdirectory of the QuickBASIC directory called \QB\LOIS. A separate version of SETUP.TXT resides in each location. Executable programs are only moved to the \LOIS directory after they have been fully tested. Alternately, by switching to a version of SETUP.TXT with a different path specified in record number twenty, totally different LOIS data bases can be maintained on the same hard disk. During operation of a carbon column pilot study, this ability to maintain two (or more) separate LOIS data bases has proven quite useful. A separate data base was created and used to maintain data on the performance of the pilot plant without affecting the main plant data base. Also, the size of the files for the pilot could be much shorter (two years instead of six), saving several megabytes of hard disk space.

The SETUP.TXT record number 20 contains a path to the main LOIS database. This path may contain a drive and a path name. The path is referenced by all modules as SET$(20). Actually the path is a holding directory which contains two subdirectories; the data directory and the definition directory. The files in the data directory are designated by the expression:

```
SET$(20)+"\DAT"+Filename
```

It contains the main data base files *.RAW and *.CAL. The

DAT directory also contains the comment (LABCOM.TXT and OPRCOM.TXT) and adjustment files (ADJUST.TXT).

The files in the definitions directory are designated by the expression:

SET$(20)+"\SETS\"+Filename

The SETS directory contains the files which contain the data base definitions. These include:

1. RAWFILES.TXT - List of active raw data Files
2. CALFILES.TXT - List of active calculated files
3. *.LAL Files - Label and Limit files for raw and calculated data files.
4. *.DEF Files - Definition files for calculated files.
5. REPORTS.TXT - List of all active reports with type and filename.
6. CONSTANT.TXT - List of all constants used in calculation definitions.
7. REASON.TXT - List of limits exceeded during data input to RAW files.
8. REPORT.TXT - Report definition files.

There are two reasons for dividing the data and definition files into two directories. First, data files need to be backed up on a near daily basis as additions are made to the data base. Automatic back up of data files is easier when all data files are in the same directory and no other files are present. The data base definitions change infrequently once the data base is well established and only need to be backed up when changes are made to the definitions. The second reason for the division is performance. The data files can be packed into contiguous disk sectors in a common directory without the presence of the relatively short definition files. This allows quicker disk access during report or statistical analysis.

Table IV

SETUP.TXT File

Record	Function
1	Screen foreground color (CGA & EGA & VGA)
2	Screen background color (CGA & EGA & VGA)
3	Screen border color (CGA)
4	Start date of data base - MM/DD/YY
5	Julian date offset of data base start from 1/1/76
6	Path and file name for screen printing control file
7	Default printer width - # columns
8	Printer control - Form Feed /nnn/nnn/nnn... : nnn= ASCII codes
9	Printer control - Condensed Print
10	Printer control - 10 CPI
11	Printer control - 12 CPI
12	Printer control - 6 LPI
13	Printer control - 8 LPI
14	Printer control - Default
15	Printer control - Reset
16	Graphics Adapter 1 = CGA ; 2 = VGA ; 3 = EGA ; 4 = Hercules
17	Spare
18	Graphics Menu Toggle : 1 = ON
19	Title for Main Menus
20	Path to Main Data Base
21	Path to QC Data Base
22	Spare
23	Path & File Name for Auto Back-up
24	Path & File Name for QC Back-up
25	Spare
26	Graphics Foreground Color (EGA & VGA)
27	Graphics Background Color
28	Graphics X Range Color
29	Graphics Y Range Color
30	Graphics Z Range Color

File Specification

RAW and CAL Data Files

The main files of the LOIS system are the RAW files, which hold the data input by laboratory and operations personnel. All active raw data files are listed in the definitions directory in the text file RAWFILES.TXT. Each record in RAWFILES.TXT contains three fields that describe a single data file. The first field is a 20 character string that describes the contents of the file to the user. Typical descriptors are "TSS VSS (C)","BOD (C-5)", and "%TS %TVS (C-1)". While the contents of the file descriptor have no effect on the operation of the LOIS programs, they do serve to make it easier for humans to identify the data contained in the various files. The C/G convention adopted for lab files is an excellent example. The C in the file descriptor designates a composite sample while a G designates a grab sample. A negative number such as C-5 for BOD samples indicate that the information is available 5 days later than the normal composite data. The second field contains the proper DOS filename for a data file. An eight character root is allowed. The .RAW extension is included for raw data files. No path is allowed in the file names. The third and final field to describe a file is the Last

Entry Date field in the format YY/MM/DD. The INEDIT module updates this field whenever data are added to the file via the input routine.

The second major type of file is the calculated data file or CAL file. The CAL file is identical in structure to the RAW data file. The major difference is that the raw data file is directly input from the keyboard while the CAL files are mathematically derived from the contents of RAW files, other CAL file parameters and constants. The CALFILES.TXT file has the same format and function with regard to calculated files as the RAWFILES.TXT. The file names have the .CAL extension added to the eight character name. Whenever a data point is defined in LOIS, the first division is RAW or CAL type data file. The second division is the file selection from the RAWFILES.TXT as displayed by the common SELFILE subroutine in the COMLOIS module.

The raw and calculated files are random access type files. The files consist of a single record for each day. The days are arranged sequentially and accessed by a julian calendar routine contained in the common subroutine package COMLOIS.BAS. The SETUP.TXT record number 5 (SET$(5)) contains the offset from January 1, 1976, for the first record in the data base. Each record is 128 bytes in length (a convenient power of 2 for DOS to handle efficiently). The record is divided into 32 fields of 4 bytes each.

Thirty fields are used for data storage. The last two 4 byte fields are used as a check sum field and as a record lock indicator field. A single raw file can hold data for a maximum of thirty parameters. Most of the data files were not packed to the maximum of thirty parameters for two reasons. First, files were divided into logical groupings of parameters that corresponded to data on existing laboratory or operational log sheets. For instance, all TSS analysis was entered in one file and all operational flow and weather data was entered into another file. It did not make sense to split logical data divisions such as these to pack the files. An additional natural dividing factor is the time data becomes available. Grab pH data is available on the sample date. Many composite tests are available the day after the sample date. Operational flow data is usually available shortly after the end of the day. Sludge samples that must be placed in an oven for a day are available two days after the sample date. And, of course, five day BOD data on composite samples is not available for six days. In order to facilitate easy data input, parameters that become available at different times should not be included in the same file. Second, it was felt prudent to have spare parameters in files for future expansion needs.

The field size of 4 bytes corresponds to the IEEE (Institute of Electrical and Electronics Engineers, Inc.)

specification for single precision real floating point numbers. Single precision values are accurate to six decimal places and have a range of -3.402823E+38 to +3.402823E+38 (note E+38 denotes the mantissa multiplied by the indicated power of ten). The smallest positive, non-zero number that can be represented is +1.40129E-45. The IEEE format is used in floating point operations performed by math coprocessors of the Intel 80x87 family. This level of accuracy and data range seems sufficient for all values that might be reasonably encountered. Double precision numbers were however used for accumulators in some of the statistical and graphical evaluation routines where overflow could occur. The BASIC language does not include an internal mechanism for indicating the absence of data in a numeric field. For the LOIS program, negative one (-1) was selected as an indicator of no data. Most values in the operation of a wastewater treatment plant are positive. Weather temperature data points are one of the few values that may have valid values of negative one. In the event a valid negative one should be encountered, the entry of -0.999 will result in a satisfactory statistical approximation of the real value without tripping the no data exception handling routines in the LOIS modules.

The number of records in a file is determined when the file is created. The original set of files were created with the expectation that a five year data base would be maintained. Later the data base was expanded to hold six years so that five years of past data would always be available. The size of a raw file can then be calculated as follows :

Bytes = 128 * (# Years * 366)

281088 = 128 * (6 * 366)

The extra day is added to each year to allow ample space for leap years. When files are created by the SYSOP module, the file is written in its entirety and filled with -1 values for all days of all years. This process allows the file to be packed into contiguous disk sectors which will not move during normal disk operations. Furthermore, this prevents the files from increasing in size with time, which could eventually lead to the "Insufficient Disk Space" DOS error message.

Associated with every raw and calculated data file there exists in the \SETS definition directory a file with the same root name as the raw file but with a .LAL extension. The LAL designation stands for LAbel and Limit. The first record in the LAL file is the number of active parameters in the file. Providing this value first can save program modules from excessive time delays reading inactive data. The next 30 records describe each of the possible parameters in a data file. Each record is divided into delimited fields as follows:

Field #	Type	Function
1	15 Character	Parameter Name
2	5 Character	Parameter Units
3	Single Precision	Low-Low Limit
4	" "	Low Limit
5	" "	High Limit
6	" "	High-High Limit
7	Integer	Active for Input = 1 Inactive- Fill w/0 = 0 Inactive- Fill w/-1 = -1
8	Integer	Number Significant Decimals

The string descriptors (Name and Units) are used to identify parameters for selection, during input or edit operations, as export file headers and in all graphical and statistical operations.

During input or edit of raw data files, the four limit values serve to prevent input of vastly erroneous data. If an input value is between the low and low-low limit the data point must be entered a second time to confirm the input. If the data value is below the low-low limit, it will not be accepted into the database. The INEDIT module will prompt for input until an acceptable input is received (the negative one - no data indicator is always an acceptable value). High limit exceptions are handled in the same manner. Whenever a limit is exceeded during input or edit, a record is added to the REASON.TXT file indicating the date, file, parameter, limit, original input and second input involved. The REASON.TXT file may be viewed, printed, archived or deleted from the SYSOP module. Occasional review of this file can indicate parameters with incorrect data limits or where the system users are uncertain of a parameter's status. Calculated files do not use the limits to stop the entry of data to the file. The calculation program (CENG) does, however, contain an option to print limit exceptions to the screen, to a printer or to the CALCERR.TXT file. Additionally, the daily report program, PCDAILY.EXE, prints all limit exceptions of raw or calculated data for the current day and the previous two days. This ensures that every limit exception comes to the attention of several key personnel on a daily basis.

Typically, some data points are not used throughout a year or represent treatment alternatives that may or may not be currently applicable. At the Alexandria Sanitation Authority, chemical feed points are available at numerous locations in the treatment scheme, many of which are not normally used or are used seasonally. The data base was developed with parameters included for all chemical addition points. Chlorine is a prime example. It may be added at the headworks, at the primary effluent, at the RBC influent, at the RBC effluent, at the Intermediate Pump wet well, at the floc tanks, at the filters or at the contact tanks. Normally chlorine is only added at one point, though that point may change or two point addition may be adopted to meet operational needs. In such a case, requesting data for all addition points wastes time and distracts people assigned to data input. The Active flag in field seven of the LAL file is used to determine the status of a parameter during normal input operations and during generation of standard reports. A one in this field indicates an active state, input will be requested for this point and report data generated. The zero (0) option indicates a parameter should be automatically filled with a zero during standard input. Flow data and chemical use data are typically zero filled. A negative one (-1) indicates a parameter should be automatically filled with a negative one during input. Analytical data is filled with the no data indicator.

The last field in the LAL file record for a parameter indicates the number of decimal places normally reported for the parameter. Input is usually entered with the appropriate degree of accuracy. Calculations however are performed by BASIC to six significant figures. This would result in values being reported that are misleading if no provision were made to round values to the appropriate number of decimal places.

Associated with CAL data files are definition files that contain the codes which select the exact mathematical operations to be performed and the inputs required to derive values for the parameters contained therein. The CAL file definition files located in the \SETS directory are denoted by the .DEF extension. Each DEF file corresponds to the CAL file of the same name. The definition files have 30 records describing the calculation and inputs for the corresponding thirty parameters in the CAL data file.

The definition records have the following format :

Field	Type	Bytes	Significance
1	Integer	2	Type calculation
2	Integer	2	Subtype calculation
3	Integer	2	spare
4	Integer	2	spare
5	Integer	2	Input #1 - Data file #
6	Integer	2	Input #1 - Parameter #
7	Integer	2	Input #2 - Data file #
8	Integer	2	Input #2 - Parameter #
.	.	.	. . . .
.	.	.	. . . .
63	Integer	2	Input #30 - Data file #
64	Integer	2	Input #30 - Data file #

The total length of each record is a DOS convenient 128 bytes. The record's first two bytes select one of the seventeen calculations currently defined to the system. Several of the calculation types have subdefinition types as indicated. These calculations are listed in Table V.

While the list of seventeen major calculation types hardly exhausts all the calculations that have been used in wastewater treatment, it has been sufficient to describe all desired calculations at the Alexandria facility. The list would need to be expanded to meet the needs of an activated sludge plant. It should be noted that the use of an extra unit conversion (UC) multiplier greatly increases the flexibility of each calculation in the system.

The two integers that describe an input parameter refer to a data file parameter or a constant. The first integer (referred to as the input file number or IFN) identifies the file containing the desired input parameter or the position of the desired record in the external list of constants defined in the CONSTANT.TXT file. The second integer (referred to as the input file position number or IFP) in the input definition pair identifies the position of the parameter in the data file if the input is from a RAW or CAL data file. The second position has no significance if the input parameter is a constant.

The coding of the input file number parameter imposes one limit on the LOIS system. The first file descriptor integer is coded as follows:

VALUE	Significance
1 - 99	File number of RAW file
100 - 199	File number of CAL file + 100
200 - 299	Position of Constant in the external file CONSTANT.TXT

Because of this system of coding parameter locations, the LOIS system is limited to 99 RAW and CAL data files.

The second input parameter descriptor also utilizes an addition to signify different handling of the input parameter. Since the data files contain a maximum of thirty parameters, thirty would normally be considered the maximum value for the input file position (IFP). However, data are not always available on a particular day for some parameters whose values could be as well calculated using a previous day's value. The chemical dose equations require a current specific gravity for alum or ferric chloride addition. This value changes over a very narrow range and because of mixing in the storage tanks, does not change precipitously. This is one example where it would be permissible to perform the desired calculation using a previous day's value. In the same calculation, however, it would be misleading to use the previous day's flow or gallons of chemical applied to calculate the dosage for the day. A signal to the calculation program is provided in the input file position as to the appropriateness of looking back in the data base for a valid value for an input parameter. If the value of the IFP is thirty or less, no "look-back" is permitted. If no data is available for the current day, the value of the calculation is forced to the No Data indicator (-1). If the value of the IFP is greater than one hundred, the file position is equal to the IFP minus one hundred and the look back procedure is enabled. As a practical compromise, the time limit for the look back procedure was set to ten days. Data older than ten days was considered dubious even if look back was appropriate and execution time of the calculation data retrieval process had to be considered eventually.

The CONSTANT.TXT file is a sequential ASCII data file containing linked pairs of fields. The first field in the pair is a real number, the constant defined. The second field in the pair is a twenty character descriptor. The descriptor has no effect on calculation execution and serves only to identify the value to the operator. Forty constants were found to be sufficient for the needs of the Alexandria project though there is no inherent limit to the number of constants that could be defined. Typical constants are a standard multiplier or the volume of a tank :

8.34,"Lbs per Gallon"

0.42,"Pri Tank Vol MG"

The calculation procedure progresses sequentially through the calculation definitions. The first parameter in the first calculated file is executed first; the second parameter follows. The day's calculations are completed when the last parameter in the last CAL data file is evaluated. This requires some attention when using the results of one calculation as the input to another calculation. The inputs must be evaluated before the calculation is performed to obtain valid results.

Table V

Calculation Equations

1. HYDRAULIC LOADING
    (Flow / (No. Units * Area Unit))* Unit Conversion)
2. ORGANIC LOADING
    ((Flow * Conc * Units) / (No. Units * Area Unit))* UC
3. Per Cent REMOVAL
    (((IN - OUT) * 100) / OUT)) * Unit Conversion
4. DETENTION TIME
    ((No. UNITS * Unit Volume) / Flow) * UC
5. Average of Parameters
    (A + B + C + ... Xi) / i
6. Sum (Difference) of Parameters
    (A + B + C + ... i)
7. Simple RATIO
    (A / B) * C
8. Clarifier Loading
    Subtype 1 - Rectangular Tank
    ((Flow * Units) / (Length * Width * No. Tanks)) * UC
    Subtype 2 - Round Tank
    ((Flow * Units) / (π * Radius^2 * No. Tanks)) * UC
9. Weir Loading
    Subtype 1 - Rectangular Tank
    ((Flow * Units) / (Length Weirs * No. Tanks)) * UC
    Subtype 2 - Round Tank
    ((Flow * Units) / (2 * π * Radius * No. Tanks)) * UC
10. Digester Solids Reduction
    ((In - Out) / (In - (In * Out))) * UC
11. Simple LINE
    A + (B * C)
12. Complex RATIO
    ((A * B) / (C * D)) * E
13. Chemical Dose"
    Subtype 1 - Weight (Pounds Cl2 etc.)
    (Weight(lbs) / (Flow * Units(8.34)) * Unit Conversion
    Subtype 2 - Volume (Gallons FeCl3, Alum etc.)"
    ((Volume * Sp Gr * % Weight) / (Flow * Units)) * UC
14. Digester Solids Retention Time
    ((%TS * Unit * Volume)/(Withdrawal(Feed) * Unit)) * UC
15. AVERAGE (Single Parameter vs Time)
    (Ai + Ai-1 + Ai-2 + ... Ai-n) / n
16. Mass Balance
    (((A * B) + (C * D)) / (A + C)) * E

17 Rolling Inventory
    Yesterday + A + B - C

Comment Files - OPRCOM.TXT and LABCOM.TXT

Two sequential txt files are provided for comments to be entered by lab and operations personnel. The comment files are located in the \DAT directory as the comments are considered data and are utilized on a daily basis. Each comment file contains records with three fields. The first field is an integer; the julian number of the date on which the comment was made. The second field is the same date in the standard eight character YY/MM/DD format. The third field contains the comment in a quote delimited field of indeterminate length.

The comment files are manipulated by the INEDIT module. Associated functions are input, edit, output to printer and archive. The comment data are also available to reports.

Error Files - CALCERR.TXT and REASON.TXT

As mentioned, both CAL and RAW files have associated dual low and high reasonability limits. Two files indicate that values have entered the data base beyond the expected norms. These files are located in the \SETS subdirectory. When calculations are performed, values which exceed the expected limits may be output to the CALCERR.TXT file for later review. This file is a sequential text file. Each record has the following format :

Field	Type	Bytes	Significance
1	Char	8	Date YY/MM/DD
2	Char	15	Parameter Descriptor
3	Char	3	Limit Exceeded (L2, L1, H1, H2)
4	Real	8	Limit Value
4	Real	8	Calculated Value

The equivalent RAW file exception file is the REASON.TXT file. This file is opened for append and updated automatically whenever input exceeds expected limits. Records are generated in pairs. When a limit is exceeded the input routine calls for a new input to be made. Both inputs generate a record in the REASON.TXT file. The record format for the REASON.TXT file is as follows:

Field	Type	Bytes	Significance
1	Char	8	Date YY/MM/DD
2	Char	12	Parameter File Name
2	Char	15	Parameter Descriptor
3	Char	3	Limit Exceeded (L2, L1, H1, H2)
4	Real	8	Limit Value
4	Real	8	Input Value

Both error files may be accessed from the SYSOP module. Functions available include screen display of file contents, printer output and archive functions.

ADJUSTMENT FILE

Occasionally, data entering the LOIS data base requires adjustment even after passing the reasonability limit tests. Normal keypunch errors are normally edited without comment.

Instrumentation malfunction or contaminated samples can lead to data adjustments. When data is adjusted due to professional judgement some record should be kept as to the reason and person making the adjustment. The ADJUST.TXT file is a sequential text file in the \DAT directory designed to track alterations made to the data base. Each record of the ADJUST.TXT file has the following format:

Field	Type	Bytes	Significance
1	Integer	4	Julian Date
2	Char	8	Date - YY/MM/DD
3	Integer	2	File Number
4	Char	12	File Name
5	Integer	2	Parameter Number
6	Char	15	Parameter Descript.
7	Integer	2	Parameter Class
8	Real	8	Replaced Value
9	Real	8	New Value
10	Char	3	Initials
11	Char	80	Reason - Comment

Adjustments are accessed in the INEDIT module. Functions provided include input, edit, print, search and archive.

REPORT.TXT

The report listing file is a sequential text file located in the \SETS subdirectory. It is a list of reports that have been defined to the LOIS system under the DEFREP module SYSOP. In addition, REPORT.TXT gives information that defines the type of report. LOIS recognizes three main types of reports; standard, defined and external. The mechanics of LOIS report generation are covered under the module function descriptions later.

The REPORT.TXT file has one record which contains four fields for each report. The first field in a record is a 20 character descriptor that will appear in the list presented in the report menu of the main LOIS module. The second field indicates the report type; standard, defined or external. The third field indicates the time frame for standard reports; daily, weekly or monthly. The third field is not used for defined or external reports. The fourth field names a definition file for standard or defined reports. The definition file associated with standard or defined reports indicates the files or parameters to be included in the report. In the case of external reports, the fourth field indicates the file name to be called for execution. Any BASIC program can be accessed as an external program.

LABQC Files

The file structure for the laboratory quality control files is substantially different from the data files used by the main LOIS program. Where the LOIS data files contain only numeric data (thirty numeric parameters per record); the QC data files contain a mix of numeric and character data.

All the files related to quality control are grouped in two subdirectories whose parent directory is identified in the SETUP.TXT file record number twenty one. The two directories contain data and file definition parameters and are designated SET$(21)+\DAT and SET$(21)+\SETS respectively. The QC files are divided into three subsets; precision files, accuracy files and other data point files. A list of active files is maintained in the \SETS subdirectory for each type of file. The PREFILES.TXT, ACCFILES.TXT and DATFILES.TXT each have the following format:

```
Record 1 - integer - number of active files - N
Record 2 - N :
     Field 1 - 20 character file descriptor
     Field 2 -  8 character file name
     Field 3 -  integer - number of records in file
```

Each parameter in the QC section can be identified by the selection of one of three types and a selection of a specific file from the appropriate file list file.

Data files in the \DAT subdirectory all have the same structure whether precision, accuracy or other data point types. The first record in the random access data files contains an integer indicating the number of records in the file. All subsequent records contain a data record defined by the following BASIC data type definition:

```
TYPE DAT              ' ESTABLISH RECORD TYPE
    JDATE AS INTEGER          ' Julian date
    DDATE AS STRING * 8       ' Character Date YY/MM/DD
    TINT  AS STRING * 4       ' Technician initials
    LABID AS STRING * 8       ' Optional Lab Identifier
    DP1 AS SINGLE             ' Data Point 1
    DP2 AS SINGLE             ' Data Point 2
    V1 AS SINGLE              ' Volume 1 ( Accuracy Only )
    V2 AS SINGLE              ' Volume 2 ( Accuracy Only )
    SP AS SINGLE              ' Spike Mass ( Acc. Only )
    QC AS SINGLE              ' Calculated QC Point
    AV AS SINGLE              ' Previous Average
    STD AS SINGLE             ' Previous Standard Deviation
    PF AS STRING * 1          ' Pass / Fail (P/F)
    CCOM AS STRING * 70       ' Comment
END TYPE
```

The use of the BASIC user defined data type avoids the necessity of creating complex field and input/output buffer control statements in the program source code. Each record contains all the data that will be stored associated with a quality control test.

Associated with each data file is a sequential text definition file in the \SETS directory. The definition file shares the same root name as the data file but has the DEF extension. The DEF file serves the same functions as a LOIS LAbel and Limit (LAL) file. Several additional items are required to fully describe a quality control file. Thedefinition file contents are listed in Table VI.

The file label, data label, data units and descriptor are used in the report generation sections as well as in the control chart generation program sections to thoroughly identify a file. The subtype value identifies the calculation that is performed to derive the quality control point for each record. The subtypes for each type of file correspond to the following equations:

```
Precision : Subtype 1 : Standard
                QC = ( ABS ( D1 - D2 ) )
            Subtype 2 : Signed
                QC = ( D1 - D2 )
            Subtype 3 : Relative
                QC = ( ABS ( D1 - D2 ) / ((D1+D2)/2))
Accuracy :  Subtype 1 : Standard
                QC = ((D2 * V2 - D1*V1)*100)/Mass
Data Point :Subtype 1 : Simple
                QC = D1
            Subtype 2 : Average
                QC = ( D1 + D2 +... +Dn ) / n
            Subtype 3 : Standard Deviation
                QC = STD ( D1 ... Dn )
            Subtype 4 : Percentage
                QC = ( D1 * 100 / D2 )
```

The limit values for input have the same effect as their counterparts in the main LOIS system. The Number of Significant Digits value also has the same effect on output reporting formats as was established in the LOIS main modules. The Roll Size value determines the number of data points that are used to calculate the current average and standard deviation and therefore the current acceptance limits, the Upper Control Limit and Lower Control Limit. Relative Error is a numeric value that can be used to adjust the sensitivity of the pass-fail decision criteria. The use of relative error values requires considerable professional judgement on the part of the chemist who determines an appropriate value. The MinLIM and MAXLIM values may be used to set outside pass/fail criteria regardless of the current average and standard deviation.

Table VI

QC Definition File Contents

Field	Type	Significance
1	Char	File Label - Graph X Axis Label
2	Char	Data Label - Graph Y Axis Label
3	Char	Data Units - Added to Data Label
4	Int	Subtype - Identify calculation for QC Point
5	Char	Descriptor - Second Optional X Axis Label
6	Real	LOW-LOW - Input Limits
7	Real	LOW - " "
8	Real	HIGH - " "
9	Real	HIGH-HIGH - " "
10	Real	Roll Size - Number of Data Points used for Average and Standard Deviation
11	Int	NSD - Number Significant Digits
12	Real	RELERR - Relative Error
13	Real	MinLIM - Minimum Acceptable Limit
14	Real	MAXLIM - Maximum Acceptable Limit
15	Real	V1 - Default Volume 1 (Accuracy Only)
16	Real	V2 - Default Volume 2 (" ")
17	Real	Mass - Default Spike Mass (" ")

<u>User Interface</u>

The design of the LOIS user interface hinged on two considerations. First, the LOIS system is primarily designed for the manipulation of numeric data. Second, while some of the systems users had fairly substantial computer backgrounds, for other users the operation of the LOIS system was their first experience with a computer keyboard. These two facts lead to the decision to use a menu system that responded to numeric input. Additional considerations in the design of the user interface were :

* Minimize training time
* Provide consistent interface between modules
* Prevent accidental data lose
* Automate back up activities
* Provide printer control from the program
* Provide graceful exits from menus and all operations
* Provide rapid access to all program functions.

One factor favoring the use of a menu driven user interface is the ease of training inherent in such a system. A menu system must however present the choices in a logical manner. The user must be able to readily identify the options and understand the consequences of a selection. One of the objectives of the design of the LOIS menu system was to limit the number of menus that must be presented to reach any program functions. The "depth" of the menu system was limited as much as practical. Each module of the system was associated with a menu that listed the main functions of that module. A trade-off exists in menu design between the number of functions available on a menu and the depth of the menu system. Generally, the more options on each menu, the fewer menus are required and a system with less depth is attainable. On the other hand, too many options on each menu can clutter and confuse the menu. The standard LOIS menu was designed to present up to eight variable options and three standard functions; call the LOIS Main Menu, Exit to DOS and call the Help Menu.

Screen 1 presents the LOIS main menu. This menu is first encountered whenever the program is started. The main menu is also the return point for other modules (INEDIT, STATPACK, SYSOP and LABQC) and the functions in the LOIS module (Reports, File Import - Export and DOS functions). One of the advantages of using modular code is to provide a consistent interface. The COMLOIS module provides services to all the LOIS modules, including the MENU subprogram. The main menu demonstrates the attributes of menus generated with the MENU subroutine. The current date and time are presented at the ends of the first line. The title found in the SETUP.TXT file is centered in the middle of the first line. A subtitle passed to the menu subprogram is centered on the third line. Up to eight menu selections are listed vertically. Menu option nine always closes any open files and returns control to the LOIS main menu. An entry of X (upper or lower case) always closes any open files and returns control to the operating system. An entry of H always presents the help menu. Other entries are invalid and the menu is maintained until a valid selection is made. All menus, in all modules, that have more than two inputs and less than eight possible selections utilize the MENU subprogram.

Screen 1 : LOIS Main Menu

```
--------------------------------------------------------------------------------
02:54              Alexandria Sanitation Authority              02-18-1989

              Lab - Operations Information System (LOIS)
  Desired Function :

                        1. Input / Edit Files (*.RAW , *.CAL, & COMMENTS)

                        2. Report Menu

                        3. Files Export / Import

                        4. STATPACK

                        5. DOS Function Menu & Printer Set Up Commands

                        6. SYSOP ( LOIS Systems Operations )

                        7. Laboratory QC

                        9. LOIS Menu

  X - Exit to DOS                                    H -  HELP
--------------------------------------------------------------------------------
```

The main menu also demonstrates a tenant of good menu design, the most commonly used functions are presented first. The least commonly utilized functions are listed last. Therefore the input/edit options and report generation options are the first two selections on the main menu. The SYStem OPerations (SYSOP) and Laboratory QC options are listed last. Screen 2 shows the primary menu of the INput and EDIT (INEDIT) module. The most common options utilized, the RAW and CAL files are listed first. Less common functions such as editing the LAL files are listed further down the list.

Screen 2 : INEDIT Main Menu

```
--------------------------------------------------------------------------------
02:59             Alexandria Sanitation Authority            02-18-1989

                        FILE INPUT / EDIT SECTION
   Desired Function :
                     1.  RAW Files

                     2.  CAL Files

                     3.  COMMENT Files

                     4.  ADJUSTMENT File

                     5.  Edit REASONABILITY Limits

                     6.  Print REASONABILITY Limits

                     7.  Change Order of Input Files

                     8.  Print RAW File Worksheet

                     9. LOIS Menu
   X - Exit to DOS                                     H -  HELP
```

Data point identification does not lend itself to use of the common menu routine as more than eight files or parameters are usually available for selection. The process for selecting a data point for operation is identical across all modules. Data points are identified by type (RAW or CAL), file number, file parameter and date. A range of data points is often identified by a start date and an end date in report, export, graphical and statistical operations. Screen 3 presents the common File Selection Menu. Files are listed with a descriptor, the proper DOS file name and the last date of input. An integer input corresponding to the selected file is accepted. Input values less than one or greater than the number of available files are not accepted. Screen 4 is the Parameter Selection Menu. Parameters are listed in two columns by parameter label and units. Besides an integer input corresponding to the desired parameter, a Q may be input. A Q(uit) input will pass control back to the beginning of the current parameter selection process. The input function of INEDIT provides an example of some of the user interface considerations that went into the development of the LOIS system. Data input to a RAW file is accessed from the INEDIT main menu by selecting option one, RAW files. The user is next prompted to select 1. Input or 2. Edit. The target file is then selected from the RAW file list. The user is prompted to input the date next. Dates are always entered in the YY/MM/DD format. If a Q is entered, the process is aborted and control is returned to the module main menu. Illegal date entries generate context sensitive help in the form of a brief description of the required date input format. In the case of input or edit operations, the date is compared to the DOS system date for a reasonability check. If the selected date is in advance of the current date or more than eight days prior to the current date, a warning is issued to the user with an opportunity to abort the process. For data editing, allowance is made for editing the prior months data for the monthly report. The date reasonability check for editing is therefore set to fortyfive days prior to the current system date. The time warning is intended to prevent users from accidently entering data on the wrong date. Before the date error warning was implemented, a user once entered data for a date well into the next century. For data input, a further check is made. The target file and record are checked for valid data. Normally, before input, a data record will be filled with no data place holders (minus ones). If valid data is encountered, a warning will be issued to the user with the opportunity to abort the operation to the INEDIT main menu. The record lock field of the target record is also checked. If the record has been locked, the input operation is aborted after an explanation is presented on screen.

Screen 3 : File Selection Menu

```
--------------------------------------------------------------------------------
03:10                 Alexandria Sanitation Authority                 02-18-1989

                              Choose File by Number :     ?
  #                            FILE Name                 Last Entry
   1 : Alak. F.Coli      (C) BODCOMP  .RAW              89/02/01
   2 : pH DO Temp SGrav(G) BODGRAB  .RAW              89/02/02
   3 : TSS VSS           (C) SSCOMP1  .RAW              89/02/01
   4 : Set S  pH         (C) SSCOMP2  .RAW              89/02/01
   5 : TCOD SCOD         (C) CODCOMP  .RAW              89/02/01
   6 : Sldg pH  Dig TS (C) CODSLDG  .RAW              89/02/01
   7 : %TS %TVS        (C-1) CODTS    .RAW              89/01/31
   8 : PO4               (C) NUTPO4   .RAW              89/02/01
   9 : pH Cl2 (grabs)        SSGRAB   .RAW              89/02/01
   10 : Digest grabs    (G)CODGRAB  .RAW              89/02/02
   11 : BOD            (C-5)BODBOD   .RAW              89/01/27
   12 : Cl2 (24)           PCCL2    .RAW              89/02/01
   13 : Flow               PCMGD    .RAW              89/02/01
   14 : Fe; Al; Cl2; Polm. PCCHEMAD.RAW              89/02/01
   15 : Sidestream Data    PCSIDEST.RAW              89/02/01
   16 : Dig & Thick Level  PCLEVELS.RAW              89/02/01
   17 : On Line Units      PCUNITS  .RAW              89/02/01
   18 : Applic. Site ; pH  PCLIME   .RAW              89/02/02
   19 : Sludge Tickets     pcticket.RAW              89/02/01
--------------------------------------------------------------------------------
```

Screen 4 : Parameter Selection Menu

```
--------------------------------------------------------------------------------
03:11                 Alexandria Sanitation Authority                 02-18-1989

                              \LAB\SETS\PCMGD    .LAL
Select Parameter Number : ?

  1  TOTALIZER-RECL  MG                12  Rain   inch
  2  Totalizer 1  MG                   13  Snow (in)  inch
  3  Totalizer 2  MG                   14  Electric Use  KWH
  4  Main Bld Flow  MG                 15  Util. Gas Use   Cu Ft
  5  Main Bld - Recl  MG               16  Util. Water Use  K Gal
  6  Recycle Flow  MG                  17  Grit   Loads
  7  Max Flow  MG                      18  Screenings   Cans
  8  Min Flow  MG                      19  Grit lbs
  9  Avg. Raw Temp  Deg F              20  Plnt Bypass MGD
  10  High Air Temp  Deg F             21  Avg. PE Temp. Deg F
  11  Low Air Temp  Deg F              22
 Q for Previous Menu
```

If the input request passes the date, valid data and record lock checks, data input commences. Each active parameter is presented sequentially for input. The previous day's data and the parameter label and units are displayed to help the user identify the parameter. Normally, a single numeric entry is accepted for each parameter. An ENTER alone is interpreted as no data, a minus one is inserted for that parameter. At any point during the input of a file record, an input of a Q allows the input operation to be aborted without changes being written to the data base. An additional feature of the input process is the averaging of a series of inputs. If an input of A is made, numeric inputs are accepted until an input of A is again made. The average of the series of inputs is then written to the parameter's field. Input parameter values are compared to the reasonability limits established for that parameter in the LAL file. If the input is beyond the first set of limits, it must be reentered to be accepted. If the value is beyond the outer limits, the value will not be accepted. After all the parameters for a file are input, the edit page for the record is presented. The input may be reviewed and corrected as needed. After review of the edit page, input operations may either cease or the next data file may be input or data may be input to the same file for the next day. The order in which files are input is determined by the order listed in the JFIO.TXT file.

The common menu routine is appropriate where the selections may occupy the entire screen. Often, current data needs to be presented along with menu selection. The Edit Page presented in Screen 5 is an example. The header of the Edit Page maintains the familiar date - time - title format. The current file name and the active date are presented in the next two lines. The majority of the page lists the active parameters labels and units nd the actual values of the parameters for the active date. The last line presents the menu options available. The menu options have the following consequences:

1. Exit to Menu	: Saves currently displayed data Returns to control to INEDIT main menu
2. Edit	: Allows alteration of data
3. Day Before	: Saves currently displayed data : Decrements active date and displays data
4. Day After	: Saves currently displayed data : Increments active date and displays data

If data input is underway, options three and four are replaced by options which allow the input of the next file or the option to input data for the next day.

Screen 5 : Edit Page

03:02 Alexandria Sanitation Authority 02-18-1989

Data File Edit

FILE - PCMGD .RAW

1474	89/01/13	Friday		
1 TOTALIZER-RECL MG		37.422	12 Rain inch	0
2 Totalizer 1 MG		24.032	13 Snow (in) inch	0
3 Totalizer 2 MG		20.138	14 Electric Use KWH	554.4
4 Main Bld Flow MG		44.11	15 Util. Gas Use Cu Ft	21.9
5 Main Bld - Recl MG		37.362	16 Util. Water Use K Gal	88.1
6 Recycle Flow MG		6.748	17 Grit Loads	0
7 Max Flow MG		60	18 Screenings Cans	10.5
8 Min Flow MG		27	19 Grit lbs	0
9 Avg. Raw Temp Deg F		60	20 Plnt Bypass MGD	0
10 High Air Temp Deg F		48	21 Avg. PE Temp. Deg F	59
11 Low Air Temp Deg F		29	22	-1

CHOOSE: 1. EXIT TO MENU OR 2. EDIT OR 3. DAY BEFORE OR 4. DAY AFTER?

The Edit function requests the number of the parameter to be altered and then prompts the user for a new value for that parameter. The data is then stored in the appropriate file and record; the file is closed and the altered record is displayed. It should be noted that whenever the Edit Page is visible, the displayed data is actually stored in the file and the file is closed. Power disruptions or other mishaps will not corrupt the data base.

There are several situations in the LOIS system where the limit of eight selections imposed by the standard menu is not appropriate or the current status of switches may need to be presented. Screen 6 is the Report Generation Menu. The number of reports that may be defined to the LOIS system is only limited to eighty nine to allow ninety to be used as an exit to the LOIS main menu. In some cases, where more than eight options are available, the options are split between two groups, where the second group display is called from one of the options in the first group. The Statistical Services Package (Screen 7) menu utilizes the common MENU subprogram. Option one calls the Statistical Data Review Menu (Screen 8) which also utilizes the common MENU subprogram. The two statistical services main menus correspond to the division of the graphical and statistical functions into the STATPACK and STATREV modules. This division was forced by system memory constraints. The large number of code lines required to implement the statistical and graphical functions and the requirement to handle up to five years of data in dynamic arrays necessitated separate code modules. The Graph Setup Menu (Screen 9) is typical of a menu where the current status of switches must be displayed. The first nine options are toggle or rotary switches. The current position is listed in the left hand column. The possible alternatives are listed in the right hand columns. When options are selected, the display is updated accordingly. The edit pages for the SETUP.TXT file controlled by the SYSOP module are similarly arranged.

Screen 6 : Reprot Menu

```
03:03              Alexandria Sanitation Authority              02-18-1989

                        Report Generation Menu
   CHOOSE :  ?
  1 .  Lab Evening Report
  2 .  Daily Report
  3 .  Lab Weekly Report
  4 .  Monthly Report
  5 .  Nutrient Rep.
  6 .  BOD Calc Report
  7 .  Plant Display
  8 .  Metric Converter

                    90 .  Return to LOIS
                   100 .  Exit to DOS  (SYSTEM MENU)
```

Screen 7 : Stat-Graph Menu

```
03:05              Alexandria Sanitation Authority              02-18-1989

                     Statistical Services Package
 Desired Function :

                    1.  Stat Review  RAW & CAL Parameters

                    2.  Linear Regression ( up to 2 Ind. Parameters )

                    3.  Parameters vs Time ( up to 3 Parameters )

                    4.  Parameter vs Times ( up to 3 Time Ranges )

                    5.  Control Chart     ( 1 Parameter )

                    6.  Change Graph Options (Auto Range etc.)

                    7.  Screen / Data Source Options


                    9. LOIS Menu
 X - Exit to DOS                                     H -  HELP
```

Screen 8 : Stat Review Menu

```
03:07                Alexandria Sanitation Authority            02-18-1989

                     Statistical Data Review Menu
   Desired Function :

                     1.  View Parameters    ( 3 Parameters )

                     2.  View 1 Parameter   ( 3 Time Ranges )

                     3.  View Monthly Data ( 18 Months : 1 Parameter )

                     4.  Print Single RAW or CAL Data File

                     5.  Print ALL  RAW & CAL Parameters

                     6.  View Multiple Regression - Two Variables

                     7.  View Multiple Regression - Three Variables

                     8.  STAT Menu


                     9. LOIS Menu
   X - Exit to DOS                                   H -  HELP
```

Data Back Up

In a LOIS type system, the investment in both hardware and software development is quickly overgrown by the value of the man-hours committed to data input. In short, the data base is worth more than the machine or the program. The LOIS system was designed to minimize opportunities for data loss. The most common and catastrophic cause of data lose is hard disk failure. The first defense against hard disk failure is the production of frequent back up copies of the data base. LOIS allows an external DOS batch file to be called to automate the back up process for both the main data base and the quality control data base. A separate commercial program intended to speed the use of back up copies on floppy disk is utilized. This program can be initiated in command line mode from a batch file. The path and name of the back up batch programs is stored in the SETUP.TXT file records number twenty three and twenty four. Of course, users must be trained to make back up regularly for this defense to succeed. A second program method that helps protect the data base is to close a file whenever it is not actually being processed. While this extracts a performance penalty, the time loss is not significant compared to the mayhem that can occur if the computer crashes for whatever reason while a file is open. A third technique to avoid data loss or corruption is to make back up copies on the hard disk before certain critical operations are performed. The LABQC module makes extensive use of this technique when data files are sorted or recalculated. A final method for data lose prevention is to require confirmation before critical tasks are performed. The SYSOP module contains numerous critical tasks. Before access is granted to this module, the user must respond by typing YES completely, any other response returns control to the LOIS module main menu. The use of confirmation steps represents a trade off between speed of use and avoidance of mistakes. Functions that drastically alter the structure of the data base, such as deleting data files or changing calculation definitions, always require confirmation. Normal functions that do not alter the data base structure such as report generation or statistical analysis do not require confirmation.

System Functions

In the design of an information system, most functions performed by the system flow automatically from the union of the information model, the file specifications and the user interface. The majority of functions required to implement the information model, support the data files and implement the user interface are self-evident. Provisions must be made to input and edit data files, to create and edit the label and limit (LAL) and definition files that correspond to the main data files and to create and edit the system environment definition file (SETUP.TXT). One issue concerning the main data files required special consideration, the timing of calculation performance. Three other functions require additional comment as the range of functions required was not clearly defined by the high level information model: report generation, data export and statistical services.

Calculations

Ideally, every time an input is made, all calculated values affected would be automatically updated. This is the standard behavior of most spreadsheet programs and traditionally one of spreadsheet programs strengths and weaknesses. Spreadsheet that recalculate everything every time an input is made become very slow when a large quantity of data is contained in the spreadsheet. An alternative is to recalculate the entire spreadsheet only on demand. This alternative raises the possibility that a spreadsheet may not be internally consistent if a recalculation has not just been performed. A third spreadsheet option (called incremental calculation) has become available where each cell "knows" which cells are dependent on that cell value. When that cell value is changed, all dependent cells are recalculated. This options requires a large overhead in the form of an index showing the interdependencies involved in the spreadsheet.

The LOIS calculated database bears a resembalacne to a spreadsheet. The ideal of recalculation of all CAL data files upon the input of any RAW data parameter is not practical, especially since data files contain years of data. Incremental calculation was also deemed impractical for the LOIS system; the overhead required to index all the possible interrelationships was considered too great. The second option, calculation on demand, therefore became the method selected. The INEDIT module calls the CENG module on demand. The CENG module performs calculations for all parameters in all CAL files over a specified period of days. To calculate all data files for five years would require about three hours of computer time. The problem of internal inconsistency when data inputs or edits are not reflected in the calculated files does remain a potential source of problems. To mitigate this source of inconsistency, the calculation routines from the CENG module were incorporated into the daily report program. The date range for the daily report calculation was set to range from the date of the report requested back nine days. The date range was set back to insure that it included BOD inputs and to reflect any edits that may have been made in the last week. The inclusion of the calculation routine in the daily report assures that a calculation will be performed every morning after the operations data has been entered. Normally, calculation on demand under INEDIT is only required when edits are made for the weekly or monthly report.

Report Generation

Though the maintenance of data files is the backbone of the LOIS system, the reason for LOIS to exist is the production and dissemination of information based on the data files. For that reason, a substantial effort was made to provide a set of report generation alternatives that would meet a wide and varying set of information requirements. The three types of reports that may be generated are standard, defined and external program. These reports are available for definition on the report menu page of the SYSOP module subprogram DEFREPT.

The most simple report generation method is the standard report. A number of files are designated as source files and a standard time frame for the report is utilized (daily, weekly, monthly). A laboratory weekly report is an illustration of a standard report (Appendix A). Data files are presented in a block format. Parameter labels and units are listed down the left column. Each day's data values are listed across the page. Averages, minimums, maximums and standard deviations are recorded for each parameter on the right portion of the page. The defined report functions in much the same way as the standard report except that individual parameters are selected as sources instead of entire files.

External program reports are by far the most flexible of the LOIS report types, and the most difficult to implement. External program reports may be any BASIC program that can be called by the CHAIN statement. Since

BASIC programs can call DOS batch programs, C programs and Assembly programs, there is no limit on the flexibility or scope of external programs beyond the limits inherent in the microprocessor environment. However, the services of an experienced programer are required to take the full advantage of the power of external reports. In effect, external reports can have no relation to the LOIS program or data base.

Data Export

Although the LOIS system was designed to meet the needs of a wide variety of information consumers, it would be both arrogant and naive to assume that all possible requests can be meet within the resources of the LOIS system. The LOIS system does not include a word processing package. The data from the data base may need to be incorporated in a report that is best generated with a standard commercial word processor. Likewise, the LOIS package does not have all of the flexibility of a spreadsheet program, although it does have advantages in the size of the data base that LOIS handles. In many cases, it may be more effective to transport a subset of the LOIS data base to a spreadsheet for further manipulation than to write an external report program to perform a one time analysis. The learning curve for spreadsheets tends to be less steep than for high level languages. Export of data to spreadsheets allows more users greater flexibility in dealing with the information without the services of a programmer. Information consumers external to the Authority (regulatory agencies, consulting engineers, etc.) may wish to use the LOIS information in different program environments or in conjunction with data from other wastewater plants. In all of these cases, and others not yet foreseen, a flexible export system should be included in any information system.

The LOIS export routines are included in the main LOIS module. Entire RAW or CAL files may be exported for a given date range or an array of twenty parameters may be exported for a date range up to two years in length. Output formats available for export include:

* Disk files with delimited headers and dates converted to the julian dates used by Lotus spreadsheets,
* ASCII disk files with dates in eight character strings suitable for common word processors or database import,
* Printer output in 80 or 132 column mode at six or eight lines per inch.

To date, no information consumer has been encountered that will not accept data in either the Lotus or ASCII format. If need arose, it would not be difficult to write a program that translated one of these formats into any desired format. The direct printer output format is similar to the standard and defined report format but can be accomplished on a one time basis without the overhead of defining a report procedure.

An additional import/export mode was created to copy segments of all the LOIS database files for a short period of time to and from computers operating the LOIS system. In the course of the project, a microcomputer became available to shift supervisors. The time involved to copy the entire LOIS data base to the shift supervisors computer was prohibitive, especially since it was only equipped with 360 K floppy disk drives. The ability to update file segments covering a few days enhanced the ease with witch a mirror image of the main LOIS data base could be maintained on the supervisor's computer. In the future, this concept may be extended to update other copies of the LOIS database maintained on a Local Area Network.

Graphical Analysis

In the operation of a wastewater treatment plant, the value of trend graphs nearly conforms to the old adage "A picture is worth a thousand words." A better rendition of the adage in this case might be "A graph is worth a thousand numbers." Three basic type of graphs were included in the

STATPACK module; regression, time series and control chart. Each type serves to present data in a graphical context that conveys more information to the user than a corresponding table of numbers would provide. Often trends and relationships are intuitively obvious when graphed though easily buried in a long listing of raw numbers.

Regression analysis seeks to find dependent relationships among parameters. LOIS implements a least squares regression algorithm that expresses the relationship between two vectors in the form of the equation for a straight line:

$$Y = a + b * X$$

where X is the independent variable and Y is the dependent variable. The slope of the line of best fit is b and the X intercept is a. The Y intercept is given by the expression (-a / b). Figure 12 presents a simple linear regression generated by the LOIS system. The R value is an indicator of the "closeness of fit". An R value of one (1.00) indicates a perfect fit with a positive slope. An R value of zero (0.00) would indicate no correlation at all between the two vectors. An R value of minus one (-1.00) would indicate a perfect fit with a negative slope.

Several variations of the basic least square regression can be generated with the LOIS system. Figure 13 presents a simple linear regression with two dependent variable plotted against the same independent variable. Relationships in the operation of a wastewater treatment plant are not always linear. The LOIS system attempts two models of non-linear regression fitting built upon the least squares method. Simple curve fitting can be performed by substitution into the equation for a straight line. The first set of substitutions yield the following series of equations :

```
Equation Set 1 - Simple Curves
  1        Y = A + B * X
  2        Y = A + B * 1/X
  3        Y = A + B * LOG(X)
  4        Y = A + B * X^2
  5      1/Y = A + B * X
  6   LOG(Y) = A + B * X
  7      Y^2 = A + B * X
  8      Y^2 = A + B * X^2
  9      1/Y = A + B * 1/X
 10    LOG Y = A + B * LOG X
```

In a similar fashion, more complex curves may be generated by making the following set of substitutions into the equation for the least squares equation :

```
Equation Set 2 - Complex Curves
  1       Y = A + BX + CX^2
  2       Y = A + B/X + C/X^2
  3       Y = A + B LOGX + C LOGX^2
  4       Y = A + BX^2 + CX^4
  5     1/Y = A + BX + CX^2
  6   LOG Y = A + BX + CX^2
  7     Y^2 = A + BX + CX^2
  8     Y^2 = A + BX^2 + CX^4
  9     1/Y = A + B/X + C/X^2
 10    LOGY = A + BLOGX + CLOGX^2
```

Normally, the curve with the highest absolute R value is selected as the best approximation of the relationship. Judgement should be used in the selection however. If the difference in R values between the simple linear equation ($Y = a + b * X$) and a more complex equation is very small, the simple equation should be used to model the relationship. Figures 14 and 15 demonstrate examples of appropriate uses for the simple and complex curve fitting models.

A variation on the regression procedure is to utilize time as the independent variable. Up to three dependent parameters may be plotted simultaneously versus time. For the LOIS system, time is considered only in units of days with the first day in the specified date range considered to have a value of one. Successive days are numbered sequentially thereafter. Figure 16 is an example of a regression curve with the independent variable, time, plotted on the X axis. Simple and complex curve fitting may be employed with time series regressions. Figure 17 demonstrate three dependent parameters versus time using the simple curve fitting technique described above.

The most common curve requested in the operation of a wastewater treatment plant is the simple plot of variables on the Y axis versus time (Figure 18). Often it is convenient to view several parameters plotted for the same period (Figure 19). A useful alternative to plotting a parameter for several years is to plot the same parameter for several time periods. Figure 20 utilizes the same data as Figure 18, however the X axis covers only a one year period; different symbols and colors are used for each of the three year's data.

Another alternative which allows greater statistical information to be displayed is the control chart (Figure 21). Terminology for the control chart option is borrowed from the quality control field. Five horizontal lines represent (from bottom to top) the Lower Control Limit, Lower Warning Limit, Average, Upper Warning Limit and Upper Control Limit. Each line has the following definition :

LCL = Average - (3 * Standard Deviation)

LWL = Average - (2 * Standard Deviation)

Average = Sum of Values / Number of Observations

UWL = Average + (2 * Standard Deviation)

UCL = Average + (3 * Standard Deviation)

The average, standard deviation and number of observations are printed across the top of the control chart.

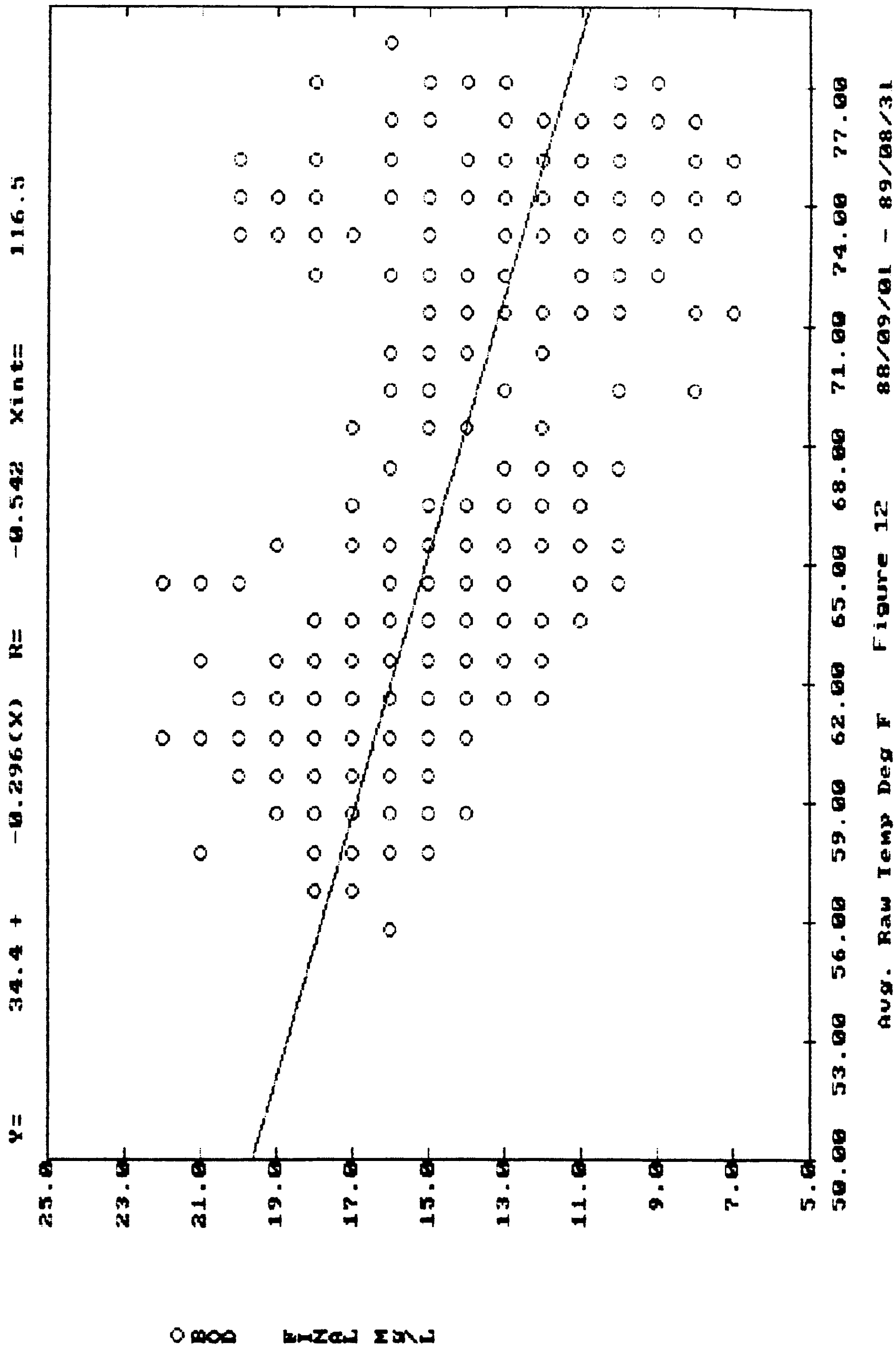
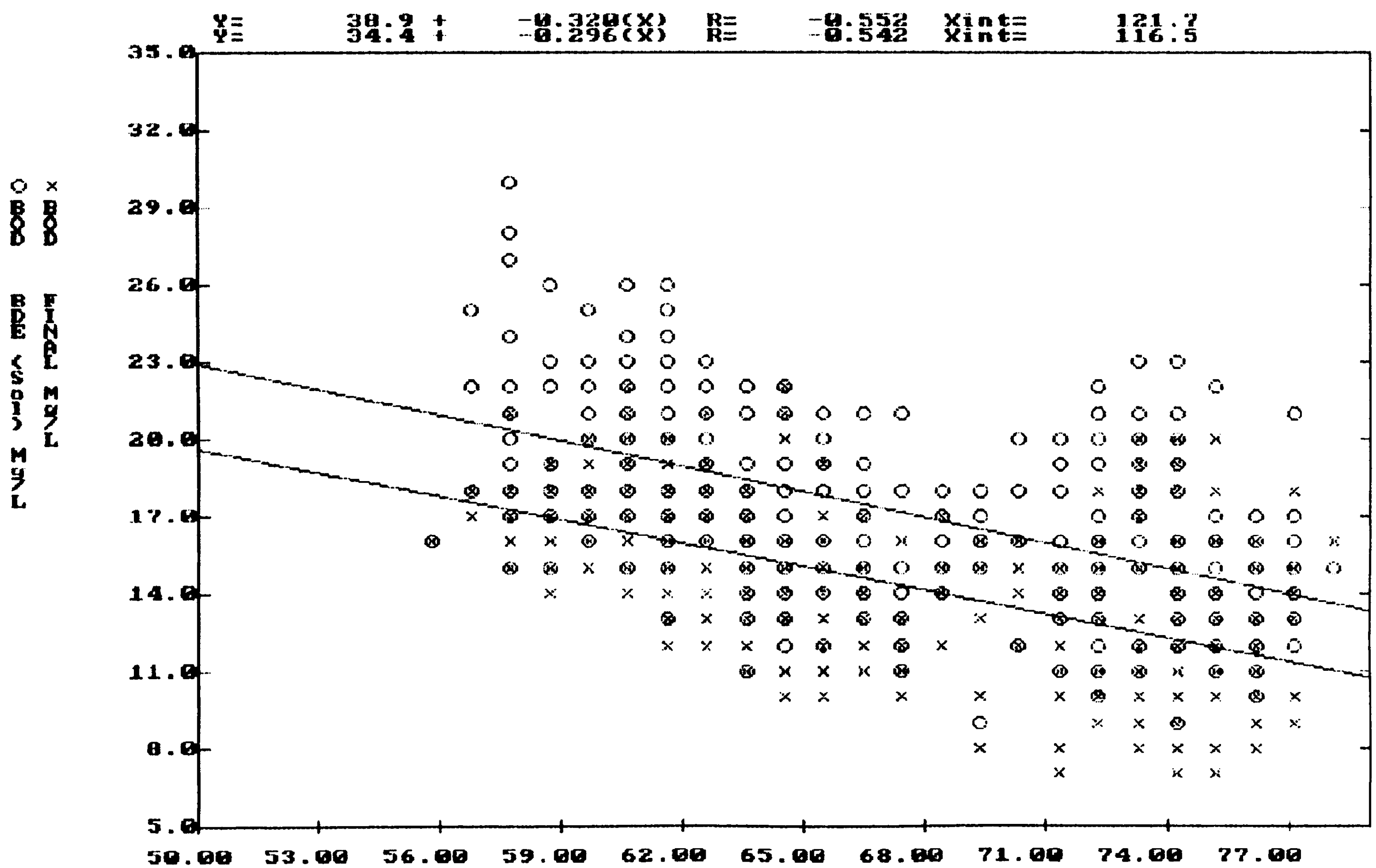

Y= 34.4 + -0.296(X) R= -0.542 Xint= 116.5
25.0
23.0
21.0
19.0
17.0
15.0
13.0
11.0
9.0
7.0
5.0
50.00
53.00
56.00
59.00
62.00
65.00
68.00
71.00
74.00
77.00
Avg. Raw Temp Deg F
88/09/01 - 89/08/31

Figure 12



Avg. Raw Temp Deg F   Figure 13   88/09/01 - 89/08/31

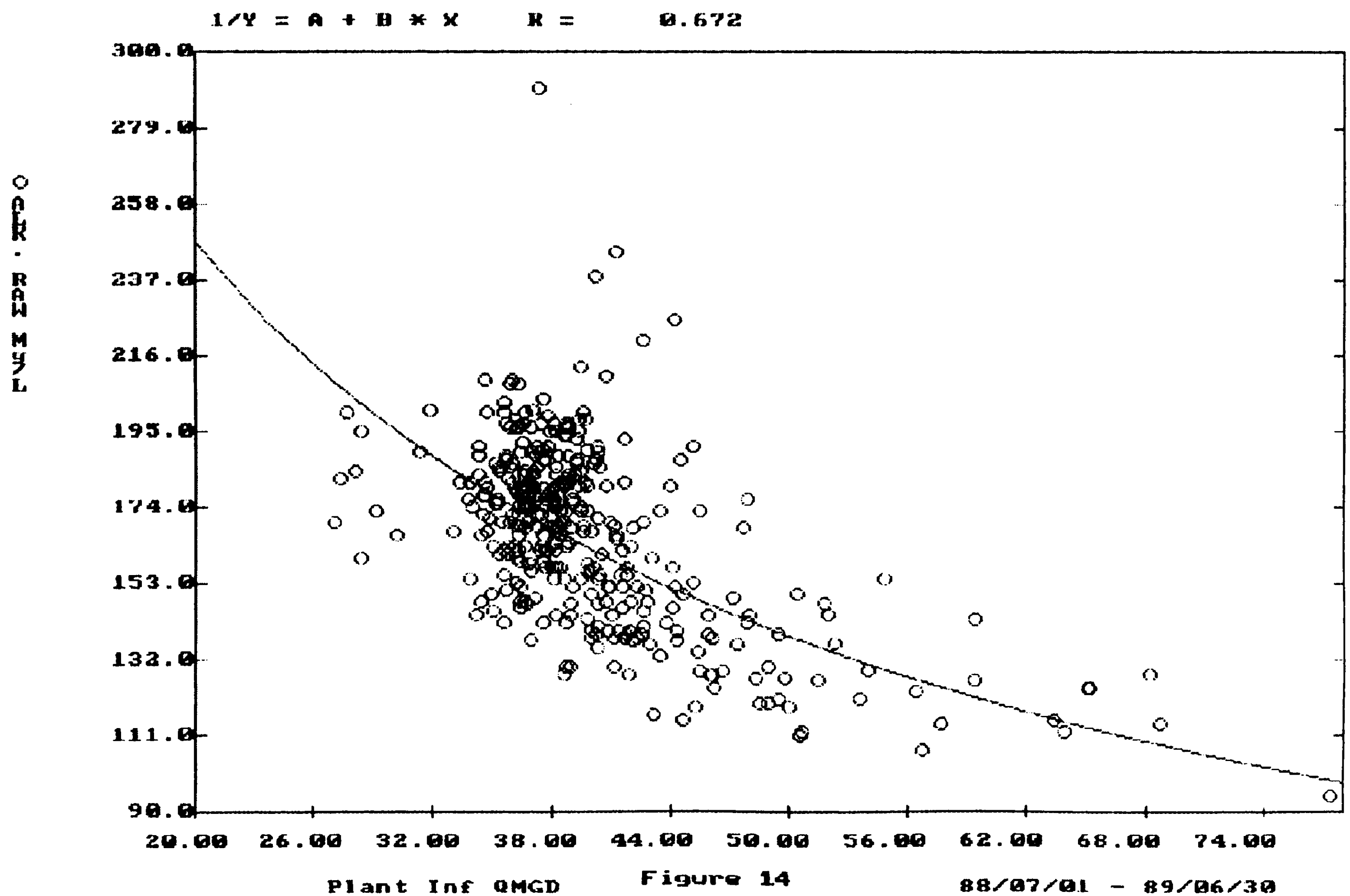
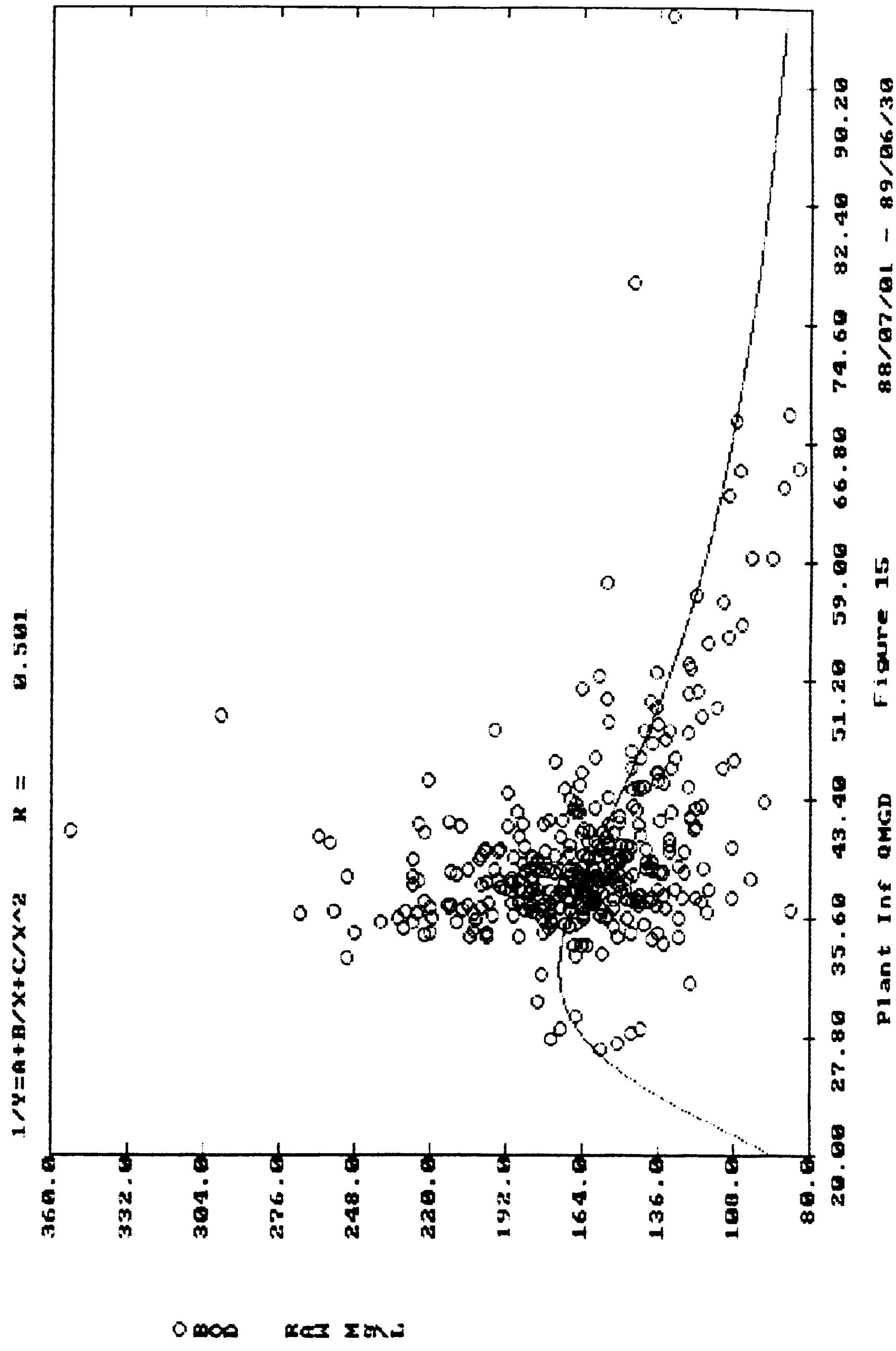

1/Y = A + B * X   R =   0.672
O ALK. RAW Mg/L
300.0
279.0
258.0
237.0
216.0
195.0
174.0
153.0
132.0
111.0
90.0
20.00
26.00
32.00
38.00
44.00
50.00
56.00
62.00
68.00
74.00
Plant Inf QMGD
88/07/01 - 89/06/30

Figure 14



1/Y=A+B/X+C/X^2
R = 0.501
360.0
332.0
304.0
276.0
248.0
220.0
192.0
164.0
136.0
108.0
80.0
20.00
27.80
35.60
43.40
51.20
59.00
66.80
74.60
82.40
90.20
Plant Inf QMGD
88/07/01 - 89/06/30

Figure 15

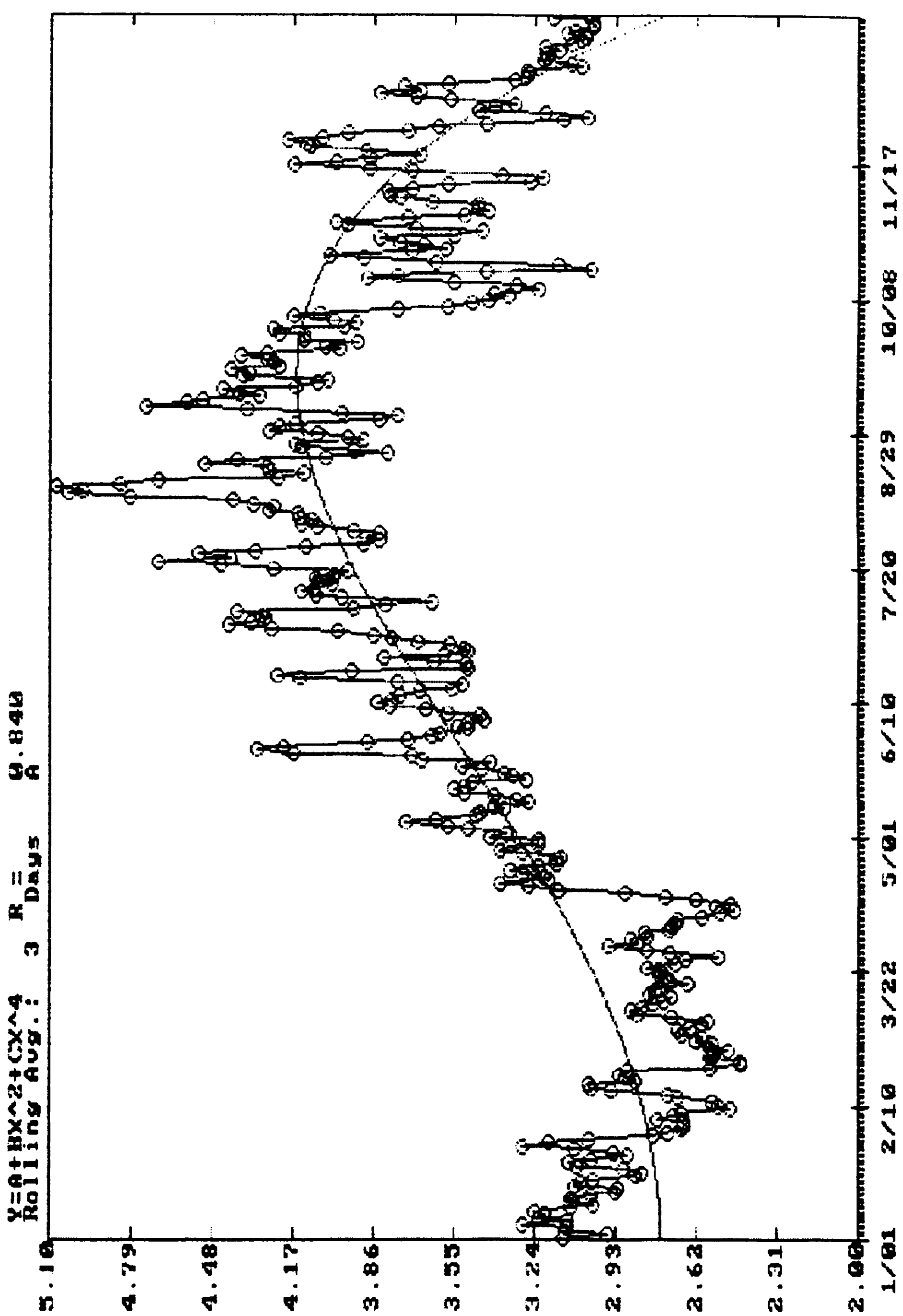

Y=A+BX^2+CX^4
Rolling Avg.: 3 Days
R = 0.840
5.10
4.79
4.48
4.17
3.86
3.55
3.24
2.93
2.62
2.31
2.00
1/01
2/10
3/22
5/01
6/10
7/20
8/29
10/08
11/17
Dates
87/01/01 - 87/12/31

Figure 16

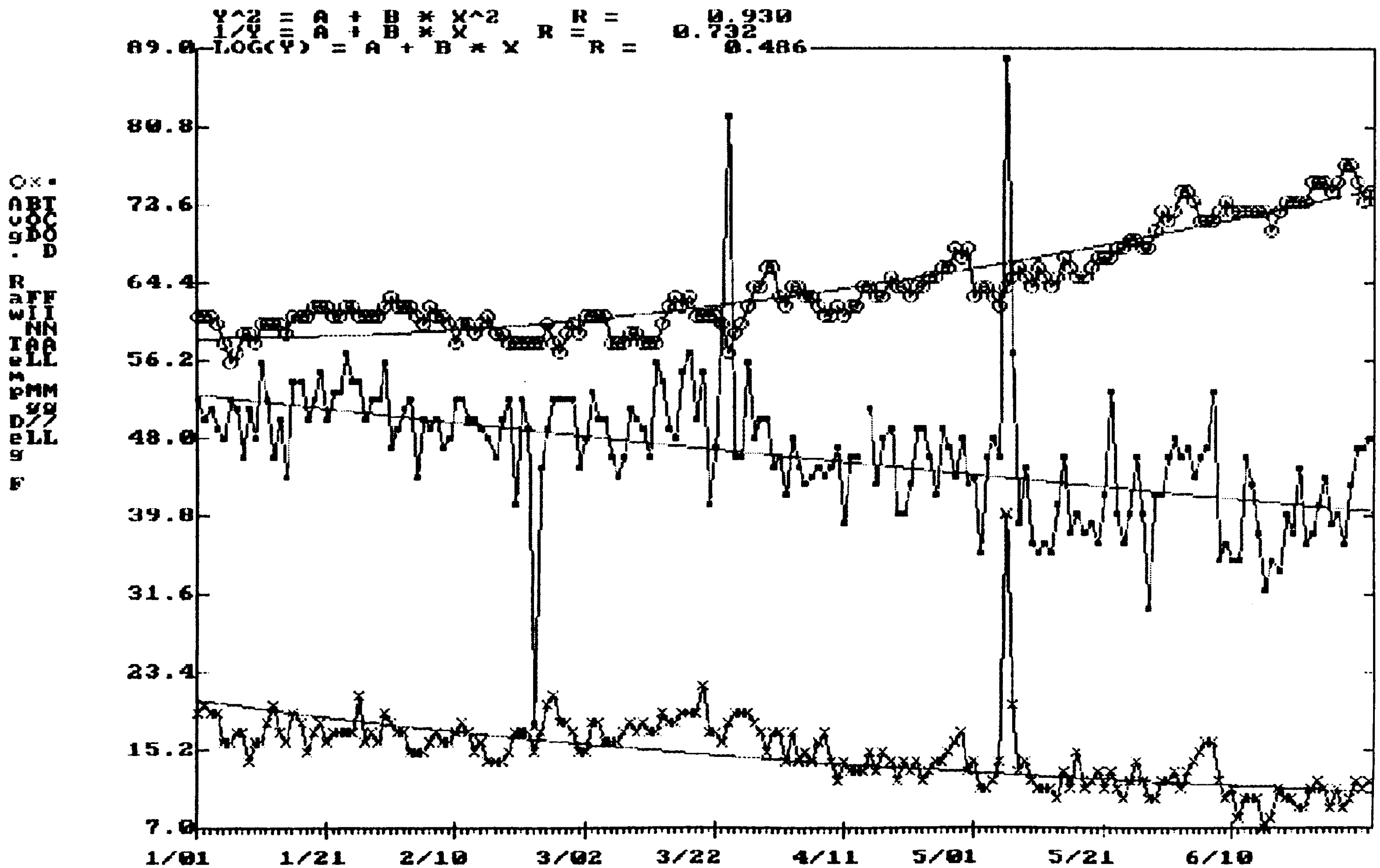
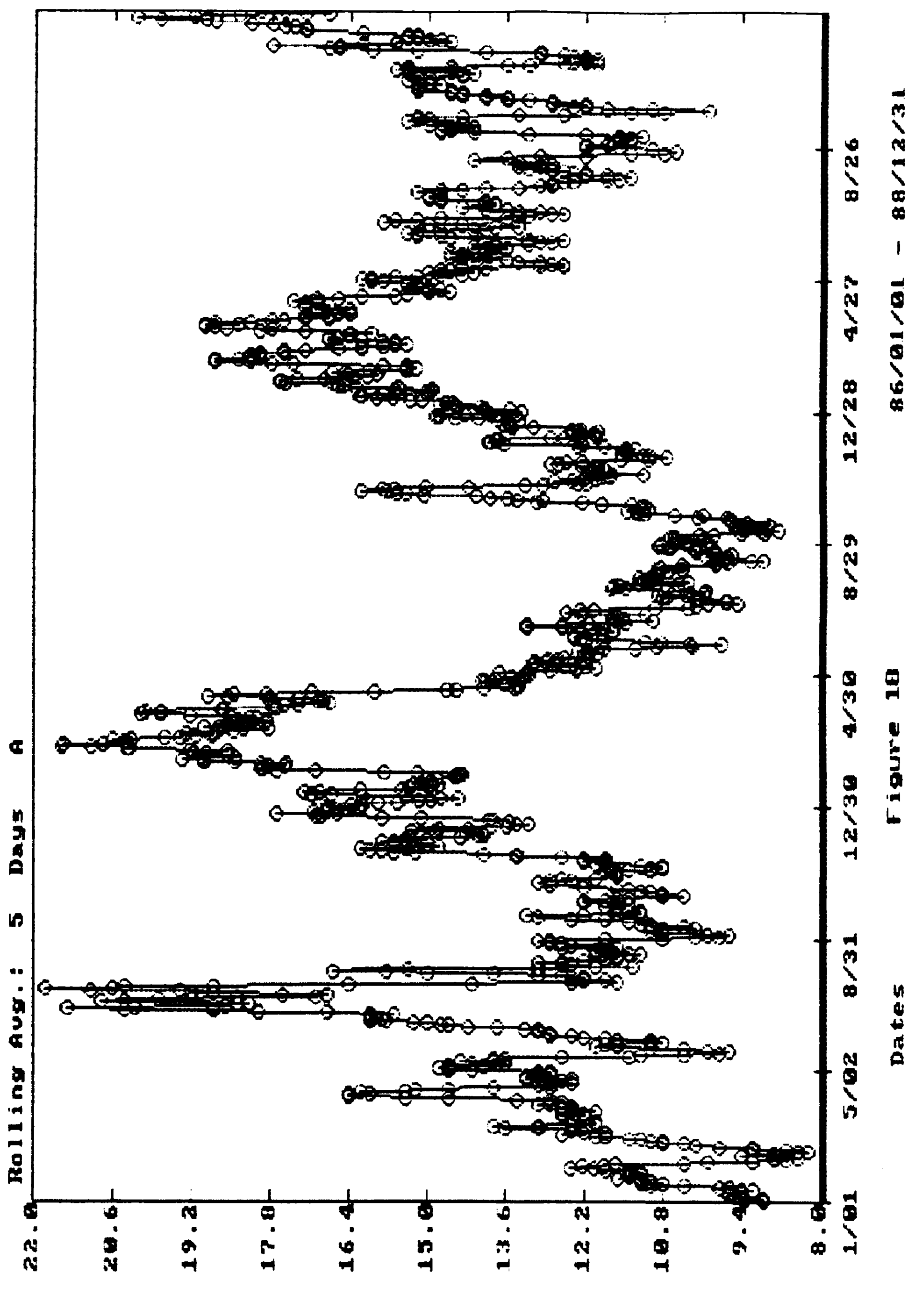
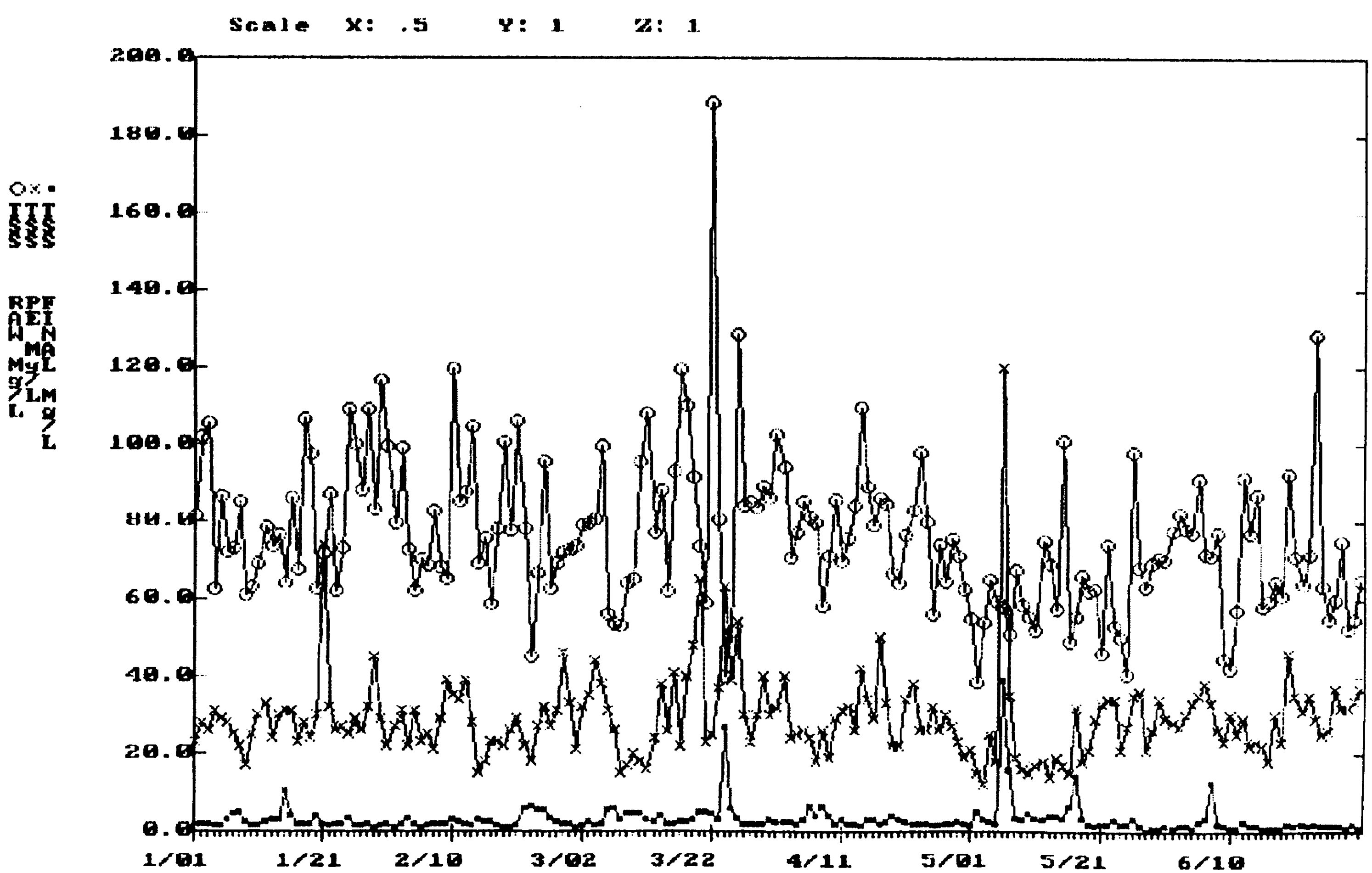

Y^2 = A + B * X^2 R = 0.930
1/Y = A + B * X R = 0.732
LOG(Y) = A + B * X R = 0.486
89.0
80.8
73.6
64.4
56.2
48.0
39.8
31.6
23.4
15.2
7.0
1/01
1/21
2/10
3/02
3/22
4/11
5/01
5/21
6/10
Dates
89/01/01 - 89/07/01

Figure 17



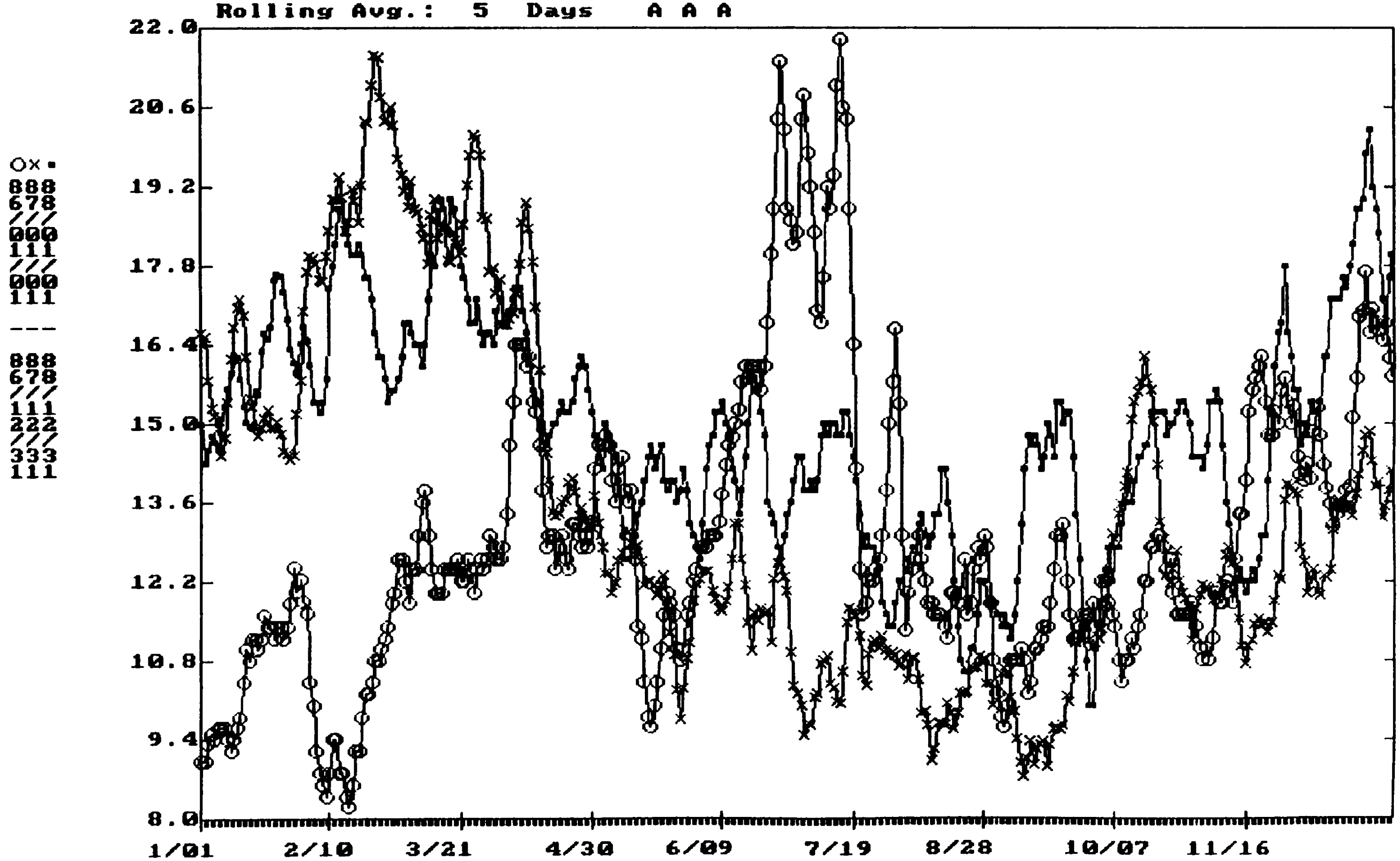
Rolling Avg.: 5 Days A
22.0
20.6
19.2
17.8
16.4
15.0
13.6
12.2
10.8
9.4
8.0
1/01
5/02
8/31
12/30
4/30
8/29
12/28
4/27
8/26
Dates
86/01/01 - 88/12/31

Figure 10



Dates Figure 19 89/01/01 - 89/06/30

Rolling Avg.: 5 Days A A A



Dates Figure 20 BOD FINAL Mg/L

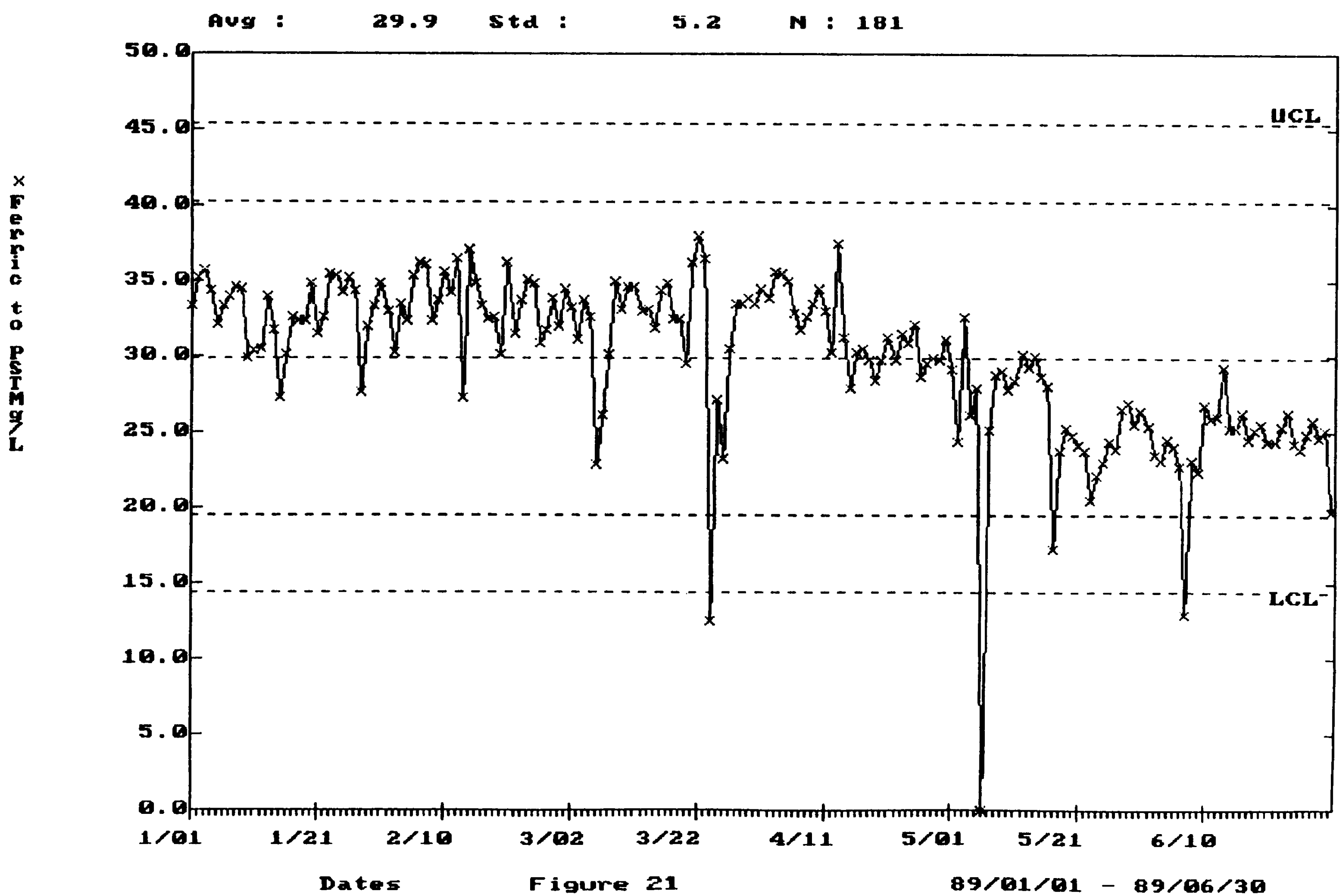

Avg : 29.9 Std : 5.2 N : 181
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
UCL
LCL
× Ferric to PSI Mg/L
1/01
1/21
2/10
3/02
3/22
4/11
5/01
5/21
6/10
Dates
89/01/01 - 89/06/30

Figure 21

Screen Options

The graphics analysis routines were designed to support any of the four common standard video adapter cards for the IBM compatible family of microcomputers. Video resolutions are generally quoted in terms of the number of picture elements (pixels) in the horizontal direction by the number of pixels in the vertical direction. Note that two colors is a euphemism for black and white. The following standard adapters and resolution modes are supported by LOIS:

1. Color Graphics Adapter (CGA)
   * 640 H X 200 V , 2 color
2. Enhanced Graphics Adapter (EGA)
   * 640 H X 200 V , 16 color
   * 640 H X 350 V , 16 color
3. Hercules Monographics Adapter
   * 720 H X 348 V , 2 color
4. Video Graphics Array Adapter (VGA)
   * 640 H X 480 V, 16 color

The EGA 640 H X 350 V and Hercules 720 H X 348 V are both suitable for high resolution graphics displays whenever sufficient hardware is present to support their use. The VGA 640 H X 480 V is the display mode of choice. The two color 640 H X 200 V CGA mode is acceptable but the four color CGA mode lacks the resolution to properly implement LOIS graphics displays. The default video mode is defined in the SETUP.TXT file but may be changed for the current session in the Screen/Data Source Options menu.

Graph Options

The LOIS graphs package allows a variety of graph options that enhance the flexibility and usefulness of the system. Screen 9 illustrate the graphs option page. Not all options are applicable to every graph type. Each option will be briefly discussed, the default condition stated and any limits on the applicable types:

1. Auto / Manual Range Input : Normally, LOIS will attempt to determine the appropriate ranges for the X and Y scales with the autorange algorithm. Occasionally the user may wish to input the Max and Min values for the ranges. Applicable to all types.

2. Line Connect Data Points : Normally, all contiguous data points will be connected. Breaks will occur when there are missing data points. The line connection option may be suppressed to enhance clarity. Not applicable to parameter vs parameter regression graphs.

3. Straight/Simple/Complex Regression fitting : Defaults to straight line curve fit algorithm. Acts as a switch to cycle through the options.

Applicable only to regression type graphs.

4. Autorange sets origin : Normally LOIS attempts to set best range. The alternative option forces the origin to (0,0) but allows LOIS to set Maximum value for range. Applicable to all graph types.

5. NO / Rolling Averages : Normally no rolling average is performed. If switch is set, user is prompted for number of data points to average in the range of three to thirty data points. The user is also prompted whether or not to average each of three possible data ranges. Applicable to all graph types.

6. Date Range Set : Normally the user is prompted for the start and end date to define each graph. This option allows one date range to be set while the user defines successive graphs. This can speed operations when viewing several parameters or graph types for the same period of time. Not applicable for parameter vs multiple time range graphs.

7. NO / Scale Time Plot Data : Normally no multiplication is performed on data points. If this option is set, the user is prompted for each parameter for a scaler. This option allows comparison of parameters with grossly different

value ranges on the same graph. Applicable to parameter vs time graphs only.

8. Display Regression Statistics : Normally, the best fit curve equation(s) are displayed on top line(s) of the display. When the NO display option is set, display of equation(s) are suppressed. Applicable to regression graphs only.

9. NO / Data Filter : Normally all data is displayed. When this option is set, the user is prompted for maximum and minimum cutoff limits for each parameter graphed. Applicable to all display types.

10. Setup printer : Allows calling a routine to set up a printer to accept graphics mode screen dumps. The path and filename of the graphics set up program are defined in the SETUP.TXT file. The calling of this routine is normally best done from the DOS prompt before LOIS is initiated. Most of the routines to allow graphic screen dumps are Terminate and Stay Resident (TSR) type programs. Loading a TSR while LOIS is active can cause unpredictable memory conflicts depending on .

11. Change Graph Colors : Allows the colors for foreground, background, X data range, Y data range and Z data range to be changed while a graph is

defined. Default color ranges are set in the SETUP.TXT file. Applicable only to EGA color monitors.

Screen 9 : Graph Options Menu

```
--------------------------------------------------------------------------------
03:08              Alexandria Sanitation Authority              02-18-1989

                            Graph Setup Menu

Select Function : ?

         Current                               Alternate
        ---------                             -----------

   1.   Autorange                             Manual Range Input
   2.   Line Connect Data Points              NO Connect
   3.   Straight Linear Regression            Curve/Parabola
   4.   Autorange Sets Origin                 0 Origin
   5.   NO Rolling Averages                   Roll. Avg.
   6.   Date Range NOT Set                    SET Date Range
   7.   NO Scale Time Plot Data               Scale Multiplier
   8.   Display Regress. Statistics           Display OFF
   9.   NO DATA Filter                        High/Low Filter

  10.    Setup Printer to Print Screen Graphics
  11.    Change Graph Colors (EGA ONLY !)

                            Q or Enter to Quit Menu
--------------------------------------------------------------------------------
```

The attached charts contain several examples of the use of the graph options. Figure 19 illustrates the ability to apply a multiplier to a parameter (Option 7). This options allows the comparison of values with ranges that differ by orders of magnitude. Without the scaler option in a two parameter versus time graph, the parameter range with the higher values would be set the maximum range value. The parameter with the lower values would set the minimum range value. Often this would result in both parameters losing definition; one parameter range might appear as a straight line at the top while the other appeared as a straight line at the bottom of the graph.

One of the advanced effects that can be achieved with the LOIS graph options is demonstrated in Figure 22. The multiple parameter vs time graph has two parameters defined. Both ranges are defined as the same parameter, however a rolling average has been applied to the data in one of the ranges. This has the effect of presenting a very complex curve fit for the data in the original (no rolling average) range.

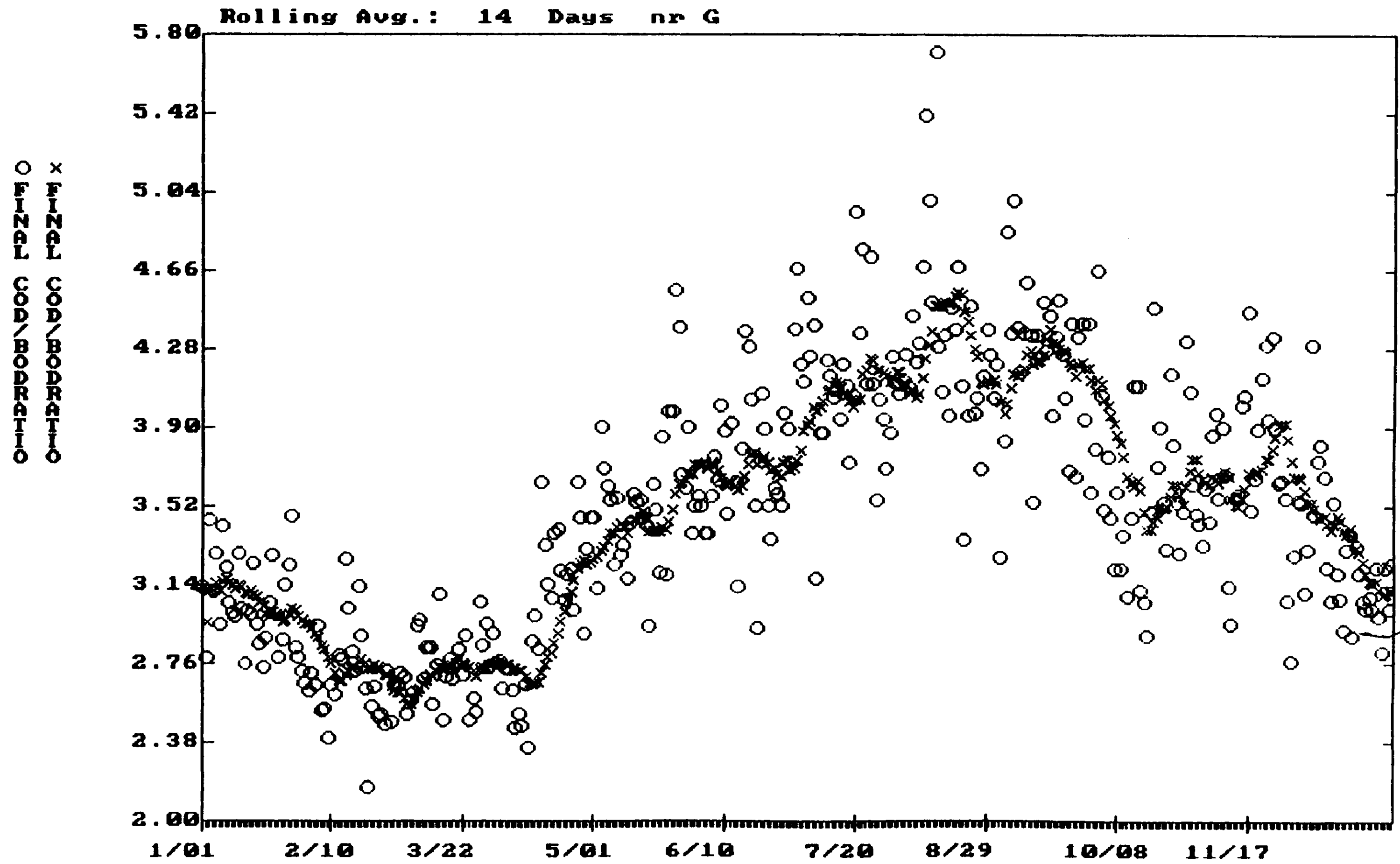

Rolling Avg.: 14 Days nr G
5.80
5.42
5.04
4.66
4.28
3.90
3.52
3.14
2.76
2.38
2.00
1/01
2/10
3/22
5/01
6/10
7/20
8/29
10/08
11/17
Dates
87/01/01 - 87/12/31
× FINAL COD/BODRATIO
○ FINAL COD/BODRATIO

Figure 22

Graphical Interface with Printers and Other Programs

Several widely accepted standards exist for the transfer of character based data as described under data export. When graphics based data must be transferred between programs, few standards have been well established. The ASCII character set is a common denominator for most character based programs. The ubiquitous nature of the Lotus spreadsheet programs have made their data character based formats a defacto standard. The IEEE numeric format is widely accepted by programs ranging from minicomputers to supercomputers. Unfortunately, few standards though many formats have been established for the transfer of graphics. A third party WordPerfect users manual (79) lists seven object-oriented and bit-mapped graphical formats which are acknowledged by WordPerfect. Certainly many more graphics data file formats exist. Fortunately, the arrangement of screen display information in the video buffer memory of the CGA and EGA display adapters has been well established by IBM (14). The memory arrangement of the Hercules adapter, while less well established, is published with every Hercules user manual (80). The limited number of arrangements of display data in a microcomputer's display adapter allows drivers to be written to communicate to a printer the contents of display buffer memory. The standard

IBM or Microsoft Disk Operating System (DOS) provides a facility to match graphic display adapters and standard IBM/Epson dot matrix printers via the external GRAPHICS command (81). Many other printer manufacturers provide similar utility programs to perform the same function. The NEC P5XL color, 24 pin, dot matrix printer used by the Authority provides drivers for both monochrome and color video dumps (82).

While many graphics programs use novel data formats for disk storage, several have taken advantage of the limited number of standard graphics adapters by providing screen capture utilities. The screen capture utilities are generally of the Terminate and Stay Resident (TSR) variety which are invoked by a unique combination of keyboard entries. When invoked, the utility reads the video buffer memory of the currently displayed graphic and saves the information to a disk file in a format acceptable to the "parent" program. The Authority has found two commercial programs with this capability to be useful. Word Perfect was selected as the Authority's word processor of choice for a number of unrelated reasons. The ability to transfer unadorned LOIS graphs to Word Perfect documents was a convenient method for incorporating data graphs with text reports. The second program used by the Authority with LOIS graphs is the PC Paintbrush (83) program. This program allows LOIS graphs to be "dressed up" with more sophisticated labels, colors and comments. Figure 23 demonstrates some of the effects that can be achieved by transferring LOIS graphs to the paint program for "touch up" work. While the Authority is generally not in the presentation graphics business, attractive graphs can have uses for training or public relations purposes. Though only these two programs are used extensively by the Authority, numerous other programs that are capable of graphic screen capture could use the standard LOIS graphs as input.

Another approach to the transfer of graphical data is provided by the LOIS system. The unadjusted values of the data ranges and the range labels may be saved to an ASCII data file. This file may be recalled to the LOIS system at a later date. The data source option of the Screen / Data Source Option menu allows selection of input file among the default LOIS data base filed, external files saved by LOIS or created with another program in the proper format, or LABQC data files. The format of saved graph data is also consistent with the structured text import format of Lotus spreadsheets. Likewise, data from other sources may be massaged into a format acceptable to the LOIS graphical analysis program.

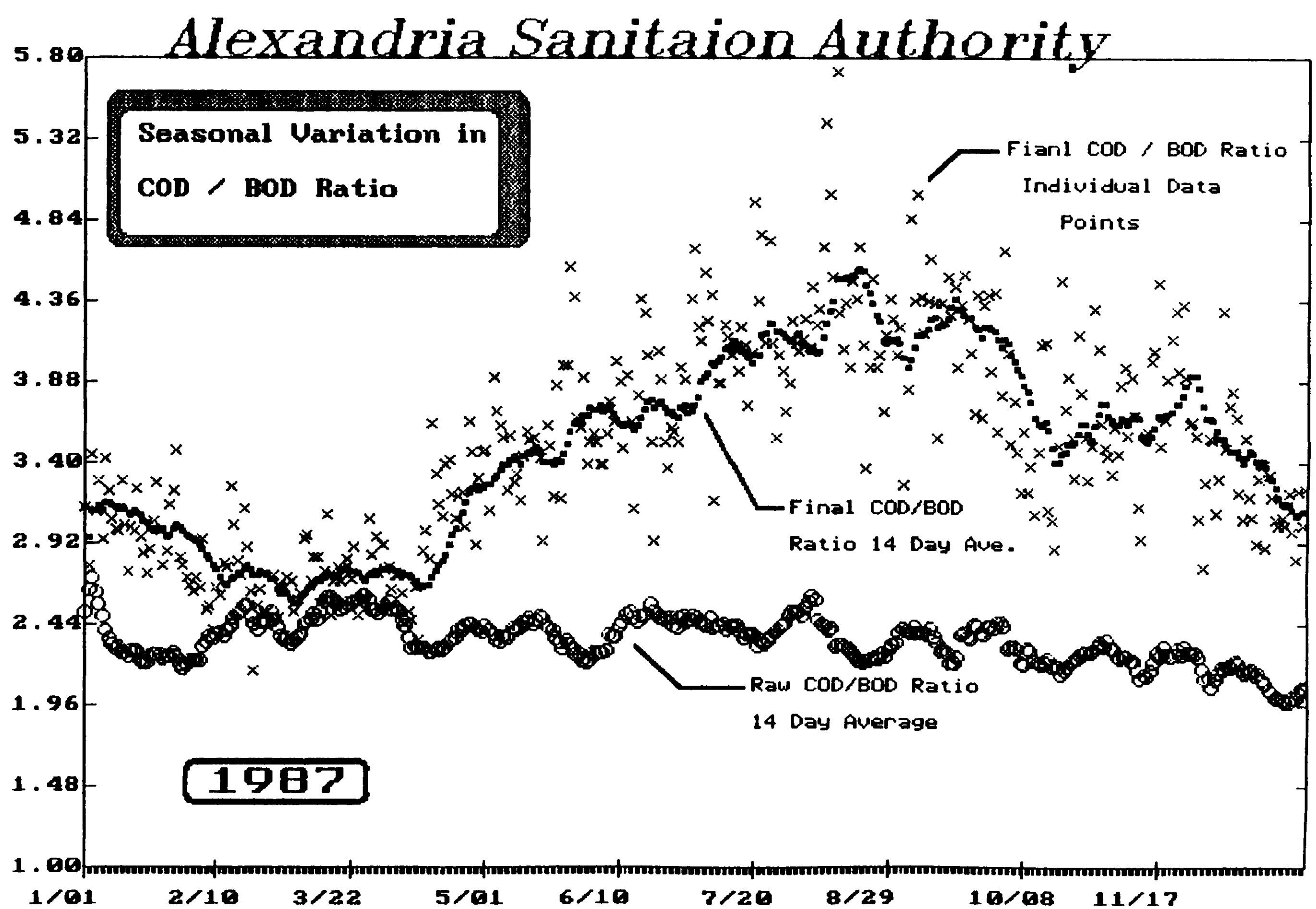

Alexandria Sanitaion Authority
Seasonal Variation in
COD / BOD Ratio
Fianl COD / BOD Ratio
Individual Data
Points
Final COD/BOD
Ratio 14 Day Ave.
Raw COD/BOD Ratio
14 Day Average
1987
5.80
5.32
4.84
4.36
3.88
3.40
2.92
2.44
1.96
1.48
1.00
1/01
2/10
3/22
5/01
6/10
7/20
8/29
10/08
11/17

Figure 23

Alternate Inputs to Graphics Analysis

While the main LOIS data base (RAW and CAL files) are normally the source of input to the graphical analysis routines, two further options are available. The LABQC module provides control chart graphics of a single QC data file with the applicable standard options. The LOIS graphics package allows import of two or three different QC files for cross comparison of QC files. As an example, COD precision and accuracy files may be subjected to regression to determine if the same samples yield unusual results for both determinations. The values of data point one and data point two for a precision series could reveal a significant pattern.

Direct keyboard input to the LOIS graphical system is provided as an option. The user is prompted for the number of parameter ranges, the number of data groups, the appropriate labels and the individual data points specified. The input is graphed according to the graph type selected. The file may be saved for future reference or may be modified with an ASCII text editor. The authority laboratory staff has found this option useful for the production of standard curve regression graphs.

Statistical Analysis

While graphical analysis of data trends provides an important window on the combination of laboratory and operational data and the resultant calculation values data base, there are times when a rigorous statistical analysis of data is more appropriate to generate useful information. Information is required in a variety of formats depending on the particular use intended. The LOIS system was designed to meet the most common needs for statistical analysis. Requirements that surpass the capabilities of the LOIS system may be meet by exporting LOIS data to specialized statistical software packages or by writing external programs that may be called from the Reports menu.

Screen 8 is the menu for the statistical analysis package. Menu choices one to three present quick statistical summaries of parameter data. Option four and five provide printer output of entire files for a date range. Options six and seven represent regression analysis in the form of two equations which allow a dependent value to be defined by two or three independent variables. Option eight returns control to the graphics menu.

LOIS provides rapid analysis of parameter statistics with the view options one to three. While these options are formatted for display on the computer screen, the screen can easily be dumped to the printer for hardcopy output. Screen 10 is an example of the display presented with the 3 parameter, 1 time range option. Analysis includes the arithmetic average, the geometric mean and the standard deviation of the parameter values of the given time range. The minimum and maximum values are presented as well as the first date on which the value occurs. The inclusion of the date can help the user identify unusual values in the data base edit routine. The number of valid data points , N (not equal to the minus one "no data indicator") and the number of positive, N>0 (not including zero) data points is presented to help evaluate the meaning of the statistics. The standard statistical values for ranges that contain many zero values can often be misconstrued. Chemical feed quantities that are not used on a daily basis produce averages that are easily misused. The control chart upper and lower control limits are represented by the Av-3STD and Av+3STD values. The 1 parameter, 3 time range option is shown in Screen 11. The format is essentially identical to the previous option, however the same parameter is analysied over three time ranges. The time ranges selected may overlap or may be subsets of another time range.

Screen 10 : Statistical Data Review - 3 Parameters
1 Time Range

Parameters / Units : Dates : 87/06/01 - 87/10/01

Parameters / Units	N	Average	Geomet. Mean	Std. Dev.	Av-3STD	Minimum	Maximum	Av+3STD	N>0	Date (Minimum)	Date (Maximum)
BOD RAW Mg/L	122	141.4	139.8	22.5	74.0	86.0	265.0	208.9	122	87/09/12	87/09/29
BOD BDE (Sol) Mg/L	121	13.1	12.8	2.54	5.44	8.00	19.0	20.7	121	87/07/02	87/08/06
BOD FINAL Mg/L	123	10.7	10.6	1.44	6.38	7.60	15.1	15.0	123	87/09/06	87/06/26

Screen 11 : Statistical Data Review - 1 Parameters
3 Time Ranges

Parameters / Units : BOD RAW Mg/L

Dates	N	Average	Geomet. Mean	Std. Dev.	Av-3STD	Minimum	Maximum	Av+3STD	N>0	Date (Minimum)	Date (Maximum)
86/06/01 - 86/10/01	120	163.4	161.7	25.0	88.5	103.0	300.0	238.3	120	86/08/21	86/09/14
87/06/01 - 87/10/01	122	141.4	139.8	22.5	74.0	86.0	265.0	208.9	122	87/09/12	87/09/29
88/06/01 - 88/10/01	123	161.0	159.7	19.9	101.3	102.0	214.0	220.7	123	88/08/06	88/08/07

A commonly requested data format is the monthly summary. Screen 12 presents a typical monthly output. In order to fit on a twenty five line screen, the maximum number of months selected is limited to eighteen. The arithmetic average, maximum, minimum, standard deviation, and number of valid points are presented for each month. The column of sums may be suppressed when the option is selected. The sum of concentrations would have no significance.

Screen 12 : Stat. Data Review - Monthly Summaries
1 Parameter

Parameters / Units : Wet SludgeTons

Month /Yr	Average	MAX	Min	Std Dev	N	Sum
June 87	209.9	294.6	75.8	45.5	27	5666.0
July	180.3	254.8	44.8	59.5	31	5590.6
August	186.5	297.9	21.2	75.2	31	5782.0
September	180.6	271.3	44.6	59.5	29	5236.0
October	247.3	305.3	166.4	37.0	27	6677.7
November	214.7	303.4	98.5	55.6	24	5152.5
December	200.0	337.4	94.4	61.1	26	5200.2
January 88	198.8	255.6	138.1	36.3	26	5169.2
February	219.6	316.2	141.1	41.7	25	5490.1
March	215.2	280.9	148.4	29.0	27	5811.4
April	216.3	307.5	126.5	48.6	26	5625.0
May	251.5	330.5	108.7	48.7	26	6538.4
June	223.9	336.4	131.9	58.2	26	5820.7
July	235.8	356.4	131.3	43.9	28	6602.8
August	216.6	328.3	87.0	52.0	27	5847.8
September	246.0	394.9	115.7	69.0	28	6889.1
October	273.4	463.3	158.6	63.8	26	7109.2
November	254.4	350.3	139.4	57.6	25	6360.0

The file statistical review (options four and five) provide the same basic statistical analysis provided by options one and two. The geometric mean is excluded as this analysis is usually only associated with fecal coliform counts. The print options operate either on an entire data file (RAW or CAL) or on all data files listed in the RAWFILES.TXT and CALFILES.TXT file lists. Output is formatted for and directed to the printer. Both options are normally used for review of the LAbel and Limit (LAL) high and low data alarm limits. The single file summary may be appropriate for review of long term data trends for a group of parameters. The entire data base (option five) summary is usually reserved for periodic review of all data base limits. Both options can be useful for identifying aberrant data that has inadvertently entered the data base.

The regression analysis options six and seven allow computation of regressions based on two or three independent variables. The two basic equations utilized are:

$$Z = a + b * X + c * Y$$

$$A = a + b * X + c * Y + d * Z$$

The capital letter variables (A,X,Y,Z) represent parameter ranges (vectors). The small letter variables (a,b,c,d) represent the appropriate coefficients in the best fit equation. The solution algorithm utilizes Cramer's rule for the solution of the matrix. The R value is also determined to indicate the closeness of fit. Screens 13 and 14 show typical output of the regression process. The number of valid data groups is presented by the N value. If there is no data for any parameter on a day, all other values on that day are excluded from the solution algorithm. The average, standard deviation, minimum and maximum are also determined for each range of parameters that serve as inputs to the solution.

Screen 13 : Statistical Data Review
Regression - 2 Independent Variables

00:23 Alexandria Sanitation Authority 02-25-1989

Multiple Regression - Two Variables

	Start	End
	87/01/01	87/12/01

INDEPENDENT VARIABLES

X Avg. Raw Temp Deg F

Y Plant Inf Q MGD

DEPENDENT VARIABLES

Z FINAL TBOD KLbs

Z	=	a	+ b * X	+	c * Y
		7.65	-0.125		0.143

N = 335 R = 0.882

	X	Y	Z
Average	70.5	40.0	4.55
Std. Dev.	7.16	5.12	1.51
MAX	81.0	77.0	13.0
Min	59.0	31.9	2.27

Screen 14 : Statistical Data Review
Regression - 3 Independent Variables

00:27	Alexandria Sanitation Authority	02-25-1989

Multiple Regression - Three Variables

Start	End
87/01/01	87/12/31

INDEPENDENT VARIABLES

X Avg. Raw Temp Deg F

Y Plant Inf Q MGD

Z PE SBOD LBS

DEPENDENT VARIABLES

A FINAL TBOD KLbs

A =	a	+ b * X	+ c * Y	+ d * Z
	3.78	-0.094	0.132	1.69E-04

N = 360 R = 0.913

	X	Y	Z	A
Average	70.0	39.9	12,087	4.53
Std. Dev.	7.07	4.98	2,670	1.45
MAX	81.0	77.0	21,709	13.0
Min	59.0	31.9	4,555	2.27

Quality Control

The LABQC module provides functions supporting the maintenance of QC data files, the production of QC control charts and the production of a variety of reports. In practice, the QC function was determined to be best implemented on a separate microcomputer located physically in the laboratory. The module is set up to function independently of the main LOIS data base and programs though the user can switch between the QC program and the LOIS system without exiting to the operating system. The LOIS data base is copied to the laboratory computer and the QC data base is copied to the main LOIS computer frequently. This arrangements allows users in both areas to utilize both data bases and provides security in the case either machine should fail. Several of the LOIS support routines such as editing the SETUP.TXT file and printer control functions are duplicated in the LABQC module.

The LABQC Main Menu (Screen 15) presents the primary function groups in order of most frequent expected use. Option one allows standard input of QC data records in a manner similar to the input of LOIS RAW files. Before each input is made, a rolling average and standard deviation is performed on the preceding selected number of passing records to determine the appropriate control limits. The number of records to be included in the rolling average is determined in the data files' definition file. After the input is complete, the quality control data point is calculated depending on the type and subtype of the data file as defined in the definition file. The calculated data point is compared to the current control limits and a pass / fail determination is made. If the quality control test fails, the record is retained in the file but the value is not used in the determination of future control limits.

Screen 15 : QC Main Menu

```
03:04:00              Alexandria Sanitation Authority            02-25-1989

                               Lab QC Main Menu
   Desired Function :

                      1. Input Data File

                      2. Edit Data File

                      3. Display Control Chart Graphs

                      4. Report Menu

                      5. QC Utilities

                      6. Define New &/or Edit File Definitions

                      7. DOS Function & Printer Set Up

                      8. Edit SETUP.TXT File


                      9. LOIS Menu
   X - Exit to DOS                                    H -  HELP
```

Screen 16 : QC Edit Page

```
03:05:48              Alexandria Sanitation Authority              02-25-1989

                              DATA RECORD EDIT
 File : PHOSSTD - PE PO4 SPIKE                        Record Number :  144
   Units: %    ACCURACY OF PE PO4 SPIKE.
    1. DATE       : 88/12/28       1458
    2. Tech Init. :     RM
    3. Run ID#    :                              ______________________
    4. Data 1     :       .154                   |  UCL :      109     |
    5. Data 2     :       .303                   |  UWL :      106     |
                                                 |                     |
    6. VOL  1     :       50                     |  AVG :       99     |
    7. VOL  2     :       50                     |                     |
    8. SPIKE      :       7.5                    |  LWL :       93     |
                                                 |  LCL :       90     |
    9. QC POINT   :            99                |                     |
   10. Aver.      :            99                |_____________________|
   11. STD        :             3

   12. PASS/FAIL  :     P
   13. COMMENT    :

 Choose: 1. QC Menu   2. Edit   3. Next   4. Previous
         5. Specific Record Number   6. Edit New File    ?
```

The edit page (Screen 16) is presented at the end of each input or when called by main menu option two. As noted in the file specification description, quality control records have substantially different data format than the solely numeric data contained in the LOIS data files. The box on the right side of the edit page contains the rolling average and control limits based on the previous selected number of values. While that information is part of the record, it can not be edited. The limits in effect for a record can only be changed if one of the following conditions is met:

* A previous data record within the scope of the selected rolling average range number is altered,
* The size of the rolling average range is changed in the data file definition,
* The relative error applied to adjust the sensitivity of the control limits is changed in the file definition,
* Different records are included in the scope of the rolling average as the result of a sort operation.

Any of the above changes will not take immediate effect. The data file must be recalculated for the results of the above types of changes to be reflected throughout the data file. During the recalculation process, each data point will be reevaluated with regard to the new control limits and new pass / fail determinations will be made.

The LABQC module's graph functions are based on the same concept as the LOIS STATPACK's control chart graph type. Some notable enhancements have been made to reflect the needs of the laboratory quality control program. Figure 24 is the default QC control chart graph. Two obvious enhancements are incorporated. The inclusion of separate shaped and colored symbols for each technician allows comparison of the results obtained by each member of the laboratory staff. Caution should be used in interpreting quality control results as a measure of technician performance. Quality control results can often be the result of a complex matrix of factors, only a few of which are under the direct control of the technician. The use of individual symbols does however give the laboratory manager another tool to evaluate the quality control program. The use of "dynamic control limits" shows the average and control limits that were in effect when each test was performed. Long term trends regarding the width of the control window are readily apparent. The graph selection menu for quality control charts (Screen 17) shows the type of selections that may be made. Option one is the default graph type, only passing values are shown for the size of the rolling average window defined in the data file definition file. Graphs may also be based on specific record number ranges or for specific date ranges. Failing data points may also be optionally included. Sometimes ones failings are more interesting than ones success. Graphs may also be selected for an individual technician though the option showing all technicians is the default option. Figure 25 demonstrates a long term control chart with failing data points included. The LABQC graph option menu has been modified from the LOIS STATPACK graph option menu to delete all options that are not applicable to control charts. An option to add or modify the symbol and color associated with technician symbols has been included.

Screen 17 : QC Graph Selection Menu

```
--------------------------------------------------------------------------------

03:07:11             Alexandria Sanitation Authority            02-25-1989

                          Data Selection Method

 File : GandGBOD  G+GBOD                   Last Record :  305
                  Start Date : 88/2/22     Last Date : 88/12/23

Desired Function :
                      1. Last  30  Records - Pass Only (DEFAULT)
                      2. Last  30  Records - Pass & Fail

                      3. Input Record Number Range - Pass Only
                      4.                           - Pass & Fail

                      5. Input Date Range - Pass Only
                      6.                  - Pass & Fail
1. ALL  or  2. Individual ? 1


    Start Record Number ? 200
    End Record Number ?
```

A variety of standard reports has been included with the LABQC program. Screen 18 presents the QC Report Menu. Exception reports for a day or a date range list only quality control test that failed. Activity reports for a day or a date range list all control tests performed. The summary report lists numbers of test performed, numbers that passed and failed for each data file. The Current Limit Report lists the current control limits for each active file. Samples of all report types are included in Appendix A.

Screen 18 : QC Reprot Menu

```
03:09:39              Alexandria Sanitation Authority              02-25-1989

                                  LAB QC REPORTS
   Desired Function :

                        1. Exception Report - Single Day

                        2. Exception Report - Multiple Days

                        3. Activity Report - Single Day

                        4. Activity Report - Multiple Days

                        5. Summary Report

                        6. Current Limit Report

                        7. Form Feed Printer

                        8. QC Menu


                        9. LOIS Menu
   X - Exit to DOS                                       H -  HELP
```

Screen 19 : QC Utiltiy Menu

```
--------------------------------------------------------------------------------
03:10:31              Alexandria Sanitation Authority              02-25-1989

                              QC UTILITY MENU
    Desired Function :

                        1.  Print File

                        2.  Transfer File to LOTUS Format OR SCREEN

                        3.  Sort File

                        4.  Graph Options

                        5.  Change File Input Order

                        6.  Archive Records

                        7.  Verify / Recalc QA File / Delete Record

                        8.  Return to QC Menu

                        9. LOIS Menu
    X - Exit to DOS                                      H -  HELP
```

The LABQC main menu option five is listed as being QC Utilities. The utilities menu (Screen 19) lists the functions necessary to the maintenance of the quality control program. Option one provides a detailed printing of the contents of a data file. This option is provided primarily for off line review of the contents of a data file. The data export option is provided to convert files to spreadsheets, word processors or statistical packages for further manipulation. The export option is also useful for transferring quality control data to information consumers outside the Authority. The screen output option of the export function can be used for quick review of the contents of a data file showing several records on screen at a time.

The main LOIS data base files were built on the basic assumption that data would normally be available for each parameter each day, therefore the one to one correspondence of records and days was a convenient expedient. Multiple instances of the same parameter would be assigned different fields, as is evidenced by the chlorine residual file. The LABQC files were built without a similar structural linking of records and dates. It was assumed that many quality control tests would not be performed on a daily basis or that several tests may be performed on the same day. While records are normally input sequentially with regards to time, the possibility exists that records could occasionally be input out of temporal order. Option three (Sort) of the Utilities menu allows a data file to be sorted on the basis of dates.

The fourth option on the utilities menu allows the graph options to be set for a series of similar graphs. The graph option menu is the same as the menu presented when the option menu is selected after a graph has been defined. The fifth option on the utilities page allows the input order of files to be altered. Normally all precision files would be input in the order listed in the PREFILES.TXT file listing file, followed by all the accuracy files followed by all data point files. A more logical sequence of file input order may be selected, for example all BOD related files may be input followed by all COD related files and so forth.

As mentioned, changes to a data files contents or to the order of records within a data files do not automatically result in recalculation of limits for effected records. The algorithm to determine which records would be effected would be difficult to implement. While it would seem that only the records within the scope of the rolling average would be effected by a single change, if the change resulted in any other records pass / fail evaluation changing, the effected range would shift forward. In practice, a change to the first data record could have a ripple effect through the entire data file. Changes to the selected scope of the rolling average for a data file or to the relative error would cause changes to the entire data file. A sort that moved a number of records could have effects on the current limits calculated for all records beyond the point where the first record changed position. The development of an algorithm to determine the extent and perform the necessary recalculations for all possible changes to the data base was considered overly complex. The utilities option seven allows a recalculation to be performed on demand by the user. It is left to the experience of the user to determine when changes to the data file have been made which would require the files limits to be recalculated. During the recalculation, which proceeds from the first data record (actually record number two) to the last data record, each record is compared to the previous values for that record. If a record has changed, the new and old values can be output in one of four ways. Changed and previous records may be output to a printer, to the screen, to a disk file or no output may be selected. The recalculation procedure also allows an option to remove selected records from the data file. The first record, which contains the number of valid data records in the file, is decremented appropriately, the file is packed (records are moved to fill the void left by the deletion), and a recalculation is performed.

The LABQC main menu options six provide the functions necessary to create new quality control data files or to modify the definition of existing files. Analogous functions for the LOIS RAW and CAL data files are provided in the SYSOP module. To add a file, the file name must be added to the file list that matches the new files type (PREFILES.TXT, ACCFILES.TXT, or DATFILES.TXT) and a definition file must be created with the appropriate labels, input limits, rolling average size and relative error. A blank data file is created with a file size record pointing to the second record for the start of input. Data files may be removed from active status by deleting them from the file list files. Definition files may be edited, though changes to the rolling average size or the relative error value will require that the data file be recalculated.

The final two options on the LABQC main menu, seven and eight, duplicate the DOS functions, printer control functions and edit of the SETUP.TXT file functions that are provided in the main LOIS and SYSOP modules. These functions were duplicated to allow the LABQC module to serve as a stand alone quality control program on a microcomputer separate from the main LOIS data base.

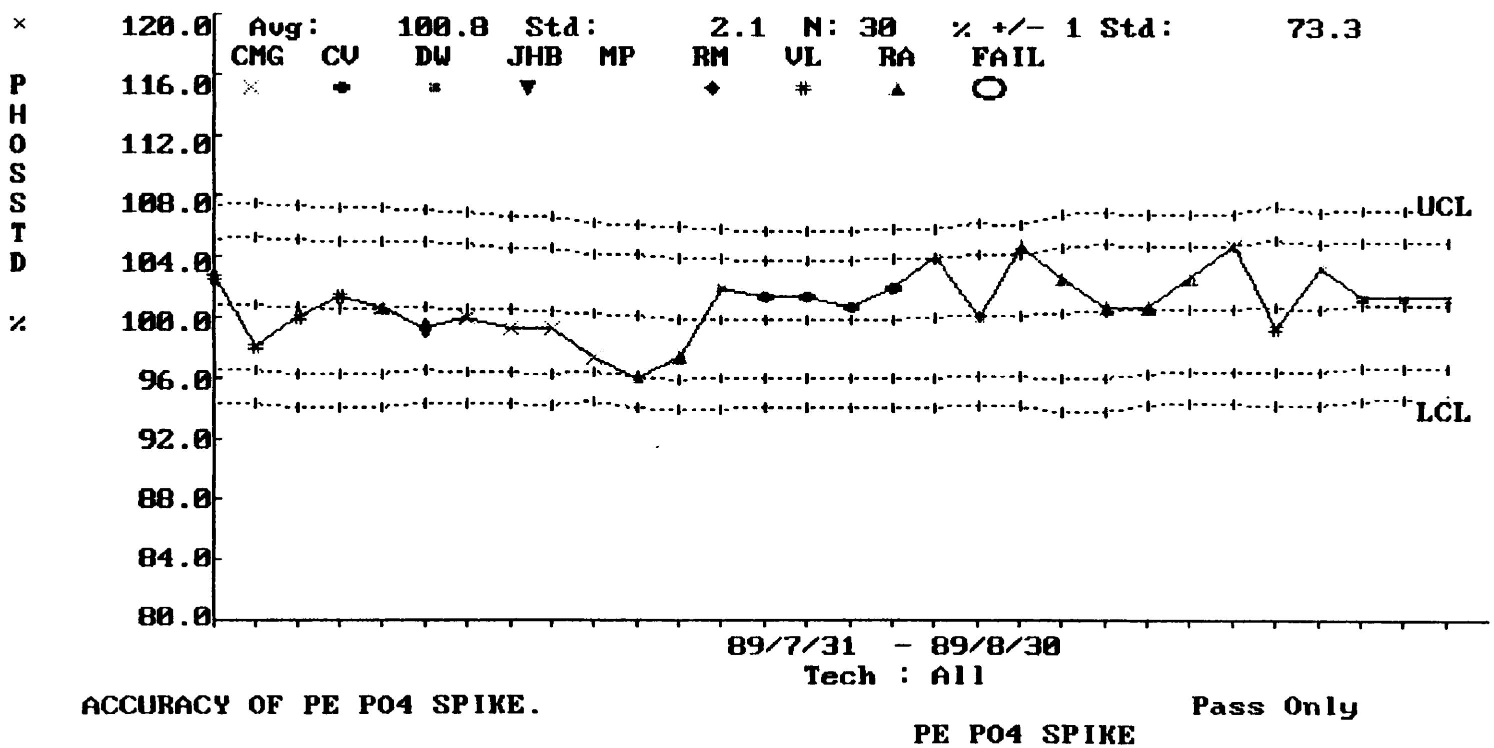
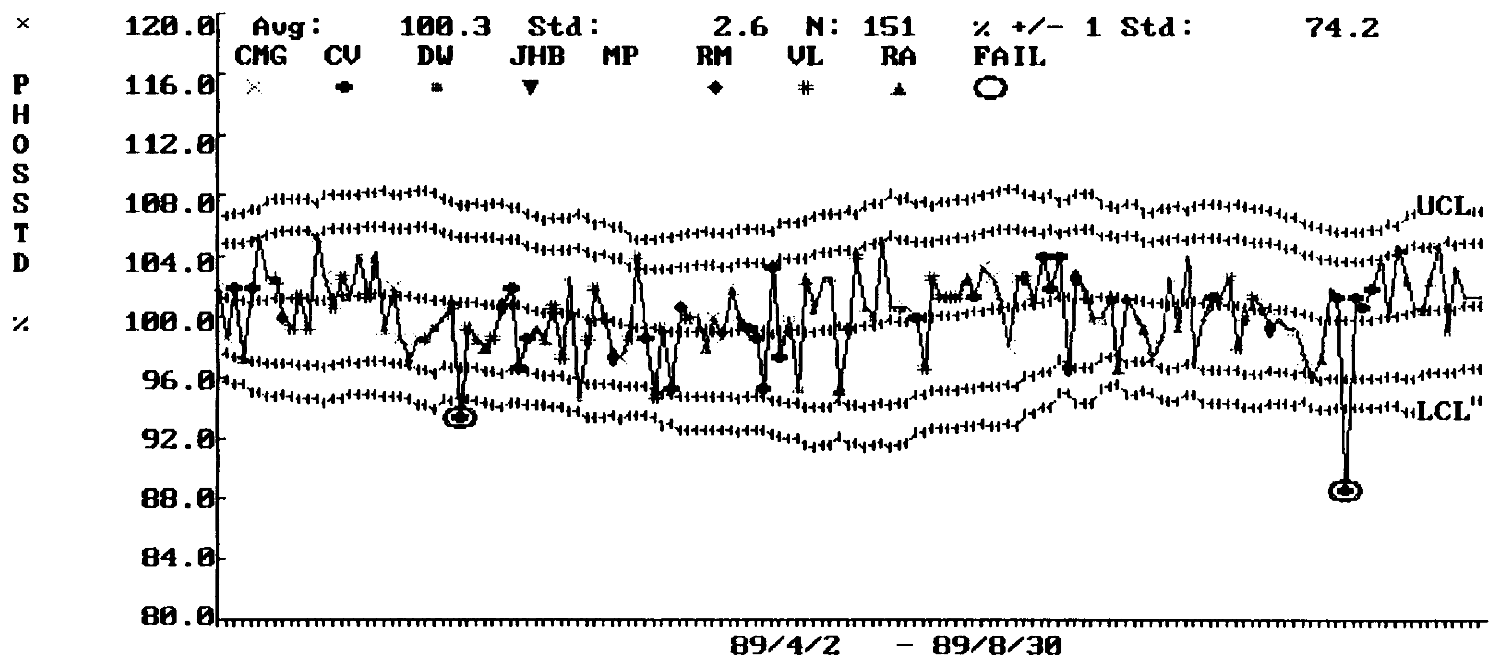

% PHOSSTD
120.0
116.0
112.0
108.0
104.0
100.0
96.0
92.0
88.0
84.0
80.0
Avg: 100.8 Std: 2.1 N: 30 % +/- 1 Std: 73.3
CMG CV DW JHB MP RM VL RA FAIL
UCL
LCL
89/7/31 - 89/8/30
Tech : All
ACCURACY OF PE PO4 SPIKE.
Pass Only
PE PO4 SPIKE

Figure 24



ACCURACY OF PE PO4 SPIKE. Pass & Fail

Figure 25 PE PO4 SPIKE

VI. Program Development and Implementation

A project the size and scope of the Alexandria Sanitation Authority Laboratory Operations Information System does not come to fruition overnight. The development of the program source code is only one of the processes that must be considered. Other tasks that must be incorporated in the development and implementation of a LOIS program involve:

* Definition of data files
* Definition of calculation files
* Definition of reports
* Establishment of procedures for data input and verification
* Definition of standard reports
* Training users in system use
* Debugging both program code and procedures
* Accepting user input for system refinement
* Maximizing system utilization

To an extent, these tasks must follow in a certain order; the program code must be first generated to allow creation and input to data files before any users can be trained in data input. However, to a larger extent, no process is ever thoroughly complete and tasks must overlap. As the system matures, the percent of time dedicated to some tasks diminished while the time allocated to other tasks increases. As long as a treatment plant is a dynamic operation within a changing environment, the development of a LOIS system is an ongoing process.

RAW Data File Definition

One of the first and most important tasks in the implementation of the LOIS system is the definition of data files. The parameters must be grouped so as to maximize the ease of input. Similar parameters should be placed in the same file; for example all COD data should be in one file and all TSS data in another file. File names and labels should be selected to convey the greatest possible information to the user as to file contents. Parameter labels and units need to be created that readily identify the parameter to laboratory technicians, operators, management and external information consumers. Initial input limits need to be established using professional judgement. Later, limits can be adjusted by a combination of statistical review or the data base and experience. Limits should be wide enough so as to include all reasonable data yet narrow enough to exclude errors. The refinement of limits is a task that will last as long as the system is in use. Data files should be designed with enough spare parameters allocated to meet future expansion. Where possible, all feasible variations in process control should be allowed, unused parameters can be marked as inactive so as not to waste the time and patience of the user tasked with data input. Different parameters generated for the same day often become available at different times. Grab samples such as pH, chlorine residual and temperature are usually available for input on the day of collection. Composite samples are frequently available the next day though tests that require extensive time for analysis such as total solids may become available the day after. And, of course, Biochemical Oxygen Demand values trail in five days later. Data files should be grouped so that all parameters within the file become available for input on the same day. All data file label and limit file definitions are included in Appendix (B).

At the Alexandria Sanitation Authority, laboratory RAW files were defined first and a simple daily report was developed. One process variable, plant flow, was included with the original laboratory data files to allow computation of mass loadings required for calculation of NPDES permit values. An external program was developed to calculate the values required for the monthly NPDES permit. The elimination of the repetitive manual calculations required for the permit was one of the primary objectives of the LOIS system. The permit program was developed before any of the statistical or graphical function modules were coded and before any additional operations data files were defined. The laboratory weekly report was established as the next report to allow rapid data checks of the input data to be performed by laboratory personnel. The weekly report was also distributed to key decision makers to allow an interim overview of plant performance between the daily report and the monthly report.

When the operations data files were developed, the total plant flow parameter was moved to the operations file and deleted from the laboratory file. Responsibility for the chlorine residual data file was also transferred from the laboratory to operations. All operations data files were given names that began with the first two letters PC (process control). This naming convention made it clear which files were the responsibility of the laboratory and which were the responsibility of operations.

Operations Data Log Review

The advent of the LOIS system combined with the availability of a word processing program paved the way for an evaluation of the process control logs. The process managers developed new versions of the process control logs on the computer. The evaluation of the process logs was in itself a considerable undertaking but had several advantages. The traditional practice (typing a master copy of a log and thereafter making copies of it) had several disadvantages. Often, the original form was lost or misplaced. Copies were then made of previous copies, a process that lead to deterioration of legibility. The production of complex forms on a typewriter being an arduous task, forms often remain static for long periods, even if the information requirements have changed. It was not uncommon to see operational logs with some sections never used or some column headings crossed out and new headings penciled in. The movement to computer based log forms allowed a reevaluation of the pertinence of the data collected on each log. Additionally, the data logs were developed in an order designed to make input of data to the LOIS data files as straight forward and logical as possible. In general, a data file contains information that corresponds to one log sheet, additional files are utilized for data from different logs. Hopefully the use of word processor based logs will allow more rapid and timely modifications to be made to the logs in the future. Certainly, clean masters are more readily available from which to make copies.

Calculation Data File Definition

The development of the process data files allowed the LOIS project to advance on to the next logical step. The calculation files could now be developed. The Assistant Engineer-Director, the Director of Operations, the chemist and the process managers were served as an informal committee to define the required parameters to meet the Authority's informational requirements. The staff engineer, with the aid of the process managers, was primarily responsible for the development of the calculations and the identification of input parameters and constants. Parameter definition worksheets were developed for each calculation type. Each worksheet lists the following information about the parameter:

* Equation formula
* CAL File and position within the file of the parameter
* Parameter label, units, and reasonability limits
* Date and person defining the file
* The inputs to be used for calculating the parameter
* Comments and special notes.

The inputs may be RAW or CAL parameters or constants. Parameters are identified by type (RAW or CAL), file number within the specified type and file position within the specified file. Whether the "look back" option is set for each input parameter is also specified. Constants are identified by position in the CONSTANT.TXT file.

During the development of the calculation files, worksheets were filled in by manually and placed in a binder. The worksheets were organized by file and file position. Care was taken to insure that the parameters that served as inputs to other calculations would be calculated in the proper order. Each calculation was performed on a calculator using sample data to insure that the resultant value was correct. After the Calculation ENGine (CENG) module was coded, extensive test runs were performed to insure the accuracy of the results. All parameters were manually calculated for several days and compared with the contents of the CAL files. After the CENG code was verified and the calculations definitions defined, a routine was written to print the current calculation files in a consistent format.

Training

Originally, the laboratory chemist was trained in the use of LOIS for data input and report generation. The chemist trained the senior laboratory technician and together, they trained the remaining technicians. The daily input of laboratory data and the production of the daily laboratory report quickly became a standard task that could be assigned to any technician. A similar pattern was followed in operations. Initially, the data files were defined by the staff engineer and the two process managers. While the operations data files were being developed, the engineer and managers assumed responsibility for data input. Shortly thereafter, the shift supervisors were trained by the process managers. The input of operations data became a standard task of the shift supervisor on duty after midnight when the previous day's data could be compiled form the operations logs.

A series of one hour lectures were given on a bi-weekly basis during the early phases of the LOIS project. The lectures were not solely for the benefit of the LOIS users however. The Authority was experiencing a growth in computer usage in other departments as well as in operations and laboratory. The lectures were designed to give a broad base of understanding for those using computers for word processing, accounting, corrective and preventive maintenance management, purchasing data management, inventory and ,of course, LOIS. The lecture series, which continued approximately six months, covered basic microcomputer architecture, hard disks (especially back up procedures), the Disk Operating System basic commands (copy, format, DIRectory etc.), data base structures (files, records, fields, etc.), graphics standards, printer types and capabilities, basic spreadsheet functions, and other related topics. The last several lectures allowed a representative of each department to present a summary of their departments use of microcomputers. One such lecture was dedicated to the LOIS project.

While the lecture series was a notable successes, attempts to develop a complete set of on-line help files was not. While the process of program code development was underway, the tendency was to write help documentation that was too detailed and too closely related to the program code. Attempts to write help pages that were simple and general in nature produced help that was not noticeably more helpful than the menu selection titles. In both cases, users of the LOIS system ignored the on-line help files. Most users learned the basics of the system from coworkers. Additional expertise seemed best developed from experimentation. The LOIS data files are generally immune from disruption caused by experimentation except operations that must be carried out from the SYStem OPerations module. In the early stages of implementation, entry to the SYSOP module was password protected and users were encouraged to experiment with the system. The password protection seemed unnecessary as users became more comfortable with the system. The statistical and graphical functions and the data export functions are among the most popular and flexible routines in the LOIS system. These routines were written so that they read the data base files but never write to the data base files. The routines are there fore safe from inadvertent damage.

The combination of one on one instruction, freely encouraged experimentation and a menu driven user interface has proved sufficient for most of the training needs required by the Authority to implement and use the LOIS system. The menu commands for data input, data editing and standard report generation are sufficiently simple that new users are often trained in two or three one hour sessions. Unfortunately, new users are then often not further trained in the statistical, graphical, export and custom report functions. Top management personnel particularly do not have the time to learn the system by trail and error. The development of a comprehensive set of instructions and full documentation would help users gain access to all system functions and maximize system utilization.

Process Daily Report

The next milestone in the implementation of the LOIS project was the development of the process daily report (Appendix A). The daily report is generated during the early hours after the previous day's operational data is available. The report is then distributed to the key operations decision makers. It is generally on their desks when they arrive in the morning. The process daily report is a daily report in the sense that it is produced on a daily basis but not in the sense that is contains only one day's data. The process daily report was designed to present the most current data available to the LOIS data base at the time the report is generated along with some recent historic data to indicate trends. The three page report has main stream information on the first page, sidestream information on the second page and reasonability limit excursions and comments on the third page.

The first page is split in to three time zones as follows :

Zone one : current day -

* Main stream - flow, weather, chemical and utility use data
* Calculated unit detention times and loadings
* Chlorination feed, dose and residual result summary

Zone two : previous day -

* Lab composite results for TSS, COD, Total P, etc.

Zone three : Ten day trends -

* Final TSS, COD, BOD, Predicted BOD
* Flow and Rain
* Average BOD month to date

The importance of final BOD results to the Authority is evident. The predicted BOD for a day is calculated from the day's COD and the ten day rolling average of the COD/BOD ratio. As can be seen in Figure 22, the COD/BOD ration changes gradually but over a substantial range seasonally. The use of the most current ten days rolling average value both adjusts for seasonal variation and dampens the effects of extreme variations possible for a particular day. Significant variations of the COD/BOD ration are often associated with high flow events driven by rainfall.

The second page of the process daily report presents sidestream information in an order corresponding to the process train order; thickening, digestion and dewatering. The most current available data is severely impacted by the extra days delay imposed by the total solids and total volatile solids test procedures. The following information is available for the three sidestream process units:

Thickening :

* Feed - % TS and % TVS, Flow and Pounds from the primary and secondary clarifiers
* Thickener overflow - Concentration and Pounds
* Thickener level - three days of blanket levels are presented to show trends

Digester :

* Level - three days levels are presented to show trends

* Feed - thickener underflow concentration and pounds
* Average retention time
* Volatile solids per cent reduction
* Loading as pounds volatile solids per cubic foot
* Grab operating parameters - Volatile Acids, Alkalinity, VA/ALK Ratio, Temperature, % Methane

Dewatering :

* Feed - concentration (TS and TVS), flow and pounds
* Centrate - concentration (Mg/L TSS), and pounds
* Chemical addition - pounds polymer and lime used, pounds per dry ton, pH after two hours
* Sludge hauled - wet and dry tons, destination

During the course of the LOIS project development, the Authority's sludge disposal method changed dramatically. The previous procedure had consisted of hauling wet sludge to a composting facility at the Fairfax County landfill site in Lorton, VA. The compost operation was closed and a private contractor began land application at various sites Virginia and Maryland. Concurrent with the switch to land application, the Authority began a post-dewatering lime addition operation. The switch required the process data files to be expanded to account for lime usage, sludge pH values for every truck load, and a destination code. The calculated files were expanded to compute per cent lime added per dry ton and to keep a running inventory of the lime silo inventory.

The third page of the process daily report has two sections. The first section is generated by a comparison of every parameter in the data base for a three day period to the currently assigned reasonability limits. Any limit excursion triggers a report line for the day that consists of the following information:

* Parameter file
* Label and Unit
* Reported Value
* Value of Limit exceeded

The second section of the third page lists comments, if any, entered by laboratory or operations personnel for the report date.

Monthly Report

The development of the operations raw data files and the calculation files allowed the development of a more comprehensive monthly report. While the NPDES program was completed early in the LOIS project development scheme, the NPDES focuses entirely on the final effluent. Historically, the Authority had produced a monthly report which included commentary in operations, financial and regulatory affairs. Included in the monthly report was a summary of plant operations statistics. One of the design goals of the LOIS project was to eliminate the manual calculations and tedious copying of data to the monthly report sheets. The LOIS monthly report (Appendix A) was developed to meet this goal. The monthly report features a two page summary sheet and six pages of detailed data. Parameters included in the monthly report are :

* Weather data - temperature and rain
* Flow data - daily totals, maximum and minimum
* Utility Use data - water, electricity and natural gas
* Chemical Use data - Alum, Ferric Chloride and Chlorine mass used and computed dose concentration
* Main Stream concentration and pounds of TSS, BOD, Phosphorous, pH, Dissolved Oxygen at key points in the process train.
* Digester Operations - Feed (gallons, concentration and pounds), pH, Volatile Acids, Alkalinity and Temperature
* Grit and screening volumes removed.
* Dewatering operations - Feed (gallons, concentration and pounds), Cake (concentration, wet and dry tons), polymer and lime usage, pH of cake after lime addition.
* Monthly averages, minimums, maximums and , where appropriate, totals for all parameters.
* Wet tons for each land application site each day and all sludge truck pH values.

The first monthly report developed included a single page summary however the switch to land application and lime addition to the sludge cake necessitated an expansion to a two page summary. The first page includes weather and main stream information, the second page includes information covering sidestream operations, sludge disposal and utility use.

Program Module Development

Obviously, the total LOIS project could not be transformed overnight from an information model to a complete and debugged set of programs. The task of creating the program codes was broken down into a set of modules that could be created and tested one at a time. Each new module added to the system would further meet the original system goals. Modules could be further developed by stepwise refinement after being installed in the system. Many of the refinements in the system came about at the suggestion of the systems users. The basic data input and edit functions were implemented first. The functions required to create data files; set up label and limit files and add to the file lists; were performed with a text editor before these functions were available through the SYSOP modules. Likewise, the SETUP.TXT environment table was originally manipulated with a text editor. The section of the LOIS main module that provided transfer of control between the other modules was developed early in the project.

The initial file export routines were also written early in the project. File export to commercial spreadsheet programs allowed graphical analysis before the LOIS statistical and graphical analysis modules were completed. The refinement which allowed parameters from different files to be mixed within one export file enhanced the usefulness of this procedure. Still, the time and training required to transfer data to an export file, import the data in a spreadsheet, and create a graph within the spreadsheet, limited the usefulness of graphical analysis. One of the major drawbacks of spreadsheets was the cumbersome process that was required in order to perform a linear regression or a control chart. Observation of the uses developed for spreadsheet graphs and statistics along with user comments did provide the basis of design for the LOIS graphical and statistical functions.

As the LOIS project progressed, creation of modules became easier as a library of tested routines was developed. When a subprogram was developed that would be useful to other programs, it was moved to a module containing common subroutine called COMLOIS. Thus, when a routine was developed to select a data file, a new module did not have to reinvent that procedure, a call to the appropriate subroutine could be placed. The COMLOIS module contains the subprograms listed in Table VII.

The subroutines utilized by multiple modules may be split into groups. One group covers system functions such as reading the SETUP.TXT file and setting the screen colors. Another group maintains the common user interface. The three subroutines MENU, ENT123, and CTITLE give all of the LOIS modules the same basic look and feel. The group that covers file selection, parameter selection and reading the LAL files, SELFILE, MESSELECT and LABELREAD also help maintain a common user interface between modules. The GGET and PPUT subroutines allow common services in the reading and writing of random access data files.

The use of a common include file at the beginning and end of all modules also helps maintain a common environment in all modules. The starting common include file (COMLOISB.BAS) contains the declare statements required to support the common subroutines, allows the SETUP.TXT values to be shared between all modules by declaring the SET$() array to be common, dimension arrays used in all modules, defines variables starting with I or J to be short integers, and sets the default error trapping routine to be XERR. The include file (COMLOISE.BAS) contains two functions. The common error trap program (XERR) prints the number and descriptor for almost any error that is encountered while the program is running. The user is presented with options to resume on the same or next program line, restart the program at the beginning of the current module or quit to DOS. This function has proven invaluable during program development and testing. Often the user can continue a program in place when the error is something simple such as a printer turned off or a disk drive door open. The second subroutine in the ending include file is a common field statement utilized by all random access data files. Why this subroutine could not be included in the COMLOIS module of subroutines is not addressed in the QuickBASIC documentation.

The development of the SYStems OPerations (SYSOP) module and it's subprograms, DEFine CALculation (DEFCALC) and DEFine REPort (DEFREPT), did not begin until the laboratory data files were well established and the operations data files were under development. The SYSOP module allows easy creation of RAW data files, CAL data files, reports and editing of the SETUP.TXT system definition file. The RAW data files had previously been established using a text editor, a process that required intimate familiarity with the systems file specifications. The SYSOP module allows the user to create or add parameters to files by answering questions as to parameter labels, units and limits. This alleviate need for the user to be concerned with the exact placement of information in the files or the required punctuation. Likewise, the SETUP.TXT file may be modified by menu selections. With a text editor, the user must know which line number of the file corresponds to which system functions and which values are valid.

The LABoratory Quality Control (LABQC) module was the last major module developed. While the structure of the data files for the LABQC module was different than the LOIS data files, the LABQC program did borrow heavily from the common routines developed for the LOIS modules. The control chart graphics package was initially borrowed completely from the STATREV module. The graphics routines were modified later to allow dynamic limit plotting and the autorange functions was modified to allow greater resolutions around the one hundred ranges common for accuracy plots. The file selection subroutines needed to be modified to meet the needs of the three type of QC files (Precision, Accuracy and Data Point) as opposed to the two type normal in the LOIS main data base (RAW and CAL). The standard reports provided with the QC program also had to be written from scratch.

While the completion of the LABQC module represented the end of the main program development phase of the LOIS project, the need to update the system to meet changing circumstances must to be stressed. The environment in which the LOIS system operates is constantly in flux. Though the system was designed with the flexibility for users to be able to add new parameters, define new calculations and create new reports, the need for changes that require a programers efforts never seems to disappear entirely. The intent in the development of the LOIS project's code was to be logically enough written and clearly enough documented so that future maintenance needs will be small and the system can be utilized for many years.

Table VII

COMLOIS Subprograms

Name	Function
SETS	Reads SETUP.TXT file, assigns values to array SET$().
SETCOLOR	Sets screen colors per SETUP.TXT values if SET$(16)is not four indicating Hercules adapter.
CAL	Allows date input in YY/MM/DD format, returns julian date. Input of Q returns ICALERR% set to one. Checks input for valid date. Calls RCAL to return date strings.
RCAL	Accepts Julian date - returns YY/MM/DD and MM/DD.
DCAL	Accepts Julian date - returns day of week (Monday, Tuesday, etc.) Returns day code : Sunday = 1 , Monday = 2...
CTITLE	Accepts a Title, clears screen page, prints time and date on screen, centers string in SETUP.TXT position 19 on first line, centers passed title on third line.
MENU	Accepts a Title and eight menu selection strings in an array calls CTITLE to display title, displays up to eight menu options plus Quit, Help and Main Menu options; returns number options elected. Includes help menu routine and quit to DOS routine.
ENT123	Loops waiting for keyboard input of number, returns number. Enter key is interpreted as input of one (default selection).

(Cont)

Table VI (Cont)

COMLOIS Subprograms

Name	Function
SELFILE	Accepts three options : 1. User select RAW file 2. User select CAL file 3. Read RAW and CAL files to array FF$() Returns file name, number and label for options 1 and 2. Returns arrays of file names and labels and number of files for option 3.
MESSELECT	Accepts selected file number and type and calls LABELREAD for parameter labels and limits. Allows user selection of individual parameter within selected file.
LABELREAD	Accepts selected file number and type, reads appropriate LAL file contents to arrays for labels, units and limits.
GGET	Reads data record from disk buffer for standard LOIS data file; returns 32 numeric values in array O().
PPUT	Writes 32 values to disk record for opened LOIS data file from array O().
COMRND	Accepts numeric data point, determines nine character print mask (PF$) depending on magnitude of value.
PRTCOM	Accepts number of print command in SETUP.TXT SETUP.TXT, parses print command in \nnn format routes ASCII character corresponding to of nnn printer.

VII. Discussion

An evaluation of the Laboratory and Operations Information System (LOIS) developed for the Alexandria Sanitation Authority (ASA) must hinge on the projects value to the organization. Did the project meet the design goals? Are the needs of information consumers being meet? Are fewer or more errors being made in data management? Are fewer or more hours being spent on data management? Can the system be expected to serve the needs of the organization for a long period?

The eleven goals enumerated under Information System Requirements could be used as a scorecard for evaluating the success of the LOIS project. Certainly the Deputy Director-Engineer has been relieved of the tedious tasks of copying data and performing repetitive calculations (Goal 1). The process daily report substantially meets the goals of providing information on a timely basis to key decision makers and the field staff (Goals 2 and 3). The combination of daily, weekly, monthly reports and the functions available through the statistical and graphical functions provided by LOIS largely meets the requirements of goal 4. Further training of top management in the use of the LOIS statistical functions combined with the availability of computers with the LOIS data base installed in their offices would complete this requirement. The Laboratory Quality Control program has matched the requirements of goal five to the satisfaction of those involved.

Goal 6 was stated as "Provide data integrity and error detection methods." This goal is difficult to measure or judge. Certainly the system of input reasonability limits has helped eliminate the kind of gross errors that have given computers a bad reputation. Occasionally errors are detected in the input or computation of flow data, usually involving the transposition of numbers. This type of input error is difficult to trap. To help avoid mistakes, all laboratory values are double checked against the bench sheets when the weekly reports are generated. The generation of the monthly report is used as an opportunity for data to be reviewed by several people, including the chemist, Director of Operations, Staff Engineer and process managers.

A further problem arises when samples are not representative. Infrequently, a test seems to be performed properly but the result does not seem credible. When an exceptional value does not seem to be supported by any other samples taken on that day, nor by historic patterns, a question arises as to how that data point should be treated. Instances such as this require professional judgement and can not reliably be left to the computer program. The adjustment procedure and file were developed to track when humans needed to exercise judgment over the values entering the data base.

The requirements of the LOIS system that were listed as goals seven, eight and nine refer to long term reports: permit, monthly and annual. The permit and monthly reports have proven themselves reliable over a period of many months. To date, only one annual report has been generated, utilizing a program that borrows heavily from the monthly report code. The compilation of long term report values had been one of the major time consuming functions of the old pen and ink system. The LOIS system has excelled at relieving the monotony and chance for mistakes associated with the long term report generation process.

The combination of flexible report formatting, external file export capabilities and statistical and graphical services has meet the needs of all external information consumers to date. The only wish expressed was has that the LOIS data base extended further back in time. The manpower required has not been available to enter data which predated the start of the LOIS project. However, the mainstream process manager has undertaken voluntarily to backfill process data to the point where laboratory data began to be entered.

The LOIS project has met the initial goals that were developed for the project. That is not to say that the system does not have limitations nor that further goals should not be established. The inclusion of utility and chemical costs could facilitate the use of the LOIS system as a tool in cost control and budgeting. While the LOIS system provides a dramatic increase in the ability of users to view operational trends and relationships, this does not automatically translate into improved plant performance. The capability to observe trends does not necessarily imply the ability to change such trends. For example, one of the most common patterns apparent in the operation of the Authority's treatment plant is the degradation of final BOD on a seasonal basis. The Laboratory Operations Information System has no ability to overcome basic shortcomings in the design of the treatment plant or to make winters warmer.

The LOIS project could be expanded in several areas. The system was designed to accept laboratory data as final values from the traditional laboratory benchsheets. The calculations performed on the benchsheets are repetitive and permit the possibility of error. This presents an ideal opportunity for computerization. A front end data reduction program could be designed to accept raw analytical data, compute the final analytical values and insert them in the main LOIS data base. For BOD analysis, the initial and final dissolved oxygen values, dilution factor, blank and seed depletions would be entered into the data reduction program. The program could check for reasonability ranges of all data inputs and maximum acceptable depletions before the final value was calculated. Duplicate and spiked samples could automatically generated quality control records to be automatically inserted in the QC data base. The calculated BOD for the sample would be inserted into the LOIS main data file. The development of laboratory equipment with direct digital or analog outputs provides another opportunity to eliminate manual data manipulation and the inherent chance of error. Direct digital output or analog outputs that may be converted by fairly common analog to digital (A/D) circuit boards are available for a wide range of laboratory instrumentation.

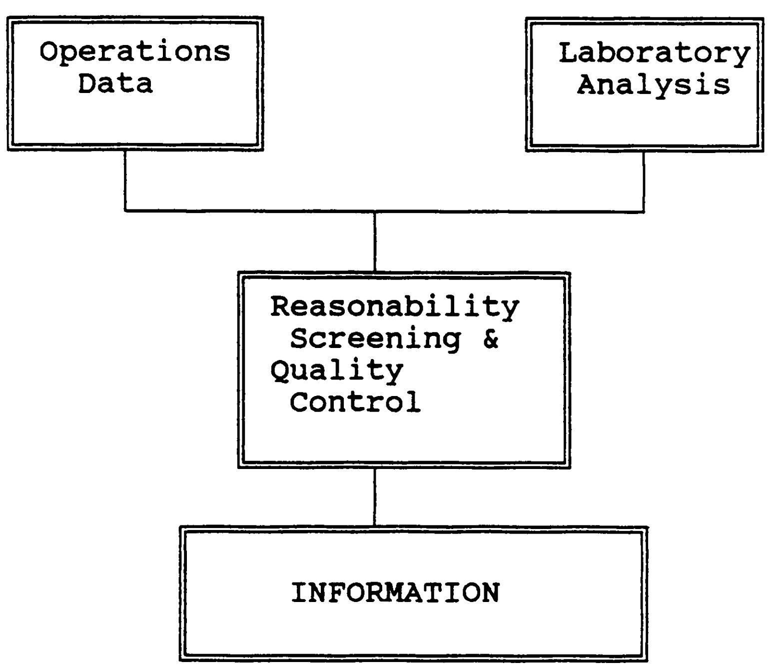
An analogous situation exists for direct operational data input. The industry is moving away from the behemoth central computers which characterized the early Computer Control Systems (CCS). In their place, a new generation of distributed process systems utilizing Programmable Logic Controllers (PLC) are being incorporated in wastewater treatment plant control systems. Frequently, the PLC networks include gateways for communications with microcomputers. The most common gateways match the RS-232 serial communications ports standard on microcomputers. Often, the PLC logic may be developed on a microcomputer and downloaded to the PLC. The gateway is also frequently utilized for output of operational data in format compatible with microcomputers. ASCII data files, DIF files and Lotus spreadsheet files have been made available by some vendors for operational data capture by microcomputer programs. The LOIS programs already include an ASCII data file import function. Modifying the import function or writing a translation routine would not pose a major difficulty.

A logical expansion of the LOIS project would be to implement the system on a local area network. Currently, the main LOIS data base resides on a computer in a common office area of the AWT building. All input to the main data base is accomplished on the AWT office computer. Reports and graphs are generally produced on the same microcomputer. The LABQC data base is maintained on a microcomputer located in the chemists office. Copies of the two data bases are periodically transferred on floppy disk between the two microcomputers. A third copy of the LOIS main data base is maintained on the microcomputer in the shift supervisors office. Only one copy of the LOIS data base or the QC data base is guaranteed to be current at any time however. Currently, this arrangement suffices and a local area network has not seemed to be a cost effective option. However the system is strained by several factors. The AWT computer is also used for several other functions including but not limited to; system development, pretreatment record keeping and correspondence, local limit development. The users of the AWT computer include the shift supervisors, the process managers, the laboratory staff, the staff engineer and the pretreatment coordinator. Obviously, this has become a highly utilized microcomputer. The Director of Operations and the Deputy Director-Engineer have not felt fully comfortable taking a place in line to learn and experiment with the LOIS system. If the system were expanded to include direct input of laboratory instrumentation or input via benchsheet data reduction programs, a facility for input over a network would become necessary. The inclusion of more microcomputers in the offices of key decision makers who needed to utilize the LOIS data base would also render the current practice of walking a pile of floppy disks around to update copies of the database untenable. Ultimately, the LOIS data base could accept inputs from and provide information to computers in the laboratory, the AWT office area, and the offices of the Director of Operations, the Staff Engineer and the Deputy Director-Engineer. The Authority will continue to evaluate both the needs of the Authority and the cost effectiveness of local area networks as the network market matures.

A more speculative use of the LOIS data base might be to serve as the basis of an expert system. Advances are required on two fronts to bring artificial intelligence to the wastewater treatment field in this century. First, more interest and effort is needs to be focused on dynamic modeling of the forces at play in a complex treatment process. Traditional static design models are not a sufficient basis for an artificial intelligence system. Second, the computer software currently used to implement artificial intelligence programs requires further refinement and greater sophistication before such programs prove a practical investment for a publicly owned treatment works.

VIII. Conclusions

The implementation of a Laboratory and Operations Information System (LOIS) at the Alexandria Sanitation Authority Advanced Wastewater Treatment facility was founded on previous developments in Laboratory Information Management Systems (LIMS), wastewater treatment plant Computer Control Systems (CCS) and the advances in microcomputer hardware and software. Particular emphasis was placed on innovations in structured programming and the development of information models that relate the total flow of information in the organization with the computerized portions of the operation. The complex LOIS information model may be summarized in the following manner :



The LOIS project demonstrated that an information system using microcomputers at a major wastewater treatment plant provided the following benefits over traditional "pen and ink" data management systems :

1. Elimination of tedious and error prone data transcription and manual calculation of process loadings.
2. Provision of timely information reports to managers and supervisors in the organization.
3. Flexible graphical and statistical analyses that would not be feasible without computer assistance.
4. Provision of information for external consumption in a variety of formats: printed, in various computer file formats and graphs.
5. Provision for growth, maintainability and flexibility to meet future conditions.

Finally, it must be emphasized that the cooperation and suggestions of system users form the top of the organization down to operations shift supervisors and laboratory technicians is essential to the success of any LOIS project.

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Appendix A - LOIS Reports

Alexandria Sanitation Authority
Summary Sheet
Monthly Report: September 1989

Description	Units	Monthly Total	Average Daily	Maximum Daily	Minimum Daily
Temperature	F° Max.		80	96	74
	Min.		63	65	46
Precipitation					
Rain	in.	6.71		1.84	
Snow	in.	0.0		0.0	
Sewage Flow Treated					
Volume	M. G.	1148.302	38.475	55.714	31.024
Flow Rate (Max.)	M.G.D.		65	100	46
(Min.)	M.G.D.		28	46	20
Grit Removal					
Cubic Feet Removed (Wet)		2569	86		
Total Solids	%		64		
Volatile Solids	%		16		
Dry Grit Removed	KLbs	114.1	3.8		
Screenings Removed					
Cubic Feet (wet)		976	33		
Biochemical Oxygen Demand					
Raw	Mg/L		152	193	98
	KLbs	1453	48		
Final	Mg/L		10	14	7
	KLbs	99.2	3.3		
Removal	%		93.2		
	KLbs	1354	45		
Suspended Solids					
Raw	Mg/L		152	214	113
	KLbs	1463	49		
Final	Mg/L		2.5	5.6	0.9
	KLbs	24.8	0.8		
Removal	%		98.3		
	KLbs	1438	48		
Total Phosphorous					
Raw	Mg/L		4.19	6.42	2.70
Final	Mg/L		0.04	0.09	0.02
Removal	%		98.9		
Chlorination					
Total Feed	LBS	70510	2350	2680	1930
Outfall Residual	Mg/L		0.49	0.54	0.42

Alexandria Sanitation Authority
Summary Sheet 2
Monthly Report: September 1989

Description	Units	Monthly Total	Average Daily	Maximum Daily	Minimum Daily
Total Raw Sludge to Digestion					
Volume	KGal	5768	192		
Total Solids	KLbs	2242	75		
Volatile Solids	KLbs	1407	47		
Digester Operations					
Digester #1 Loading	#VS/CuFt		0.12		
#2 Loading	#VS/CuFt		0.12		
Dig #1 V. Acid / Alk. Ratio			0.18		
#2 V. Acid / Alk. Ratio			0.15		
Volatile Reduction Dig #1 %			36.4		
Dig #2 %			39.3		
Gas Production	KCu Ft	10940	365		
Total Sludge to Dewatering					
Volume	K Gal	6081	203		
Total Solids	KLbs	1711	57		
Volatile Solids	KLbs	875	29		
Sludge Cake					
Total Wet (Inc. Lime)	Tons	6008	231.1		
% Solids (Before Lime)	%		20.1	21.6	18.1
** Dry Sludge Solids	Tons	1152	44.3		
pH Test 24 Hr	pH		12.3	13.0	12.0
** Dry Tons = ((Wet Tons - Lime) * %TS)					
Lime: Added	Tons	272.6	10.5		
% of Dry Cake	%		24.0		
Utilities					
Electric	100 KWH	15655	522	643	454
Water	KGal	2293	76	130	41
Gas	KCuFt	1220.0	40.7	57.5	13.6

Alexandria Sanitation Authority
NPDES Report

Dates : 89/ 9/ 1 - 89/ 9/ 30

Report run : 10-06-1989 10:51:48

PARAMETER / UNITS	AVERAGE	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM	EXCEPTIONS
FLOW (MGD)	38.5	55.7				
pH (SU)			6.0		7.0	0
BOD5 (KG/D - Mg/L)	1506	1722		10	11	0
T. Sus. Solids (KG/D - Mg/L)	376	454		2.5	2.9	0
Total Cl2 (Mg/L)			0.25		1.00	2
Fecal Coli. (N/CMl)				1	2	0
Dis. Oxygen (Mg/L)			6.7			0
T. Phosphorous (KG/D - Mg/L)	6.6	8.2		0.04	0.05	0
T. Cl2 (max) (Mg/L)					1.00	0
Alkalinity (Mg/L)				80.5	93.6	
O. Phosphorous (Mg/L)				0.02	0.03	
TKN (Mg/L)				19.8	24.9	
NH3 - N (Mg/L)				17.2	22.3	
NO3 - N (Mg/L)				0.1	0.1	
NO2 - N (Mg/L)				0.1	0.1	

Alexandria Sanitation Authority
Monthly Report: September 1989 Page: 1

Day		Weather: Air Temp Max	Air Temp Min	Precipit. Rain	Precipit. Snow	Flow (MGD) Total	Flow (MGD) Max	Flow (MGD) Min	Sewage Temp	Plant Bypass MGD
1	F	87	69	0.01	0.0	42.626	67	32	76	0.0
2	S	89	70	0.01	0.0	42.037	67	31	76	0.0
3	S	80	63	0.00	0.0	38.208	66	29	76	0.0
4	M	79	60	0.00	0.0	40.825	73	29	74	0.0
5	T	80	61	0.00	0.0	41.156	65	29	74	0.0
6	W	82	66	0.00	0.0	41.384	66	28	74	0.0
7	T	84	67	0.00	0.0	41.382	65	31	75	0.0
8	F	83	65	0.00	0.0	39.085	64	30	74	0.0
9	S	89	69	0.00	0.0	33.317	53	24	76	0.0
10	S	96	72	0.00	0.0	35.665	58	20	75	0.0
11	M	94	74	0.00	0.0	41.196	72	30	77	0.0
12	T	80	70	0.03	0.0	42.300	66	30	76	0.0
13	W	79	72	1.62	0.0	48.081	99	30	75	0.0
14	T	86	72	0.01	0.0	44.815	66	30	75	0.0
15	F	83	73	0.00	0.0	34.013	64	31	76	0.0
16	S	77	67	1.84	0.0	39.631	85	21	75	0.0
17	S	80	64	0.00	0.0	34.863	64	26	74	0.0
18	M	75	60	0.00	0.0	31.024	46	26	76	0.0
19	T	68	63	0.29	0.0	34.160	76	25	74	0.0
20	W	78	64	1.10	0.0	40.369	66	32	74	0.0
21	T	89	74	0.01	0.0	35.830	59	30	75	0.0
22	F	86	74	0.10	0.0	36.097	56	26	77	0.0
23	S	81	50	0.18	0.0	35.793	70	26	73	0.0
24	S	65	46	0.00	0.0	32.810	54	24	71	0.0
25	M	66	48	0.36	0.0	33.471	53	24	72	0.0
26	T	73	56	1.15	0.0	55.714	100	46	71	0.0
27	W	65	49	0.00	0.0	34.419	55	26	71	0.0
28	T	67	46	0.00	0.0	33.061	54	24	70	0.0
29	F	74	52	0.00	0.0	32.282	52	24	71	0.0
30	S	70	60	0.00	0.0	32.688	53	26	72	0.0
Tot.				6.71	0.0	1148.302				0.0
Avg		80	63	0.22	0.0	38.277	65	28	74	0.0
Max		96	74	1.84	0.0	55.714	100	46	77	0.0
Min		65	46	0.00	0.0	31.024	46	20	70	0.0

Day		Utilities: Elect 100KWH	Water KGal	Gas KCuFt	Chemical Feed: Ferric Gal	Ferric Mg/L	Alum Gal	Alum Mg/L	Chlorine LBS	Chlorine Mg/L
1	F	554	92	52.4	8900	33	1600	24	2450	0.54
2	S	535	61	40.3	7800	29	1400	21	2430	0.49
3	S	456	60	29.9	7000	28	1300	22	2220	0.53
4	M	547	59	38.2	8500	32	1600	25	2310	0.43
5	T	526	80	50.1	8900	34	1400	22	2480	0.48
6	W	530	91	50.2	8900	33	1200	21	2580	0.49
7	T	528	95	54.0	8300	30	1200	18	2490	0.50
8	F	516	130	35.6	8600	34	1200	20	2560	0.49
9	S	494	100	50.8	6600	31	1300	26	2540	0.47
10	S	482	77	40.8	6700	29	1400	26	2490	0.46
11	M	586	109	13.6	8400	32	1200	19	2580	0.49
12	T	502	73	47.2	8700	32	1300	19	2380	0.48
13	W	545	95	37.5	8200	26	1400	19	2650	0.51
14	T	576	87	41.0	6800	23	1300	19	2390	0.50
15	F	497	85	44.4	7800	35	1400	26	2530	0.50
16	S	514	56	36.2	9000	34	1800	30	2680	0.49
17	S	509	41	31.3	4700	16	1600	29	2200	0.50
18	M	526	64	38.5	6100	28	1300	26	2230	0.49
19	T	504	56	57.5	9300	42	1100	19	2200	0.50
20	W	535	71	23.0	9100	33	1500	23	2160	0.42
21	T	506	87	42.3	7600	31	1400	23	2160	0.51
22	F	509	62	46.7	7100	29	1400	25	2210	0.49
23	S	526	66	40.4	8000	34	1400	24	2500	0.50
24	S	468	43	39.8	8400	40	1200	22	2100	0.50
25	M	530	50	37.9	8100	37	1100	22	2200	0.51
26	T	643	60	47.5	9800	26	1400	16	2240	0.49
27	W	514	70	35.6	7800	35	1300	25	2360	0.49
28	T	516	82	35.5	6200	28	1300	25	2060	0.48
29	F	528	84	35.8	6500	29	1300	25	1930	0.49
30	S	454	109	46.0	7400	32	1200	24	2200	0.48
Tot.		15655	2293	1220.0	235000		40800		70510	
Avg		522	76	40.7	7800	31	1400	23	2350	0.49
Max		643	130	57.5	9800	42	1800	30	2680	0.54
Min		454	41	13.6	4700	16	1100	16	1930	0.42

Alexandria Sanitation Authority
Monthly Report: September 1989 Page: 2

Day		BOD 5 RAW Mg/L	RAW KLbs	PE Mg/L	BDE Mg/L	FINAL Mg/L	FINAL KLbs	F.Coli FINAL N/100 Ml	D.O. FINAL Mg/L
1	F	193	69	53	18	14	5.0	89	7.3
2	S	173	61	71	24	14	4.9	4	7.0
3	S	135	43	44	12	11	3.5	0	7.2
4	M	181	62	60	19	12	4.1	1	7.3
5	T	152	52	49	16	11	3.8	0	7.2
6	W	158	55	48	18	10	3.5	1	7.2
7	T	173	60	52	16	12	4.1	0	7.0
8	F	167	54	43	13	9	2.9	1	6.8
9	S	154	43	54	16	8	2.2	0	7.0
10	S	169	50	62	16	11	3.3	11	7.0
11	M	156	54	56	18	13	4.5	0	6.7
12	T	155	55	48	14	11	3.9	0	7.2
13	W	170	68	63	15	11	4.4	0	7.2
14	T	156	58	62	17	12	4.5	0	6.9
15	F	151	43	58	15	12	3.4	1	6.8
16	S	115	38	50	11	8	2.6	0	6.9
17	S	135	39	72	16	10	2.9	1	7.3
18	M	148	38	74	16	11	2.8	2	7.3
19	T	141	40	56	11	12	3.4	1	7.3
20	W	98	33	33	10	7	2.4	0	7.4
21	T	123	37	34	10	8	2.4	0	7.2
22	F	155	47	45	12	9	2.7	0	7.1
23	S	150	45	45	12	7	2.1	0	7.3
24	S	148	40	44	10	9	2.5	0	7.5
25	M	170	47	59	15	8	2.2	0	7.4
26	T	124	58	39	12	9	4.2	1	7.6
27	W	137	39	37	13	9	2.6	22	7.3
28	T	141	39	53	13	9	2.5	0	7.8
29	F	155	42	66	14	11	3.0	0	7.5
30	S	167	46	64	17	11	3.0	0	7.5
Tot.			1453				99.2		
Avg		152	48	53	15	10	3.3	1	7.2
Max		193	69	74	24	14	5.0	89	7.8
Min		98	33	33	10	7	2.1	0	6.7

Day		TSS RAW Mg/L	RAW KLbs	PE Mg/L	BDE Mg/L	FINAL Mg/L	FINAL KLbs	TOTAL P RAW Mg/L	TOTAL P FINAL Mg/L
1	F	154	55	31	35	2.6	0.9	4.35	0.04
2	S	152	53	42	36	3.3	1.2	4.65	0.06
3	S	143	46	23	33	2.6	0.8	4.78	0.05
4	M	176	60	39	30	3.2	1.1	4.90	0.05
5	T	161	55	23	24	1.8	0.6	4.25	0.03
6	W	120	41	25	25	1.7	0.6	6.42	0.03
7	T	158	55	25	23	1.6	0.6	5.05	0.03
8	F	143	47	20	31	1.9	0.6	4.30	0.03
9	S	133	37	29	38	1.4	0.4	3.72	0.03
10	S	173	51	31	36	2.2	0.7	4.08	0.04
11	M	162	56	28	31	2.2	0.8	4.32	0.04
12	T	153	54	24	28	2.1	0.7	3.80	0.04
13	W	214	86	48	34	3.1	1.2	3.78	0.06
14	T	177	66	48	34	4.4	1.6	4.32	0.08
15	F	170	48	41	34	4.6	1.3	4.35	0.09
16	S	134	44	50	30	2.0	0.7	3.10	0.02
17	S	113	33	52	32	4.8	1.4	2.70	0.07
18	M	135	35	58	55	2.6	0.7	4.72	0.06
19	T	168	48	44	45	3.2	0.9	4.38	0.08
20	W	141	47	20	22	1.2	0.4	3.96	0.02
21	T	138	41	18	20	1.1	0.3	3.45	0.02
22	F	143	43	27	29	1.2	0.4	3.50	0.02
23	S	150	45	28	27	0.9	0.3	4.58	0.02
24	S	138	38	26	52	1.1	0.3	3.88	0.02
25	M	196	55	36	34	1.2	0.3	4.90	0.03
26	T	124	58	38	31	5.6	2.6	3.10	0.09
27	W	146	42	21	23	2.9	0.8	3.92	0.03
28	T	134	37	46	32	2.2	0.6	3.92	0.03
29	F	136	37	38	42	3.4	0.9	4.10	0.06
30	S	188	51	36	40	4.0	1.1	4.42	0.07
Tot.			1463				24.3		
Avg		152	49	34	33	2.5	0.8	4.19	0.04
Max		214	86	58	55	5.6	2.6	6.42	0.09
Min		113	33	18	20	0.9	0.3	2.70	0.02

Alexandria Sanitation Authority
Monthly Report: September 1989 Page: 3

DIGESTER 1

Day		Feed KGal	% TS	KLb TS	% TVS	KLb VS	Operation pH	V.Acid	Alk	Temp
1	F	120	4.78	48	63.8	31	6.9	520	2200	92
2	S	120	4.78	48	65.5	31	7.0	490	2100	92
3	S	120	4.58	46	66.1	30	6.9	500	2200	92
4	M	70	4.66	27	67.0	18	6.9	530	2300	92
5	T	100	5.04	42	66.7	28	6.9	380	2300	92
6	W	100	4.94	41	64.5	27	7.0	490	2300	92
7	T	100	4.74	40	64.2	25	6.9	420	2400	92
8	F	100	5.04	42	65.2	27	7.0	500	2300	92
9	S	100	4.67	39	65.4	25	6.9	560	2300	92
10	S	80	4.66	31	65.0	20	7.0	440	2200	92
11	M	100	4.81	40	65.8	26	7.1	320	2300	93
12	T	100	4.74	40	65.1	26	7.1	440	2400	92
13	W	120	5.10	51	60.8	31	7.0	340	2300	92
14	T	80	5.68	38	57.4	22	7.0	340	2400	92
15	F	80	5.89	39	57.7	23	7.0	410	2300	92
16	S	80	5.63	38	56.6	21	7.0	560	2500	92
17	S	80	5.18	35	55.9	19	7.0	450	2400	92
18	M	100	4.90	41	59.8	24	7.0	380	2500	92
19	T	100	4.68	39	62.7	24	7.0	370	2400	92
20	W	100	4.40	37	60.8	22	6.9	340	2300	92
21	T	100	4.18	35	60.4	21	7.0	340	2100	92
22	F	100	4.81	40	62.1	25	7.0	300	2200	92
23	S	100	4.07	34	63.5	22	7.0	290	2200	92
24	S	74	3.92	24	63.3	15	7.0	210	2000	92
25	M	80	3.31	22	62.5	14	7.0	370	2200	92
26	T	80	3.98	27	62.6	17	6.9	460	2100	92
27	W	100	3.82	32	59.6	19	7.0	360	2000	92
28	T	100	4.14	35	63.0	22	6.9	400	2100	92
29	F	100	4.32	36	64.1	23	6.9	340	2100	92
30	S	100	4.39	37	64.5	24	6.9	330	1900	92
Tot.		2884		1121		704				
Avg		96	4.66	37	62.7	23		410	2200	92
Max		120	5.89	51	67.0	31	7.1	560	2500	93
Min		70	3.31	22	55.9	14	6.9	210	1900	92

DIGESTER 2

Day		Feed KGal	% TS	KLb TS	% TVS	KLb VS	Operation pH	V.Acid	Alk	Temp
1	F	120	4.78	48	63.8	31	7.0	340	2300	92
2	S	120	4.78	48	65.5	31	7.0	370	2200	93
3	S	120	4.58	46	66.1	30	6.9	380	2400	92
4	M	70	4.66	27	67.0	18	6.9	390	2600	93
5	T	100	5.04	42	66.7	28	7.0	410	2400	93
6	W	100	4.94	41	64.5	27	7.0	380	2400	92
7	T	100	4.74	40	64.2	25	7.0	320	2300	92
8	F	100	5.04	42	65.2	27	7.1	260	2300	93
9	S	100	4.67	39	65.4	25	7.1	340	2400	92
10	S	80	4.66	31	65.0	20	7.0	350	2300	92
11	M	100	4.81	40	65.8	26	7.1	340	2300	93
12	T	100	4.74	40	65.1	26	7.1	260	2400	92
13	W	120	5.10	51	60.8	31	7.0	380	2300	92
14	T	80	5.68	38	57.4	22	6.9	450	2300	92
15	F	80	5.89	39	57.7	23	7.0	440	2300	92
16	S	80	5.63	38	56.6	21	7.0	470	2400	92
17	S	80	5.18	35	55.9	19	7.0	490	2300	92
18	M	100	4.90	41	59.8	24	7.0	220	2500	92
19	T	100	4.68	39	62.7	24	6.9	200	2400	92
20	W	100	4.40	37	60.8	22	7.0	260	2500	92
21	T	100	4.18	35	60.4	21	7.0	460	2400	92
22	F	100	4.81	40	62.1	25	7.1	240	2300	92
23	S	100	4.07	34	63.5	22	7.1	370	2300	92
24	S	74	3.92	24	63.3	15	7.0	240	2200	92
25	M	80	3.31	22	62.5	14	7.0	250	2100	92
26	T	80	3.98	27	62.6	17	6.9	230	2100	92
27	W	100	3.82	32	59.6	19	7.0	330	2000	92
28	T	100	4.14	35	63.0	22	6.9	270	2000	92
29	F	100	4.32	36	64.1	23	6.9	400	2100	92
30	S	100	4.39	37	64.5	24	7.0	210	2000	92
Tot.		2884		1121		704				
Avg		96	4.66	37	62.7	23		330	2300	92
Max		120	5.89	51	67.0	31	7.1	490	2600	93
Min		70	3.31	22	55.9	14	6.9	200	2000	92

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Day		Grit Cu.Ft.	Grit Wet Lbs.	Grit Dry KLbs.	Screen Cu.Ft.	Digested Sludge to Dewatering KGal	TS %	TS KLbs	TVS %	TVS KLbs	Dig pH
1	F	0.0	0	0.0	33.6	263.3	3.39	74	53.8	40	6.9
2	S	0.0	0	0.0	30.4	454.5	3.51	133	53.1	71	7.0
3	S	0.0	0	0.0	20.8	0.0	3.49	0	54.3	0	6.9
4	M	172.8	11520	8.0	28.8	188.6	3.39	53	53.5	29	6.9
5	T	0.0	0	0.0	30.4	317.1	3.41	90	53.9	49	6.9
6	W	201.9	13460	9.8	40.0	256.1	3.38	72	53.6	39	7.0
7	T	0.0	0	0.0	41.6	290.4	3.38	82	52.7	43	6.9
8	F	121.8	8120	4.6	33.6	231.3	3.55	68	53.2	36	7.0
9	S	162.9	10860	6.1	30.4	116.0	3.49	34	53.3	18	6.9
10	S	0.0	0	0.0	27.2	0.0	3.45	0	53.7	0	7.0
11	M	156.9	10460	4.6	22.4	356.8	3.36	100	52.6	53	7.1
12	T	0.0	0	0.0	38.4	238.0	3.35	66	52.0	35	7.1
13	W	176.4	11760	8.3	60.8	252.1	3.32	70	52.4	37	7.0
14	T	191.7	12780	9.1	28.8	172.3	3.43	49	52.5	26	6.9
15	F	152.7	10180	7.3	25.6	226.9	3.49	66	51.2	34	7.0
16	S	0.0	0	0.0	64.0	91.7	3.63	28	50.5	14	7.0
17	S	0.0	0	0.0	17.6	0.0	3.55	0	49.1	0	7.0
18	M	202.5	13500	10.3	17.6	237.9	3.49	69	48.0	33	7.0
19	T	228.0	15200	9.6	35.2	262.6	3.49	76	48.7	37	6.9
20	W	77.4	5160	3.8	48.0	203.1	3.46	59	48.7	29	6.9
21	T	0.0	0	0.0	28.8	220.4	3.46	64	48.7	31	7.0
22	F	133.8	8920	6.2	24.0	215.1	3.42	61	48.5	30	7.0
23	S	0.0	0	0.0	56.0	135.8	3.38	38	48.6	19	7.0
24	S	0.0	0	0.0	19.2	0.0	3.28	0	49.0	0	7.0
25	M	155.1	10340	6.0	28.8	273.3	3.22	73	49.2	36	7.0
26	T	183.9	12260	9.2	35.2	236.8	3.12	62	48.5	30	6.9
27	W	0.0	0	0.0	30.4	217.5	3.24	59	49.2	29	7.0
28	T	194.1	12940	8.8	25.6	254.8	3.18	68	49.1	33	6.9
29	F	0.0	0	0.0	27.2	107.6	3.14	28	49.4	14	6.9
30	S	57.0	3800	2.6	25.6	261.5	3.12	68	48.7	33	6.9
Tot.		2568.9	171260	114.1	976.0	6081.5		1711		875	
Avg		85.6	5709	3.8	32.5	202.7	3.38	57	51.0	29	
Max		228.0	15200	10.3	64.0	454.5	3.63	133	54.3	71	7.1
Min		0.0	0	0.0	17.6	0.0	3.12	0	48.0	0	6.9

Day		CAKE WET TONS	CAKE TS %	CAKE TVS %	CAKE DRY TONS	POLYMER LBS	POLYMER LBS / TON	LIME Added TONS	LIME %	Avg pH
1	F	289.3	18.1	53.7	50.3	500	9.9	12.0	23.9	12.4
2	S	424.4	20.2	49.6	81.9	700	8.5	19.0	23.2	12.4
3	S	*	*	*	*	*	*	*	*	*
4	M	218.4	20.0	53.3	41.6	400	9.6	10.0	24.0	12.3
5	T	286.4	20.3	53.8	55.6	600	10.8	13.2	23.8	12.3
6	W	279.8	20.6	52.1	55.0	650	11.8	12.1	22.0	12.3
7	T	296.0	19.4	52.6	54.8	500	9.1	14.3	26.1	12.3
8	F	249.2	21.1	48.4	49.9	500	10.0	12.1	24.2	12.3
9	S	181.9	20.2	50.0	35.2	300	8.5	8.0	22.7	12.3
10	S	*	*	*	*	*	*	*	*	*
11	M	334.3	19.0	48.0	61.2	600	9.8	12.0	19.6	12.4
12	T	251.5	19.5	47.5	46.9	500	10.7	11.0	23.4	12.4
13	W	252.5	20.0	48.3	48.1	500	10.4	12.1	25.2	12.2
14	T	183.1	20.3	51.1	35.4	400	11.3	8.8	24.8	12.5
15	F	229.1	20.5	49.4	44.7	400	9.0	11.0	24.6	12.3
16	S	116.9	20.9	48.4	23.2	300	12.9	5.5	23.7	12.3
17	S	*	*	*	*	*	*	*	*	*
18	M	207.5	20.6	47.3	40.7	500	12.3	9.9	24.3	12.3
19	T	255.6	21.6	48.8	53.9	500	9.3	6.1	11.2	12.4
20	W	189.5	19.7	45.5	35.4	400	11.3	9.9	28.0	12.1
21	T	170.2	21.2	49.2	34.0	400	11.8	10.0	29.5	12.2
22	F	242.0	20.2	47.7	47.1	400	8.5	9.0	19.1	12.7
23	S	142.4	20.6	48.0	27.7	350	12.6	7.7	27.8	12.5
24	S	*	*	*	*	*	*	*	*	*
25	M	200.6	20.2	46.6	38.5	450	11.7	10.0	26.0	12.2
26	T	217.8	20.0	47.6	41.4	500	12.1	11.0	26.6	12.3
27	W	203.3	18.5	48.4	35.7	350	9.8	9.9	27.7	12.2
28	T	235.5	20.0	45.6	44.9	500	11.1	11.0	24.5	12.2
29	F	109.7	20.4	46.1	21.3	200	9.4	5.0	23.5	12.3
30	S	240.6	20.8	50.0	47.5	500	10.5	12.1	25.5	12.4
Tot.		6008			1152	11900		272.6		
Avg		231.1	20.1	49.1	44.3	458	10.5	10.5	24.0	12.3
Max		424.4	21.6	53.8	81.9	700	12.9	19.0	29.5	13.0
Min		109.7	18.1	45.5	21.3	200	8.5	5.0	11.2	12.0

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Sludge Distrubution Summary
(Preliminary Estimates Only)

Day		K. George Co VA	Queen Anne Co MD	Howard Co MD	Frederick Co MD	Carroll Co MD
1	F			289.3		
2	S			424.4		
4	M			218.4		
5	T			286.4		
6	W			279.8		
7	T			296.0		
8	F			249.2		
9	S			181.9		
11	M		334.3			
12	T				251.5	
13	W				252.5	
14	T				183.1	
15	F				229.1	
16	S				48.0	68.9
18	M				207.5	
19	T				127.8	127.8
20	W					189.5
21	T					170.2
22	F					242.0
23	S					142.4
25	M			74.7	125.3	
26	T				44.4	173.4
27	W				203.3	
28	T				235.5	
29	F				109.7	
30	S				240.6	
TOTAL			334.3	2300.0	2258.9	1114.3

Grand Total Wet Tons : 6008

Individual 2 + Hour pH Sludge Tests

1	F	12.3	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.3	12.3	12.3			
2	S	12.5	12.4	12.3	12.4	12.4	12.4	12.4	12.3	12.3	12.4	12.4	12.4	12.4	12.4	12.3
4	M	12.4	12.4	12.3	12.4	12.1	12.3	12.2	12.2							
5	T	12.3	12.3	12.3	12.3	12.3	12.3	12.4	12.2	12.3	12.3	12.2	12.4			
6	W	12.3	12.3	12.2	12.2	12.3	12.2	12.3	12.4	12.3	12.2	12.3				
7	T	12.2	12.3	12.3	12.3	12.4	12.2	12.3	12.2	12.3	12.4	12.3	12.4	12.3		
8	F	12.3	12.2	12.3	12.3	12.3	12.2	12.3	12.3	12.3	12.2	12.3				
9	S	12.3	12.3	12.4	12.3	12.3	12.3	12.3	12.3							
11	M	12.3	12.2	12.5	12.6	12.6	12.6	12.1	12.6	12.6	12.4	12.1	12.5	12.4	12.4	
12	T	12.1	12.0	12.6	12.2	12.5	12.3	12.5	12.5	12.5	12.5	12.4				
13	W	12.3	12.3	12.2	12.1	12.4	12.2	12.1	12.4	12.2	12.3	12.4				
14	T	12.5	13.0	12.5	12.5	12.5	12.5	12.5	12.4							
15	F	13.0	12.3	12.2	12.1	12.2	12.2	12.2	12.2	12.3	12.3					
16	S	12.4	12.3	12.3	12.3	12.4										
18	M	12.3	12.3	12.3	12.2	12.2	12.2	12.2	12.2	12.3						
19	T	12.3	12.4	12.4	12.4	12.4	12.4	12.3	12.3	12.3	12.4	12.3				
20	W	12.1	12.2	12.2	12.1	12.1	12.1	12.1	12.1	12.2						
21	T	12.2	12.2	12.2	12.1	12.3	12.2	12.3	12.2	12.2	12.3					
22	F	12.2	12.2	12.0	12.9	13.0	13.0	13.0	13.0	12.4	13.0					
23	S	12.4	12.2	12.3	12.7	12.6	12.7	12.7	12.7							
25	M	12.3	12.4	12.3	12.1	12.1	12.0	12.2	12.2	12.2	12.2					
26	T	12.4	12.3	12.2	12.2	12.3	12.3	12.3	12.3	12.3	12.2					
27	W	12.2	12.3	12.3	12.2	12.2	12.3	12.2	12.2	12.2						
28	T	12.3	12.3	12.3	12.2	12.2	12.3	12.2	12.1	12.3	12.3	12.2				
29	F	12.2	12.3	12.2	12.3	12.3										
30	S	12.4 -	12.4	12.4	12.4	12.4	12.3	12.3	12.4	12.3	12.4	12.4				

Number of pH Tests : 262 Number Less Than 12 : 0

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Process Daily Report

Date : 89/ 10/ 2 Monday
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MAIN STREAM :

Net Flow	56.026	Ferric feed(Fe)	16.8	Elect(100KWH)	576
Recycle Q	5.681	Alum feed	15.1	Water (KGal)	80.4
Max Q	96	Screenings(CuFt)	38.4	Gas (KCuFt)	40.1
Rain	0.96	Grit (CuFt)	128.1		
Snow	0.0	T1/T2 Ratio	1.1546		
Raw Temp.	71				

(UTILITIES : Elect, Water, Gas)

DETENTION TIMES :

		Units on Line	LOADINGS :	
Primary DT (Hrs)	1.2	7		
RBC DT (min)	17.2	14	RBC Hyd. Load (GPD/SF)	10.5
SST DT (Hrs)	1.8	12		
Filters (BW)	39	12	Filt Hyd Load (GPM/SF)	5.2
Cl2 Tank DT (Min)	37.0	2		

CHLORINATION :

		NO. OF CL2 VIO. :		pH DATA :	
Feed Lbs	2350	Low	0	Grab pH	6.7
Dose (Mg/L)	5.0	High	0		
Avg. Residual	0.55	Above 2.0	0		
Lo Value	0.25				
Hi Value	0.75				

LAB RESULTS : DATE : 10/ 1 Sunday

	TSS	COD	P. TOT.	D.O.	F.COLI
RAW :	99	270	4.10		
PE :	32	-	0.96		
BDE :	38		0.98		
FINAL :	4.0	47	0.07	7.2	1
% REMOVAL :	96.0	82.6	98.3		

NUM. OF D.O. VIOLATIONS : (MONTH) 0

TREND :

DATE	FINAL RESULTS (Mg/L) TSS	COD	BOD	ESTIMATED BOD	FLOW (MGD)	RAIN (IN.)
9/ 23	0.9	40	7	9.3	35.793	0.18
9/ 24	1.1	37	9	8.6	32.810	0.00
9/ 25	1.2	38	8	8.7	33.471	0.36
9/ 26	5.6	32	9	7.4	55.714	1.15
9/ 27	2.9	37	9	8.7	34.419	0.00
9/ 28	2.2	38	9	8.8	33.061	0.00
9/ 29	3.4	43	11	10.0	32.282	0.00
9/ 30	4.0	49	11	11.6	32.688	0.00
10/ 1	4.0	47	-	11.0	36.561	-

AVERAGE BOD FOR THE MONTH OF SEPTEMBER - 10.3
Number of BOD Data Points For SEPTEMBER - 30
AVERAGE TSS FOR THE MONTH OF SEPTEMBER - 2.5
Number if TSS Data Points for SEPTEMBER - 30

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Process Daily Report

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SIDESTREAM PROCESS : DATE : 9/ 30 Saturday

THICKENER FEED :

	% TS	% TVS	FLOW MGD	LBS
PSC :	0.31	65.6	3.693	95479
SSC :	0.09	40.3	3.068	23031

THICK. OVERFLOW : Mg/L : 44 POUNDS : 2481

		9/ 30	10/ 1	10/ 2
THICKENER LEVELS (FT) :				
	1 -	4.4	3.4	4.4
	2 -	3.4	4.2	5.4
	3 -	4.6	5.0	5.2
	4 -	3.4	3.4	4.4
	5 -	4.2	3.4	4.4
DIGESTER LEVELS (FT) :				
	1 -	24.2	24.4	24.6
	2 -	23.9	24.6	24.9

DIGESTER FEED :

	FEED (GAL)	THICK. SLUDGE (%TS)	TOT.S (KLB)	VOL.S (%)	VOL.S (KLB)	#VS/CUFT	AVG. RT (DAY)	VS % REDUC.
DIG1:	100000	4.39	37	64.5	24	0.12	15.0	45.9
DIG2:	100000	"	37	"	24	0.12	15.3	49.5

FEED/WITHDRAW VOL. RATIO (30 DAY AVG.) : 0.948

Date : 10/ 2

DIGESTERS :	VOL ACID	ALKALINITY	VA/ALK RATIO	TEMP °F	% METHANE
# 1	310	2000	0.16	93	
# 2	242	2024	0.12	92	
AVG.	276	2012			70

DEWATERING : DATE : 9/ 30 Saturday

CENT. SLUDGE KGAL : 262
CENT. SLUDGE : % TS : 3.12 % TVS : 48.7 K LBS : 68
CENT. CAKE : % TS : 20.80 % TVS : 50.0
CENTRATE : Mg/l TS : 610 LBS : 1330

SLUDGE HAULED :
K LBS : 298.31 LOADS LEFT : 4 K LBS LEFT : 182.86

TOTAL WET TONS ON 9/ 30 : 240.6
DRY TONS ON 9/ 30 : 47.5

Lb Polymer : 500 LB POLY/DRY TON : 10.5
Lb Lime : 24200 % LIME/DRY TON : 25.5
AVG Truck pH : 12.4 MAX : 12.4 MIN : 12.3

Destination	Wet Tons
Frederick Co	241

Lime Storage Est. Inventory : 213450 116 % Full

Alexandria Sanitation Authority

Process Daily Report

Date : 89/ 10/ 2 Monday
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File		Parameter Label	Units	Reported Value	Limit	Init.
10/ 2						
BODCOMP	.RAW	Fecal Coli	#/100	920	400	
SSCOMP1	.RAW	TSS Com. Int	Mg/L	74	100	
SSCOMP1	.RAW	VSS Com. Int	Mg/L	60	99	
CODCOMP	.RAW	TCOD CI-24 HOUR	MG/L	128	200	
PCUNITS	.RAW	Filt Backwashes		39	30	
PCLIME	.RAW	Truck #2	pH	13.11	13	
PCLIME	.RAW	Truck #3	pH	13.04	13	
PCLIME	.RAW	Truck #4	pH	13.09	13	
PCLIME	.RAW	Truck #5	pH	13.08	13	
PCLIME	.RAW	Truck #6	pH	13.16	13	
PCLIME	.RAW	Truck #7	pH	13.05	13	
PCLIME	.RAW	Truck #8	pH	13.09	13	
FLOW	.cal	Filt Hyd. Load	GPD/SF	5.235541	5	
FLOW	.cal	TSS Remove	%	93.39806	95	
FLOW	.cal	COD Removal	%	79.90868	82	
FLOW	.cal	Totalizer Ratio		1.154649	1.15	
LBTSS	.cal	FINAL TSS	KLbs	3.177347	2	
LBTSS	.cal	Lime Inven.	LBS	213450	200000	
LBBOD	.cal	FINAL BOD/TSS	RATIO	1.617647	3	
10/ 1						
SSCOMP1	.RAW	TSS Com. Int	Mg/L	91	100	
SSCOMP1	.RAW	VSS Com. Int	Mg/L	75	99	
FLOW	.cal	Totalizer Ratio		1.170684	1.15	
DIGEST	.cal	#1 HRT	Days	35.95104	25	
DIGEST	.cal	#2 HRT	Days	36.13051	25	
LBBOD	.cal	FINAL BOD/TSS	RATIO	2.75	3	
9/ 30						
PCMGD	.RAW	Util. Water Use	K Gal	109.3	100	
FLOW	.cal	Totalizer Ratio		1.178901	1.15	
LBBOD	.cal	FINAL BOD/TSS	RATIO	2.75	3	

LAB COMMENTS :

OPERATIONS COMMENTS :

89/10/02
Chemical feed to settling tanks was discontinued during high flow period.

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File : BODCOMP .RAW

Parameter/Unit	09/24	09/25	09/26	09/27	09/28	09/29	09/30	Avg.	Min	Max	SDev.
ALK. RAW / Mg/L	187	194	129	166	178	168	198	174	129	198	22
ALK. PS / Mg/L	79	114	84	80	96	98	123	96	79	123	16
ALK. 3DE / Mg/L	76	107	65	77	102	100	116	92	65	116	18
ALK. FINAL / Mg/L	58	65	44	65	68	85	96	69	44	96	16
Fecal Coli / #/100	0	0	1	22	0	0	0	3	0	22	8
TURB PS / NTU	17.0	25.0	18.0	16.0	25.0	27.0	28.0	22.3	16.0	28.0	4.7
TURB FINAL / NTU	1.3	1.7	4.5	2.6	1.7	1.6	2.5	2.3	1.3	4.5	1.0

File : BODGRAB .RAW

Parameter/Unit	09/24	09/25	09/26	09/27	09/28	09/29	09/30	Avg.	Min	Max	SDev.
D.O. FINAL / Mg/L	7.5	7.4	7.6	7.3	7.8	7.5	7.5	7.5	7.3	7.8	0.1
Final Temp / Deg C	23.3	23.7	23.5	23.1	23.5	23.6	23.2	23.4	23.1	23.7	0.2
TIME FINAL /	1400	1350	1400	1400	1400	1400	1400	1393	1350	1400	17
pH RAW / pH	7.13	6.78	6.99	7.16	6.92	7.14	6.84	6.99	6.78	7.16	0.14
TEMP (C) RAW / Deg C	23.0	24.0	22.0	23.0	23.0	23.0	23.0	23.0	22.0	24.0	0.5
TIME RAW /	1030	1010	1010	1015	1000	1020	1000	1012	1000	1030	10
Split pH 1 / pH	6.5	-1.0	6.9	6.4	6.2	6.6	6.4	6.5	6.2	6.9	0.2
Split Alk 1 / Mg/L	54	-1	60	43	38	68	49	52	38	68	10

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Weekly Data Report 89/09/24 -- 89/09/30

File : SSCOMP1 .RAW

Parameter/Unit	09/24	09/25	09/26	09/27	09/28	09/29	09/30	Avg.	Min	Max	SDev.
TSS RAW / Mg/L	138	196	124	146	134	136	188	152	124	196	26
TSS PE / Mg/L	26	36	38	21	46	38	36	34	21	46	8
TSS 3DE / Mg/L	52	34	31	23	32	42	40	36	23	52	9
TSS FINAL / Mg/L	1.1	1.2	5.6	2.9	2.2	3.4	4.0	2.9	1.1	5.5	1.5
TSS CE / Mg/L	-1	570	640	670	640	510	610	607	510	670	53
TSS 3TO / Mg/L	26	24	24	32	38	44	44	33	24	44	8
VSS RAW / Mg/L	110	151	82	117	112	110	157	120	82	157	24
VSS PE / Mg/L	18	23	21	11	32	28	23	22	11	32	6
VSS 3DE / Mg/L	32	22	20	14	22	28	26	23	14	32	5
VSS FINAL / Mg/L	0.8	0.6	3.2	1.5	1.2	2.2	2.6	1.7	0.6	3.2	0.9
VSS CE / Mg/L	-1	460	520	520	510	400	490	483	400	520	43
VSS 3TO / Mg/L	22	22	16	24	32	32	34	26	16	34	6
TSS Com. Int / Mg/L	130	138	134	116	136	144	148	135	116	148	10
VSS Com. Int / Mg/L	110	108	94	98	116	122	116	109	94	122	9

File : SSCOMP2 .RAW

Parameter/Unit	09/24	09/25	09/26	09/27	09/28	09/29	09/30	Avg.	Min	Max	SDev.
Set S RAW / Ml/L	6.0	8.5	4.0	7.0	4.0	-1.0	-1.0	5.9	4.0	8.5	1.7
Set S PE / Ml/L	0.0	0.0	0.1	0.0	0.0	-1.0	-1.0	0.0	0.0	0.1	0.0
Set S 3DE / Ml/L	4.5	2.0	1.5	0.3	1.5	-1.0	-1.0	2.0	0.3	4.5	1.4
Set S FINAL / Ml/L	0.0	0.0	0.0	0.0	0.0	-1.0	-1.0	0.0	0.0	0.0	0.0
pH RAW / pH	7.40	7.37	7.34	7.39	7.35	7.33	7.25	7.35	7.25	7.40	0.05
pH PE / pH	6.70	6.81	6.69	6.86	6.95	6.94	6.90	6.84	6.69	6.95	0.10
pH 3DE / pH	7.09	7.19	6.97	7.27	7.30	7.24	7.21	7.18	6.37	7.30	0.11
pH FINAL / pH	7.02	7.06	6.68	6.96	7.02	7.08	7.04	6.98	6.68	7.08	0.13
COND RAW / uS/cm	651	690	525	694	660	634	653	644	525	694	52
COND PE / uS/cm	738	790	613	710	722	708	663	706	613	790	52
COND 3DE / uS/cm	725	783	620	711	725	696	705	709	620	783	45
COND FINAL / uS/cm	720	789	602	716	744	715	760	721	602	789	55
COND CI 24 / uS/cm	644	680	548	586	587	614	601	609	548	680	40

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File : CODCOMP .RAW

Parameter/Unit	09/24	09/25	09/26	09/27	09/28	09/29	09/30	Avg.	Min	Max	SDev.
TCOD RAW / Mg/L	337	449	255	337	318	284	366	335	255	449	58
TCOD FINAL / Mg/L	37	38	32	37	38	43	49	39	32	49	5
TCOD CI-24 HOUR / MG/L	387	315	272	296	318	297	346	319	272	387	35

File : CODSLDG .RAW

Parameter/Unit	09/24	09/25	09/26	09/27	09/28	09/29	09/30	Avg.	Min	Max	SDev.
pH BTS SLUDGE / pH	6.55	6.55	6.78	6.67	6.59	6.74	6.21	6.58	6.21	6.78	0.17
%TS DIG #1 / %TS	3.35	3.28	3.22	3.29	3.24	3.25	3.23	3.27	3.22	3.35	0.04
%TVS DIG #1 / %TVS	49.4	48.9	49.1	49.8	49.2	50.2	49.5	49.4	48.9	50.2	0.4
%TS DIG #2 / %TS	3.20	3.15	3.02	3.19	3.13	3.04	3.00	3.10	3.00	3.20	0.08
%TVS DIG #2 / %TVS	48.5	49.5	48.0	48.7	49.0	48.7	47.8	48.6	47.8	49.5	0.5

File : CODTS .RAW

Parameter/Unit	09/24	09/25	09/26	09/27	09/28	09/29	09/30	Avg.	Min	Max	SDev.
%TS PTF /	-1.00	0.36	0.24	0.43	0.25	0.26	0.31	0.31	0.24	0.43	0.07
%TVS PTF /	-1.0	60.6	56.7	60.3	60.2	67.1	65.6	61.7	56.7	67.1	3.5
%TS STF /	0.08	0.08	0.10	0.08	0.08	0.09	0.09	0.09	0.08	0.10	0.01
%TVS STF /	39.0	39.7	43.8	30.2	46.4	48.5	40.3	41.1	30.2	48.5	5.6
%TS BTS /	3.92	3.31	3.98	3.82	4.14	4.32	4.39	3.98	3.31	4.39	0.34
%TVS BTS /	63.3	62.5	62.6	59.6	63.0	64.1	64.5	62.8	59.6	64.5	1.5
%TS C. CAKE /	-1.00	20.20	20.01	18.46	20.00	20.36	20.80	19.97	18.46	20.80	0.73
%TVS C. CAKE /	-1.0	46.6	47.6	48.4	45.6	46.1	50.0	47.4	45.6	50.0	1.5
%TS GRIT /	59.8	58.2	74.8	35.9	67.9	-1.0	-1.0	59.3	35.9	74.8	13.1
%TVS GRIT /	11.1	16.5	6.6	62.2	7.2	-1.0	-1.0	20.7	6.6	62.2	21.0

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File : NUTPO4 .RAW

Parameter/Unit	09/24	09/25	09/26	09/27	09/28	09/29	09/30	Avg.	Min	Max	SDev.
PO4 RAW / Mg/L	3.88	4.90	3.10	3.92	3.92	4.10	4.42	4.03	3.10	4.90	0.51
PO4 PE / Mg/L	0.63	0.35	0.82	0.46	1.06	1.13	1.04	0.56	0.46	1.13	0.23
PO4 3DE / Mg/L	-1.00	0.72	0.64	0.45	0.66	-1.00	-1.00	0.62	0.45	0.72	0.10
PO4 FINAL / Mg/L	0.02	0.03	0.09	0.03	0.03	0.06	0.07	0.05	0.02	0.09	0.02
ORTHO P RAW / Mg/L	-1.00	-1.00	-1.00	0.51	-1.00	-1.00	-1.00	0.51	0.51	0.51	
ORTHO P FINAL / Mg/L	-1.00	-1.00	-1.00	0.02	-1.00	-1.00	-1.00	0.02	0.02	0.02	
TKN RAW / Mg/L	-1.00	-1.00	-1.00	25.30	-1.00	-1.00	-1.00	25.30	25.30	25.30	
TKN FINAL / Mg/L	-1.00	-1.00	-1.00	21.60	-1.00	-1.00	-1.00	21.50	21.50	21.60	
NH3-N RAW / Mg/L	-1.00	-1.00	-1.00	16.80	-1.00	-1.00	-1.00	16.80	16.80	16.80	
NH3-N FINAL / Mg/L	-1.00	-1.00	-1.00	16.30	-1.00	-1.00	-1.00	16.30	16.30	16.30	
NO2-N FINAL / Mg/L	-1.0	-1.0	-1.0	0.1	-1.0	-1.0	-1.0	0.1	0.1	0.1	
NO3-N FINAL / Mg/L	-1.00	-1.00	-1.00	0.10	-1.00	-1.00	-1.00	0.10	0.10	0.10	

File : SSGRAB .RAW

Parameter/Unit	09/24	09/25	09/26	09/27	09/28	09/29	09/30	Avg.	Min	Max	SDev.
pH FINAL / pH	6.43	6.87	6.98	6.40	6.28	6.58	6.42	6.58	6.28	6.98	0.24

File : CODGRAB .RAW

Parameter/Unit	09/24	09/25	09/26	09/27	09/28	09/29	09/30	Avg.	Min	Max	SDev.
pH DIGEST 1 / pH	7.0	7.0	6.9	7.0	6.9	6.9	6.9	6.9	6.9	7.0	0.0
TEMP DIGEST 1 / Deg C	30.0	29.0	31.0	30.0	30.0	31.0	30.0	30.1	29.0	31.0	0.6
VOL ACID DIG 1 / Mg/L	214	366	460	364	402	342	330	354	214	460	70
ALK. DIG 1 / Mg/L	2048	2184	2140	2016	2072	2088	1900	2064	1900	2184	85
pH DIGEST 2 / pH	7.0	7.0	6.9	7.0	6.9	6.9	7.0	7.0	6.9	7.0	0.0
TEMP DIGEST 2 / Deg C	29.0	29.0	32.0	30.0	29.0	31.0	30.0	30.0	29.0	32.0	1.1
VOL ACID DIG 2 / Mg/L	240	250	226	332	272	398	210	275	210	398	62
ALK. DIG 2 / Mg/L	2164	2108	2080	2000	2024	2068	2012	2065	2000	2164	54

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File : BODBOD .RAW

Parameter/Unit	09/24	09/25	09/26	09/27	09/28	09/29	09/30	Avg.	Min	Max	SDev.
BOD RAW / Mg/L	148	170	124	137	141	155	167	149	124	170	15
BOD PE / Mg/L	44	59	39	37	53	66	64	52	37	66	11
BOD PE (Sol) / Mg/L	25	36	21	27	26	42	39	31	21	42	7
BOD BDE / Mg/L	38	34	32	-1	31	58	61	42	31	61	12
BOD BDE (Sol) / Mg/L	10	15	12	13	13	14	17	13	10	17	2
BOD FINAL / Mg/L	9	8	9	9	9	11	11	9	8	11	1
BOD FINAL (s) / Mg/L	8.0	9.0	7.0	9.0	8.0	10.0	10.0	8.7	7.0	10.0	1.0

Appendix B - Data Label and Limit (LAL) Files

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FILE :BODCOMP .RAW Alak. F.Coli (C)
File Number : 1
Current Reasonability Limits

# Data ID	unit	L 2	L 1	H 1	H 2	A / P	NSD
1 ALK. RAW	Mg/L	10	75	250	500	1	0
2 ALK. PE	Mg/L	10	40	250	500	1	0
3 ALK. BDE	Mg/L	10	40	250	500	1	0
4 ALK. ITE	Mg/L	10	40	250	500	-1	0
5 ALK. STE	Mg/L	10	40	250	500	-1	0
6 ALK. FINAL	Mg/L	10	20	175	300	1	0
7 Fecal Coli	#/100	0	0	400	1E+07	1	0
8 TURB PE	NTU	0	1	30	101	1	1
9 TURB BDE	NTU	0	1	25	50	-1	1
10 TURB FINAL	NTU	0	.5	20	40	1	1
11 HARDNESS FINAL	Mg/L	0	20	400	999	-1	1

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FILE :BODGRAB .RAW pH DO Temp SGrav(G)
File Number : 2
Current Reasonability Limits

#	Data ID	unit	L 2	L 1	H 1	H 2	A / P	NSD
1	pH FINAL	pH	3	6	9	10	-1	2
2	D.O. FINAL	Mg/L	0	6	12	14	1	1
3	Final Temp	Deg C	4	6	28	35	1	1
4	ALK. FINAL	Mg/L	5	20	16	400	-1	1
5	TIME FINAL		0	0	2400	2400	1	0
6	pH RAW	pH	3	5	9	12	1	2
7	D.O. RAW	Mg/L	0	0	7	12	-1	1
8	TEMP (C) RAW	Deg C	4	6	28	35	1	1
9	ALK. RAW	Mg/L	20	40	150	500	-1	0
10	TIME RAW		0	0	2400	2400	1	0
11	TURB PE	NTU	0	1	25	50	-1	1
12	TURP FINAL	NTU	0	1	20	40	-1	1
13	Ferric Sp Grav		.5	1	1.4	2	1	3
14	Alum Sp Grav		.4	1	1.5	2.1	1	3
15	Split pH 1	pH	3	6	9	11	1	1
16	Split Alk 1	Mg/L	5	15	110	199	1	0
17	Split pH 2	pH	3	6	9	11	-1	1
18	Split Alk 2	Mg/L	5	15	110	199	-1	0

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FILE :SSCOMP1 .RAW TSS VSS (C)
File Number : 3
Current Reasonability Limits

#	Data ID		unit	L 2	L 1	H 1	H 2	A / P	NSD
1	TSS	RAW	Mg/L	10	30	330	900	1	0
2	TSS	PE	Mg/L	1	10	75	300	1	0
3	TSS	BDE	Mg/L	1	10	150	300	1	0
4	TSS	ITE	Mg/L	1	5	95	200	-1	0
5	TSS	STE	Mg/L	1	3	95	200	-1	0
6	TSS	SFE(COMP)	Mg/L	0	.1	55	100	-1	1
7	TSS	SFE(INDV)	samp#	0	1	55	100	-1	1
8	TSS	FINAL	Mg/L	0	.05	13	50	1	1
9	TSS	CE	Mg/L	200	300	1500	3000	1	0
10	TSS	BTO	Mg/L	5	20	500	3000	1	0
11	TSS	STO	Mg/L	5	20	300	2000	-1	0
12	VSS	RAW	Mg/L	10	30	330	900	1	0
13	VSS	PE	Mg/L	1	10	75	300	1	0
14	VSS	BDE	Mg/L	1	10	150	300	1	0
15	VSS	ITE	Mg/L	1	5	95	200	-1	0
16	VSS	STE	Mg/L	1	3	95	200	-1	1
17	VSS	SFE(COMP)	Mg/L	0	.1	55	100	-1	1
18	VSS	SFE(INDV)	Mg/L	0	.1	55	.1	-1	1
19	VSS	FINAL	Mg/L	0	.05	13	50	1	1
20	VSS	CE	Mg/L	150	300	1500	3000	1	0
21	VSS	BTO	Mg/L	5	20	500	3000	1	0
22	VSS	STO	Mg/L	5	10	300	2000	-1	0
23	SFE	# 1-16	Mg/L	0	.01	55	100	-1	1
24	TSS	Com. Int	Mg/L	50	100	400	900	1	0
25	VSS	Com. Int	Mg/L	50	99	400	900	1	0

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FILE :SSCOMP2 .RAW Set S pH (C)

File Number : 4

Current Reasonability Limits

#	Data ID	unit	L 2	L 1	H 1	H 2	A / P	NSD
1	Set S RAW	Ml/L	0	1	15	100	1	1
2	Set S PE	Ml/L	0	0	5	35	1	1
3	Set S BDE	Ml/L	0	0	15	50	1	1
4	Set S ITE	Ml/L	0	0	20	60	-1	1
5	Set S STE	Ml/L	0	0	1	10	-1	1
6	Set S FINAL	Ml/L	0	0	1	10	1	1
7	pH RAW	pH	4	6	9	14	1	2
8	pH PE	pH	3	6	9	14	1	2
9	pH BDE	pH	3	6	9	10	1	2
10	pH ITE	pH	3	6	9	10	-1	2
11	pH STE	pH	3	6	9	10	-1	2
12	pH SFE(COMP)	pH	3	6	9	10	-1	2
13	pH SFE(INDV)	pH	3	6	9	10	-1	2
14	pH FINAL	pH	3	6	9	10	1	2
15	pH BTO	pH	3	6	9	10	-1	2
16	pH STO	pH	3	6	9	10	-1	2
17	COND RAW	uS/cm	250	400	800	1000	1	0
18	COND PE	uS/cm	250	400	800	1000	1	0
19	COND BDE	uS/cm	250	400	800	1000	1	0
20	COND FINAL	uS/cm	250	400	800	1000	1	0
21	COND CI 24	uS/cm	250	400	800	1000	1	0

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FILE :CODCOMP .RAW TCOD SCOD (C)
File Number : 5
Current Reasonability Limits

#	Data ID	unit	L 2	L 1	H 1	H 2	A / P	NSD
1	TCOD RAW	Mg/L	20	100	1000	2000	1	0
2	SCOD RAW	Mg/L	20	40	900	2000	-1	0
3	TCOD PE	Mg/L	10	20	200	900	1	0
4	SCOD PE	Mg/L	10	20	200	900	-1	0
5	TCOD BDE	Mg/L	10	15	200	900	1	0
6	SCOD BDE	Mg/L	10	15	200	500	-1	0
7	TCOD ITE	Mg/L	10	15	100	400	-1	0
8	TCOD STE	Mg/L	10	15	100	400	-1	0
9	TCOD FINAL	Mg/L	0	20	99	200	1	0
10	SCOD FINAL	Mg/L	0	20	99	100	1	0
11	SCOD CIS	Mg/L	50	100	999	2000	-1	0
12	TCOD CI-24 HOUR	MG/L	100	200	500	700	1	0

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FILE :CODSLDG .RAW Sldg pH Dig TS (C)

File Number : 6

Current Reasonability Limits

#	Data ID	unit	L 2	L 1	H 1	H 2	A / P	NSD
1	pH ITF SLUDGE	pH	3	6	9	10	-1	2
2	pH PTF SLUDGE	pH	3	6	9	10	-1	2
3	pH STF SLUDGE	pH	3	6	9	10	-1	2
4	pH BTS SLUDGE	pH	3	6	9	10	1	2
5	pH STS SLUDGE	pH	3	6	9	10	-1	2
6	pH CENTRATE SLG	pH	3	6	9	10	-1	2
7	%TS DIG #1	%TS	1	2	5	10	1	2
8	%TVS DIG #1	%TVS	10	40	60	99	1	1
9	%TS DIG #2	%TS	1	2	5	10	1	2
10	%TVS DIG #2	%TVS	10	40	60	99	1	1

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FILE :CODTS .RAW %TS %TVS (C-1)
File Number : 7
Current Reasonability Limits

#	Data ID		unit	L 2	L 1	H 1	H 2	A / P	NSD
1	%TS	ITF		.05	.1	2	12	-1	2
2	%TVS	ITF		10	30	70	99	-1	1
3	%TS	PTF		.05	.1	2	12	1	2
4	%TVS	PTF		10	30	73	99	1	1
5	%TS	STF		.05	.08	2	12	1	2
6	%TVS	STF		10	30	70	99	1	1
7	%TS	BTS		.5	1	9	15	1	2
8	%TVS	BTS		10	30	73	99	1	1
9	%TS	STS		.5	1	9	15	-1	2
10	%TVS	STS		10	30	70	99	-1	1
11	%TS	C. SLUDGE		.5	1	10	20	-1	2
12	%TVS	C. SLUDGE		10	30	70	99	-1	1
13	%TS	C. CAKE		.5	1	25	40	1	2
14	%TVS	C. CAKE		10	30	70	99	1	1
15	%TS	GRIT		2.5	5	90	100	1	1
16	%TVS	GRIT		.01	.05	70	99	1	1
17	GRIT	MASS	Oz.	1	5	30	99	-1	1

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FILE :NUTPO4 .RAW PO4 (C)

File Number : 8

Current Reasonability Limits

#	Data ID	unit	L 2	L 1	H 1	H 2	A / P	NSD
1	PO4 RAW	Mg/L	1	2	9	15	1	2
2	PO4 PE	Mg/L	.01	.1	4	10	1	2
3	PO4 BDE	Mg/L	.01	.1	4	10	1	2
4	PO4 ITE	Mg/L	.01	.1	2	10	-1	2
5	PO4 STE	Mg/L	.01	.03	2	10	-1	2
6	PO4 FINAL	Mg/L	-.05	-.05	1	10	1	-2
7	FUTURE		0	0	0	0	-1	0
8	FUTURE		0	0	0	0	-1	0
9	ORTHO P RAW	Mg/L	.1	1	8	10	1	2
10	ORTHO P FINAL	Mg/L	-.05	-.05	1	2	1	-2
11	FUTURE		0	0	0	0	-1	0
12	TKN RAW	Mg/L	1	10	40	60	1	2
13	TKN FINAL	Mg/L	1	10	40	60	1	2
14	FUTURE		0	0	0	0	-1	0
15	NH3-N RAW	Mg/L	1	10	40	60	1	2
16	NH3-N FINAL	Mg/L	1	10	40	60	1	2
17	FUTURE		0	0	0	0	-1	0
18	OXN RAW	Mg/L	-.05	-.05	5	20	-1	2
19	OXN FINAL	Mg/L	-2.1	-.05	10	50	1	2
20	FUTURE		0	0	0	0	-1	0
21	NO2-N RAW	Mg/L	-5	-.05	10	50	1	2
22	NO2-N FINAL	Mg/L	-5	-.05	10	50	1	1
23	FUTURE		0	0	0	0	-1	0
24	NO3-N RAW	Mg/L	-5	-.05	5	10	1	2
25	NO3-N FINAL	Mg/L	-5	-.05	10	50	1	2

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FILE :SSGRAB .RAW pH Cl2 (grabs)

File Number : 9

Current Reasonability Limits

#	Data ID	unit	L 2	L 1	H 1	H 2	A / P	NSD
1	TIME 1 pH		0	0	2400	2400	-1	0
2	pH FINAL	pH	1	3.5	9	10	1	2
3	TIME 2 ph		0	0	2400	2400	-1	0
4	pH FINAL	pH	3	6	9	10	-1	2
5	TIME 3 ph		0	0	2400	2400	-1	0
6	pH FINAL	pH	3	6	9	10	-1	2
7	TIME 4 pH		0	0	2400	2400	-1	0
8	pH FINAL	pH	3	6	9	10	-1	2
9	TIME 5 pH		0	0	2400	2400	-1	0
10	pH FINAL	pH	3	6	9	10	-1	2
11	TIME 6 pH		0	0	2400	2400	-1	0
12	pH FINAL	pH	3	6	9	10	-1	2
13	TIME 7 pH		0	0	2400	2400	-1	0
14	pH FINAL	pH	3	6	9	10	-1	2
15	TIME 8 pH		0	0	2400	2400	-1	0
16	pH FINAL	pH	3	6	9	10	-1	2
17	TIME 1 Cl2		0	0	2400	2400	-1	0
18	Cl2 FINAL	Mg/L	0	0	2	6	-1	2
19	TIME 2 Cl2		0	0	2400	2400	-1	0
20	Cl2 FINAL	Mg/L	0	0	2	6	-1	2
21	TIME 3 Cl2		0	0	2400	2400	0	0
22	Cl2 FINAL	Mg/L	0	0	2	6	-1	2
23	TIME 4 Cl2		0	0	2400	2400	0	0
24	Cl2 FINAL	Mg/L	0	0	2	6	-1	2

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FILE :CODGRAB .RAW Digest grabs (G)
File Number : 10
Current Reasonability Limits

#	Data ID	unit	L 2	L 1	H 1	H 2	A / P	NSD
1	pH DIGEST 1	pH	3	6.5	8	10	1	1
2	TEMP DIGEST 1	Deg C	10	20	35	40	1	1
3	VOL ACID DIG 1	Mg/L	20	50	1000	2000	1	0
4	ALK. DIG 1	Mg/L	500	1000	4000	6000	1	0
5	pH DIGEST 2	pH	3	6.5	8	10	1	1
6	TEMP DIGEST 2	Deg C	10	20	35	40	1	1
7	VOL ACID DIG 2	Mg/L	20	50	1000	2000	1	0
8	ALK. DIG 2	Mg/L	500	1000	4000	6000	1	0
9	C. Cake 1	pH	2	10	13.5	14	1	1
10	C. Cake 2	pH	2	10	13.5	14	1	1

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FILE :BODBOD .RAW BOD (C-5)
File Number : 11
Current Reasonability Limits

#	Data ID	unit	L 2	L 1	H 1	H 2	A / P	NSD
1	BOD RAW	Mg/L	50	80	350	500	1	0
2	BOD PE	Mg/L	10	20	100	500	1	0
3	BOD PE (Sol)	Mg/L	10	20	100	500	1	0
4	BOD BDE	Mg/L	1	10	100	500	1	0
5	BOD BDE (Sol)	Mg/L	1	10	100	500	1	0
6	BOD STE	Mg/L	1	5	40	200	-1	0
7	BOD FINAL	Mg/L	1	5	18	100	1	0
8	BOD FINAL (s)	Mg/L	1	5	18	100	1	1
9	Indv RBC BOD	Mg/L	1	10	50	100	-1	1
10	Indv RBC #		0	1	14.5	15	-1	0
11	Indv RBC BOD	Mg/L	1	10	50	100	-1	1
12	Indv RBC #		0	.5	14.5	15	-1	0
13	SBOD BTO	Mg/L	10	50	400	900	1	0
14	BOD CIS	Mg/L	50	80	400	1000	-1	0

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FILE :PCCL2 .RAW C12 (24)
File Number : 12
Current Reasonability Limits

#	Data	ID	unit	L 2	L 1	H 1	H 2	A / P	NSD
1	0100	C12	Mg/L	-.01	.1	2	9	1	2
2	0200	C12	Mg/L	-.01	.1	2	9	1	2
3	0300	C12	Mg/L	-.01	.1	2	9	1	2
4	0400	C12	Mg/L	-.01	.1	2	9	1	2
5	0500	C12	Mg/L	-.01	.1	2	9	1	2
6	0600	C12	Mg/L	-.01	.1	2	9	1	2
7	0700	C12	Mg/L	-.01	.1	2	9	1	2
8	0800	C12	Mg/L	-.01	.1	2	9	1	2
9	0900	C12	Mg/L	-.01	.1	2	9	1	2
10	1000	C12	Mg/L	-.01	.1	2	9	1	2
11	1100	C12	Mg/L	-.01	.1	2	9	1	2
12	1200	C12	Mg/L	-.01	.1	2	9	1	2
13	1300	C12	Mg/L	-.01	.1	2	9	1	2
14	1400	C12	Mg/L	-.01	.1	2	9	1	2
15	1500	C12	Mg/L	-.01	.1	2	9	1	2
16	1600	C12	Mg/L	-.01	.1	2	9	1	2
17	1700	C12	Mg/L	-.01	.1	2	9	1	2
18	1800	C12	Mg/L	-.01	.1	2	9	1	2
19	1900	C12	Mg/L	-.01	.1	2	9	1	2
20	2000	C12	Mg/L	-.01	.1	2	9	1	2
21	2100	C12	Mg/L	-.01	.1	2	9	1	2
22	2200	C12	Mg/L	-.01	.1	2	9	1	2
23	2300	C12	Mg/L	-.01	.1	2	9	1	2
24	2400	C12	Mg/L	-.01	.1	2	9	1	2

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FILE :PCMGD .RAW Flow

File Number : 13

Current Reasonability Limits

#	Data ID	unit	L 2	L 1	H 1	H 2	A / P	NSD
1	TOTALIZER-RECL	MG	10	25	99	120	1	3
2	Totalizer 1	MG	-.0001	10	99	120	1	3
3	Totalizer 2	MG	-.0001	10	99	120	1	3
4	Main Bld Flow	MG	10	30	99	120	1	3
5	Main Bld - Recl	MG	10	20	99	120	1	3
6	Recycle Flow	MG	0	2	9	15	1	3
7	Max Flow	MG	25	30	120	150	1	0
8	Min Flow	MG	5	8	50	75	1	0
9	Avg. Raw Temp	Deg F	33	45	80	99	1	0
10	High Air Temp	Deg F	-10	-5	110	130	1	0
11	Low Air Temp	Deg F	-20	-15	99	110	1	0
12	Rain	inch	0	0	9	20	1	2
13	Snow (in)	inch	0	0	15	25	1	1
14	Electric Use	KWH	0	0	1000	2000	1	0
15	Util. Gas Use	KCuFt	0	0	100	200	1	1
16	Util. Water Use	K Gal	0	0	100	300	1	0
17	Grit	Loads	0	0	9	15	1	2
18	Screenings	Cans	0	0	20	45	1	1
19	Grit	lbs	-.01	0	100000	500000	1	0
20	Plnt Bypass	MGD	-.01	0	.1	.2	0	1
21	Avg. PE Temp.	Deg F	33	45	80	99	1	0

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FILE :PCCHEMAD.RAW Fe: Al; Cl2; Polm.
File Number : 14
Current Reasonability Limits

#	Data ID	unit	L 2	L 1	H 1	H 2	A / P	NSD
1	Fe Tank #2	Gal	-1	1000	12000	900000	1	0
2	Tank #2 Sp Gr		0	1	1.6	2	1	3
3	Fe Tank #3	Gal	-1	1000	10000	1000000	1	0
4	Tank #3 Sp Gr		0	1	1.6	2	1	3
5	Al : Prim. Inf.	Gal	0	1000	10000	1000000	0	0
6	Al : IST Inf.	Gal	0	500	10000	1000000	0	0
7	Al : Int Pump	Gal	0	1000	10000	1000000	1	0
8	Tank #1 Sp Gr		0	1	1.6	2	1	3
9	Fe : Int Pump	Gal	0	100	10000	1000000	0	0
10	Cl : Prim. Eff.	Lbs	0	100	10000	1000000	0	0
11	Cl : RBC Inf.	Lbs	0	100	10000	1000000	0	0
12	Cl : BDE	Lbs	0	100	10000	1000000	0	0
13	Cl : IST #3	Lbs	0	100	10000	1000000	0	0
14	Cl : Int Pump	Lbs	0	100	10000	1000000	0	0
15	Cl : Carbon Col	Lbs	0	100	10000	1000000	0	0
16	Cl : Filter Inf	Lbs	0	100	3500	1000000	1	0
17	CL : Washwater	Lbs	0	100	10000	1000000	0	0
18	Cl : Final	Lbs	0	100	10000	1000000	0	0
19	Cl : Post Final	Lbs	0	100	10000	1000000	0	0
20	Poly : Prim Inf	Lbs	0	10	10000	1000000	0	0
21	Poly : IST Inf	Lbs	0	10	10000	1000000	0	0
22	Poly : Floc SST	Lbs	0	10	10000	1000000	0	0
23	Poly : Filt Inf	Lbs	0	10	10000	1000000	0	0
24	SO2 : Final	Lbs	0	10	10000	1000000	0	0
25	SO2 : Pst Final	Lbs	0	10	10000	1000000	0	0
26	Fe : IST	GAL	0	100	12000	20000	0	0
27	Defoamant	GAL	0	0	30	100	0	0
28	Caustic Soda	GAL	0	0	3000	5000	0	0

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FILE :PCSIDEST.RAW Sidestream Data

File Number : 15

Current Reasonability Limits

#	Data ID	unit	L 2	L 1	H 1	H 2	A / P	NSD
1	PTF Q	MG	0	0	5	9	1	3
2	ITF Q	MG	0	0	3	9	0	3
3	STF Q	MG	0	0	4	9	1	3
4	Dilution Q	MG	0	0	3	9	0	3
5	BTS to Dig 1	GAL	0	0	150000	1000000	1	0
6	BTS to Dig 2	GAL	0	0	150000	1000000	1	0
7	STS to Dig 1	GAL	0	0	120000	1000000	0	0
8	STS to Dig 2	GAL	0	0	120000	1000000	0	0
9	STS to Dewater	KGal	0	0	120	1000	0	0
10	C Sludge	K GAL	0	0	500	1000	1	1
11	Coil Filt	K GAL	0	0	500	1000	0	2
12	# Poly - Thick	LBS	0	0	400	1000	1	0
13	# Poly Dewater	LBS	0	0	500	1000	1	0
14	# Lime Used SSI	LBS	0	0	100000	300000	1	0
15	# Sludge Hauled	K LBS	0	0	500	900	1	2
16	Sldg Truck Left		0	0	9	12	1	0
17	# Sldg Prev Day	K LBS	0	0	400	600	1	2
18	Gas to Boilers	K CuFt	0	0	400	650	1	0
19	Gas to Engines	K CuFt	0	0	250	500	1	0
20	Gas to Flare	K CuFt	0	0	500	600	1	0
21	Gas to Recirc	K CuFt	0	0	750	1000	1	0
22	Thk Sldg to EE	K Gal	0	0	1500	3000	0	0
23	Dig #1 Temp	°F	0	85	99	100	1	0
24	Dig #2 Temp	°F	0	85	99	100	1	0
25	Dig % Methane	%	50	60	75	80	1	0
26	# Lime Deliv.	Lbs	0	0	300000	1000000	1	0
27	# Lime Adjust	LBS	-40000	0	40000	90000	0	0

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FILE :PCLEVELS.RAW Dig & Thick Level
File Number : 16
Current Reasonability Limits

#	Data ID	unit	L 2	L 1	H 1	H 2	A / P	NSD
1	Thick 1 Level	Feet	0	3	13	13	1	1
2	Thick 2 Level	Feet	0	0	13	13	1	1
3	Thick 3 Level	Feet	0	3	13	13	1	1
4	Thick 4 Level	Feet	0	0	13	13	1	1
5	Thick 5 Level	Feet	0	3	13	13	1	1
6	Digest 1 Level	Feet	0	5	25.1	28	1	1
7	Digest 2 Level	Feet	0	5	25.1	28	1	1

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FILE :PCUNITS .RAW On Line Units
File Number : 17
Current Reasonability Limits

#	Data ID	unit	L 2	L 1	H 1	H 2	A / P	NSD
1	Main Bld Pumps		0	2	5	6	0	2
2	Grit Channels		0	2	6	7	1	2
3	Primary Tanks		0	2	8	9	1	2
4	RBC		0	2	14	15	1	2
5	Intermed Tanks		0	0	4	5	1	2
6	Carbon Col.		0	0	24	25	0	2
7	Secondary Tank		0	4	12	13	1	2
8	Filters		0	4	12	13	1	2
9	Filt Backwashes		0	5	30	48	1	0
10	Cl2 Contact		0	1	3	3	1	0

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FILE :PCLIME .RAW Applic. Site : pH

File Number : 18

Current Reasonability Limits

#	Data ID	unit	L 2	L 1	H 1	H 2	A / P	NSD
1	Applic. Site #1	Code	-1	0	15	20	1	0
2	Sludge Site #1	WetTon	-2	0	300	400	1	0
3	Applic. Site #2	Code	-1	0	15	20	-1	0
4	Sludge Site #2	WetTon	-2	0	300	400	0	0
5	Applic. Site #3	Code	-1	0	15	20	-1	0
6	Sludge Site #3	WetTon	-2	0	300	400	0	0
7	Truck #1	pH	-1	11.99	13	14	1	1
8	Truck #2	pH	-1	11.99	13	14	1	1
9	Truck #3	pH	-1	11.99	13	14	1	1
10	Truck #4	pH	-1	11.99	13	14	1	1
11	Truck #5	pH	-1	11.99	13	14	1	1
12	Truck #6	pH	-1	11.99	13	14	1	1
13	Truck #7	pH	-1	11.99	13	14	1	1
14	Truck #8	pH	-1	11.99	13	14	1	1
15	Truck #9	pH	-1	11.99	13	14	1	1
16	Truck #10	pH	-1	11.99	13	14	1	1
17	Truck #11	pH	-1	11.99	13	14	1	1
18	Truck #12	pH	-1	11.99	13	14	1	1
19	Truck #13	pH	-1	11.99	13	14	1	1
20	Truck #14	pH	-1	11.99	13	14	1	1
21	Truck #15	pH	-1	11.99	13	14	1	1

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FILE :pcticket.RAW Sludge Tickets

File Number : 19

Current Reasonability Limits

#	Data ID	unit	L 2	L 1	H 1	H 2	A / P	NSD
1	Ticket #1	Lbs.	-1	0	60000	65000	1	0
2	Ticket #2	Lbs.	-1	0	60000	65000	1	0
3	Ticket #3	Lbs.	-1	0	60000	65000	1	0
4	Ticket #4	Lbs.	-1	0	60000	65000	1	0
5	Ticket #5	Lbs.	-1	0	60000	65000	1	0
6	Ticket #6	Lbs.	-1	0	60000	65000	1	0
7	Ticket #7	Lbs.	-1	0	60000	65000	1	0
8	Ticket #8	Lbs.	-1	0	60000	65000	1	0
9	Ticket #9	Lbs.	-1	0	60000	65000	1	0
10	Ticket #10	Lbs.	-1	0	60000	65000	1	0
11	Ticket #11	Lbs.	-1	0	60000	65000	1	0
12	Ticket #12	Lbs.	-1	0	60000	65000	1	0
13	Ticket #13	Lbs.	-1	0	60000	65000	1	0
14	Ticket #14	Lbs.	-1	0	60000	65000	1	0
15	Ticket #15	Lbs.	-1	0	60000	65000	1	0
16	Ticket #16	Lbs.	-1	0	60000	65000	0	0
17	Ticket #17	Lbs.	-1	0	60000	65000	0	0
18	Ticket #18	Lbs.	-1	0	60000	65000	0	0
19	Ticket #19	Lbs.	-1	0	60000	65000	0	0
20	Ticket #20	Lbs.	-1	0	60000	65000	0	0

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FILE :FLOW .cal Q DT LOADS
File Number : 1
Current Reasonability Limits

#	Data ID	unit	L 2	L 1	H 1	H 2	A / P	NSD
1	Plant Inf Q	MGD	10	25	99	120	1	3
2	Prim Eff Q	MGD	10	30	99	120	1	2
3	RBC Train Q	MGD	1	2	7	10	1	2
4	ITE Q	MGD	20	30	99	120	0	2
5	Backwash Q	MGD	1	2	10	30	1	2
6	STE Q	MGD	20	30	99	120	1	2
7	Screenings	Cu Ft	0	0	1E+11	1E+11	1	1
8	Grit	Cu Ft	0	10	1000	3000	1	1
9	Cl2 Residual	Mg/L	0	.2	1	3.5	1	2
10	Prim Det Time	Hrs	.5	.75	3	5	1	1
11	Total Fe Sp GR		0	.75	1.6	2	1	3
12	SST Det Time	Hrs	.3	.75	4	7	1	1
13	RBC Hyd. Load	GPD/SF	2	3	15	20	1	1
14	RBC # SBOD	/K SF	.2	.7	5	7	1	2
15	Filt Hyd. Load	GPD/SF	.5	1	5	9	1	1
16	TSS Remove	%	80	95	100	100.1	1	1
17	BOD Remove	%	60	88	99	100.1	1	1
18	RBC SBOD Remove	%	-10	10	70	95	1	1
19	Ferric Wt.	%	10	20	70	90	1	2
20	Alum Wt.	%	10	20	70	90	1	2
21	Flume Q - PI	MGD	25	30	99	120	1	2
22	Ferric	Lb/Gal	1	2	5	6	1	2
23	Alum	Lb/Gal	1	2	6	8	1	2
24	Cl2 Tank DT	Min	10	15	70	90	1	1
25	COD Removal	%	60	82	99	101	1	1
26	PO4 Removal	%	70	90	99.5	101	1	1
27	Total Cent Feed	KGal	0	0	500	700	1	0
28	Totalizer Dif.	MG	-10	-5	5	10	1	3
29	Totalizer Ratio		.9	.95	1.15	1.2	1	4

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FILE :DIGEST .cal SRT VA/ALK etc

File Number : 2

Current Reasonability Limits

#	Data ID	unit	L 2	L 1	H 1	H 2	A / P	NSD
1	#1 14 Day Avg	Feet	0	15	25	26	1	1
2	#2 14 Day Avg	Feet	0	15	25	26	1	1
3	#1 Act Volume	MGal	.9	1	1.6	1.8	1	2
4	#2 Act Volume	MGal	.9	1	1.6	1.8	1	2
5	#1 Feed	Gal	0	5000	150000	200000	1	0
6	#2 Feed	Gal	0	5000	150000	200000	1	0
7	#1 Feed SS	KLbs	0	0	1E+11	1E+11	1	0
8	#2 Feed SS	KLbs	0	0	1E+11	1E+11	1	0
9	Spare		.1	.2	150	300	1	1
10	Spare		.1	.2	150	300	1	1
11	#1 V Acid/Alk	Ratio	0	.01	.5	1	1	2
12	#2 V Acid/Alk	Ratio	0	.01	.5	1	1	2
13	#1 VS Reduction	%	10	30	60	80	1	1
14	#2 VS Reduction	%	10	30	60	80	1	1
15	#1 Feed Lb VS/	Cu Ft	0	.01	1	10	1	2
16	#2 Feed Lb VS/	Cu FT	0	.01	1	10	1	2
17	Spare		.1	.2	150	300	1	1
18	Spare		.1	.2	150	300	1	1
19	#1 Feed VS	KLbs	0	0	100000	300000	1	0
20	#2 Feed VS	KLbs	0	0	100000	300000	1	0
21	#1 HRT	Days	1	5	22	25	1	1
22	#2 HRT	Days	1	5	22	25	1	1
23	#1 HRT R. Avg.	Days	2	6	25	30	1	1
24	#2 HRT R. Avg.	Days	2	6	25	30	1	1
25	Total Dig Feed	Gal	0	1000	400000	1E+07	1	0
26	Avg Dig Feed	Gal	0	9000	400000	1E+07	1	0
27	Avg Dig Withdr	Kgal	0	40	400	700	1	2
28	Feed/Withdr	Ratio	.1	.8	1.3	2	1	3

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FILE :LBTSS .cal TSS Loading

File Number : 3

Current Reasonability Limits

#	Data ID	unit	L 2	L 1	H 1	H 2	A / P	NSD
1	Raw TSS	KLbs	10	15	200	400	1	0
2	PI TSS /w Chem	LBS	3000	4000	200000	300000	1	0
3	PE TSS	KLbs	1	4	30	70	1	2
4	PTF TSS	LBS	30000	40000	150000	200000	1	0
5	BDE TSS	LBS	3000	9000	60000	100000	1	0
6	Digest Avg TS	%	0	0	1E+11	1E+11	0	2
7	Digest Avg TVS	%	0	0	1E+11	1E+11	0	1
8	STE TSS	LBS	500	1000	6000	10000	1	0
9	STF TSS	LBS	1000	8000	60000	100000	1	0
10	DMFE TSS	LBS	75	100	3000	6000	1	0
11	FINAL TSS	KLbs	.1	.15	2	5	1	1
12	BTO TSS	LBS	500	900	6000	12000	1	0
13	C. SLUDGE	KLbs	0	0	100	400	1	0
14	CE TSS	LBS	0	0	5000	15000	1	0
15	C. SLDG VOL	KLbs	0	0	85	300	1	0
16	Dry Grit	KLbs	0	.2	15	30	1	1
17	ITE TSS	Lbs	0	0	1E+11	1E+11	1	0
18	ITF TSS	Lbs	0	0	1E+11	1E+11	1	0
19	Total Ferric	Gal	0	2000	12000	20000	1	0
20	Lime Inven.	LBS	0	24000	190000	200000	1	0
21	Sludge Hauled	Lbs.	-1	0	500000	1000000	1	0
22	Sludge Hauled	K Lbs.	-1	0	500	1000	1	2

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FILE :LBBOD .cal BOD Loading
File Number : 4
Current Reasonability Limits

#	Data ID	unit	L 2	L 1	H 1	H 2	A / P	NSD
1	RAW BOD	KLbs	10	20	500	2000	1	0
2	PE TBOD	LBS	5000	10000	25000	50000	1	0
3	PE SBOD	LBS	3000	6000	20000	40000	1	0
4	BDE TBOD	LBS	5000	10000	40000	60000	1	0
5	BDE SBOD	LBS	500	1000	8000	12000	1	0
6	STE TBOD	LBS	500	1000	8000	12000	1	0
7	FINAL TBOD	KLbs	.1	1	99	200	1	1
8	FINAL SBOD	LBS	500	1000	8000	12000	1	0
9	RAW COD/BOD	RATIO	.5	1	4	5	1	2
10	FINAL COD/BOD	RATIO	.7	1	5	7	1	3
11	FINAL BOD/TSS	RATIO	1	3	15	25	1	3
12	BOD REMOVED	KLbs	5	10	150	300	1	0
13	IND RBC BOD	LBS	50	100	700	2000	1	0
14	IND RBC BOD	LBS	50	100	700	2000	1	0
15	Ferric to PST	Mg/L	5	10	40	60	1	1
16	Alum to SST	Mg/L	4	9	90	120	1	1
17	Cl2 Feed Dose	Mg/L	.5	1	10	30	1	1
18	AVG COD/BOD	RATIO	0	1	5	10	1	1
19	EST FINAL BOD	Mg/L	0	5	20	25	1	1
20	Wet Sludge	Tons	0	80	400	800	1	1
21	Est Dry Sludge	Tons	0	15	200	400	1	1
22	Lime	Tons	0	5	50	100	1	1
23	Net Wet Sludge	Tons	0	20	400	800	1	1
24	Dry Sludge	Tons	0	15	200	500	1	1
25	Lb Poly/Dry Ton	Lb/Ton	0	5	12	20	1	1
26	% C. Cake Lime	D.Ton	0	5	40	70	1	1

The vita has been removed from the scanned document