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Evaluation of Operation and Maintenance Factors Limiting Municipal Wastewater Treatment Plant Performance

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EVALUATION OF OPERATION AND MAINTENANCE FACTORS LIMITING MUNICIPAL WASTEWATER TREATMENT PLANT PERFORMANCE

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the program.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

In this report documentation from comprehensive biological treatment plant evaluations establishes cause and effect relationships for poor plant performance and the top ten factors causing poor performance are identified. A procedure, called a Composite Correction Program, was developed and implemented to improve plant performance. Unlike existing programs, the CCP approach identifies all factors limiting plant performance at individual facilities and solutions to all the problems are implemented. Results show that many plants formerly not in compliance are performing to meet their design standards and permit requirements without the need for major construction.

Francis T. Mayo, Director
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EXECUTIVE SUMMARY

A significant number of wastewater treatment plants constructed with federal monies have not met design or NPDES permit standards. The emphasis of this research study was to identify, quantify and rank the causes of this poor performance. Research objectives were accomplished by conducting comprehensive evaluations at selected wastewater treatment facilities. Selected facilities were initially screened by regional EPA and state pollution control agency personnel. Research team members further screened facilities during half-day site visits. Many of the plants chosen for evaluation were operable facilities which were often violating permit standards.

Comprehensive evaluations were conducted at thirty wastewater treatment facilities in seven western states. The in-plant research evaluation typically lasted one week. Sanitary engineers with strong operational backgrounds collected the research information. To obtain accurate and complete information, technical assistance in plant operation was provided to develop a cooperative atmosphere that allowed for a meaningful exchange of information between plant personnel and research team members.

Factors limiting plant performance were evaluated in four major areas: operation, design, maintenance and administration. Operations factors were evaluated by observing and discussing current process control procedures and by conducting additional testing to determine process conditions that existed during the comprehensive evaluations. Design factors were evaluated by relating conventional design parameters to existing loading conditions and by attempting various process adjustments which allowed theoretical design capabilities to be evaluated relative to actual operating abilities. Maintenance scheduling and recording documents, emergency procedures and the condition of the plant grounds, buildings and equipment were assessed to determine if maintenance related factors were affecting plant performance. Administration factors were evaluated at the plant site and by interviewing officials other than in-plant personnel, so that plant operators' opinions did not dominate the research team's assessment of administrative problems.

For each comprehensive evaluation seventy factors potentially limiting plant performance were quantified in a weighing table which was developed for use in this research project. Results were combined to form an overall ranking of factors. Also, the leading cause of poor performance at each facility was documented. The highest ranking factor contributing to poor plant performance was improper operator application of concepts and testing to process control. The second highest ranking factor was inadequate sewage treatment understanding. These two factors were differentiated in meaning in that sewage treatment understanding was rated when operators had a general lack of knowledge concerning sewage treatment. The operator application of concepts factor was rated when operators had a general knowledge about sewage treatment, but were not correctly applying appropriate principles to process control. The implications of these findings are far reaching in that to improve sewage treatment understanding additional training is necessary. However, trained operators were not usually able to apply basic sewage treatment concepts to their individual situations. To overcome this deficiency, dramatic changes are necessary in the approach to operator training.

Because of the high ranking of performance limiting factors related to the plant operator, a special study was completed to evaluate operator capabilities. A major finding was that in nearly all facilities surveyed existing personnel had adequate aptitude to be taught how to achieve better plant performance. It was also determined that staff salaries and available staff size did not significantly correlate with good or poor plant performance for the facilities evaluated. It was concluded that the potential capabilities of present plant personnel are an untapped resource for achieving improved plant performance, but existing efforts to develop this resource are not sufficient.

The potential for developing the presently undeveloped capabilities of existing operators was complicated in light of the third highest ranking performance limiting factor, improper technical guidance. Improper technical guidance was documented from authoritative sources including design engineers, state and federal regulatory personnel, operator training program staff, other plant operators and equipment suppliers. These findings indicate that external sources have dramatically affected the capability of existing operations personnel to first attain adequate sewage treatment understanding, and secondly to apply this understanding to process control. It was concluded that the source of the first two high ranking factors which are plant operator oriented was not necessarily with the operators themselves, but with the technical guidance sources that provided training and assistance functions.

The conclusion that the source of most of the present performance problem is not the plant operations staff was further supported by the fact that the fifth through the tenth highest ranking factors limiting plant performance are process design oriented. These factors in order of severity are: sludge wasting capability, process flexibility, process controllability, secondary clarifier, sludge treatment and aerator capability. The inability of persons involved with plant design to apply the technology necessary to develop adequate treatment facilities, coupled with the improper technical guidance from these sources, indicated that a problem exists in an area that has typically been assumed to be sound. The capabilities of the authoritative sources that influence facility design and operation must be improved.

Some of the factors identified as limiting plant performance are addressed by on-going programs. These programs were not evaluated per se, but selected programs were discussed with respect to observations noted during the research project. Programs developed to address administrative factors include the NPDES permit and associated permit enforcement programs, which potentially influence plant performance by motivating administrative personnel. Efforts to achieve permit compliance often led to a major facility upgrade, and in several facilities poor effluent quality continued even after the upgrade was completed. The original factors limiting performance were not addressed, and at some plants a major facility modification was not warranted.

A more thorough investigation into the existing facilities' capabilities through improved O & M was warranted. To this end, permit enforcement programs should encourage optimization of existing plant capability before a major modification is initiated.

Some of the current programs developed to address design factors include the construction grant, technology transfer, federal and state design criteria and value engineering programs. The federally funded construction grant program encouraged a number of engineers and equipment suppliers to enter the wastewater treatment plant field. Federal and state design criteria and technology transfer programs provided these persons with basic information to design facilities. However, many designs were completed and equipment developed using the basic information available, but without a thorough understanding of wastewater treatment process operation and interrelationships. The result was a large number of marginally designed facilities and equipment and associated poor performance. Design criteria and technology transfer programs should not be solely blamed for these inadequacies because they were not intended to provide a total basis for well designed plants. The programs continue to be important, but should be re-evaluated and restructured to emphasize the identified high ranking factors which limit performance. The value engineering program, because of its minimum cost approach, has the potential of disallowing some plant features that can contribute to optimum performance. For example, plant flexibility and plant controllability features, whose absence was noted repeatedly, may be considered as non-essential and subsequently eliminated from plant designs as cost saving measures. All value engineering analyses should be conducted with appropriate appreciation for plant operation so that design features that potentially aid in operations control are not excluded, but are included if not present.

Programs developed to address operation and maintenance factors include operator training, operation certification and plant start-up assistance. Operator training and certification programs were observed to address the second highest ranking performance limiting factor, sewage treatment understanding. However, many operators with a good general sewage treatment understanding did not correctly apply even basic concepts of operation to process control at their individual wastewater treatment facilities. To significantly improve plant process control and plant performance, operator skills must be developed through technical guidance at individual facilities under the direction of qualified personnel. To this end the plant start-up assistance program has much potential to improve plant operation, but because of the large amount of improper technical guidance that was noted training of start-up assistance personnel is warranted. The plant start-up assistance program provides a good opportunity for this self-education.

Optimum performance of a facility occurs when all factors limiting performance are eliminated or substantially reduced. The interrelationship between the many performance limiting factors and the programs designed to address these factors was described in a concept called a Unified Concept for Achieving Optimum Plant Performance. Two broad types of correction programs were described, Individual Correction Programs and Composite Correction Programs.

Individual Corrections Programs described a program that was implemented to eliminate a specific factor or group of factors at all or at a large number of facilities. Typically, Individual Correction Programs address only a portion of the many performance limiting factors that occur at an individual facility. Most existing correction programs, like operator training, technology transfer and design criteria are Individual Correction Programs. These programs should not be abandoned because of the magnitude of factors limiting performance, but should be recognized as limited in their ability to achieve optimum facility performance.

Composite Correction Program described a program that addresses all factors limiting performance at a given facility. During the research project a Composite Correction Program was implemented at the Havre, Montana Wastewater Treatment Facility. A dramatic improvement in effluent quality resulted, and permit requirements that were previously violated were subsequently met. A long period of time (12 months) was required to optimize system performance and to transfer the capability to maintain optimum performance to the Havre plant superintendent. It was concluded that effective recommendations to optimize biological system performance in most cases should not be made when the involvement in plant operation is over a short period of time like an hour, a day, a week or maybe even a month. Several months are required to properly evaluate biological system response and achieve optimum performance. This time delay for effective recommendations was considered a major reason for the prevalence of improper technical guidance, because authoritative sources are not usually in a position to be held accountable for their operations recommendations.

The Havre plant superintendent was trained and certified, and was considered to be an above-average operator. However, proper concepts of sewage treatment were not being applied to his facility's process control. The time involved and the approach used to develop his skills illustrated the need for drastically altering present operator training procedures. An operator's skills to correctly apply concepts of sewage treatment to process control should be developed through technical guidance at his individual facility under the direction of qualified personnel.

If a Composite Correction Program were completed at all thirty facilities evaluated, the estimated BOD_5 and TSS reduction was 1350 kg/day (3000 lb/day), which represents a 65 percent improvement in the present discharge. Without a major facility upgrade an additional sixteen facilities would meet federally defined minimum secondary treatment standards now frequently violated. However, limitations to implementation of the Composite Correction Program approach to improving facility performance exist. There is a lack of qualified personnel to implement programs on a broad scale. Also, present incentives are not satisfactory to encourage the program's widespread implementation. To implement Composite Correction Programs, specialized training approaches to attain qualified personnel should be developed. Training must include in-plant operations experience at various wastewater treatment facilities over a long period of time. Conducting a Composite Correction Program and/or observing its conduct is an excellent training function. The federal construction grant plant start-up assistance program could also provide a basis for attaining qualified personnel, if the program is approached as a training function for both plant and start-up assistance personnel.

Incentives to encourage Composite Correction Programs are required. A possible incentive is more aggressive enforcement of NPDES permit requirements with respect to existing plants' operations capabilities. Another incentive is to develop a financial assistance program for existing facilities. However, financial assistance programs must be developed to provide an impetus for implementing Composite Correction Programs and not as a reward to facilities that currently are not achieving satisfactory performance. Encouraging Composite Correction Programs will not result in immediate optimum performance at all facilities. However, the soundness of the program has been demonstrated and the program's development can eventually result in widespread optimum facility performance.

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CONTENTS

Appendices

FIGURES

TABLES

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SECTION 1

INTRODUCTION

The Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) along with the 1977 amendments (PL 95-217) established goals for the water quality of the nation's public waters and programs through which these goals were to be achieved. As part of the overall program a minimum degree of treatment, "secondary treatment," was established for the 25,000 existing and also for any future publicly owned treatment works (POTW). Where secondary treatment is insufficient to protect the receiving stream, provisions were made in the 1972 Act to require more stringent treatment requirements.

The 1972 Act also established an expanded federal construction grants program through which the construction of new POTW's or upgrading of existing POTW's was to be completed to meet the new water quality goals. However, both the 1973 and 1974 editions of the U.S. Environmental Protection Agency's (EPA) Clean Water Report to Congress showed that about one-third of all treatment facilities constructed with federal grant assistance were not meeting design effluent quality. In response to these findings, the EPA's Office of Research and Development initiated a three and one-half year research program, the first phase of which was titled, "Demonstrated Improved Performance and Reliability of Selected Biological Treatment Plants." Two 24-month contracts were awarded simultaneously to private engineering consultants to initiate the research effort (Phase I), one in the Eastern United States and one in the Western United States. A second phase follow-up effort also conducted by private consultants has now been initiated to continue the Phase I investigation and conduct special studies into areas which warrant further investigation.

This report documents the findings of the contractor for the Western U.S. based on the first 24-month (Phase I) research period. A companion report has been prepared by the Eastern U.S. Contractor. (1) The primary objective of the research study as described in the EPA Request for Proposal was to demonstrate improved performance in selected biological treatment facilities through improved O & M practices. Under this original objective thirty to forty plants were to be selected as the subjects of "preliminary studies" in which factors limiting plant performance were to be identified. Recommendations to eliminate these factors were to be made in technical reports developed for each facility. Finally, demonstration projects were to be conducted at several selected facilities to document improved performance achieved through implementation of the recommendations for improved O & M practices.

The objective of demonstrating improved performance was later modified by the EPA because of an increasing need to continue identifying and documenting the most frequently occurring factors which limit plant performance. Identified factors were quantified and ranked in order of frequency and severity. This modified objective was accomplished by conducting comprehensive evaluations of operating wastewater treatment facilities instead of the formally planned preliminary studies and demonstration projects. In addition, the causes of the most frequently occurring factors limiting performance and an evaluation of programs through which these causes could be eliminated was completed by conducting three special studies. The purpose of conducting special studies was to analyze specific performance limiting factors or groups of factors that related to a number of facilities and not necessarily to "demonstrate improved performance" at a particular facility.

SECTION 2

PURPOSE AND SCOPE

The purpose of this research project was to identify, quantify and rank the major factors which limit biological wastewater treatment plant performance. Comprehensive evaluations were conducted at selected wastewater treatment facilities. When selecting plants, special emphasis was placed on "operable" facilities where O & M practices could be evaluated. The selection procedure included screening of facilities by the regional EPA offices, state pollution control agencies and research team personnel.

The scope of the project included research activities in Colorado, Wyoming, Montana, Utah, South Dakota, Nebraska and Iowa. The research area is shown in Figure 1. These states are located in EPA's Regions VII and VIII.

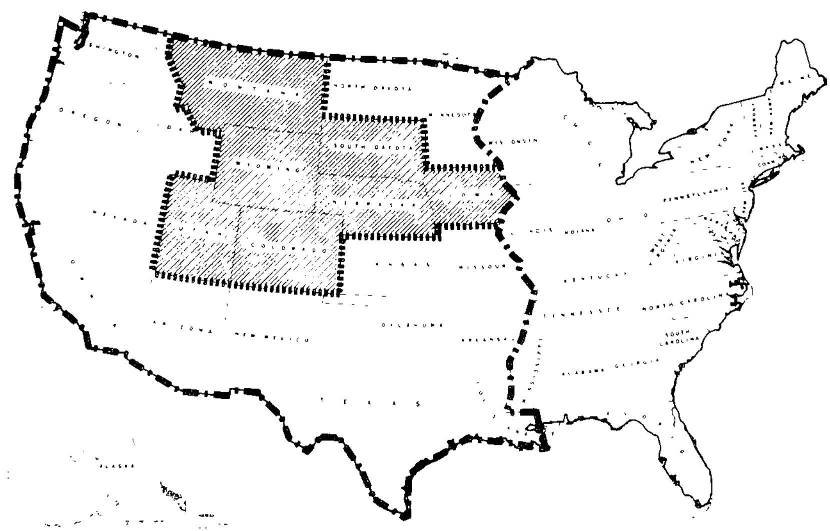

Figure 1. Study area of the Western U.S. contractor.

The regional EPA offices and state pollution control agencies screened treatment facilities within their jurisdiction and suggested a total of 163 facilities as candidates for research. Research team members further screened candidate plants and rejected 100 facilities. One-half day plant site visits were eventually conducted at 63 facilities to make a final selection of 30 facilities for which comprehensive evaluations (called preliminary surveys) were conducted. The plant selection procedure and criteria are described further in the Research Approach section of this report.

The term preliminary survey may be confusing in that it suggests some further study would follow. This was the original intent until the objective of demonstrating improved performance was modified. The preliminary survey was the major mechanism through which factors limiting plant performance were identified, quantified and ranked, and represents the final in-plant research effort expended at most facilities. Three special studies were also completed on selected subjects. Individual reports were developed for each site visit, preliminary survey and special study. The results of one special study, the site visits and the preliminary surveys are compiled in this report. The results of the other two special studies are compiled in a separate report, "A Demonstrated Approach For Improving Performance and Reliability of Biological Wastewater Treatment Plants." (2)

SECTION 3
CONCLUSIONS

1. A plant selection process was necessary to find operable facilities with cooperative personnel for thirty comprehensive plant evaluations.

2. At some facilities a decision was made by local officials to not participate in the research effort because possible improvement in existing plant performance may have lowered the community's position on the State's grant funding priority list. Present construction grant awarding procedures encourage poor performance of existing facilities.

3. The site visit aspect of the plant selection process allowed an evaluation of obvious performance limiting factors to be made.

   A. Excessive I/I was the most frequently observed problem during site visits. Plants with excessive I/I were excluded from further research due to the excessive hydraulic overload associated with this problem.

   B. Where obvious performance limiting factors were noted, arrangements were usually in progress to correct the problem(s) because existing corrective programs (i.e., construction grant funding, state and federal regulatory inspection, etc.) typically address these more obvious problems.

4. A specialized research technique was used successfully to identify and document the subtle as well as the obvious performance limiting factors at the thirty plants selected for comprehensive evaluations.

A. Design and administration problems as well as operation and maintenance problems were found to limit performance of operating facilities.

B. Because a plant selection process was used, the results obtained during the comprehensive evaluations excluded some of the obvious performance limiting factors noted during the site visits.

5. An average of 15 and a range of four to thirty performance limiting factors were documented at each of the thirty facilities evaluated. Measureable improved performance may not result at a particular plant from the elimination of one or even several factors limiting performance. All factors limiting performance must be systematically identified and eliminated until the desired performance is achieved.

6. The two highest ranking factors limiting performance at the thirty evaluated facilities were inadequate operator application of concepts and testing to process control and sewage treatment understanding. A special study on wastewater treatment plant staffing was conducted because of this high ranking of operator related performance limiting factors.

A. Total plant staff size, total plant staff cost, specific plant staff size, specific plant staff cost and plant staff salary did not significantly correlate with good or poor plant performance.

B. In nearly all facilities surveyed adequate manpower was provided for proper plant operations and maintenance. Plant maintenance was satisfactory, but plant operations was unsatisfactory even though a greater proportion of the operator's time was spent conducting "operations" tasks.

C. Current operator practices for the smallest facilities surveyed, 0-38 cu m/day (0-0.1 mgd), were poor. For larger facilities surveyed, 380-3800 cu m/day (1.0-10.0 mgd), operator practices were only fair to marginal. Improper technical guidance from "authoritative" sources played a large role in the currently inadequate operations procedures that operators use at their facilities.

D. Potential operator capability for the largest to the smallest facilities surveyed was good to fair, respectively, and was significantly better than the current operator abilities. From this evaluation it was concluded that the good operations potential of the existing plant personnel is an undeveloped resource for achieving improved plant performance.

E. Better potential operator capability correlated directly with a higher salary. However, a higher salary did not provide operators who had developed their potential capability. This potential capability was not developed because a large amount of improper technical guidance is currently being disseminated.

7. A major plant performance problem at 17 of 30 plants was attributed to technical, "authoritative" sources (i.e., design engineers, state and federal regulatory personnel, equipment suppliers, etc.).

A. Incorrect operations advice was given by plant design engineers, even at well-designed facilities.

B. In some instances incorrect operations advice was given by regulatory personnel, but more often regulatory inspections caused operator priorities to be shifted away from performance improving activities. Regulatory personnel, in general, have not had adequate training in process control and therefore tend to address side issues which do not directly affect performance, such as good housekeeping and safety.

C. Operations recommendations which were correct for a particular situation were often incorrect at a later date because of changes in the biological process. Operators were not told to make readjustments, or if they were told they did not make needed readjustments because a logical basis for the recommended change(s) was not presented.

D. The authoritative sources that gave technical guidance were not accountable for their improper and/or inaccurate recommendations, and operators were often inappropriately blamed for the continuance of the plant's poor performance.

E. Improper technical guidance not only caused poor performance to continue, but diverted a search for a legitimate solution to the problem.

8. Six of the ten highest ranking factors limiting treatment plant performance at the thirty facilities evaluated were attributed to inadequate plant design, including insufficient sludge wasting capability, process flexibility, process controllability, secondary clarification, sludge treatment and aerator capability.

A. Six of the thirty evaluated facilities had no, or totally inadequate sludge handling facilities.

B. At two facilities an immediate improvement in plant effluent quality would have occurred with improved process flexibility.

C. Poor process controlability in the form of inadequate measurement and control capability of return sludge flow limited plant performance at 17 of 20 activated sludge plants surveyed.

D. Poor clarifier surface area development limited performance at 11 plants surveyed.

E. Poor sludge treatment facilities limited sludge wasting capacity and/or required excessive operator involvement at 15 of the plants surveyed.

F. Limited aeration capability was observed at eight of ten fixed film facilities and at one of twenty suspended growth facilities surveyed.

9. Five plant performance limiting factors were not rated in the top ten factors but were the number one cause of limited performance at six facilities. These factors were: unit process layout, administrative policies, return process streams, equipment malfunction and industrial loading.

A. Totally independent activated sludge process units at one relatively small facility (one plant operator) required a duplication of effort by the operator to provide process control. Time limitations restricted the operator from accomplishing the needed tasks.

B. Administrative policies restricting trickling filter recirculation rates (thus minimizing pumping costs) was the major cause of limited performance at two plants.

C. Excessive solids in an anaerobic digester supernatant (20,000 to 30,000 mg/l) limited the performance of one of the trickling filter facilities evaluated.

D. Aeration basin equipment malfunction was the major cause of poor performance at one plant surveyed. At three other plants substandard quality equipment was observed to contribute to a degraded effluent quality.

E. Excessive industrial loading (extent not apparent and not determined during the plant site visit to be greater than the plant design load) was the leading cause of poor performance at one facility surveyed.

10. Better plant operation could have resulted in a 40 to 50 percent savings of electrical power at some facilities surveyed, as well as allowed permit standards to be met that were being violated.

11. It was determined that twenty-three of thirty facilities surveyed did not consistently meet federally defined minimum secondary treatment standards.

A. Self-monitoring records typically did not include excessive solids loss during sludge bulking from activated sludge plants.

B. Federally funded plant modifications at 22 facilities surveyed did not enable these facilities to meet NPDES permit standards because all the factors limiting performance had not been properly addressed.

C. Federally funded plant modifications at two plants were not warranted. The capability of these two facilities was not adequately assessed with respect to improved operations practices before the major upgrades were implemented.

D. A more thorough investigation into existing facility capability is necessary prior to implementation of major plant modifications.

12. Existing correction programs which have been developed to address a single factor or group of factors limiting plant performance have been only partially effective.

A. Required NPDES permit self-monitoring records that show poor plant performance have not caused administrative officials to initiate corrective actions.

B. Enforcement of NPDES Permit requirements has served to provide an incentive for administrative officials to initiate plant correction action, but enforcement has been limited and sporatic. Corrective actions observed always included construction of new or modified facilities.

C. Information dissemination programs like technology transfer and federal and state design criteria have provided basic information regarding various unit processes, but have not resulted in the application of good engineering judgment and operations understanding into facility design as evidenced by the high ranking of inadequate design and improper technical guidance factors limiting performance.

D. Value engineering, because of the actual or implied cost savings approach, coupled with improper technical guidance, has the potential of disallowing plant features that may be required to achieve optimum or even satisfactory plant performance.

E. Federal, state and local operator training and associated state certification programs need to be expanded and improved to provide operators with a better sewage treatment understanding. However, even expanded present training techniques cannot provide operators with an ability to properly apply wastewater treatment concepts to process control at their individual facilities. To develop the ability to apply concepts to process control, operators' skills have to be developed through training at the operator's own facility under the direction of qualified personnel.

F. Plant start-up assistance that is process oriented as well as equipment oriented has the potential of improving plant performance. However, because of the large amount of improper technical guidance in process control that was noted an immediate benefit of improved plant performance through this program is unlikely. Training of start-up assistance personnel in process control is warranted, and the first benefit of the start-up assistance program is that it provides a good opportunity for this self-education.

G. Plant specific O & M manuals generally included good maintenance information and a good description of the plant's flow schematic, flexibility and controlability. O & M manuals alone cannot provide operators with the information and/or ability to properly apply concepts of operation to process control.

H. Few maintenance problems were noted at facilities surveyed for a variety of reasons:

1. O & M manuals generally were maintenance oriented.

2. Plant inspections historically have judged good plant "performance" by the appearance and operational state of equipment.

3. Maintenance problems are highly specific and visible and easily recognized by the operator and his supervisors.

13. Most existing correction programs, called Individual Correction Programs, focus on specific areas of need representing a common problem at a large number of facilities. These programs are important in the overall effort to achieve better plant performance, but should be recognized as limited in their ability to eliminate all or even a sufficient number of factors limiting performance at individual facilities to allow them to meet design or permit effluent standards.

14. A Composite Correction Program established to focus on all factors limiting performance at a given facility can achieve optimum performance at a facility if properly implemented. This approach was implemented and documented at the Havre, Montana Wastewater Treatment Plant.

A. Violations of permit standards were eliminated.

B. Plant effluent BOD_5 and TSS concentrations were reduced from 31 mg/l to 10 mg/l and 30 mg/l to 9 mg/l, respectively.

15. The Havre Composite Correction Program was successful because of a long time involvement with plant personnel.

A. Factors limiting performance were systematically identified and eliminated.

B. Twelve weeks were necessary to achieve desired changes in activated sludge characteristics.

C. One year was required to transfer to the plant superintendent the ability to make timely and accurate process control adjustments.

16. The time associated with stabilizing the biological system to achieve optimum performance and the time required to train the operator to correctly apply concepts of operation to process control observed at the Havre facility supported conclusions regarding two factors limiting performance that were noted repeatedly during this research effort.

A. Recommendations to improve biological system performance are not effective when the involvement in plant operations is over a short time period, like an hour, day, week or even a month. Depending on facility size and type, a longer time period of a few months to many months is required.

B. Plant operators with a good education, training and aptitude require guidance at their individual facilities over a relatively long period of time to develop their capability to correctly apply concepts of process control to varying operational situations.

17. A Composite Correction Program without major facility construction completed at each of the thirty evaluated facilities would improve plant effluent quality significantly.

A. Sixteen of twenty-three facilities would meet federally defined secondary treatment standards now violated. The other seven facilities would require major facility modifications to meet secondary treatment standards consistently.

B. The mass of BOD_5 and TSS discharged would be reduced by an estimated 490 metric tons per year (540 tons/year) and 470 metric tons per year (515 tons/year), respectively.

C. The masses of BOD_5 and TSS discharged would be reduced by an estimated 38 percent and 37 percent, respectively.

18. Plant underloading did not promote good plant performance. Hydraulic loading averaged only 61 percent of design, yet 23 of 30 plants did not meet secondary treatment standards.

19. Broad scale implementation of Composite Correction Programs can achieve optimum performance at a large number of facilities, but qualified personnel and incentives to conduct programs are required.

A. Training to develop qualified personnel must include guided, in-plant operations experience at various wastewater treatment plants over a long period of time to develop capabilities for correct application of concepts and to develop a respect for the time associated with biological system response.

B. Incentives are required to encourage treatment plant administrators to consider Composite Correction Programs. Enforcement actions can be used to encourage Composite Correction Programs. However, enforcement coupled with the construction grant program has resulted in the construction of new or modified facilities which have failed to achieve desired effluent goals.

SECTION 4

RECOMMENDATIONS

1. In conducting studies to determine the sources of plant performance problems, use a research approach which identifies the subtle as well as the obvious factors which limit performance.

2. Modify existing operator training procedures and materials.

   A. Develop operators' skills through technical guidance at their respective facilities under the direction of qualified personnel as an extension to their classroom training experience.

   B. Eliminate or correct inaccurate, incomplete and misleading training information by using plant design and operation specialists to evaluate classroom training programs and program materials.

3. Reduce improper technical guidance given by authoritative sources.

   A. Improve training for private and governmental persons disseminating operations technical assistance. Training must include guided in-plant process control experience at various wastewater treatment facilities to develop capabilities for proper application of wastewater treatment concepts to process control and to develop an awareness of the time associated with biological system response.

   B. Increase the awareness of state and federal regulatory personnel of the high priority that most operators place on recommendations they make and of the misunderstanding operators have concerning process control suggestions that are mentioned.

C. Encourage training of plant design engineers in plant operations and process control in formal classroom training and through guided in-plant operations experience.

D. Encourage process equipment suppliers to emphasize and provide for plant flexibility, controlability and operability instead of emphasizing and providing equipment under the guise of minimum O & M requirements.

E. Select plant operators to teach short course training programs who understand and properly apply concepts of wastewater treatment, and not necessarily because they work at or are in charge of a plant that has good effluent quality.

F. Hold persons who disseminate operations technical guidance accountable for their recommendations. As a minimum, follow-up phone calls or plant visits should be used to determine if recommendations given <u>were correct</u> and <u>still apply</u>.

4. Improve design of new or modified wastewater treatment facilities, especially for those high ranking design features observed during this research.

A. Include and emphasize the need for adequate sludge handling features in smaller plants. Emphasize design, operation and management of sludge handling facilities at larger plants.

B. Emphasize optimizing the surface area development of secondary clarifiers in all plant designs.

C. Implement more conservative design requirements for fixed film biological reactors.

D. Allow and encourage separate treatment of anaerobic digester supernatant or require increased wastewater treatment process unit sizes to adequately receive and treat this recycle flow.

E. Encourage plant flexibility which would allow bypassing of ponds following mechanical plants and flexibility to operate activated sludge plants in various modes.

F. Emphasize good controllability of return activated sludge flows.

5. Recognize that existing federal and state programs are limited in their capability to substantially improve plant performance at individual treatment facilities.

6. Direct federal and state regulatory efforts toward areas of enforcemet and accountability.

A. Expand enforcement of NPDES Permits to encourage optimum performance from existing facilities.

B. Require that Composite Correction Programs (CCP's) be implemented prior to or in conjunction with construction of new or modified facilities to insure that the existing facilities capability is examined and optimized before the upgrade, and the end result will be minimization of the construction of un-needed facilities.

C. Evaluate incentives such as financial assistance and enforcement for implementing CCP's at facilities which have recently been constructed but do not achieve design and permit standards.

D. Structure information dissemination and training programs to emphasize the highest ranking factors limiting plant performance.

E. Conduct value engineering analyses with appropriate appreciation for plant operation so that design features like plant controllability and plant flexibility that potentially aid in operation are not excluded as cost savings measures, but are included if not present.

F. Orient plant start-up assistance programs toward improving process control. Allow adequate time at an individual facility for biological response and training. Recognize that the program's initial benefit is an aid for development of qualified personnel to conduct future plant start-up activities and/or a Composite Correction Program, which eventually will serve to achieve the desired benefit of improved plant performance.

7. Plant administrators who concentrate only on obtaining a grant to help construct a major plant modification should consider other alternatives for improving the plant's performance.

A. Verify the performance potential of an existing plant by conducting a Composite Correction Program, and if required include a major plant modification as part of that program.

B. Include training and education as part of the plant operating budget.

1. Encourage classroom training and associated certification to expand the operator's sewage treatment understanding.

2. Recognize that on-site training such as provided in the conduct of a Composite Correction Program is the most effective method to develop an operator's capability to properly apply wastewater treatment concepts to process control.

C. Attract personnel with better potential operations capability by offering higher salaries and benefits.

D. Realize that once an operator is adequately trained, as through a Composite Correction Program, that the training investment for that operator must be protected by keeping him employed at the plant.

SECTION 5

RESEARCH APPROACH

GENERAL SCREENING

Plants chosen for a preliminary survey were carefully selected. A random sampling procedure was not used. The selection process consisted of general screening, preliminary screening and site visit screening as shown in Figure 2. General screening criteria were defined by the EPA and limited plant selection to the Western U.S. (for this western area contract); biological processes; 0 - 37,850 cu m/day (0 - 10 mgd) design size; plants not severely hydraulically and/or organically overloaded; plants which had all major units in service; and plants in which enforcement action was not pending. Facilities violating these criteria were rejected in the general screening phase of the plant selection procedure.

PRELIMINARY SCREENING

Preliminary screening was conducted by regional EPA offices, state pollution control agencies and research team personnel. Initially, EPA and state personnel selected facilities as candidate plants using the general screening criteria. In total, 163 candidate facilities were submitted to research team members for further review. Team members screened facilities with respect to plant type and hydraulic loading. The type of treatment process was important in that a cross-section of facility types was desired. Plants with new and less common processes were desired so their O & M requirements and performance could be evaluated. Plant design flow and the current operating flow were considered so that plants with a cross-section of flows within the general criteria could be studied. It was desired to survey various plants of a

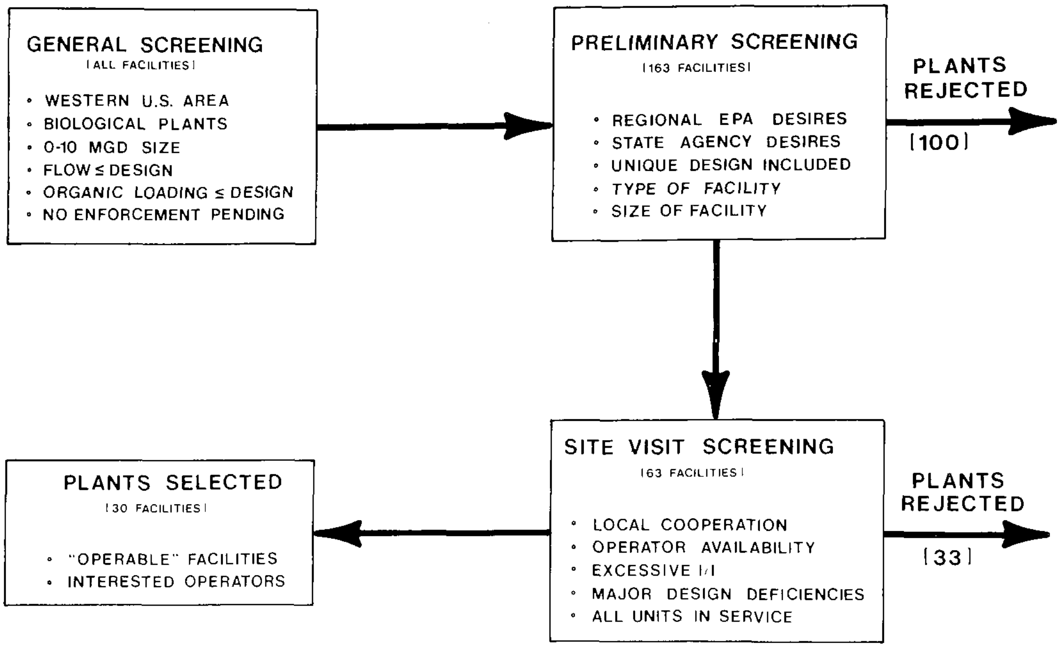

Figure 2. Plant selection procedure used for the research project.

similar type and size, so costs, major performance limiting factors and other criteria could be compared. Based on these criteria, 63 facilities were selected for on-site investigation.

SITE VISIT SCREENING

Site visit screening was completed by research team members. Typically, a one-half day visit using two team members was conducted at each plant. The research team leader was a sanitary engineer with experience in plant operations. State personnel, particularly area district engineers, were encouraged to accompany research team members on site visits and on preliminary surveys. When available, state personnel provided historical information on plant performance and previous O & M problems. They were familiar with the plant operators and administrative personnel and introduced research team members to these plant officials.

Site visit screening rejected facilities that had non-operational units, major design deficiencies, excessive infiltration/inflow and other obvious factors which precluded potentially good performance. A few facilities were rejected because town officials or plant personnel expressed a desire to not participate in the study. Some small facilities were rejected because the operator was not available to work with research team members. Some plants were chosen because they were considered to have good O & M practices. In total, 30 of the 63 facilities where site visits were conducted were selected for preliminary surveys.

Originally, the sole purpose of site visits was to insure that plants chosen for preliminary surveys would provide valuable and reliable research information. The scope of the site visit portion of the research effort was later expanded to include formal documentation of the information collected. The basic information recorded included general plant information (design flow, population served, receiving stream, etc.), general process description (wastewater and sludge flow schematic) and general plant O & M information (number of operators, lab facilities available, plant maintenance completed, etc.). An investigation checklist was used to insure that similar data was collected for each site visit. Additional documentation included factors which were noted to limit performance and the reasons the plant was not selected for further study. Information was obtained during discussions with the plant operator and during a tour of the treatment facilities. A separate report was developed for each site visit facility that was not selected for a preliminary survey. Those plants for which a site visit only was conducted and those for which a site visit plus a preliminary survey were conducted are referenced in Appendix A.

PRELIMINARY SURVEYS - GENERAL DISCUSSION

The majority of the research effort was expended by conducting thirty preliminary surveys. The primary emphasis of each survey was a detailed evaluation of O & M factors that limited the facility's performance. However, the evaluation was not limited to performance limiting factors in the areas of operation and maintenance, but included design and administration factors also.

Typically, the term O & M has been inappropriately used to describe a multitude of factors that result in inadequate treatment. Staffing requirements, operator salaries, design deficiencies, management techniques, industrial wastes, poor maintenance and inadequate budget are but a few of the items that are commonly described as O & M problems. These specific factors limiting performance and others that were evaluated in this research effort were more appropriately placed into four general categories: operation, maintenance, design and administration.

The approach used to evaluate factors limiting plant performance is extremely important because the results and conclusions made are heavily influenced by the method of evaluation. An improper approach easily results in a biased opinion rather than definitive conclusions. For example, a plant operator's evaluation concerning reasons for poor performance typically excludes or minimizes operator problems. An evaluation by the plant design engineer typically excludes or minimizes design problems. Despite the biased opinions of these sources, many performance evaluations have been conducted by simply questioning the persons that are directly associated with and often the source of the problems being assessed. An option to this approach is to obtain an evaluation from persons that are external to the plant performance problem. However, an evaluation by persons that are external to a plant performance problem and in a position to be more objective is limited by their unfamiliarity with the facility. This unfamiliarity is typically overcome through discussions with plant officials, plant personnel and/or the design engineer. During these discussions the evaluator typically encounters animosity from operations personnel toward outsiders reviewing their facilities; reluctance of design engineers to allow their facilities to be reviewed and fear from administrators regarding possible regulatory action concerning plant performance. Therefore, it was necessary when evaluating O & M problems to avoid taking information at face value. For this reason, a specialized research approach was implemented during this study with full awareness of the problems encountered when making an external evaluation.

Each survey consisted of a period of in-plant investigation followed by an analysis and documentation of the findings in a report titled, "Preliminary Survey of Wastewater Treatment Facilities." Four engineers were involved in conducting the thirty surveys. Two engineers were team leaders and two were team members. Each team leader had formal training in sanitary engineering and had extensive experience in plant operation in the form of providing in-plant operations assistance at wastewater treatment facilities. This experience and capability of the team leaders was used during the research effort to provide assistance at survey facilities in order to remove the natural barriers to communication and thus allow for a better assessment of factors limiting performance. A range of effort was expended during each in-plant survey using one team leader and one team member. In smaller facilities, the in-plant investigation was completed by these persons in three to four days. In larger plants, seven to ten days were required. Factors limiting performance that were identified during the survey were verified by conducting follow-up telephone communication and in some cases follow-up plant visits.

A similar approach to conducting the field portion of the preliminary survey was employed at each facility. Each survey was initiated with a discussion about the research contract. The background and objectives of the research effort were described so that plant personnel were familiar with the purpose and scope of the project. Specific areas of research that were dependent upon the plant personnel's participation were stressed so that these tasks could be scheduled to minimize conflict with routine duties.

An important aspect of the initial discussion was the opportunity it provided to initiate the atmosphere in which the survey was conducted. The plant superintendent was assured that the work conducted in conjunction with the survey would not be used for enforcement action against him or the city. Yet, many operators outwardly expressed apprehension toward the research team during the initial discussion. One operator made the opening statement, "You know, if it would have been up to me you wouldn't even be here, because when I heard this had something to do with EPA I figured nothing good could come of it." Another plant superintendent stated flatly, "If anything bad becomes of this, I'm going to sue you and your company." To overcome the initial animosity of most operators toward a review of their facilities, an emphasis was placed on providing assistance to the operator during the course of the research effort.

After the introductory discussion the operator was asked to show the research team through the plant. During the plant tour, which typically lasted from one to four hours, many questions were asked about plant design, operation, administration and maintenance. Questions were also asked about operations procedures that were normally used, that had been tried and that were possible. Many obvious plant deficiencies were usually identified during the initial plant tour. Later during the survey more subtle factors limiting performance were identified. It is important to note that the investigative approach allowed two levels of information to be identified, obvious and subtle. The importance of these levels of information is discussed later in the report.

During each in-plant evaluation period an emphasis was placed on discussing basic principles of wastewater treatment plant operation with plant personnel and how these principles applied to their facility. The intent was to provide the operator with something of value by participating in the research project and to develop his confidence in the survey team's technical abilities. Several specific techniques were used to gain operator confidence and overcome operator animosity. One technique was to discuss alternate operations procedures in terms of "more desirable," rather than present procedures as "wrong." Another technique was to allow the operator to come to a desired conclusion by directing his thoughts with questions or to help him by "thinking out loud." Often, treatment concepts and their application to plant operation that were discussed were obviously confusing and/or totally new, even to operators with a high level certification and many years of experience. In these cases to avoid embarassment and ill feelings one of the research team members asked questions of the other member. One might have asked, "Do you mean . . .?" or "How does that apply here?" These and other specific techniques formed an approach that was expanded to include the entire involvement at the plant. An atmosphere was developed that allowed for a meaningful and more complete exchange of information between plant personnel and research team members.

The methods used to optimize the exchange of information were coupled with other techniques used to evaluate factors limiting performance in the four major categories of design, operation, maintenance and administration. Design factors were evaluated using conventional procedures such as plans and specifications review, field measurements and calculation of typical design parameters. However, a modification to the conventional design evaluation was also employed. With the help of the plant operator, a more thorough evaluation of design features was made by actually attempting various operations adjustments. For example, activated sludge return flow rates were adjusted over broad ranges in order to evaluate if return control was a plant design limitation. Actually using or attempting to use the existing facilities allowed theoretical design capabilities to be evaluated relative to actual operating abilities. A list of plant design deficiencies observed during the research effort is contained in Appendix C.

Operations factors limiting plant performance were assessed by evaluating procedures used for process control and by observing process conditions (i.e., sludge color, trickling filter appearance, clarifier appearance, etc.). Process control testing was also conducted. These tests primarily included solids concentration tests, sludge settling tests, dissolved oxygen tests and sludge blanket depth determinations. Where applicable, other tests like alkalinity, volatile acids and specific oxygen uptake were conducted. Performance monitoring tests were also conducted as part of the research effort. Performance monitoring primarily included biochemical oxygen demand (BOD_5), total suspended solids (TSS) and coliform analyses. Monitoring analyses were used to determine total and intra-plant performance characteristics. When practical, samples were split with the plant operator as a quality control check.

Process control tests were used to assess the operating conditions at facilities surveyed. Wherever possible, process control test procedures were demonstrated to plant personnel who in turn were asked to conduct the tests prior to the conclusion of the in-plant survey. The joint conduct of the tests coupled with the subsequent test result discussion served as a basis for a common ground of communication between research team members and plant personnel. This was especially important to overcome misunderstandings due to the widely differing terminology that was frequently used to describe equivalent process control parameters. Using this procedure, plant operation was evaluated with respect to process understanding and not terminology memorization and usage.

In most of the plants evaluated, process control test results and associated discussions indicated that process adjustments were warranted. A great deal of caution was exercised in making operations changes since biological system response which resulted from process changes normally did not evolve during the in-plant evaluation period. The slow response of biological systems and its associated impact on poor plant performance is further discussed later in this report. When operations adjustments or procedures were found to be grossly out of line, changes were recommended and were often implemented during the survey to bring the facility within an acceptable operating range. More importantly, the concepts on which the recommendations were based were thoroughly described so that the operator better understood why the recommendations were made. Using this approach, the operator was less likely to misuse or misinterpret the recommendations.

The technical assistance approach used to evaluate the operational factors limiting plant performance also enabled the research team to accurately evaluate the operator's existing and potential capabilities. This evaluation was verified by maintaining telephone contact with the plant operator(s) or by conducting follow-up plant visits. This follow-up contact also served to reinforce the operator's understanding of wastewater treatment concepts described during the survey and insured the success of the recommendations which were implemented during the in-plant research effort.

Maintenance factors were evaluated by reviewing maintenance schedules and records, by observing the condition of plant equipment and by discussing maintenance activities with plant personnel. Preventive maintenance schedules for key equipment were documented on the "Preliminary Survey Information Sheets." Blank samples of these sheets are included in Appendix B. Individual pieces of equipment that required excessive or unusual maintenance were documented and are listed within the plant design inadequacies recorded in

Appendix C. Emergency maintenance procedures were observed in some plants where breakdowns during the research effort created an emergency maintenance situation. Most often, emergency maintenance procedures were only discussed with plant personnel.

Administrative factors were evaluated through discussions with operators and with personnel other than in-plant personnel. It was necessary to interview persons outside the environment of the plant to insure that the personal prejudices of the plant operators did not dominate the research team's assessment of a potential administrative problem. In addition, more accurate O & M costs could usually be attained from these persons. Typically, cost information was obtained from the city clerk, city manager, sanitation district manager or others familiar with the wastewater treatment budget. These persons were contacted early in the week of the preliminary survey and were informed of the scope of the cost information needed. The most important issues were that the cost information was to include treatment plant costs only and actual costs as opposed to budgeted costs. In addition, it was desired to reorganize the city's cost information into the specific categories established for this research project as shown in Appendix B. Later in the week a joint meeting was held among the plant superintendent, the individual supplying the cost information and a research team member. During this meeting persons representing the city were asked to help rearrange the categories to the research format. The research team member usually made suggestions as to how each category could be separated or combined.

The actual costs for smaller treatment plants was most difficult to assess. Typically the wastewater treatment plant budget was combined with potable water treatment costs or included within the general budget, which normally included monies for street repair, water treatment, water distribution and/or wastewater collection. Under this arrangement the separation of costs for the wastewater plant only was sometimes difficult. Also, operators of the smaller treatment plants usually worked part-time at the plant and part-time at other city utilities, and often the actual time worked at the treatment plant was quite different than the budgeted time. The detailed procedure used for determining cost information was necessary in order that accurate costs for wastewater treatment could be obtained. A summary of the cost information collected for the facilities surveyed is presented in Appendix G.

The in-plant investigation for each preliminary survey was concluded with a discussion among the plant staff and research team members. In most plants surveyed this discussion was much more open and comfortable than the discussion which was held the first day of the survey. However, nearly all operators were still concerned about written documentation of survey results that would be contained in the preliminary survey report. Many seemed to realize that their understanding of wastewater treatment process control was probably not adequate and were concerned that the evaluation report would document this limitation. Therefore, to avoid possible surprises to the operators this final discussion period was used to review and summarize the major conclusions and recommendations that would be included in the written report.

Preliminary survey reports were typically 25 to 50 pages long and included sections on Recommendations, Introduction, Plant Evaluation and Summary and Conclusions. In these sections existing plant performance and the major factors limiting performance were discussed. Factors which limited performance were discussed in the Plant Evaluation section under four general topics: administration, maintenance, design and operation. The discussion in the text of the reports was substantially limited to areas in which conclusions and recommendations were made. For some plants additional information was included to describe background information on an unconventional process that was being evaluated.

Two appendices were also included in all survey reports. One appendix consisted of "Preliminary Survey Information Sheets," which were developed specifically for the contract to provide a thorough documentation of diverse information about each facility. Information such as permit requirements, design and operating loads on individual processes, plant operator coverage, user fees for wastewater treatment, plant maintenance scheduling, individual equipment maintenance schedules and meeting schedules of the city council were documented on the Preliminary Survey Information Sheets. An example copy of these information sheets is included in Appendix B. The second appendix in the survey report for every facility was the EPA inspection form 7500-5. Copies of each survey report were distributed to the facility surveyed, the state pollution control agency, the regional EPA office and the EPA research project officer. Copies were also given to the facility design engineer upon request from the city.

PRELIMINARY SURVEYS - EXAMPLE SURVEY

The research approach used to identify factors limiting performance was developed to obtain information that is normally intentionally or unintentionally "covered up" by plant personnel. Intentional cover-up occurs for a variety of reasons including a fear of regulatory action concerning plant performance. Intentional cover-up for this reason was overcome by emphasizing that the project was research oriented and was not connected with enforcement. Unintentional cover-up occurs because of the plant operators' desire to demonstrate their knowledge and capabilities to the outsiders reviewing their facility. This form of cover-up was overcome by developing a common ground communication between operators and research members through the technical assistance provided and by creating an atmosphere that did not intimidate the plant operators. The approach was instrumental in identifying performance limiting factors that were less obvious or non-apparent. Additionally, the approach was instrumental in improving the performance at some facilities. An example of both benefits is described in the preliminary survey conducted at Plant 050.

Plant 050 was a recently constructed, small extended aeration activated sludge plant with chlorine disinfection. Sludge from the facility was stored in a modified Imhoff tank and wet-hauled to farmland. Brush rotors of the type generally used in oxidation ditches provided oxygen transfer and aeration basin mixing. Design flow of the facility was 680 cu m/day (0.18 mgd). The actual flow rate was 650 cu m/day (0.17 mgd). When the facility was constructed effluent treatment standards of 30 mg/1 BOD_5 and 30 mg/1 TSS were required. Subsequently, more stringent effluent requirements of 10 mg/1 BOD_5, 20 mg/1 TSS and 2 mg/1 ammonia nitrogen were adopted.

Plant 050 was a facility in which the operator expressed much initial apprehension to the research team. Despite his initial feelings the operator became much less apprehensive as the survey progressed. In fact, the operator expressed an increasing interest in the process control tests that were being demonstrated and used to assess the operating conditions of his facility. An atmosphere was eventually developed in which the operator was eager to learn as much as he could to improve his operation.

While this atmosphere was being developed, routine analysis of plant effluent quality was accomplished. Figure 3 shows effluent TSS derived from in-plant monitoring results for the first six months of 1977. Effluent quality appeared to be consistently good from the first of 1977, with a general trend of improvement starting just before the research effort that continued after the study was initiated. On the surface plant performance appeared satisfactory, but the research approach used resulted in dramatically different conclusions.

Prior to the research study the plant operator was conducting mixed liquor suspended solids (MLSS) tests and sludge settling tests, but was incorrectly interpreting test results for process control. During the study the operator's testing program was expanded to include return sludge concentration tests and depth of clarifier sludge blanket determinations, but more importantly test results were more accurately applied to process control. The operator reported that for a two-month time period prior to the survey sludge had not been wasted intentionally from the system because solids loss from the clarifier to the effluent had occurred to the extent that the mixed liquor had decreased. The operator realized that the continued solids loss was a problem,

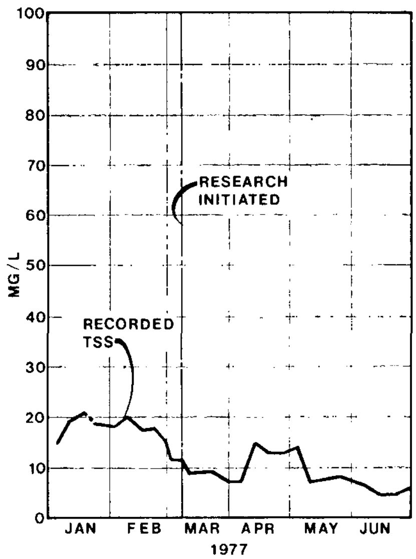

Figure 3. Recorded effluent TSS concentrations for Plant 050.

but had been advised by the design engineer to keep the mixed liquor concentration high. Therefore, the operator discontinued wasting to hold the MLSS concentration as high as possible. The need for sludge wasting had been further de-emphasized during plant construction. The operator had been advised by the aeration equipment supplier and design engineer that it would only be necessary to waste sludge a couple times per year, if at all. Based on this improper technical guidance the operator determined that routine sludge wasting was not necessary.

During the preliminary survey the need for routine sludge wasting was discussed and a regular sludge wasting program was initiated. Also, the return sludge flow rate was more appropriately adjusted to coincide with the sludge settling characteristics. The mass of sludge in the system was slowly reduced to a controllable level, and the operator continued the routine wasting program to control system sludge inventory. A graphical illustration of the sludge wasting pattern is shown in Figure 4. An average of 76 kg/day (168 lb/day) of sludge was intentionally wasted during the four-month period after the preliminary survey, whereas no sludge was intentionally wasted for a two-month period prior to the survey.

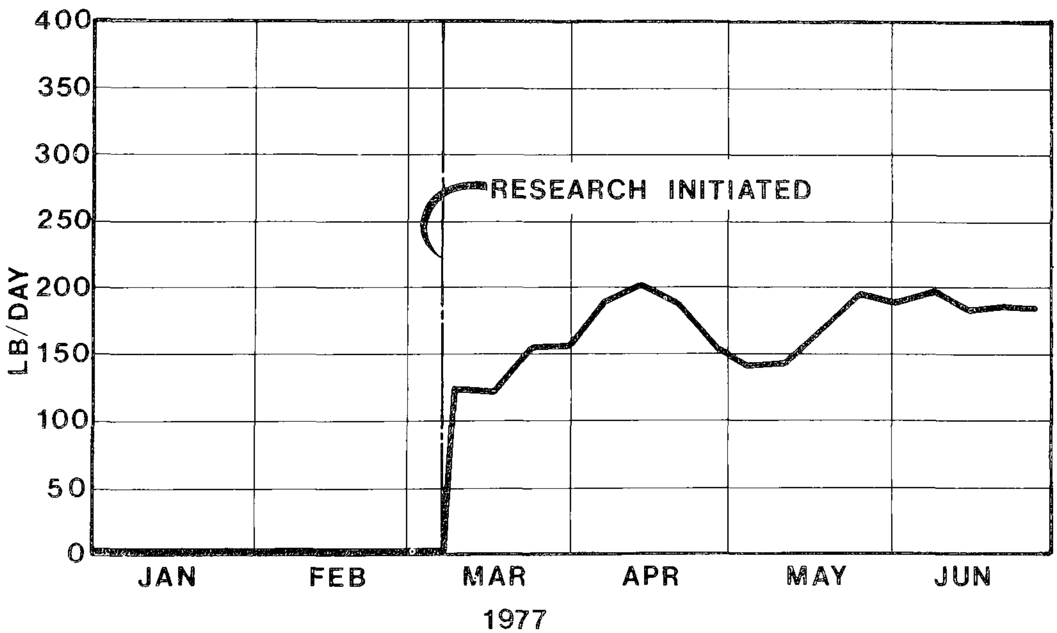

Figure 4. Mass of activated sludge wasted at Plant 050.

In Figure 3 relatively good plant effluent TSS concentration values were reported both prior to and after the preliminary survey, even though repeated excessive solids loss occurred prior to the survey. According to the plant operator the effluent samples that were collected and analyzed for TSS concentrations were grab samples taken when excessive solids loss did not occur. Therefore, the recorded effluent TSS concentrations shown in Figure 3 do not reflect the actual daily average TSS concentration discharged. The operator reported that during the two months prior to the survey excessive solids loss occurred nearly every day, but during the four months after the survey excessive solids loss occurred on only two days. These two days were just after the research team had completed the in-plant investigation. Based on this information the effluent TSS concentration for the two-month time period prior to the survey was adjusted to reflect a more accurate value. The adjusted effluent TSS concentration was calculated assuming that the quantity of sludge wasted after the survey was similar to that lost in the plant effluent prior to the survey. Appropriate adjustments for plant sewage flow rate and system sludge inventory were included in calculating the TSS concentration. Effluent TSS concentration prior to the survey was estimated to be around 93 mg/l as shown in Figure 5. The recorded TSS values after the survey were considered to accurately reflect effluent quality since a routine sludge wasting program had been adopted and excessive solids loss from the final clarifier had been stopped.

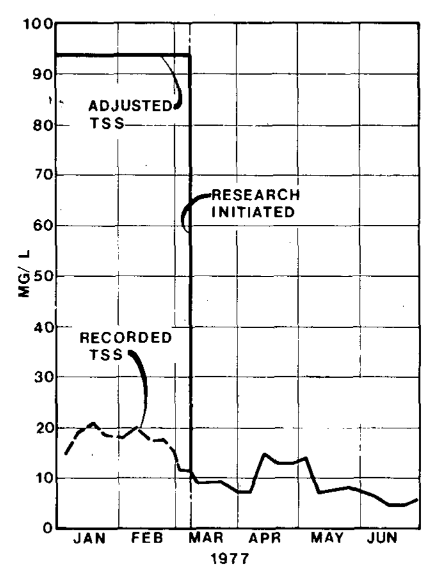

Figure 5. Adjusted effluent TSS concentrations for Plant 050.

There are two important conclusions from the above study. One is that sludge must be routinely wasted from extended aeration activated sludge facilities before they can be expected to achieve optimum performance. The second conclusion, which is most important with respect to the results obtained from this research project, is that the investigative approach used during the preliminary surveys was instrumental in uncovering information that was not readily obvious. At Plant 050 the sampling procedure and improper technical guidance were two items of information that were uncovered that were not apparent until the operator responded to the cooperative atmosphere created through the technical assistance provided. A similar assistance oriented research approach was used at all thirty facilities evaluated and resulted in significantly improved performance at some facilities such as Plant 050. However, the most important aspect of the research approach in light of the objectives of the project was that both the non-apparent and obvious factors that were limiting treatment plant performance were identified.

SECTION 6

EVALUATION OF CAUSES OF LIMITED PLANT PERFORMANCE

GENERAL

For each treatment facility in which a preliminary survey was conducted an in-depth evaluation was made to determine what factors were limiting performance. The results of each evaluation were documented in a "Plant Evaluation Summary." The Plant Evaluation Summary was originally developed to quantify and rank the factors limiting performance only at the thirty facilities where preliminary surveys were conducted. However, because it was found that a meaningful amount of information especially for design related parameters could be obtained during the half-day site visits, the Plant Evaluation Summary was also completed for each of the thirty-three facilities where only a site visit was conducted.

The Plant Evaluation Summary was developed as part of the research effort and consisted of two parts, a) a weighing table and b) a ranking table. The weighing table included seventy different factors that could possibly limit plant performance. Each factor was defined according to its specific cause of poor plant performance or reliability. The extent of each factor's detrimental impact on performance was quantified according to the weighing shown in Table 1. Each factor that received two or three points was included in the ranking table, in descending order of detrimental effect on plant performance. A copy of the Plant Evaluation Summary ranking and weighing tables and a copy of the definitions for the seventy factors evaluated are included in Appendix D.

TABLE 1. POINT SYSTEM FOR PLANT EVALUATION SUMMARY WEIGHING TABLE

Weighing Points	Effect of Specific Factor on Plant Performance
0	No significant effect on plant performance.
1	Minor effect on plant performance.
2	Minimum indirect effect on plant performance on continuous basis or major direct effect on plant performance on a periodic basis.
3	Major direct effect on plant performance.

The purpose of the Plant Evaluation Summary was to quantify and rank the factors which significantly affected plant performance. During the evaluations it was determined that many interrelated factors often impacted performance. A typical example occurred at Plant 050 which was discussed earlier. At Plant 050, the sludge wasting procedure was incorrect and was identified as a major cause of poor performance. This cause may have been brought about by many different performance limiting factors. It may have been the result of a poor application of the basic wasting concept by the operator, a lack of sewage treatment understanding by the operator and/or inadequate facilities for routine wasting. However, using the described research approach a more definitive factor was identified. At Plant 050 the operator was told by both the design engineer and the equipment supplier that frequent wasting was not necessary. Therefore, for Plant 050 in which the area of activated sludge mass control was identified as limiting performance, the more basic factor of poor technical guidance was determined to be the most significant performance limiting factor. In a similar manner the research approach was used to identify the most definitive factors limiting performance at each of the facilities evaluated.

EVALUATION OF SITE VISITS

Site visits were conducted at sixty-three facilities. Thirty of these facilities were selected for follow-up preliminary surveys. Site visit results are discussed separately from preliminary survey results because limited time was spent at each site visit and the nature of the plant selection criteria separated these facilities into a distinctly different group. The evaluation of factors for site-visited facilities did not include the same distribution of weighing points as for preliminary surveyed facilities. Only the more obvious factors limiting performance were documented during the half-day site visits, whereas more of the subtle factors were determined during the 5-day preliminary surveys. For this reason, only those factors that were given a weight of two or three points were listed for site visits. Factors which would have received one point for having only a minor effect on plant performance were not documented. The completed ranking table portion of the Plant Evaluation Summary for each site-visited facility is shown in Appendix E.

A combined overall ranking of performance limiting factors for all site-visited facilities is shown in Table 2. Twenty-eight different factors which were given two or three points are included. In Table 2 each factor was ranked according to the cumulative number of points received for the thirty-three site visits. Also shown are the Plant Evaluation Summary reference number for each factor, the number of times each factor occurred, the number of times a factor ranked No. 1 at a facility and the number of plants for which each factor was given a weight of three points and two points. The reference number indicates the major category in which the factor occurred (A.... is administration, B.... is maintenance, C.... is design and D.... is operation). Three of the twenty-eight factors noted were in the administrative category, two were in the maintenance category, seventeen were in the design category and six were in the operations category. Most of the factors identified were in the design category since design problems were more obvious than other types of problems and were identified during the relatively short plant visits, and obvious design deficiencies was a major criteria for plants falling into this category. The difference between site visit factors and preliminary survey factors limiting performance is further described later in this report.

TABLE 2. RANKING OF FACTORS LIMITING PERFORMANCE OF THIRTY-THREE SITE VISIT FACILITIES

Ranking*	Table** Reference	Factor Limiting Performance	No. of Times Factor Occurred	No. of Times*** Factor Ranked #1	Point Breakdown 3pt	2pt	Total
1	C1f	Infiltration/Inflow	11	4	5	6	27
2	D3a	Operator Application of Concepts and Testing to Process Control	10	4	4	6	24
3	C2c3	Aerator	7	5	4	3	18
4	C2g	Sludge Treatment	7	3	3	4	17
5	C2c2	Process Controllability	6	2	4	2	16
6	C2f	Sludge Wasting Capability	6	1	3	3	15
7	A1a	Administrative Policies	4	1	4	0	12
7	C1c	Industrial Loading	4	3	4	0	12
7	C2c1	Process Flexibility	6	1	0	6	12
10	D1c	Sewage Treatment Understanding	4	2	3	1	11
11	C31	Plant Inoperability due to Weather	4	1	1	3	9
12	C2e	Disinfection	2	0	1	1	5
13	D2a	Performance Monitoring	2	0	0	2	4
14	A2b1	Motivation (Staff)	1	1	1	0	3
14	B2a	Lack of Maintenance Program	1	1	1	0	3
14	C1b	Hydraulic Loading	1	1	1	0	3
14	C2c4	Clarifier	1	1	1	0	3
14	C3d1	Flow Back-Up	1	1	1	0	3
14	D3b	Technical Guidance	1	0	1	0	3
14	D5a	Equipment Malfunction	1	1	1	0	3
21	A2a1	Staff Number	1	0	0	1	2
21	B1a	Housekeeping	1	0	0	1	2
21	C1e	Seasonal Variation	1	0	0	1	2
21	C1g	Return Process Streams	1	0	0	1	2
21	C2h	Ultimate Sludge Disposal	1	0	0	1	2
21	C3a	Plant Location	1	0	0	1	2
21	C3k	Equipment Accessibility for Maintenance	1	0	0	1	2
21	D2b	Process Control Testing	1	0	0	1	2

* Ranking is based on total points.

** This reference refers to the item number on the "Plant Evaluation Summary" (A is Administration; B is Maintenance; C is Design, and D is Operation).

*** Number of times the factor limiting plant performance was the leading cause of poor performance at an individual facility.

At the site-visited facilities an Infiltration/Inflow (I/I) problem was the highest ranking factor limiting performance. Excessive I/I occurred in eleven of the thirty-three plant site visits and was the leading cause of poor performance in four facilities. Excessive I/I problems were usually apparent to research team members and were also emphasized by the operator at plants where excessive I/I existed. Other types of obvious performance limiting factors were excessive organic loading from industrial sources, excessive hydraulic overload (not I/I source) due to plant undersizing and major maintenance problems. At these facilities arrangements were usually in progress to correct the obvious problems.

Because of the nature (i.e., time, approach and objective of the visit) of the investigation, obvious factors which limited plant performance were identified during site visits. Many of the obvious factors were screening criteria used to exclude facilities from a preliminary survey. Because of this screening process the results obtained from the preliminary surveys are biased away from some of the performance limiting factors noted in the site-visited facilities. However, this does not detract from the value of the results of this research effort, because when the more obvious performance limiting factors are corrected at the site-visited facilities, factors similar to those identified in the preliminary surveys will likely be encountered.

EVALUATION OF PRELIMINARY SURVEYS

The Plant Evaluation Summary was developed to identify, quantify and rank the factors limiting performance at the thirty facilities where preliminary surveys were conducted. At each facility every factor in the weighing table was evaluated and quantified in relation to its adverse affect on plant performance. The number of factors that received one or more points at a facility ranged from four to thirty. The average facility had 15 performance limiting factors, and at no facility was only a single factor observed to be limiting performance. The completed ranking tables for each of the facilities surveyed are shown in Appendix F.

The number of points received by each of the factors in the Plant Evaluation Summary weighing table was compiled for the thirty preliminary surveys. Based on this compilation an overall ranking of factors is shown in Table 3. Also shown are the Plant Evaluation Summary reference number; the number of times each factor occurred (i.e., given one point, two points or three points); the number of plants in which the factor was ranked as the number one problem (from the individual ranking tables) and the number of plants for which a factor was given one, two or three points.

Many different performance limiting factors were noted at facilities surveyed. Sixty of the seventy factors evaluated received at least one point in at least one plant. The ranking procedure allowed for the relative severity of the factors to be established. In this report the ten highest ranked factors are discussed. In addition, five factors that were the leading cause of poor performance in at least one facility are discussed.

The highest ranking factor limiting performance at facilities surveyed, with fifty-three total points, was inadequate operator application of concepts and testing to process control. This factor was identified in twenty-eight of thirty facilities surveyed and was the leading cause of poor performance in six facilities. The operator application of concepts factor described a situation for a satisfactorily designed plant operated by a "trained" operator that did not achieve good performance. This factor was ranked when incorrect control adjustments and/or incorrect control test interpretation occurred, or when the use of existing inadequate design features continued when seemingly obvious operations alternatives or minor plant modifications could have been implemented to improve performance. The proper application of concepts required that an operator recognize when the plant limited his operational capability to apply basic fundamentals of wastewater treatment operation to process control. At some plants operator ingenuity was observed to overcome minor plant design limitations which was beneficial to improving plant effluent quality. Operator application of concepts rated high in many plants because operators were observed to understand the mechanics of process control features, but did not relate available operational controls to the needs of the biological

TABLE 3. RANKING OF FACTORS LIMITING PERFORMANCE OF THIRTY PRELIMINARY SURVEY FACILITIES

Ranking*	Weighing** Table Reference	Factor Limiting Performance	No. of Times Factor Occurred	No. of Plants*** Factor Ranked #1	Point Breakdown+ 1 pt.	2 pts.	3 pts.	Total Points++
1	D.3.a.	Operator Application of Concepts and Testing to Process Control	28	6	12	7	9	53
2	D.1.c.	Sewage Treatment Understanding	20	4	7	4	9	42
3	D.3.b.	Technical Guidance	17	5	3	8	6	37
4	D.2.b.	Process Control Testing	21	0	8	13	0	34
5	C.2.f.	Sludge Wasting Capability	18	3	9	3	6	33
6	C.2.c.1.	Process Flexibility	16	2	5	6	5	32
7	C.2.c.2.	Process Controllability	20	0	9	11	0	31
8	C.2.c.4.	Clarifier (Secondary)	11	2	4	4	3	21
9	C.2.g.	Sludge Treatment	15	0	11	4	0	19
9	C.2.c.3.	Aerator	9	2	3	2	4	19
11	D.2.a.	Performance Monitoring	15	0	13	2	0	17
12	C.2.e.	Disinfection	10	0	5	4	1	16
12	C.2.h.	Ultimate Sludge Disposal	12	0	10	0	2	16
14	C.3.i.	Laboratory Space and Equipment	14	0	13	1	0	15
15	C.2.f.	Alternate Power Source	13	0	13	0	0	13
15	C.3.b.	Unit Process Layout	6	1	1	3	2	13
15	A.1.a.	Policies (Administrators)	7	2	3	2	2	13
18	C.1.f.	Infiltration/Inflow	11	0	10	1	0	12
18	C.3.e.	Alarm Systems	12	0	12	0	0	12
20	A.2.a.2.	Plant Coverage	10	0	9	1	0	11
21	A.1.b.	Familiarity with Plant Needs (Administrators)	7	0	4	3	0	10
22	D.4.a.	Adequacy (O & M Manual)	8	0	7	1	0	9
22	C.1.g.	Return Process Streams	6	1	4	1	1	9
22	D.1.b.2.	Training (Operations)	8	0	7	1	0	9
22	D.1.a.1.	Aptitude (Operators)	6	0	3	3	0	9
26	A.2.a.1.	Number (Staff)	7	0	6	1	0	8
26	B.1.c.	Scheduling & Recording (Maintenance)	8	0	8	0	0	8
28	C.3.d.3.	Flow Proportioning to Units	6	0	5	1	0	7
28	A.2.b.4.	Working Conditions	7	0	7	0	0	7

TABLE 3. Continued

Ranking*	Weighing** Table Reference	Factor Limiting Performance	No. of Times Factor Occurred	No. of Plants*** Factor Ranked #1	Point Breakdown+ 1 pt.	2 pts.	3 pts.	Total Points++
28	A.2.b.2	Pay (Operators)	5	0	3	2	0	7
28	C.2.a.	Preliminary (Design)	7	0	7	0	0	7
32	C.3.1.	Plant Inoperability due to Weather	4	0	2	2	0	6
32	A.2.b.3.	Supervision	4	0	2	2	0	6
32	D.5.a.	Equipment Malfunction	4	1	3	0	1	6
32	A.2.c.	Productivity (Operators)	5	0	4	1	0	6
32	D.1.d.	Insufficient Time on the Job	5	0	4	1	0	6
32	A.3.a.	Insufficient Funding	6	0	6	0	0	6
38	A.2.b.1.	Motivation (Operators)	5	0	5	0	0	5
38	C.3.d.1.	Flow Backup	3	0	1	2	0	5
38	D.1.b.1.	Level of Certification	5	0	5	0	0	5
38	B.1.a.	Housekeeping	4	0	3	1	0	5
38	B.2.a.	Lack of Program (Maintenance)	4	0	3	1	0	5
38	B.1.d.	Manpower (Maintenance)	4	0	3	1	0	5
44	C.1.c.	Industrial (Loading)	2	1	1	0	1	4
44	A.3.b.	Unnecessary Expenditures	4	0	4	0	0	4
44	C.3.c.	Lack of Unit Bypass	4	0	4	0	0	4
44	C.3.a.	Plant Location	3	0	2	1	0	4
48	B.2.c.	Spare Parts Inventory	3	0	3	0	0	3
48	B.1.b.	Equipment Age	3	0	3	0	0	3
50	C.1.b.	Hydraulic (Loading)	2	0	2	0	0	2
50	C.1.d.	Toxic (Loading)	2	0	2	0	0	2
50	C.1.e.	Seasonal Variation (Loading)	2	0	2	0	0	2
50	C.3.j.	Process Accessibility for Sampling	2	0	2	0	0	2
54	C.3.h.	Lack of Stand-By Units for Key Equipment	1	0	1	0	0	1
54	C.3.m.	Quality of Equipment	1	0	1	0	0	1
54	D.1.a.2.	Level of Education	1	0	1	0	0	1
54	C.1.a.	Organic (Loading)	1	0	1	0	0	1
54	C.3.d.2.	Submerged Weirs	1	0	1	0	0	1

TABLE 3. Continued

Ranking*	Weighing** Table Reference	Factor Limiting Performance	No. of Times Factor Occurred	No. of Plants*** Factor Ranked #1	Point Breakdown+ 1 pt.	2 pts.	3 pts.	Total Points++
54	C.3.g.2.	Process Automation Control	1	0	1	0	0	1
60	A.2.d.	Personnel Turnover	1	0	1	0	0	1
60	A.3.c.	Bond Indebtedness	0	0	0	0	0	0
60	B.2.b.	References Available	0	0	0	0	0	0
60	B.3.a.	Staff Expertise (Emergency Maintenance)	0	0	0	0	0	0
60	B.3.b.	Critical Parts Procurement	0	0	0	0	0	0
60	B.3.c.	Technical Guidance (Emergency Maintenance)	0	0	0	0	0	0
60	C.2.b.	Unit Design Adequacy, Primary	0	0	0	0	0	0
60	C.3.g.1.	Process Automation, Monitoring	0	0	0	0	0	0
60	C.3.k.	Equipment Accessibility for Maintenance	0	0	0	0	0	0
60	D.4.b.	O & M Manual, Use by Operators	0	0	0	0	0	0
60	D.5.b.	Shift Staffing Adequacy	0	0	0	0	0	0

* Ranking is based on total points received.

** Weighing Table reference number (A is Administration; B is Maintenance; C is Design; and D is Operation).

*** Number of plants in which the factor was the leading cause of poor performance as obtained from the ranking table.

+ Number of plants in which the factor received one point, two points, and three points.

++ Total points received at thirty preliminary survey facilities.

system. This factor represented the gap which existed between poor and optimum plant performance at satisfactorily designed plants with a well-trained operator.

The second highest ranking performance limiting factor, with forty-two total points, was a general lack of sewage treatment understanding. This factor was identified in twenty of thirty facilities surveyed and was the leading cause of poor performance at four facilities. The first two leading causes of poor plant performance, operator application of concepts and testing to process control and sewage treatment understanding, are quite similar, but each represents a different aspect of operator abilities. Sewage treatment understanding was ranked as a factor limiting performance when it was noted that the operator had a general lack of knowledge concerning sewage treatment. These operators were not able to explain even to a limited degree the purpose or function of the treatment processes at their plant. Their only concern was that the equipment was functional.

The implications of the high ranking of sewage treatment understanding as a factor limiting performance are far reaching in that to improve understanding additional training is necessary. However, existing training has produced operators that were usually not able to apply basic wastewater treatment concepts to their individual situations as evidenced by the number one ranking of the operator application of concepts factor. Because of the high ranking of both of these plant operator related factors, the research effort included a detailed evaluation of plant staffing to quantify operator capabilities. The results of this special study are included in Section 7 of this report.

Improper technical guidance was the third highest ranking performance limiting factor at facilities surveyed. It occurred at seventeen of thirty plants surveyed and was the leading cause of poor performance in five facilities. Improper technical guidance included misinformation from "authoritative" sources including design engineers, state and federal regulatory agency personnel, equipment suppliers, operator training staff and other plant operators. Only those sources that were observed to have a direct affect on plant performance were included. It was determined that improper technical guidance was given by design engineers twelve times, by regulatory personnel five times, by equipment suppliers two times, through operator training one time, by another operator one time and by a college professor one time. It is noted that the total of the sources of improper technical guidance is greater than seventeen because inaccurate advice was given by more than one source at some plants. Improper technical guidance was not only harmful in that incorrect recommendations were followed, but was also harmful in that it sidetracked the search for a legitimate solution to the problem.

Design engineers were found to be the most prevalent source of improper technical guidance. The high frequency of occurrence for design engineers was probably due to the fact that plant operators usually looked to their design engineer for advice before they sought advice from other sources. Design engineers were considered to have given improper technical guidance when specific incorrect statements were made with respect to plant operation and not when a facility's design obviously lacked the necessary operations controls. A facility's lack of proper design features was evaluated with respect to specific design factors listed in the Plant Evaluation Summary weighing table. A list of all design features limiting performance that were noted at facilities surveyed is presented in Appendix C. The list includes numerous design deficiencies which inhibited the operational capabilities of the plants surveyed. If design engineers were aware of operations needs it would be expected that the various design deficiencies observed would not have been so universally noted. However, improper technical guidance from design engineers did not only occur in poorly designed facilities. Even in plants that had relatively good design features, improper technical guidance from the design engineer was documented. Based on this observation it appears that operations training is required for design engineers. This aspect is discussed further in this report.

State and federal regulatory personnel were another source of improper technical guidance. It was observed that poor plant performance continued as a result of the regulatory person's response or non-response to process control problems. In some plants obviously wrong operating procedures were observed because of incorrect recommendations from regulatory personnel. In other cases the regulatory person's non-response to an incorrect practice was interpreted by the operator as a vote of confidence. Because of the apparent or actual influence possessed by regulatory personnel and because of the real or imagined threat of enforcement action, plant operators generally tried to implement recommendations received from these persons whether or not the recommendations were properly prioritized. All deficiencies detected by regulatory personnel were generally interpreted as major deficiencies in the plant. Thus, the operations effort was often directed toward conducting less important tasks and away from conducting priority activities that directly influence plant performance. For example, items such as cleaning-up plant grounds, keeping screenings in covered containers, skimming final clarifiers, scrubbing weirs, etc. were implemented as priority recommendations while items such as controlling the mass of sludge in the system through wasting went unattended. This is not meant to imply that meaningful recommendations are not given by regulatory personnel, but even in cases where correct operations recommendations were given for the situation, different adjustments were required later due to biological system changes. The authority associated with state or federal regulatory agency inspections and the potential adverse impact on plant performance that could result warrants a review and modification of the present conduct of plant inspections and associated recommendations.

Equipment suppliers were observed to have a significant detrimental impact on some plant designs and on plant operation. Historically, plant equipment and associated operations concepts have been presented to design engineers and town administrators under the guise of minimum O & M requirements. The emphasis by the equipment suppliers has been to remove from their equipment and associated processes as many operations related requirements as possible. The result has been the construction of plants with inadequate operations control features and a general misconception by plant administrators and operators of the operational necessities at treatment facilities. Some equipment suppliers have made process claims that are misleading and completely contrary to the basic concepts of biological wastewater treatment plant operation. For example, the aeration equipment supplier for Plant 050 had said that sludge would not have to be wasted, but it was documented that sludge had to be routinely wasted to prevent excessive solids loss to the receiving stream. A more detailed discussion of the adverse effect on plant effluent quality of this improper technical guidance was presented earlier. It should be noted that the plant design engineer had also made a similar recommendation about a limited sludge wasting requirement at that facility.

Improper technical guidance from other plant operators was also noted. Plant over-design, unique design features and in some cases even luck has allowed some plants to perform quite well without the operator truly understanding why. This has elevated the position of these operators so that opinions on operation are accepted even though they are incomplete or fundamentally wrong. Acceptance of wrong opinions has prevented other operators from improving their plants' performance. Improper technical guidance from plant operators was not extensive on an individual operator to operator level. It was observed where the local operator was selected by training officials as a short course instructor. In that capacity the operator was considered an expert in the field and his advice was accepted.

Operator training through local, state and other programs was observed to be helpful in that it enhanced the general working knowledge of sewage treatment for many of the operators. Most of the operators who had attended most available training programs were familiar with sewage treatment processes and sewage treatment terminology. However, many times some very basic misconceptions about process control were noted. It was difficult to ascertain where the misconceptions originated. The training programs themselves may have been the source of some misconceptions, but even if they were not the source they were apparently not able to correct the misconception. If existing training programs by themselves are expected to produce operators with sufficient knowledge to optimize plant performance, it can be concluded that training programs are grossly inadequate. However, it is the opinion of the research team that training programs as currently established in magnitude and scope should not be expected to accomplish this goal. Training programs address general sewage treatment understanding and cannot address application of concepts by nature of the short-term, classroom type programs established. It should be noted that it was in this context that training was evaluated in the Plant Evaluation Summary weighing table. Operator training was evaluated in terms of an operator's non-attendance at available training programs and the possible resulting detrimental effect on performance. The adequacy of the training programs themselves was not included as part of this analysis. The weighing table factor of training tied for a ranking of twenty-second among the causes of limited plant performance. It received points at eight facilities surveyed, but was not considered a high ranking cause of poor performance at any facility. Operator training is discussed further later in this report.

A general observation that applies to all sources of improper technical guidance is related to the characteristics of biological treatment systems. It was observed that in instances where correct operations recommendations were made for a particular situation, they were often incorrect at a later date because of changes in the biological process. Operators continued to make adjustments under the original recommendations since many of them did not completely understand the biological process and the limits to the application of the recommendation. This time related factor associated with biological systems is also discussed later in this report. Based on this observation it was concluded that a general re-evaluation of the approach taken to the dissemination of technical guidance is necessary, and should include increased accountability by "authoritative" sources for the guidance that is given.

The fourth ranked factor limiting plant performance was process control testing. Inadequate process control testing involved the absence or wrong type of sampling and/or testing for operations purposes, which in turn caused improper operations decisions to be made. Inadequate process control testing was never considered a leading cause of poor performance because it was usually a secondary factor to an operator's understanding and applying treatment concepts to process control. However, better process control testing was considered necessary to achieve improved plant performance, and was identified as a performance limiting factor in twenty-one facilities surveyed.

Inadequate sludge wasting capability was the fifth highest ranking performance limiting factor at facilities surveyed and was documented in eighteen facilities. Sludge wasting capability was included as a factor when sludge handling facilities had inadequate capacity or lacked ability to adequately measure and control a desired volume of waste sludge. Sludge wasting capability was rated as having a major impact on plant performance (i.e., 3 points) when no sludge handling facilities or extremely inadequate sludge handling facilities were present. This situation existed at six facilities, and inadequate sludge wasting capability was the leading cause of poor performance in three facilities. Lower ratings of one or two points were assigned at twelve facilities where waste capacity was adequate, but sludge flow measurement and/or control were inadequate.

The sixth and seventh ranked factors limiting plant performance were inadequate process flexibility and process controllability, respectively. Process flexibility was the availability of valves, piping and other appurtenances required to operate in various modes or to include or exclude existing processes as necessary to optimize performance. Examples of good process flexibility are the ability to operate an activated sludge plant in the contact stabilization, step loading and/or conventional modes and the ability to bypass polishing ponds or other downstream processes to discharge high quality secondary clarifier effluent. Improper process flexibility limited performance at sixteen plants surveyed and was the leading cause of poor performance at two facilities. At these two plants an immediate improvement in plant effluent quality would have occurred with improved process flexibility.

Process controllability was the ability to adequately measure and control various flow streams such as return sludge flow or trickling filter recirculation rates. Process controllability was not rated as a major cause of poor performance (i.e., 3 points), but at twenty facilities the capabilities for process controllability limited performance to some extent. Adequate control and measurement of return activated sludge flow was the most frequent reason for rating the process controllability factor. Good measurement and control capability of return activated sludge flow was observed in only three of twenty activated sludge plants surveyed.

The eighth ranked factor limiting plant performance was inadequate secondary clarifier design. Performance limiting clarifiers were found in eleven plants surveyed and were the leading cause of poor performance in two facilities. The secondary clarifier factor was identified when poor clarification occurred due to the size of the clarifier, placement of the weirs, weir length or type of clarifier. The secondary clarifier factor was not noted as a performance limiting factor when solids loss due to a slow settling sludge (i.e., bulking sludge) was observed.

The most common clarifier problem observed was a poorly developed clarifier surface area. A poorly developed clarifier surface area results in the inability to maintain uniform upward velocity of treated wastewater so that the sludge blanket can remain equidistant from the liquid surface (i.e., level) even when the blanket is within 0.3 m (one foot) of the overflow weirs. The inability of clarifiers to maintain a sludge blanket in this condition was observed in both circular and rectangular clarifiers, but more often in rectangular clarifiers where the weirs were placed toward one end. In clarifiers with a poorly developed surface area, excessive solids carryover occurred even though relatively good activated sludge settling characteristics existed. Poor rectangular clarifier design was observed in ten plants surveyed. At these plants the weir location was typically at one end of the clarifier and the clarifier inlet and sludge withdrawal points were located at the opposite end. Excessive solids carryover occurred when the sludge blanket was as much as 0.9 m (3 feet) to 1.2 m (4 feet) below the liquid surface in the rest of the clarifier. Poor circular clarifier design was observed at one plant. At this plant the clarifier was relatively large (diameter of 27.4 m (90 feet)) and had a peripheral feed and peripheral withdrawal design. The center area of the clarifier was underdeveloped with weirs, and excessive solids carryover occurred when the sludge blanket was 1.5 m (5 feet) from the liquid surface in the center area of the clarifier. Good secondary clarifier surface area development was observed at some facilities surveyed. These clarifiers were observed to greatly improve the plants' operations capabilities and performance potential.

Sludge treatment tied with aerators as the ninth ranked performance limiting factor. Inadequate sludge treatment was found in fifteen facilities surveyed. It was identified as a performance limiting factor when the size or type of sludge stabilization process limited plant performance directly by limiting sludge wasting capacity or indirectly by requiring excessive amounts of operator time which could be more productively spent conducting other tasks. Sludge treatment was not ranked as a major cause (i.e., 3 points) of poor performance at any facility surveyed, but its persistant reoccurrence as an associated factor resulted in the high ranking received. In comparison to sludge wasting capability which ranked fifth, sludge treatment was not rated as critical to plant performance as was the need to waste sludge from the treatment system. Also, it was observed that other approaches could be utilized to overcome some sludge treatment limitations. For example, some operators had initiated sludge hauling to an ultimate disposal site to relieve a sludge treatment bottleneck. This is not meant to imply that disposal of inadequately treated sludge is acceptable. However, substituting ultimate disposal of inadequately treated sludge did provide a temporary alternative for achieving improved plant effluent quality at some facilities. Recycle flow streams from sludge treatment processes were evaluated as a separate factor in the Plant Evaluation Summary weighing table and are discussed later in this report.

Many inadequacies were observed in the area of sludge handling with respect to acceptable sludge treatment and disposal techniques. In some cases, the methods used represented a nuisance problem and potential health problem from the standpoint of being a breeding ground for insects. In other cases, poor sludge handling was a potential water pollution problem. At one plant undigested sludge was spread on land adjacent to a stream bed. This procedure exposed the stream to a possible pollutional load during periods of heavy runoff and/or created the potential for ground water contamination through percolation. Fly and odor problems were also evident. This condition was not rated as a major factor limiting performance because it did not directly affect plant effluent quality. It did represent a potential stream and ground water pollutional problem, an aesthetics problem and a potential health problem. This type of sludge disposal practice was not acceptable, but represented another aspect of the broad scope of sludge handling problems associated with wastewater treatment facilities. Two of the ten highest ranking causes of limited plant performance, sludge wasting capability and sludge treatment, are sludge handling related. This indicated that a much greater design, operation and management emphasis must be placed on sludge removal, treatment and disposal capability at existing and proposed treatment facilities.

Deficient aerators were found in nine facilities surveyed and were the number one cause of limited performance in two facilities. Aerator, as used in this evaluation, means the facility utilized for the conversion of soluble organic matter into settleable organic matter. Examples of aerators as used in this context are trickling filters, activated sludge aeration basins, rotating biological contactors and activated bio-filters. Aerators were assigned points (i.e., received 1, 2 or 3 points) when they exhibited limited capability to convert dissolved and colloidal organic matter to settleable solids or encouraged the development of an unstable or difficult to control sludge. Eight of the nine facilities for which an inadequate aerator was noted as a factor limiting performance were fixed film facilities, including trickling filters, rotating biological contactors and activated bio-filter systems. The ninth facility was an activated sludge plant in which the aeration basin which was so small and heavily loaded that it encouraged the development of an unstable (i.e., bulky) sludge.

A more intensive investigation was undertaken to examine the differences in performance between fixed film and suspended growth systems in a separate study also conducted under this research contract. (2) It was determined that fixed film facilities in general had a stable effluent quality but marginal performance in relation to secondary treatment standards. The performance of these facilities could not be significantly improved with better operations because major design modifications were necessary. Suspended growth systems in general had a less stable effluent quality and poorer performance, but unlike fixed film facilities effluent quality could be significantly improved through better operations. Based on these conclusions, a general recommendation was made that a more conservative design approach be considered for fixed film facilities and better operations be developed for suspended growth facilities.

The ten highest ranking performance limiting factors accounted for the number one cause of poor performance in twenty-four of the thirty facilities surveyed. The number one cause in the other six facilities included five additional factors which ranked from fifteenth to forty-fourth based on total points received. These factors are unit process layout, administrative policies, return process streams, equipment malfunction and industrial loading.

Unit process layout was identified as the number one cause of poor performance at one facility and was documented as a problem at six facilities. Unit process layout was included as a factor when the physical and/or piping arrangement of the process units were limiting plant performance. In at least two facilities the piping arrangement required that parallel units always operate as independent treatment plants. This resulted in doubling plant operational requirements for small service populations. Dual system operation has advantages, and flexibility for such operation should be provided; but the requirement for continuous separate operation limited plant performance in these instances because the limited time available for process control had to be split between two independent systems.

Administrative policies were the leading cause of poor performance in two facilities. Administrative policies limited performance when certain policies or rules established by the plant's governing body were a direct source of limited performance. At the two trickling filter plants where performance was significantly limited by administrative policies, plant effluent quality could likely have been significantly better if the plants were operated as two-stage trickling filters and/or with increased filter recirculation. This flexibility had been incorporated into the plant designs, but it was a policy of each plant's governing body to continue status quo in favor of reduced power cost. At another facility the administration had made a decision to not repair an item of equipment (note: not considered a maintenance problem) because of the possibility that a new facility would be constructed in the future as the plant progressed toward the top of the state's priority list for federal grant eligibility. Similarly, at a plant where only a site visit was conducted, the administration had made a decision to avoid operations help. In this case it was an administrative policy to do nothing that would possibly lower the city's relatively high position on the state's priority list for federal grant assistance. In some plants where administrative policies were rated, the governing body required unnecessary approval of nearly every decision made by the operator, which in turn caused necessary tasks affecting performance to be unduly delayed.

Administrative policies were observed to indirectly affect plant performance with respect to the type of person hired as the operator, the attitude extended toward plant operation and the attitude extended toward plant design. However, administrative policies were not rated for these reasons. It should be recognized that elected and/or appointed personnel comprising a plant's governing body are typically not in a position to evaluate technical policies. They rely heavily on outside technical guidance, some of which may have been incorrect. Therefore, some of the policies observed may not necessarily be the fault of the administration.

Return process streams tied as the twenty-second highest ranking factor limiting performance in facilities surveyed. It existed at six facilities and was the leading cause of poor performance at one facility. The major return flow stream limiting performance was anaerobic digester supernatant. At the facility in which the return flow stream factor was the leading cause of poor performance, the excessive solids concentration of the anaerobic digester supernatant recycle stream (20,000 mg/l to 30,000 mg/l) was too great for the trickling filter wastewater treatment process to adequately handle. Fairly good trickling filter performance was observed to be associated with four facilities that did not recycle the anaerobic digester supernatant through the facility. At these facilities performance was much better than was observed at similar facilities that had anaerobic digester supernatant recycle. Based on these results it is recommended that strong consideration be given during a plant design evaluation to treating anaerobic digester supernatant recycle separately or to increasing appropriately the wastewater treatment process unit size to adequately receive and treat this recycle flow.

Equipment malfunction was the leading cause of limited performance in one facility surveyed and tied as the thirty-second highest ranking performance limiting factor. Equipment malfunction was rated as a limiting factor when the breakdown of equipment occurred because of faulty installation or sub-standard quality. In the identified facility the bearings of the aerators in a new activated sludge aeration basin failed shortly after the in-plant survey was completed. The aerators have been replaced. In three other facilities where equipment malfunction was rated, the facility preventive maintenance program was satisfactory and the equipment malfunction was due to sub-standard quality. In these cases the makes and models of the equipment that was malfunctioning were no longer manufactured, repair parts were difficult to obtain and the operators were preparing to replace the equipment with better models.

Industrial loading was a leading cause of poor performance in one facility surveyed. It tied as the forty-fourth highest ranking cause of poor performance and was found in two facilities surveyed. The infrequency of occurrence of industrial loading as a performance limiting factor does not mean that only a few facilities surveyed had significant industrial contributors. Many facilities had large industrial contributors; however, industrial loading was not considered a factor limiting performance when the facility had been specifically designed to handle the industrial load it was receiving. Another reason for the infrequency of industrial loading as a performance limiting factor is that an excessive plant organic or hydraulic overload was part of the plant selection screening criteria. At the two facilities in which the industrial loading factor was rated, it had been indicated during the plant site visit that the facility was designed to handle the organic load from the industry. However, the extensive investigation during the preliminary survey revealed that the industrial organic load was much greater than that for which the facility was designed.

MISCELLANEOUS EVALUATIONS

An evaluation was made of the major performance limiting factors for two general types of facilities surveyed: suspended growth (i.e., activated sludge) and fixed film (i.e., trickling filter, rotating biological contactor - RBC and activated bio-filter - ABF). For both plant types the relative percentage of performance limiting factors was determined for the four major areas evaluated: administration, maintenance, design and operation. The results of this evaluation are illustrated in Figure 6. As shown, maintenance and administration type problems were relatively minor when compared to the design and operations problems that were identified.

At fixed film facilities, design features were the most prevalent performance limiting factors. Within the design category, inadequate aerator capability occurred most often. In the operations category inadequate operator application of concepts and testing to process control was found most frequently. Fixed film facility design must include better facilities for organic conversion to settleable solids to improve plant performance. Also, improved and modified training techniques are necessary to improve operator application of concepts and testing to process control.

At suspended growth facilities inadequate plant operation was the most prevalent group of factors limiting performance. Within plant operation, improper operator application of concepts and testing to process control occurred most often. Within the design category, inadequate sludge wasting capability was noted most frequently. At suspended growth facilities better plant operation practices must be implemented. Also, better facility design, especially sludge wasting capability, is required.

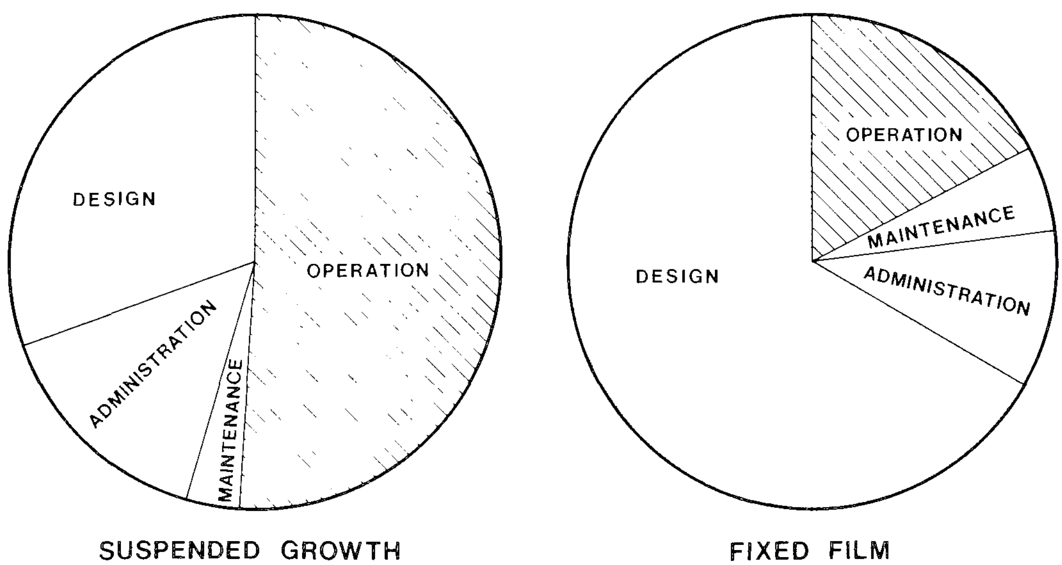

Figure 6. Types of factors limiting performance in suspended growth and fixed film facilities.

An evaluation was also made of the operations costs at facilities surveyed. Cost information for each facility is shown in Appendix G, and the average for each cost category is shown in Figure 7. The size of plants surveyed ranged from 26 to 30,660 cu m/day (0.007 to 8.1 mgd). In Figure 7, all costs to the users of the treatment facilities are shown, including the cost of capital improvements (primarily bond debt retirement). Nearly one-half of the total user costs was for capital improvements, even though most facilities surveyed had been built with partial grant funding. These capital improvement costs were somewhat independent of facility type and size and more dependent on administrative policies, construction grant funding opportunities, plant age, bond interest rates, etc. Therefore, capital improvement cost is not included in the following O & M cost comparisons among plant size and type.

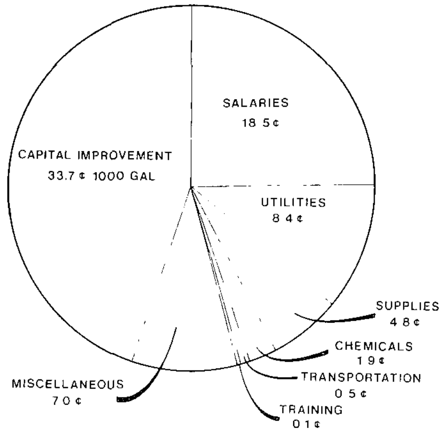

Figure 7. Average treatment costs in ¢/1000 gallons for facilities surveyed.

A summary of the cost information for various types and sizes of facilities is shown in Table 4. Of the cost categories used here, salaries accounted for the greatest share of the O & M costs at facilities surveyed, and training and education of staff members accounted for the smallest portion. This fact is significant relative to other findings of this research study. The high ranking of improper operator application of concepts and testing to process control and inadequate sewage treatment understanding factors supports the need for increasing the training and education portion of a plant's O & M budget. However, training cannot be limited to classroom activities, but must include on-the-job development of operational skills. This aspect is discussed later in this report and was also discussed in an additional report prepared under this research contract. (2)

TABLE 4. SUMMARY OF COST INFORMATION FOR TYPE AND SIZE OF FACILITY SURVEYED

Parameter	Suspended Growth			Fixed Film		
Number of Facilities	5*	12*	3	0	4	6
Size Range (mgd)**	< 0.1	0.1-1.0	1.0-10.0	< 0.1	0.1-1.0	1.0-10.0
Salary (¢/k gal)***	44.8	18.1	10.0	-	17.0	4.8
Utilities (¢/k gal)	13.2	12.2	4.4	-	4.8	1.1
Supplies (¢/k gal)	11.7	4.4	1.0	-	6.9	0.6
Chemicals (¢/k gal)	3.0	1.3	1.7	-	4.3	0.8
Transportation (¢/k gal)	0.2	1.0	0.1	-	0.4	0.1
Training and Education (¢/k gal)	0.02	0.1	0.03	-	0.2	0.02
Miscellaneous**** (¢/k gal)	20.3	8.0	3.0	-	0.6	1.5
Total - O & M Costs***** (¢/k gal)	93.32	45.1	20.23	-	34.2	8.92

* One plant not included in cost summary; information not available.

** mgd x 3785 = cu m/day

*** (¢/k gal) = (¢/1000 gal)

**** This category includes costs such as testing by private laboratories, repair services, plant insurance, computer service and some consulting services.

***** Does not include costs for capital improvements (primarily bond debt retirement).

The overall O & M costs for different types and sizes of facilities surveyed are illustrated in Figure 8. The average cost per unit of flow was greater for smaller facilities than for larger facilities, and the average O & M cost for suspended growth facilities was more than for fixed film facilities. The larger fixed film facilities had the lowest costs. However, for the thirty facilities surveyed seven were felt to require major design modifications before minimum secondary treatment standards could be met consistently, and all seven were fixed film facilities. The suspended growth facilities surveyed were felt to have the potential for meeting standards if major operations changes were implemented. If all fixed film facilities had the potential of meeting standards like the suspended growth facilities, then a higher than indicated O & M cost for fixed film facilities may have been reflected. This does not mean that the costs for fixed film facilities would be higher than for the suspended growth facilities, but the costs could be higher than those shown in Figure 8. The range of O & M costs for the categories evaluated does not provide a basis for straightforward conclusions due to the broad range of costs documented in each category and the overlapping of costs between categories.

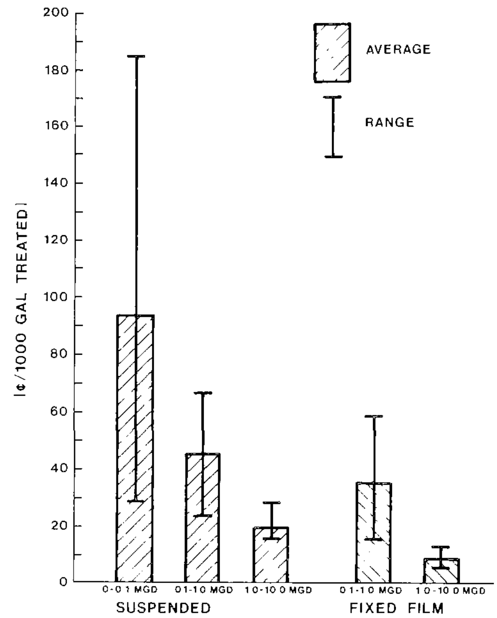

Figure 8. Plant operations costs for selected flow ranges.

An evaluation was also made of the electrical energy consumption and costs at facilities surveyed. Data for individual facilities are included in Table 5. At facilities surveyed the cost per unit of electrical power varied from 1.17¢/kwh to 3.85¢/kwh, including power demand and power factor charges. This variation of electrical charge inhibits the direct comparison of cost for electricity. Therefore, the analyses of electrical energy consumption is presented in terms of usage (kwh per 1000 gallons). Higher energy usage is shown for suspended growth facilities, especially those with lower wastewater

TABLE 5. ELECTRICAL CONSUMPTION AND COSTS AT FACILITIES SURVEYED

Plant No.	Plant Type*	Actual Flow cu m/day	mgd**	% Design	KWH/1000 gal***	¢/KWH	¢/1000 gal ****
002	ASEA	1,628	0.43	54	3.0	1.53	4.6
007	ODEA	155	0.041	59	3.2	3.06	9.8
012	TF/CS	30,660	8.1	68	0.83	2.28	1.9
013	AS	1,892	0.5	63	2.7	2.23	6.0
014	AS	3,785	1.0	50	2.4	1.89	4.5
015	TF	6,434	1.7	47	1.0	1.50	1.5
019	ASEA	132	0.035	54	4.3	2.20	9.5
020	ASEA	26	0.007	28	-	-	-
021	ODEA	2,233	0.59	66	0.87	3.54	3.1
022	ASEA	45	0.012	80	-	-	-
024	ABF	18,550	4.9	69	0.43	1.37	0.6
026	ASEA	568	0.15	30	-	-	-
027	AS	20,820	5.5	55	1.3	1.26	1.6
028	ASCS	568	0.15	60	2.1	2.49	5.2
029	AS	5,185	1.37	78	2.7	1.17	3.2
032	TF	833	0.22	50	0.40	3.28	1.3
034	TF	20,820	5.5	68	-	-	-
035	TF	20,060	5.3	98	0.52	1.96	1.0
036	TF	6,056	1.6	87	0.61	2.36	1.4
039	ODEA	795	0.21	51	2.3	3.85	8.9
040	RBC	1,438	0.38	60	0.72	1.51	1.1
041	TF	492	0.13	33	1.1	2.87	3.2
047	ASEA	189	0.05	80	3.1	3.24	10.0
048	AS	1,287	0.34	89	4.3	2.56	11.0
050	ASEA	643	0.17	96	2.7	3.58	9.7
053	ASEA	416	0.11	68	4.2	2.96	12.4
055	ASEA	1,136	0.30	52	-	-	-
060	ABF	1,855	0.49	47	2.3	3.31	7.6
061	ASCS	643	0.17	34	5.8	2.35	13.6
063	AS	2,650	0.7	47	-	-	-

* ASEA - Activated Sludge Extended Aeration
ODEA - Oxidation Ditch Extended Aeration
TF/CS - Trickling Filter Plus Contact Stabilization
AS - Activated Sludge
TF - Trickling Filter
ABF - Activated Bio-Filter
ASCS - Activated Sludge Contact Stabilization
RBC - Rotating Biological Contactor

** mgd x 3785 = cu m/day

*** Kwh/1000 gal x 0.264 = kwh/cu m

**** ¢/1000 gal x 0.264 = ¢/cu m

flows. However, the contact stabilization facility, Plant 061, which had the highest energy usage at 1.53 kwh/cu m (5.8 kwh/1000 gal), had dual units loaded at only 34 percent of design flow. Both units were in service, but better plant operation could have enabled only one unit to be used. A considerable savings in electricity could have been achieved by taking one unit out of service. For this reason, as well as the fact that many of the facilities shown in Table 5 were not operating at optimum levels, data presented should not be interpreted as the most economical use of electrical energy.

SECTION 7

WASTEWATER PLANT STAFFING AND PLANT PERFORMANCE

GENERAL

This section describes the results of a special study on wastewater treatment plant staffing conducted as part of the research effort. Plant staffing was evaluated in detail because of the frequent occurrence and high ranking of operations related factors limiting the performance of plants evaluated. As discussed earlier, each preliminary survey involved about one week of on-site field work. During that week numerous items of information were obtained concerning the facility. Also, an effort was extended toward improving plant performance. Using this approach, research team members worked closely with plant personnel and were in a position to evaluate their capabilities and their influence on plant performance.

PLANT STAFFING RELATIONSHIPS AND PLANT PERFORMANCE

The analysis of the facilities' staffing cost included only the personnel working directly with the plant. As such, city administrators, the town clerk, staff working on collection lines and other personnel indirectly involved with the facility were not included. Table 6 presents a summary of staff size and cost for each of the thirty plants where preliminary surveys were conducted. The percentage of the plant salary cost to the total operations cost is also shown. Capital improvement and bond debt retirement costs were not considered part of the total operations budget and were excluded from this analysis.

In Table 6 three selected unit costs are shown to present staffing information for the various sized plants on a common basis. These unit costs are

TABLE 6. SUMMARY OF STAFF AND COST FOR THIRTY FACILITIES SURVEYED

Plant No.	Type	Flow		Staff	Budget		Unit Relationships		
	Type of Treatment	Actual Flow	Percent of Design	Man-Year	Staffing Costs	Percent of Operations Budget	Specific Staff Size	Adjusted Salary	Specific Staff Cost
-	-	(mgd)*	(%)	(my)	($)	(%)	(my/mgd)	($/my)	(¢/k-gal)
002	Activated Sludge	0.43	54	3.0	28,685	27.5	7.0	9,562	18
007	Activated Sludge	0.041	59	0.30	3,540	17.2	7.3	11,800	24
012	Trickling Filter	8.1	68	12	189,970	64.0	1.5	15,831	6.4
013	Activated Sludge	0.5	63	3.0	34,164	43.2	6.0	11,388	19
014	Activated Sludge	1.0	50	5.0	50,000	49.6	5.0	10,000	14
015	Trickling Filter	1.7	47	3.0	30,312	43.1	1.8	10,104	4.9
019	Activated Sludge	0.035	54	0.60	5,191	23.1	17	8,652	41
020	Activated Sludge	0.007	28	0.26	2,500	52.7	37	9,615	98
021	Activated Sludge	0.59	66	1.5	17,878	37.0	2.5	11,919	8.2
022	Activated Sludge	0.012	80	0.30	3,600(est)	50.0(est)	25	12,000	82
024	Activated Bio-Filter	4.9	69	7.3	84,141	40.5	1.5	11,526	4.7
026	Activated Sludge	0.15	30	1.6	18,186	57.4	11	11,366	33
027	Activated Sludge	5.5	55	7.5	118,782	43.2	1.4	15,838	5.9
028	Activated Sludge	0.15	60	0.88	9,610	42.2	5.9	10,920	18
029	Activated Sludge	1.4	78	4.0	51,732	47.1	2.9	12,933	10
032	Trickling Filter	0.22	50	0.35	3,780	30.5	1.6	10,800	4.7
034	Trickling Filter	5.5	68	7.0	87,917	50.4	1.3	12,560	4.4
035	Trickling Filter	5.3	98	4.2	54,162	52.4	0.79	12,896	2.8
036	Trickling Filter	2.5	87	3.8	49,746	58.6	1.5	13,091	5.5
039	Activated Sludge	0.21	51	1.0	10,000	25.0	4.8	10,000	13
040	Rotating Biological Surface	0.38	60	1.3	13,316	54.6	3.4	10,243	9.6
041	Trickling Filter	0.13	33	1.5	15.755	56.9	12	10,503	33
047	Activated Sludge	0.05	80	0.30	3,132	60.0	6.0	10,440	17
048	Activated Sludge	0.34	89	1.9	18,470	45.0	5.6	9,721	15
050	Activated Sludge	0.17	96	0.57	7,717	30.2	3.4	13,539	12
053	Activated Sludge	0.11	68	0.73	13,400	64.8	6.6	18,483	33
055	Activated Sludge	0.30	52	0.50	4,992	18.8	1.7	9,984	4.6
060	Activated Bio-Filter	0.49	47	3.0	36.500	45.3	6.1	12,167	20
061	Activated Sludge	0.17	34	0.80	10,296	30.9	4.7	12,870	17
063	Activated Sludge	0.70	47	4.0	57,148	66.3	5.7	14,287	22

* mgd x 3785 = cu m/day

number of man-years per million gallons per day of sewage treated (my/mgd - specific staff size), staff cost per man per year ($/my - adjusted salary cost), and staff cost per one thousand gallons of sewage treated (¢/1000 gal - specific staff cost). Specific staff size relates staff size for all facilities to a common basis of one mgd. Adjusted salary relates staff salary, including fringe benefits, to a common basis of the salary for one full-time man for one full year. Specific staff cost relates staff cost to a common basis for treating one thousand gallons of wastewater.

In Table 6 much scatter exists in the data presented. The actual sewage flow for facilities ranged from a low of 26 to a high of 30,660 cu m/day (0.007 to 8.1 mgd). Hydraulic loadings on facilities ranged from 28 to 98 percent of design. Because of the difference in size and type of facilities surveyed, expected differences occurred in total staff size and associated total salary cost. Total staff size ranged from 0.26 to 12 man-years. Total staffing cost ranged from $2,500 to $189,970 per year. At the same time, large differences existed in calculated unit costs. The specific staff size ranged from 0.79 to 37 my/mgd. The adjusted staff salary cost ranged from $8,652/my to $18,482/my. The specific staff cost ranged from 2.8¢/1000 gal to 98¢/1000 gal.

A detailed evaluation of the performance capabilities of each facility was completed under this research contract. (2) A summary of this information is presented in this report so that plant staffing can be related to facility performance. The effluent from 23 of 30 plants evaluated did not consistently meet minimum secondary treatment standards, even though the mean hydraulic loading for these twenty-three plants was only about 61 percent of the design flow. However, sixteen of the twenty-three facilities could meet standards by implementing changes in plant operation and in some cases minor design changes. The remaining seven would require substantial design modifications plus operations changes before standards could be met. The seven facilities that met standards had an average hydraulic loading of 59 percent of design flow, which is very similar to those that did not meet standards. Table 7 depicts which treatment facilities are included in each of the three categories (i.e., standards met; standards not met - operation changes required; and standards not met - design and operation changes required).

TABLE 7. SUMMARY OF PLANT PERFORMANCE FOR THIRTY FACILITIES SURVEYED

Plant No.	Type of Treatment	Flow: Actual Flow	Flow: Percent Design	Minimum Secondary Treatment Standards****: Met	Not Met	Not Met
-	-	(mgd)*	(%)	-	Operation**	Design*** & Operation
002	Activated Sludge	0.43	54		X	
007	Activated Sludge	0.041	59		X	
012	Trickling Filter	8.1	68			X
013	Activated Sludge	0.5	63		X	
014	Activated Sludge	1.0	50		X	
015	Trickling Filter	1.7	47			X
019	Activated Sludge	0.035	54		X	
020	Activated Sludge	0.007	28		X	
021	Activated Sludge	0.59	66	X		
022	Activated Sludge	0.012	80		X	
024	Activated Bio-Filter	4.9	69			X
026	Activated Sludge	0.15	30	X		
027	Activated Sludge	5.5	55		X	
028	Activated Sludge	0.15	60		X	
029	Activated Sludge	1.4	78		X	
032	Trickling Filter	0.22	50			X
034	Trickling Filter	5.5	68			X
035	Trickling Filter	5.3	98	X		
036	Trickling Filter	2.5	87	X		
039	Activated Sludge	0.21	51		X	
040	Rotating Biological Surface	0.38	60			X
041	Trickling Filter	0.13	33	X		
047	Activated Sludge	0.05	80		X	
048	Activated Sludge	0.34	89		X	
050	Activated Sludge	0.17	96		X	
053	Activated Sludge	0.11	68		X	
055	Activated Sludge	0.30	52	X		
060	Activated Bio-Filter	0.49	47			X
061	Activated Sludge	0.17	34		X	
063	Activated Sludge	0.70	47	X		

* mgd x 3785 = cu m/day

** Standards could be met with changes in plant operation procedures and in some cases minor design modifications. (2)

*** Standards could be met with substantial modifications to plant design and also some changes in plant operating procedures. (2)

**** As defined in Federal Register, Volume 38, Number 159, Part II, August 17, 1973.

EVALUATION OF STAFF SIZE AND COST VERSUS PLANT PERFORMANCE

Among the items associated with good or poor plant performance are plant type, sewage characteristics, plant design, plant age, staff number and staff qualifications. The scope of this evaluation included only plant staff considerations. Since plant operators are most directly involved with the treatment facility, it was presumed that they are in a position to directly influence facility performance. Several staffing relationships that influence plant performance were investigated. Some biases existed. The facilities selected for a preliminary survey were screened, as previously discussed, and surveys were not made at some very small facilities where the operator was unable to spend an adequate amount of time at the facility to accomplish the objectives of the research. As such, the staffing number and cost values presented may be biased upward for the smallest size range of facilities.

Total staff size and total staffing cost were expected to increase as plant size increases. At facilities surveyed a general increase in staff size and staff cost versus plant flow rate was observed, as shown in Figures 9 and 10, respectively. However, a large variation in the number of staff persons and associated staffing cost was observed for any given plant flow rate. For example, for the three plants whose actual flow was between 0.2 and 0.3 mgd the total number of staff persons ranged from 0.35 to 1.0 my and the total staffing cost ranged from $3,700 to $10,000/year. For the three plants whose actual flow was between 5.0 and 6.0 mgd the total number of staff persons ranged from 4.2 to 7.5 my and the total staffing costs ranged from $54,000 to $118,500/year.

In Figures 9 and 10, fully shaded dots represent plants where standards were met. If staff size or staffing cost alone were responsible for good plant perforance, then all or a significant number of plants where standards were met would have a relatively higher staff size and staff cost. This condition would be represented by a significantly large number of fully shaded dots above the least squares lines of best fit shown for staff size and staffing cost. However, four of the seven plants meeting standards had relatively low staff size and staffing costs. Conversely, many facilities where standards

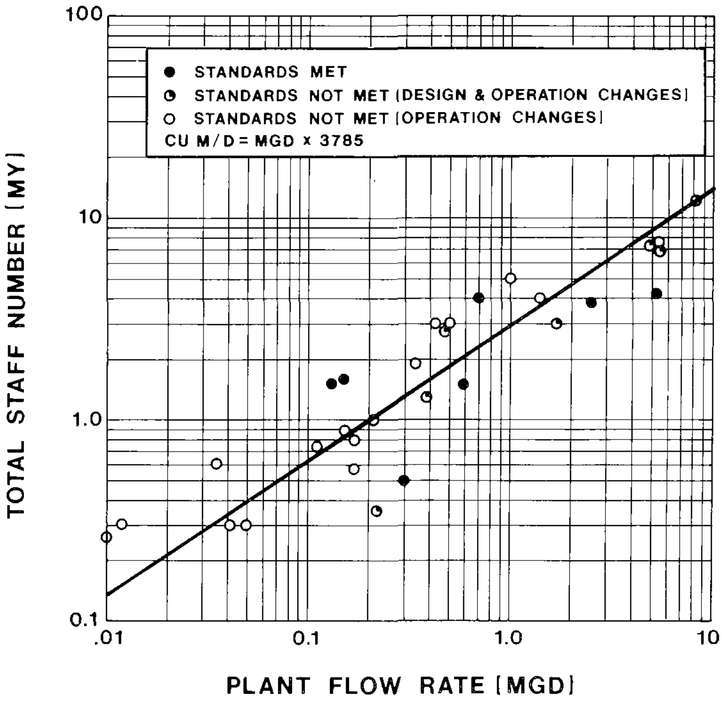

Figure 9. Staff size versus plant flow rate.

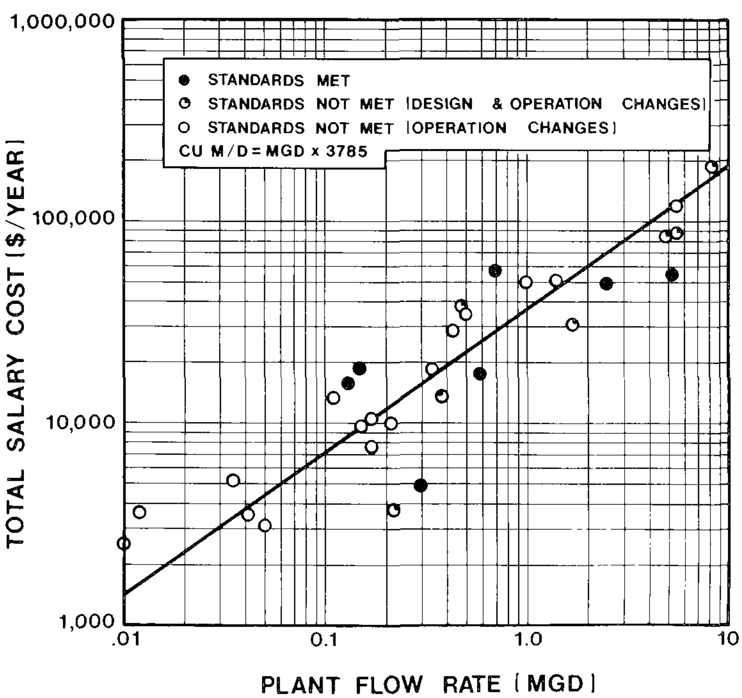

Figure 10. Total salary cost versus plant flow rate.

were violated had relatively high staff size and staffing cost values. Based on this data no definite correlation existed between total staff size or total staff cost and plant performance.

Specific staff size (i.e., staff size per unit of plant flow) and specific staff cost (i.e., staff cost per unit of plant flow) were also evaluated respective to plant performance and actual plant flow rate. Specific staff size versus plant flow rate is shown in Figure 11. Specific staff cost versus plant flow rate is shown in Figure 12. Significantly wide variations in the data exist, particularly in plants below 3785 cu m/day (1 mgd). However, the specific staff size and specific staff cost values, in general, decrease as the plant flow rate increases. Relative to plant performance, a definite correlation between specific staff size and specific staff cost would exist if a significant number of fully shaded dots were located near the top of the data points presented. These points are widely scattered, and for the plants evaluated no definite correlation existed. It was concluded that a large specific

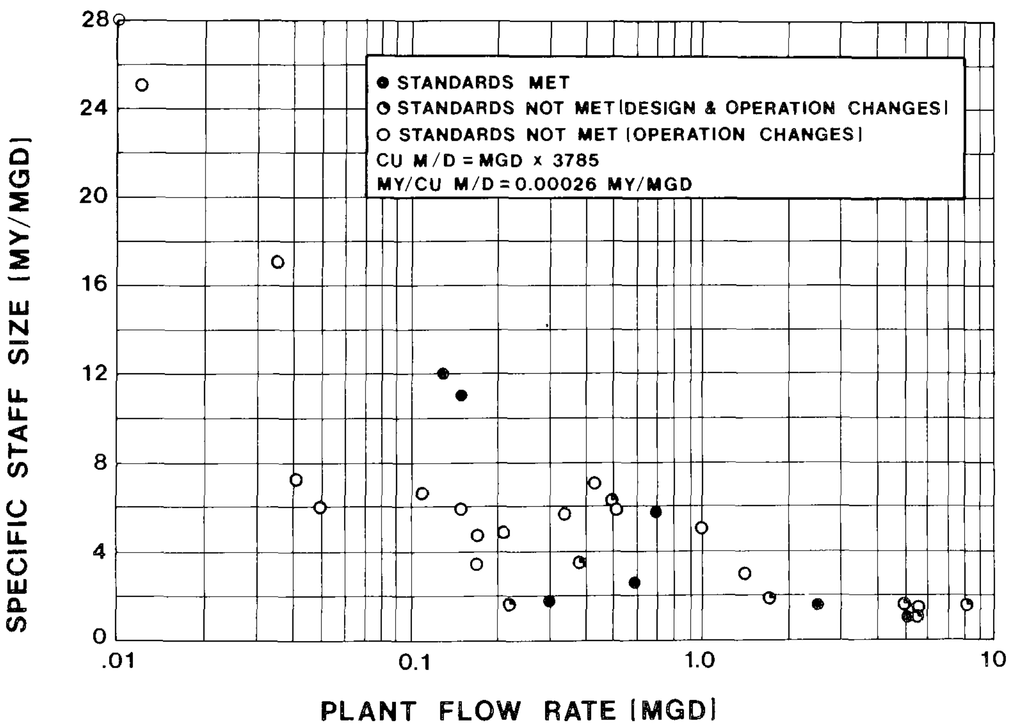

Figure 11. Specific staff size versus flow rate.

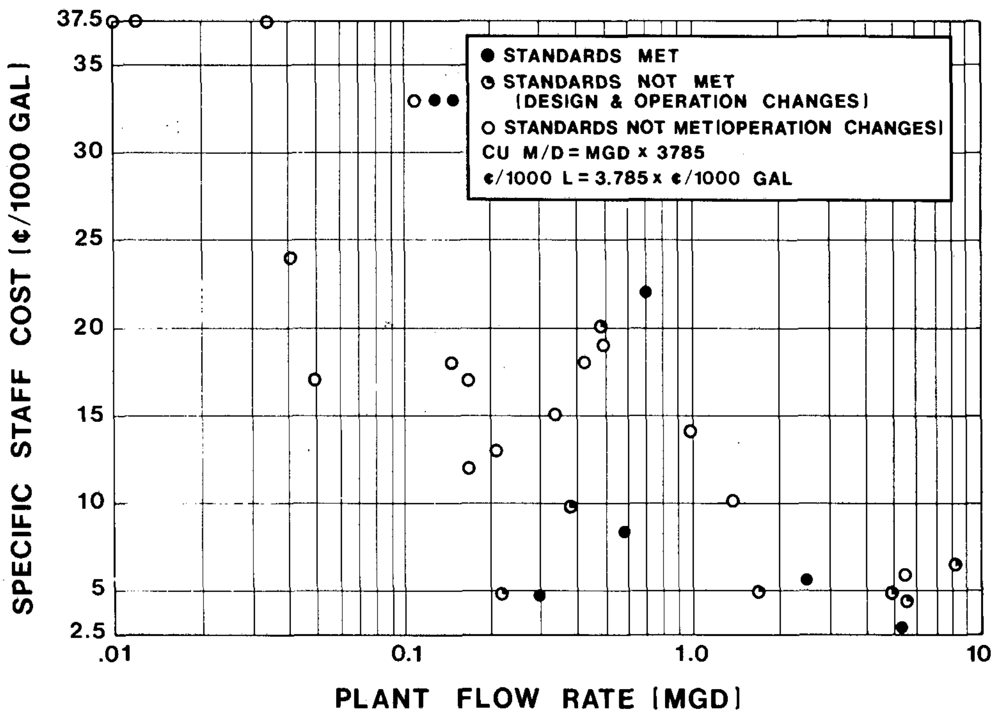

Figure 12. Specific staff cost versus plant flow rate.

staff size and high specific staffing cost did not alone improve plant performance. Conversely, a small specific staff size and low specific staffing cost were not alone responsible for poor plant performance.

An evaluation was also made to determine if higher salaries correlated with good performance by attracting more highly qualified personnel. Figure 13 shows the relationship between staff salary, plant flow rate and plant performance. It should be noted that staff salary includes base pay plus fringe benefits and that part time salaries were developed on a basis of one man for one year. Staff salary appeared to increase as plant flow rate increased. This fact is noteworthy and will be discussed later in this report. A correlation between staff salary and plant performance would be indicated on Figure 13 if the fully shaded dots were located near the top of the data points presented. These points again are widely scattered, and for the plants evaluated staff salary <u>alone</u> does not appear to be responsible for good or poor plant performance.

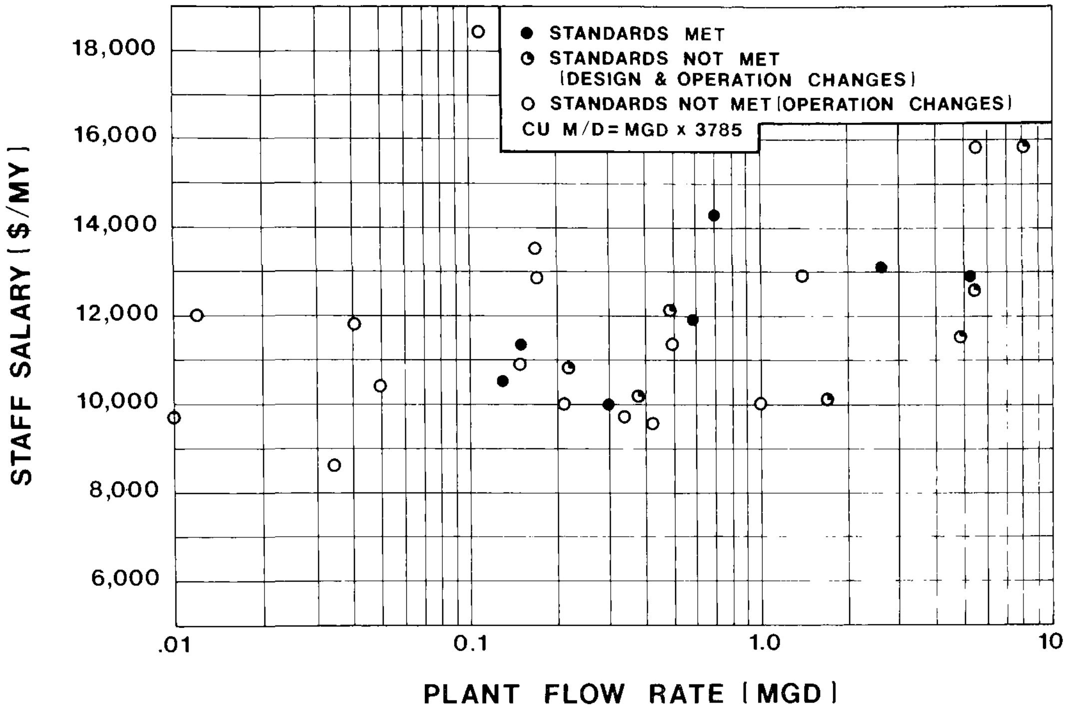

Figure 13. Staff salary versus plant flow rate.

Another correlation evaluated was the percentage of staffing cost to the total operations budget. This evaluation is shown in Figure 14. As shown, the percent of staff cost to the total operations budget varied from 17 percent to 67 percent and did not appear to correlate directly with good or poor plant performance. Good plant performance occurred at a staff budget percentage of less than 20 percent. However, 5 of the 7 good performing facilities had staff budget percentages greater than 50 percent. The implications of this data are difficult to interpret, especially in view of the fact that total staffing cost and staff salary alone did not appear to correlate with good plant performance. A possible explanation could be that the high staffing budget percentage reflects competent operations judgement on the part of the operators, which reduced other operation expenditures and therefore proportionally elevated the staff cost in relation to the total operations cost. Competent staffing will be discussed further.

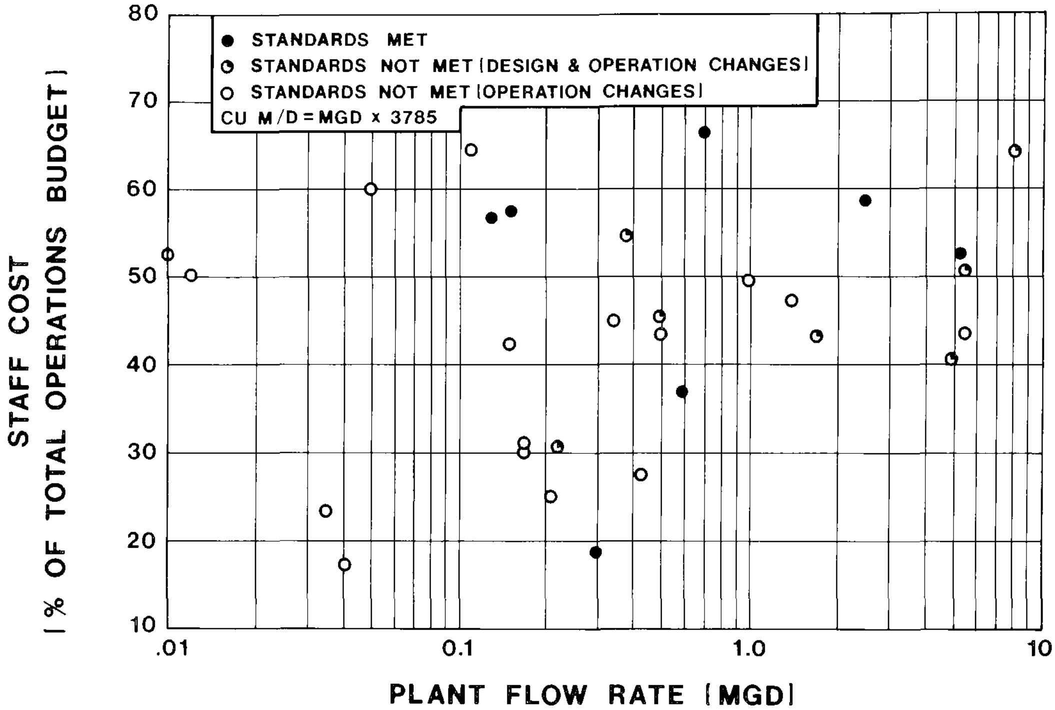

Figure 14. Staff cost versus plant flow rate.

EVALUATION OF STAFF ADEQUACY AND PLANT PERFORMANCE

An adequate plant staff to achieve good plant performance incorporates many features. Four items of particular importance are sufficient manpower for maintenance, sufficient manpower for operations, judicious use of available operations time and competency in making wise operations decisions. These items were individually evaluated for the thirty plants surveyed.

To evaluate manpower for maintenance and operations activities a rating was given ranging from good to poor, where:

Rating		Points	Description
Good	=	0	Sufficient number of manpower available
Fair	=	1	Additional manpower helpful
Marginal	=	2	Additional manpower desirable
Poor	=	3	Additional manpower necessary

Results are shown in Table 8. Manpower adequacy was quite good for nearly all facilities surveyed. In only two instances was plant maintenance manpower marginal and in only two instances was plant operations manpower marginal.

TABLE 8. MANPOWER ADEQUACY FOR THIRTY FACILITIES SURVEYED

Plant No.	Type	Flow: Actual Flow	Flow: Percent of Design	Manpower Adequacy**: Maintenance	Manpower Adequacy**: Operations
-	-	(mgd)*	(%)	-	-
002	Activated Sludge	0.43	54	0	0
007	Activated Sludge	0.041	59	0	2
012	Trickling Filter	8.1	68	0	0
013	Activated Sludge	0.5	63	0	0
014	Activated Sludge	1.0	50	0	0
015	Trickling Filter	1.7	47	0	0
019	Activated Sludge	0.035	54	0	0
020	Activated Sludge	0.007	28	0	0
021	Activated Sludge	0.59	66	0	0
022	Activated Sludge	0.012	80	0	0
024	Activated Bio-Filter	4.9	69	0	1
026	Activated Sludge	0.15	30	0	0
027	Activated Sludge	5.5	55	0	0
028	Activated Sludge	0.15	60	0	0
029	Activated Sludge	1.4	78	0	0
032	Trickling Filger	0.22	50	0	0
034	Trickling Filter	5.5	68	0	0
035	Trickling Filter	5.3	98	0	0
036	Trickling Filter	2.5	87	0	0
039	Activated Sludge	0.21	51	0	0
040	Rotating Biological Surface	0.38	60	0	0
041	Trickling Filter	0.31	33	0	0
047	Activated Sludge	0.05	80	0	1
048	Activated Sludge	0.34	89	0	0
050	Activated Sludge	0.17	96	0	0
053	Activated Sludge	0.11	68	0	0
055	Activated Sludge	0.30	52	2	2
060	Activated Bio-Filter	0.49	47	2	0
061	Activated Sludge	0.17	34	0	0
063	Activated Sludge	0.70	47	0	0

* mgd x 3785 = cu m/day

** Good = 0; Fair = 1; Marginal = 2; and Poor = 3

A summary of manpower adequacy for selected flow ranges is shown in Table 9. Adequate manpower for maintenance was not considered to be a significant problem in any plant size range. In nearly all facilities surveyed, key equipment was observed to be in good operational condition and was adequately maintained. Also, the operators appeared to have sufficient knowledge or access to knowledgeable persons in the general areas of preventive and emergency maintenance. Staff manpower for operations was also considered quite good. The only exception was for the smaller facilities 0 - 380 cu m/day (0 to 0.1 mgd), where operations manpower was rated at an overall value of 0.6 points. This rating was still fairly good, but poorer than the other sized facilities. It should be noted that none of the plants in this lower flow range met minimum secondary treatment standards.

TABLE 9. MANPOWER ADEQUACY FOR SELECTED FLOW RANGES

Flow Range	Number of Plants Surveyed	Average Staff Adequacy* for Manpower	
(mgd)**	-	Maintenance	Operations
0. - 0.1	5	0	0.60
0.1 - 1.0	17	0.24	0.12
1.0 - 10	8	0	0.13

* Good = 0; Fair = 1; Marginal = 2; and Poor = 3

** mgd x 3785 = cu m/day

Since it was concluded that a lack of adequate manpower to accomplish the needed maintenance and operations tasks was not a problem, it may be that judicious use of available operations time and/or a lack of competency in making wise operations decisions accounts for much of the observed poor plant performance.

Judicious use of available time was further investigated in two plants surveyed by determining the relative amount of time spent conducting "operations" tasks, "maintenance" tasks and "other" tasks. Operations tasks included plant observation, sampling, laboratory testing, process control adjustments, data calculations, etc. Maintenance tasks included housekeeping, preventive maintenance and corrective maintenance activities. Other activities included coffee breaks, non job-related discussion sessions, etc. A summary of the percentages of time spent at each of the three categories of tasks is shown in Table 10.

TABLE 10. SUMMARY OF OPERATOR TIME CONDUCTING "OPERATIONS", "MAINTENANCE" AND "OTHER" TASKS FOR TWO FACILITIES SURVEYED

	Plant No.* 048 Activated Sludge	Plant No.* 060 Activated Bio-Filter
Percent of Time Spent on "Operations" Tasks	58	63
Percent of Time Spent on "Maintenance" Tasks	36	33
Percent of Time Spent on "Other" Tasks	6	4

*Neither treatment facility met minimum secondary treatment standards.

A lesser amount of time (i.e., 36% and 33%) was spent on maintenance tasks, but both plants had relatively good maintenance as evidenced by the general appearance and condition of the plant equipment. The majority (i.e., 58% and 63%) of the operators' time was spent conducting operations tasks including laboratory testing and making operational adjustments. Although not evaluated in the detail that was used for Plants 048 and 060, it was observed that at most of the thirty facilities surveyed, the majority of the available staff time was used for operations oriented activities. It was concluded that the lack of operations time was not a major performance limiting factor.

Since operation time was not a factor, possibly operators' competency in making wise operations decisions was a performance limiting factor. An evaluation was conducted for all facilities surveyed utilizing a rating system to evaluate operator capabilities whereby:

Rating	Points	Description
Good	0	Adequate capability - good judgement in nearly all areas.
Fair	1	Poor judgement in some areas.
Marginal	2	Poor judgement in most areas.
Poor	3	Inadequate capability - poor judgement in nearly all areas.

Results are shown in Table 11. Operator capabilities were given greater weight if the plant staff, primarily the operations decision making individual, was not making appropriate decisions to optimize plant performance. For example, a poorer rating was given if available process controls were not appropriately used, if appropriate process control testing was not being completed, or if operational decisions were made that resulted in poorer rather than improved plant performance. Examples of operations tasks that were conducted without a complete understanding of fundamental concepts of operation to process control include: activated sludge not being wasted because it "completely burned itself up," activated sludge return flow rates being set significantly too high or too low, activated sludge settling tests used to determine sludge concentration results without regard to sludge quality characteristics (i.e., bulking sludge) and trickling filter recirculation flow directed through the primary clarifier without regard to decreased clarifier performance from the higher clarifier overflow rate.

To obtain a good rating in making competent operations decisions, the operator was required to understand the important concepts of operation relative to his facility and to make appropriate adjustments with available process controls. Additionally, the operator was required to recognize the need for a minor plant design modification which was necessary for him to make the appropriate process adjustments. It may be concluded that the requirement to recognize design limitations is not the operator's responsibility. However, it was observed that operators who understood the concepts of process control and recognized the need for design modifications were in a position to correct, or at least identify and document the design problems that existed. Most operators with good capabilities were able to correct minor plant limitations.

This is not meant to imply that operators should design plants or indiscriminately make design changes, but rather that operator changes to design can be extremely beneficial to improving plant performance if changes are based on correct concepts of operation.

TABLE 11. CURRENT OPERATIONS CAPABILITIES OF EXISTING STAFF PERSONNEL AT THIRTY FACILITIES SURVEYED

Plant No.	Type	Flow: Actual Flow	Flow: Percent of Design	Staff Adequacy — Current Operations Capabilities: Good	Fair	Marginal	Poor
-	-	(mgd)*	(%)				
002	Activated Sludge	0.43	54				3
007	Activated Sludge	0.041	59				3
012	Trickling Filter	8.1	68		1		
013	Activated Sludge	0.5	63				3
014	Activated Sludge	1.0	50			2	
015	Trickling Filter	1.7	47			2	
019	Activated Sludge	0.035	54			2	
020	Activated Sludge	0.007	28				3
021	Activated Sludge	0.59	66	0			
022	Activated Sludge	0.012	80				3
024	Activated Bio-Filter	4.9	69		1		
026	Activated Sludge	0.15	30		1		
027	Activated Sludge	5.5	55			2	
028	Activated Sludge	0.15	60		1		
029	Activated Sludge	1.4	78			2	
032	Trickling Filter	0.22	50		1		
034	Trickling Filter	5.5	68			2	
035	Trickling Filter	5.3	98		1		
036	Trickling Filter	2.5	87	0			
039	Activated Sludge	0.21	51				3
040	Rotating Biological Surface	0.38	60				3
041	Trickling Filter	0.31	33		1		
047	Activated Sludge	0.05	80				3
048	Activated Sludge	0.34	89			2	
050	Activated Sludge	0.17	96			2	
053	Activated Sludge	0.11	68			2	
055	Activated Sludge	0.30	52			2	
060	Activated Bio-Filter	0.49	47		1		
061	Activated Sludge	0.17	34			2	
063	Activated Sludge	0.70	47				3

* mgd x 3785 = cu m/day

As shown in Table 11, nine facilities had operators that were considered to be implementing poor (i.e., received 3 points) operations practices. Only two facilities had operators that implemented good practices, and many operators implemented fair to marginal practices. It should be noted that plant operators were not necessarily given a good rating if their facility met secondary treatment standards. Some facilities that met standards did so because of conservative plant design and not necessarily because of good plant operation. These plants could have achieved significantly better performance with good operation.

A summary of the current operations practices for selected flow ranges of the facilities surveyed is shown in Table 12. None of the three flow ranges had good staff adequacy in making wise operational decisions and in implementing good operations practices. It appears that significant problems in plant operation are occurring in the smaller facilities, but at the same time a large number of operations problems also occur in the larger facilities. The need to improve operations practices at all sizes of facilities is equally warranted.

TABLE 12. SUMMARY OF CURRENT OPERATIONS CAPABILITIES FOR SELECTED FLOW RANGES

Flow Range	Number of Plants Surveyed	Staff Adequacy* Current Operations Capabilities
(mgd)**	-	-
0.0 - 0.1	5	2.8
0.1 - 1.0	17	1.9
1.0 - 10.0	8	1.4

* Good = 0; Fair = 1; Marginal = 2; Poor = 3

** mgd x 3785 = cu m/day

Currently, staff adequacy in making wise operations decisions contributes significantly to the existing poor plant performance that was documented. Two possible reasons for this occurrence were evaluated. They are:

1. Existing operations personnel are not suited for their jobs.

2. Existing operations personnel have not developed and/or are not allowed to implement their capabilities.

The first reason implies that the existing operators cannot adequately operate treatment facilities because they do not have the required aptitude. The second reason implies that most operators have an adequate aptitude, but have either not developed their abilities and/or have not been allowed to exercise their abilities because of other influences on the plant. In an attempt to reach a conclusion as to where the problem area occurs, an evaluation was made of the potential operations capability of existing operators. The evaluation criteria assumed that the operators would receive technical guidance and training at their facility. The rating system ranged from 0 to 3 points as follows:

Rating	Points	Description
Good	0	Excellent aptitude and attitude to accept and implement technical guidance and training received in a short period of time.
Fair	1	Satisfactory aptitude and attitude to accept and implement technical guidance and training received, but would require a longer period of time.
Marginal	2	Unsatisfactory aptitude and/or attitude to accept and implement technical guidance and training received and would require a significantly long time period.
Poor	3	Unsatisfactory aptitude and/or attitude not conducive to further training.

The results for the potential operations capability of existing staff personnel are shown in Table 13. As shown, operators at many facilities had good

TABLE 13. POTENTIAL OPERATIONS CAPABILITY OF EXISTING PERSONNEL AT THIRTY FACILITIES SURVEYED

Plant No.	Type	Flow: Actual Flow	Flow: Percent of Design	Staff Adequacy — Potential Operations Capability**: Good	Fair	Marginal	Poor
-	-	(mgd)*	(%)	Good	Fair	Marginal	Poor
002	Activated Sludge	0.43	54			2	
007	Activated Sludge	0.041	59		1		
012	Trickling Filter	8.1	68	0			
013	Activated Sludge	0.5	63			2	
014	Activated Sludge	1.0	50		1		
015	Trickling Filter	1.7	47		1		
019	Activated Sludge	0.035	54		1		
020	Activated Sludge	0.007	28		1		
021	Activated Sludge	0.59	66	0			
022	Activated Sludge	0.012	80	0			
024	Activated Bio-Filter	4.9	69	0			
026	Activated Sludge	0.15	30	0			
027	Activated Sludge	5.5	55		1		
028	Activated Sludge	0.15	60		1		
029	Activated Sludge	1.4	78	0			
032	Trickling Filter	0.22	50		1		
034	Trickling Filter	5.5	68	0			
035	Trickling Filter	5.3	98	0			
036	Trickling Filter	2.5	87	0			
039	Activated Sludge	0.21	51		1		
040	Rotating Biological Surface	0.38	60			2	
041	Trickling Filter	0.13	33	0			
047	Activated Sludge	0.05	80			2	
048	Activated Sludge	0.34	89	0			
050	Activated Sludge	0.17	96	0			
053	Activated Sludge	0.11	68	0			
055	Activated Sludge	0.30	52			2	
060	Activated Bio-Filter	0.49	47	0			
061	Activated Sludge	0.17	34		1		
063	Activated Sludge	0.70	47			2	

* mgd x 3785 = cu m/day
** Good = 0; Fair = 1; Marginal = 2; and Poor = 3

and fair potential operations capability. None had poor potential operations capability and only a few had marginal capability. The potential capability of the operators in all plants was significantly better than the existing capability which was shown in Table 12 (i.e., current capability). The conclusion was that significant improvements are possible in current operations practices when it is considered that the existing operators would have access to proper technical guidance and training at their facility.

A summary of the potential operations capability for selected flow ranges is shown in Table 14. The potential staff operations capability of the smallest sized facilities was fair, for the intermediate sized facilities was good to fair, and for the largest sized facilities it was quite good. It appears that the larger facilities have personnel with a better aptitude for plant operations responsibilities. However, this does not imply that the operators at the smaller facilities should be replaced. The potential operations capability rating for the operation of the smaller sized facilities was acceptable. It does indicate that the operators at the smaller facilities will probably require proportionally more technical guidance and training relative to the size of the facility and therefore should be incorporated into a program that includes the necessary operations expertise (i.e., regional management or ongoing O & M assistance).

TABLE 14. SUMMARY OF POTENTIAL STAFF OPERATIONS CAPABILITY AND STAFF SALARY FOR SELECTED FLOW RANGES

Flow Range	Number of Plants Surveyed	Average Staff Salary	Potential Operations Capability*
(mgd)**	-	($/my)	-
0 - 0.1	5	10,501	1.0
0.1 - 1.0	17	11,632	0.88
1.0 - 10.0	8	13,107	0.23

* Good = 0; Fair = 1; Marginal = 2; Poor = 3

** mgd x 3785 = cu m/day

Also shown in Table 14 is the average staff salary for the selected flow ranges. Staff salary correlates well with the potential operations capability of the existing operators. As the potential operations capability improves the staff salary increases. A higher salary also correlates well with better current operations practices as shown in Table 12. However, in Figure 13 it was shown that a high salary alone <u>was not</u> instrumental in allowing plants to achieve good performance. It was concluded that a higher salary encourages operators to the wastewater treatment field that have a better aptitude for understanding the concepts of operation, but does not provide operators who can develop proper operation techniques on their own. To encourage personnel with better potential operations capability into the field of wastewater treatment operation, paying a higher and more adequate salary should be encouraged. This recommendation must be coupled with an improved approach for operators to obtain adequate technical guidance and training if an overall improvement in plant effluent quality is to be achieved.

Improved technical guidance and training will require many modifications to existing programs and approaches. In many cases operator development has been limited because conflicting and confusing concepts of plant operation exist in various training texts and because misleading technical guidance has often been given. Improper technical guidance was the third highest ranking performance limiting factor noted in this research project. In other cases operators have not been able to exercise their capabilities because they are in a lesser position than others who also influence plant operation like the district manager, city engineer, design engineer, state and/or federal regulatory agency personnel and federal, state and/or local training officials. These officials have exerted external pressures that have forced many operators to maintain "status quo" with their facilities. Three specific recommendations are made relative to these observations:

1. Conflicting or confusing concepts of plant operation should be verified for accuracy by plant operation and design specialists and eliminated from training texts so that operators may be better able to more accurately develop their abilities.

2. Proper technical guidance should be given at individual facilities with consideration to the time required for changes to the biological system so that operators may learn from the changes that occur and further develop their plant operations abilities.

3. Proper technical guidance in plant operation should be expanded to include others who influence plant operators so that the operators' abilities gained may be implemented to improve plant performance with appropriate supervision and encouragement.

SECTION 8

EVALUATION OF EXISTING PROGRAMS IN RELATION TO FACTORS LIMITING PERFORMANCE

The majority of treatment facilities evaluated in this research project (23 of 30) did not meet federally defined minimum secondary treatment standards. National trends also confirm that many facilities are not operating at a satisfactory level of performance. (3) As discussed in the previous sections of this report, the leading cause of limited plant performance varies from one plant to another and several factors were noted to contribute to limited performance in each individual plant. Each of these factors must be addressed at an individual facility before that facility will achieve optimum performance. Many of the causes of poor performance have been the subject of existing programs which were developed specifically to eliminate one particular factor or group of factors which limit plant performance. These programs were not evaluated per se, but are discussed in this section of the report as they relate to the observations and conclusions of the research study.

The established programs that influence plant performance can be separated into categories depending upon the factors limiting performance they are designed to address. These categories are discussed as: 1) administrative oriented programs, 2) design oriented programs and 3) operations and maintenance oriented programs. Programs that address administrative factors include the NPDES permit and permit enforcement programs. Those that address design oriented factors include construction grants, technology transfer, state and federal established design criteria and/or guidelines, and value engineering. Operations and maintenance oriented programs include general and plant specific O & M manuals; federal, state and local operator training; state operator certification and plant start-up assistance.

The existing program that has the greatest potential of influencing wastewater treatment plant performance is the NPDES permit program. Based on the objectives of the permit program it is no longer adequate to simply keep a plant running. The permit program requires a totally new approach in that a specific degree of treatment is required from every facility. Maximum benefit is achieved from the permit program when it creates an awareness in plant administrators that they must have an acceptable effluent from their plant. The self-monitoring aspect of the permit program provides plant performance information and should emphasize the need for better treatment to both the facility's operation and administration personnel. However, poor performance data alone has not caused administrators to initiate actions at many facilities that violate their permit standards.

Enforcement of NPDES permit requirements has served to provide more incentive for plant administrators to initiate programs to improve performance. However, the typical approach observed to achieve compliance was to expand the facilities by completing some type of construction program without a complete knowledge and understanding of all factors adversely affecting performance. For example, at two facilities evaluated the plant design capacity had recently been doubled; however, neither upgraded facility met permit requirements for secondary treatment. Additionally, these two major facility upgrades would not have been required if the priority factors limiting performance had originally been addressed. Only minor facility modifications would have been necessary. The original facilities' capability had not been adequately addressed in the federally funded "201" facilities planning process, and the overall effort to achieve permit compliance was unsuccessful. Regulatory agencies could change this approach by encouraging the optimization of the operational capability of existing plants before a major facility upgrade is pursued. This suggestion must be implemented with caution due to the widespread prevalence of improper technical guidance provided by both design engineers and state and federal regulatory personnel documented in this research project and the associated widespread inability of these persons to evaluate or monitor the evaluation of existing facility capability. It was concluded that enforcement of the NPDES permit program can provide an incentive to plant administrators to implement programs to improve performance. However, a more thorough investigation into existing facility capability through improved O & M is necessary prior to selecting a major plant modification alternative. This conclusion applies whether facilities are evaluated as part of the federal "201" facilities planning process or are evaluated outside the scope of the federal construction grants program.

The federal construction grants program has encouraged new construction and upgrades of many wastewater treatment facilities. A large amount of funding has been available and many consulting engineers and equipment suppliers have been encouraged to enter the field of wastewater treatment. Local consulting engineers whose expertise was in highways, drainage, hydraulics, etc. began designing wastewater treatment plants. Equipment suppliers began to market new equipment to fill the need for the many new and upgraded plants. Many of these engineers and suppliers were not experienced in all facets of wastewater treatment. Most engineers and equipment suppliers who entered the wastewater treatment field were conscientious and sought assistance in plant design. Assistance was available from information disemination programs like technology transfer and from federal and state design criteria materials. These programs and materials provided useful design supplements, but they were not developed to provide a basis for a comprehensive design. Technology transfer programs were oriented toward process selection and facilities planning rather than plant flexibility, process controllability and other plant O & M requirements. Design criteria materials were typically broad in scope and presented only the minimum design requirements. Using this information facilities and equipment were designed and constructed without a thorough understanding of the operation and interrelationships of wastewater treatment plant processes. The result has been marginally designed facilities and equipment that have limited plant operation and performance. This chain of events may have occurred by necessity in order that many treatment facilities be constructed in a short period of time. The established design criteria materials and technology transfer programs have been and continue to be important as supplements to a complete design. As such, they should be re-evaluated and restructured to include and emphasize the documented high ranking factors which limit performance.

The value engineering program was recently established in the EPA's continuing effort to achieve cost-effective, well designed facilities. Two areas of concern exist with respect to value engineering in view of the high ranking of certain causes of limited plant performance noted in this research effort. One concern is that design engineers with operations experience are limited, as evidenced by the large amount of improper technical guidance noted; thus only a limited number of good comprehensive value engineering analyses can be conducted. The second concern is that the actual or implied emphasis on a cost savings from a value engineering analysis, coupled with improper technical guidance, combine to potentially disallow plant features that would improve plant operation and performance. For example, some plant flexibility and controllability features whose absence was noted repeatedly in plants surveyed could be considered nonessential features in a value engineering analysis and subsequently eliminated from a plant design as a cost savings measure. Value engineering analyses can be beneficial, but all value engineering analyses must be conducted with an appropriate appreciation for plant operation so that design features that potentially aid in process control are not excluded as cost saving measures but, rather are included if not present.

The federal, state and local operator training and state operator certification programs are generally geared toward the development of a broad scope understanding of sewage treatment, yet inadequate sewage treatment understanding ranked high as a factor limiting plant performance and training ranked relatively low. Training was rated when operators did not participate in existing available training programs, thus most operators had attended training programs. The conclusion was that existing training programs did not provide the basis and motivation to develop good sewage treatment understanding. If operators attended training programs but had poor sewage treatment understanding, it may be argued that they have inadequate aptitude. However, in the preceeding section of this report it was judged that plant operators had relatively good aptitude. It was concluded that existing operator training programs are not sufficient and should be expanded and upgraded to incorporate new and better training materials and techniques into their curriculum. An example new technique is described later in this report.

Other major limitations of existing training programs were noted during the research effort. Training programs were sources of improper technical guidance and have exposed operators to many different approaches to process control, some of which were confusing, conflicting or incorrect. For example, operators related that they had been told at training classes to adjust their mixed liquor suspended solids concentrations to specific values, but to waste only on an infrequent basis. The end result was that improper classroom solutions were being implemented in facility operations which caused poor performance to continue. Increased operator training is essential, but operator training material should be routinely verified for accuracy by plant operation and design specialists and inaccurate information should be eliminated from training materials.

Improved training techniques and corrected operator training material can provide operators with better sewage treatment understanding. However, many operators were unable to apply information received at training sessions to their plants' operation. Training was usually associated with certification, and facts rather than concepts were stressed. Also, operators typically received general training in a classroom or at another facility and did not apply this training to their facilities which had a different piping arrangement, different valving procedure, different basin size plus other differences. For example, the operator may have been told in a classroom that the return activated sludge flow rate was usually adjusted with variable speed pumps, and since the operator did not have variable speed pumps in his plant he ignored return flow adjustments rather than searching for alternative methods. In conclusion, operator training and certification programs were developed to provide operators with good sewage treatment understanding, which they did with some degree of success. However, these programs generally did not provide operators with the skills to correctly apply concepts of operation to process control at their individual facilities. In order to correctly apply wastewater concepts to process control, an operator's skills should be developed through proper technical guidance at the operator's facility under the direction of qualified personnel. This would require dramatic changes in existing training techniques which will be discussed later in this report.

At facilities surveyed it was observed that plant specific O & M manuals generally included good maintenance information and good descriptions of the plant's flow schematics, flexibility and controllability. On the other hand, misinformation and/or insufficient information on the use of plant features was included in most manuals, and overall it was observed that O & M manuals by themselves did not provide operators with an ability to apply concepts of operation to process control. The use of O & M manuals did not lead to good operations practices, but were beneficial as a reference for plant maintenance and various piping arrangements described therein.

Few maintenance problems were noted at facilities surveyed. One reason for good facility maintenance was attributed to the use of maintenance oriented O & M manuals. Another reason was that good plant "performance" has historically been judged by the appearance and operational state of equipment rather than effluent quality. As a result, plant operators have worked diligently on plant maintenance. A third and probably primary reason for good maintenance was that maintenance problems are highly specific and visible and can be directly related to a piece of equipment that is malfunctioning. As such, operators, supervisors, regulatory agency personnel and others have quickly recognized maintenance problems. The quick assessment and correction of a maintenance problem was responsible for the low ranking of maintenance related factors limiting performance determined in this research. Good plant maintenance should continue to be stressed, but it should be recognized that a well maintained plant is only a base level from which to work toward good performance.

The federal construction grant program has recently included plant start-up assistance conducted by the plant design engineer or others identified by the design engineer as a grant eligible cost. This assistance program has much potential to improve plant performance due to the mutual on-site effort by both the design engineer and plant operator to achieve a well performing facility. A potential problem exists with the start-up assistance endeavor if it consists of equipment start-up only and not process start-up. Plant start-up assistance must not be limited to equipment start-up and hydraulic checks, but must include process start-up and most importantly a transfer of the proper application of concepts of process control to the plant operators so that a high quality effluent may be discharged. Even with a process start-up emphasis improper operations procedures and poor plant performance may continue because of the limited operations experience by design engineers, as evidenced by the high ranking of the improper technical guidance and design limiting factors noted in this research. Process start-up by design engineers will provide opportunities for operations experience presently not available. Because of this experience, plant effluent quality will eventually improve, not only due to the on-site training the operator will receive but also due to the training that the start-up assistance personnel will obtain.

Grant eligible start-up assistance applies only to new or upgraded facilities. Serious problems were observed at existing facilities that are not eligible for start-up assistance. Many of these facilities were less than five years old and were not meeting permit standards. Typically, these facilities had problems in all four major areas evaluated: design, operation, maintenance and administration, but the approach to solve the problem was usually to expand the plant. One option that was not being investigated was technical assistance in plant operation. It is recommended that plant administrators be encouraged to obtain operations technical assistance as an option to plant expansion, or at least prior to plant expansion, in the effort to improve plant performance. At the same time existing programs discussed in this section of the report should be directed toward encouraging and supporting this option. The benefits of technical assistance in plant operation are described in the next section of the report.

SECTION 9

METHODS OF ACHIEVING OPTIMUM PLANT PERFORMANCE

Previous information developed in this report indicates that a broad range of diverse factors limit performance at most existing treatment facilities. The analysis of individual factors did not lead to specific recommendations that could be implemented on a broad scale to improve overall plant performance. The evaluation of existing programs indicated that even if these programs were continued, optimum performance still would not be achieved at many facilities. The types of factors limiting performance and the numerous programs to attain their correction indicates the complexity of the O & M problem. In this section of the report, the relationship between the problems and solutions is described in a "Unified Concept for Achieving Optimum Plant Performance." The concept describes the interrelationship among the factors limiting performance and the correction programs that have been and should be implemented to address these factors.

UNIFIED CONCEPT FOR ACHIEVING OPTIMUM PLANT PERFORMANCE

The Unified Concept for Achieving Optimum Plant Performance is illustrated in Figure 15. The goal is to obtain optimum performance from a given treatment plant. The horizontal line represents the position of a treatment facility with respect to optimum performance. The length of the horizontal line represents the magnitude of less than optimum performance. Factors limiting performance tend to increase the length of the horizontal line and move a plant further away from the goal. These factors are indicated by the number of arrows pointing downward and their relative severity is indicated by the length of the arrows. A large number of factors and/or a few severe factors would cause a facility to be far removed from optimum performance.

The elimination of factors limiting performance through the implementation of a correction program would tend to move a plant's position closer toward the goal of optimum performance. Correction programs are indicated by the arrows pointing upward, as shown on Figure 15. The length and number of upward arrows indicates the relative influence and number of correction programs applied to a given treatment facility. As factors limiting performance are eliminated by correction programs, the plant's position moves closer toward optimum performance and the length of the horizontal line becomes shorter, indicating fewer or less severe performance limiting factors remain between the current plant status and optimum plant performance.

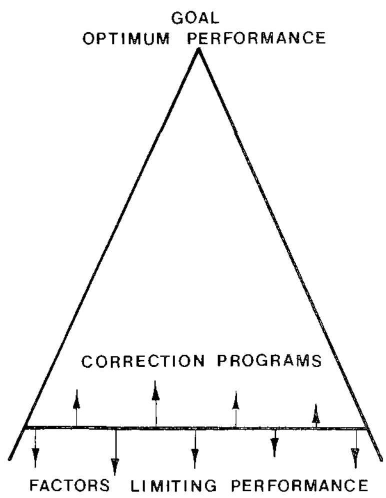

Figure 15. Unified Concept for Achieving Optimum Plant Performance.

As described in the Unified Concept, all of the factors limiting performance must be addressed and eliminated through some type of correction program to achieve the desired performance goal. The term correction program is used to describe any public or private activity, national, regional or local in scope that eliminates the effect of an adverse factor or group of factors and causes a facility to move toward optimum performance. Correction programs to eliminate factors affecting plant performance are many and varied, probably because the factors that need to be eliminated are so diverse. In this section the multitude of correction programs are not discussed separately. Rather, correction programs are divided into two groups identified as Individual Correction Programs and a Composite Correction Program.

INDIVIDUAL CORRECTION PROGRAMS

An Individual Correction Program is implemented with the purpose of addressing and eliminating specific factors or groups of factors at all or at a large number of facilities. The role of Individual Correction Programs in the Unified Concept is depicted in Figure 16. Three example correction programs used are the construction grants program, the NPDES permit enforcement program and operator training programs. These correction programs attempt to improve performance at many treatment facilities by directing their activities toward specific factors limiting performance at a large number of plants. The construction grants program focuses on the construction of new or upgrading of existing facilities, and thereby addresses factors such as hydraulic overload and inadequate clarification capacity. The NPDES permit program focuses on the effluent quality of facilities and potentially could use the associated enforcement capability to motivate administrative personnel. Operator training programs focus on plant operators and address factors like sewage treatment understanding. In like manner, other Individual Correction Programs focus on specific factors or groups of factors limiting performance at many treatment facilities.

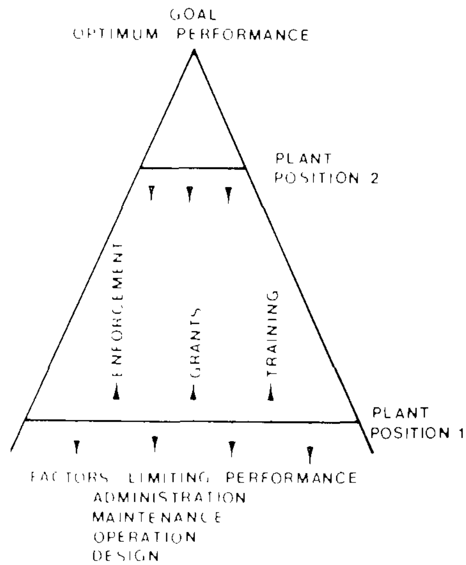

Figure 16. Individual correction programs and the Unified Concept.

The major emphasis since PL 92-500 was enacted in 1972 has been to improve treatment plant performance through Individual Correction Programs. The results have been partially successful in that some new or upgraded facilities are performing at a satisfactory level. However, many facilities are not performing well. (2,3) One of the reasons for only a moderate success of the Individual Correction Programs is the manner in which these programs have been implemented. Individual Correction Programs were established to concentrate on specific areas of need representing a common problem at a large number of treatment facilities. However, every factor that limits performance at a given facility must be eliminated for that facility to achieve optimum performance. Individual Correction Programs have not, and typically cannot address the unique combination of performance limiting factors at an individual facility.

The role of Individual Correction Programs in the Unified Concept theory is further explained using an example. Consider a facility with two major and other minor factors limiting performance. Assume the major factors are hydraulic overload and improper operator application of concepts and testing to process control. At this example facility the hydraulic overload factor would likely be obvious and overshadow the operator application factor. With these two major factors limiting performance the plant would be far removed from optimum performance and would be at Plant Position 1 in the Unified Concept as shown in Figure 16.

Now, assume that by implementing an Individual Correction Program, such as an engineering study and associated plant upgrade using a construction grant, that the hydraulic overload problem is corrected. When this overload problem is corrected the operator application of concepts and testing to process control factor becomes prominent in that facility's inability to achieve optimum, or maybe even satisfactory performance. This example facility could now be at Plant Position 2 in the Unified Concept as shown in Figure 16. Addressing only the obvious factor of hydraulic overload would not allow the example facility to achieve the desired performance goal. This example illustrates why many facilities that have been upgraded have not achieved satisfactory performance.

In the preceding example it was shown that Individual Correction Programs do not necessarily influence or eliminate all the factors limiting performance at a particular facility, thus many facilities continue to operate at poor performance levels. This is not meant to imply that Individual Correction Programs should be abandoned. There is a continued need for these programs because of the multitude of performance limiting factors that exist. However, Individual Correction Programs are limited in their ability to achieve optimum performance.

An important aspect of the research study was also described in the example given for the limitations of the Individual Correction Program approach. In the screening process used to select plants for this study, facilities with gross and obvious limitations such as excessive hydraulic overload, infiltration/inflow and organic overload were purposely excluded. Included were many facilities that were believed operable, yet were achieving less than desired performance. Therefore, this research has documented the less obvious types of problems that are, or will be encountered by facilities as they move closer toward optimum performance. These problems must also be eliminated before optimum, and maybe even acceptable facility performance will result.

COMPOSITE CORRECTION PROGRAM

A program that can advance a significantly large number of facilities to optimum performance is a Composite Correction Program (CCP). A CCP is different from an Individual Correction Program in that it addresses all factors limiting performance at a given facility. A CCP for a typical plant in relation to the Unified Concept is illustrated in Figure 17. Factors limiting performance in the areas of administration, maintenance, operation and design tend to move the plant away from the goal of optimum performance (Plant Position 1). The CCP addresses all of these factors, and if properly implemented can achieve optimum performance at that facility (Plant Position 2). To demonstrate the value of the CCP a program was implemented as a part of this research effort. A separate report was prepared describing the results obtained. (2) The results are summarized and presented in this report as they relate to the overall findings of the research effort.

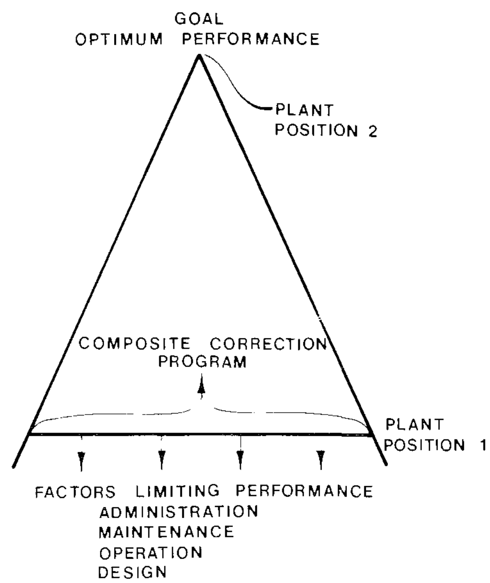

Figure 17. Composite Correction Program and the Unified Concept.

The CCP was implemented at the Havre, Montana Wastewater Treatment Plant. The Havre facility is an activated sludge plant designed to treat a sewage flow of 6800 cu m/day (1.8 mgd). Treatment facilities consist of a grit chamber, flow measurement, comminutors, two aeration basins, two secondary clarifiers, a chlorine contact chamber, two aerobic digesters and a lagoon for ultimate sludge disposal. The plant flow diagram is shown in Figure 18.

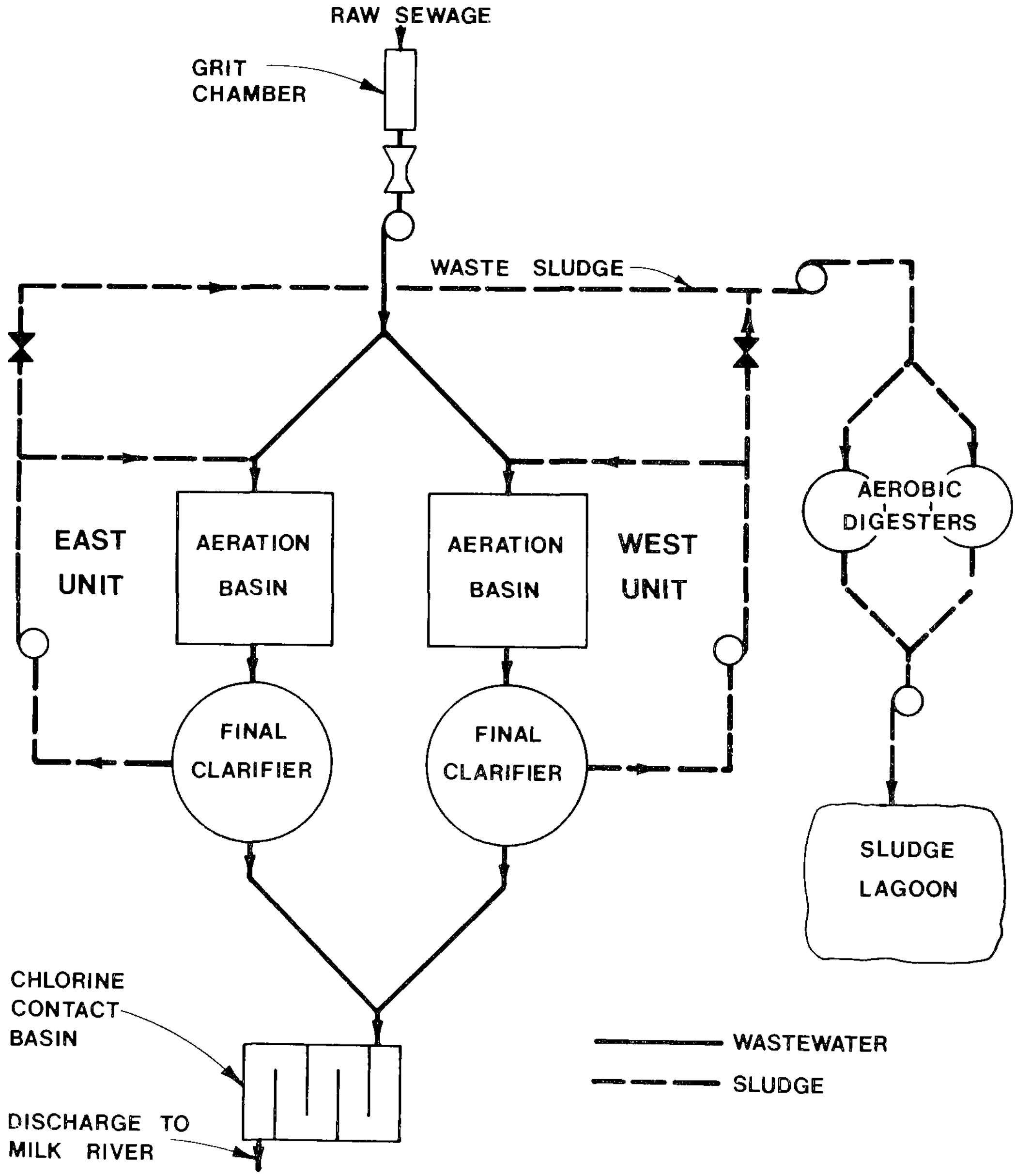

Figure 18. Plant flow schematic for the Havre, Montana wastewater treatment plant.

Havre was selected for a CCP for a variety of reasons, but primarily because of the plant superintendent's ready acceptance of the program. During the field portion of the preliminary survey operations assistance was provided. Modifications to operations data collection and organization, and major adjustments in process control were made. The operations data was used to interpret process status, observe process response to adjustments made and describe concepts of operation to the plant operators. Following the initial seven-day field effort, telephone consultation was established on a routine basis (several times per week). Telephone contact continued at less frequent intervals for about one year. Factors limiting performance which were addressed as a part of the CCP are presented in detail in another report. (2) A summary of the factors addressed is presented below:

Operations Factors

- Improved and expanded process control testing was initiated.
- Operator skills were developed with respect to applying proper operation concepts to process control.

Design Factors

- Short circuiting in final clarifiers was eliminated.
- Inherent difficulties with plant design (aerator capacity, return sludge control, and aerobic digester capacity) were overcome by increased plant operations.

Administrative Factors

- City council was made aware of importance of plant operation.
- Plant staffing was increased to provide twenty-four hour operator coverage to overcome limitations in plant design.

Maintenance Factors

- Emergency maintenance procedures were improved because of awareness of impact on the biological system.

Completion of the Havre CCP resulted in many benefits, one of which was achieving optimum facility performance. Figure 19 shows a seven point moving

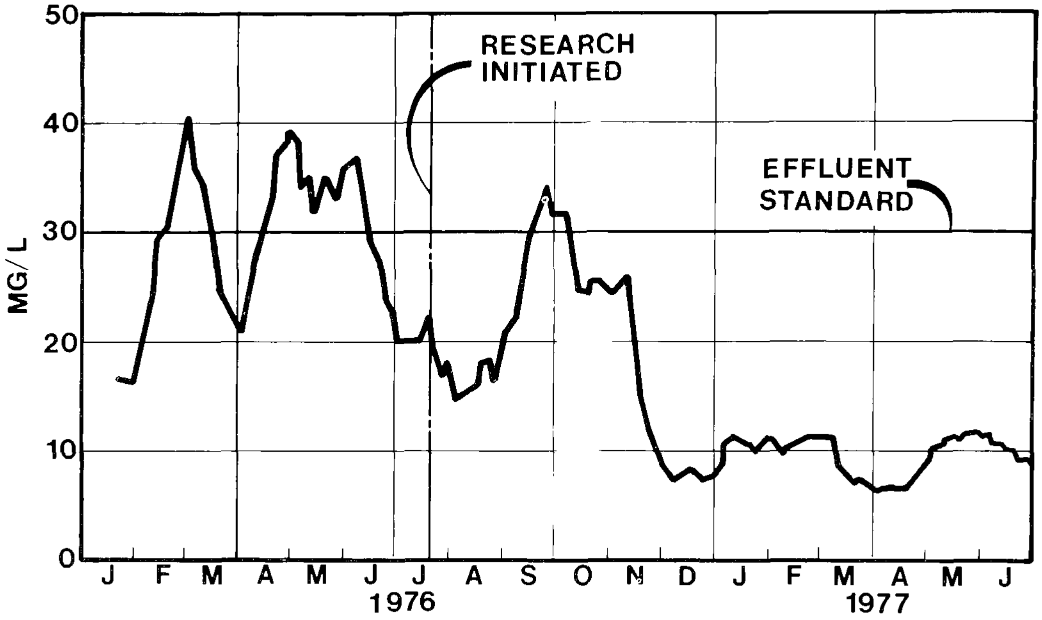

Figure 19. Final effluent BOD_5 at Havre, Montana.

average of chlorine contact basin effluent BOD_5 concentrations. A dramatic improvement in plant performance occurred. Effluent quality for the six-month period prior to initiation of the CCP averaged 31 mg/l for BOD_5 and 30 mg/l for TSS. After stabilized process control was achieved, effluent quality for the seven-month period of December 1976 through June 1977 averaged 9.7 mg/l for BOD_5 and 9.1 mg/l for TSS. This translates to a 70 percent reduction in the former BOD_5 and TSS load discharged to the receiving stream. The Havre facility consistently met its NPDES permit standards that were previously violated. Another benefit that resulted from the Havre CCP was related to the fact that the plant served as a training facility for local community college students in Water and Wastewater Treatment Technology. Students frequently visited the plant for on-the-job instruction. The impact of a well performing full-scale plant accentuated the training that the students received.

Other benefits from the Havre CCP were more far reaching than the specific gains made at the Havre facility. At Havre, stabilization of the biological process required three months of effort during fairly good conditions and with above average process control. Constant changes to process controls were required throughout that time period. Some plant upsets occurred which resulted in a great deal of pressure by the plant operators to return the plant to status quo. Continued training and process guidance by the research team was required to avoid changing the system back to its original status. If technical guidance were given for only a short time, the performance improvement gained at Havre would not have been achieved. It was concluded that to properly evaluate biological system response and achieve system stability a long time period (i.e., many months) is required. This conclusion demonstrates the need for altering typical approaches to the evaluation of biological systems. The conclusion also provides insight into the possible causes of the high ranking factors limiting performance of improper technical guidance and inadequate operator application of wastewater treatment concepts to process control.

Typically, technical guidance to plant operators is provided during short plant visits by authoritative sources (i.e., design engineer, equipment supplier or state or federal regulatory inspector). Recommendations are made and implemented. Slow response of the biological system, as demonstrated at Havre, allows these persons making the recommendations to be far removed from the facility when the operator encounters difficulties associated with the recommendations. As such, most authoritative sources do not experience the problems encountered and the limitations of their advice, and thus do not improve their operations capability. The time delay inherent in stabilizing a biological process is probably a major reason that improper technical guidance has become a significant factor limiting biological wastewater treatment plant performance.

Another factor addressed in the Havre CCP was the operator's capability to properly apply correct concepts of plant operation to process control. The Havre superintendent had two years of college training and had received formal training for an additional two years at a Water and Wastewater Technology School. The superintendent also had an excellent aptitude. Even with this good background and aptitude, guidance at the operator's facility over a nine-month period was necessary to properly develop his capabilities to fully apply concepts to varying operational situations. The time involved and the approach used to develop the operator's skills in the area of application of concepts that was demonstrated at Havre provides a basis for drastically altering present operator training procedures. It was concluded that an operator's skills and ability to apply concepts of operation to process control should be developed through technical guidance at his individual facility under the direction of qualified personnel.

An important point noted during the research effort was the capability of operators to achieve optimum facility performance. Much blame has been placed on plant operators as the source of poor performance. However, this blame was often not warranted because operators usually were not in a position to address a large number of critical factors limiting performance in all four major areas of operation, maintenance, design and administration. Plant operators were usually limited to addressing operation and maintenance factors only, and therefore could not and should not be expected to solely achieve optimum facility performance.

If Composite Correction Programs, excluding major capital improvements, were applied to the other twenty-nine facilities evaluated in this research project, dramatic improvements in plant performance would result. In many cases NPDES permit standards would be met that are now being violated. Improvement in performance that could result is described along with the Havre CCP in the other report developed under the research contract. (2) Table 14 presents a summary of the performance of the thirty facilities surveyed in relation to permit standards.

TABLE 15. PERFORMANCE OF THIRTY FACILITIES EVALUATED VERSUS SECONDARY TREATMENT STANDARDS

	Standards Frequently Violated	Standards Consistently Met
Prior to Evaluation	23	7
Potential After Composite Correction Programs	7*	23

*Seven facilities would require a major facility upgrade, which for purposes of this evaluation was excluded as part of the Composite Correction Program.

During the preliminary surveys it was determined that twenty-three of thirty facilities did not meet secondary treatment standards even though their average hydraulic loading was only 61 percent of design flow. It was estimated that if CCP's were completed at all thirty plants and if major capital improvements were not an available option, an additional sixteen facilities would consistently meet standards. Seven would continue to violate standards because a major plant upgrade would be necessary at these facilities before permit compliance could be achieved.

The typical approach to improve plant performance has been to expand the existing plant through some type of construction modification. However, simply expanding facilities has not allowed permit standards to be met, as evidenced by the relatively low hydraulic loading (61 percent of design flow) of facilities violating standards. A greater level of facility over-design does not appear warranted. Rather than more construction, the efficient use of existing facilities developed through CCP's represents a more cost-effective approach to improving plant performance. If needed, major plant modifications through construction should be part of and not a substitute for a CCP.

In addition to allowing facilities to consistently meet permit standards, the implementation of CCP's at all thirty facilities surveyed would dramatically decrease the BOD_5 and TSS pollutional load discharged to the receiving streams. The potential decrease was an estimated 1340 kg/day (2960 lb/day) for BOD_5 and 1278 kg/day (2822 lb/day) for TSS. This reduction represents an average 14 mg/l decrease in both the BOD_5 and TSS concentration in all of the plant discharges. It is important to realize that this improvement would occur at existing treatment facilities and without major capital expenditures. The capability of CCP's to improve the existing facilities' performance requires consideration for their widespread implementation.

Limitations to the widespread use of CCP's to improve facility performance exists. There is a lack of qualified personnel to successfully implement programs on a broad scale, as evidenced by the high ranking of the improper technical guidance factor limiting plant performance. Specialized training approaches to gain additional qualified technical assistants should be developed. Specialized training must include in-plant operations experience at various wastewater treatment facilities over a long period of time to properly develop capabilities for the correct application of wastewater treatment concepts to process control and to develop a respect for the time associated with biological system response. Conducting CCP's is a good mechanism through which existing technical assistants can be properly trained. In this regard, initial CCP's will involve costs and time for the training of the technical assistants. The federal construction grant plant start-up assistance program could also provide a basis for attaining qualified personnel, if it is process control oriented, allowed to continue for an adequate time at an individual facility and approached as a training function for both plant and start-up assistance personnel.

Another limitation to the widespread use of CCP's is that present incentives for their implementation are not satisfactory. Incentives are usually directed toward making a plant modification. For example, administrators of plants that are violating permit standards typically look to a construction grant (i.e., Individual Correction Program) to upgrade their facility rather than to a Composite Correction Program to improve the existing facility's performance. An alternative to change this approach is through the permit enforcement program. Enforcement could encourage local administrators to act to improve the existing facility's performance. At the same time a critical review of the present construction oriented programs for improving performance is needed to insure that existing facility capability, as developed through a Composite Correction Program, is evaluated before a construction solution is initiated. Another incentive to improve plant performance is to develop a financial assistance program for existing facilities comparable to the plant start-up assistance program for new facilities. Such a program would have a dual effect of improving existing facility performance and expanding the basis for developing qualified technical assistants.

The cost of implementing Composite Correction Programs could vary significantly depending on facility size, type and scope of factors limiting plant performance. The cost would be substantially less than the cost of completing major facility modifications, and more importantly the end result of optimum performance would be achieved. Encouraging CCP's will not result in immediate optimum performance of all facilities. However, the soundness of the program has been demonstrated and the program's development can potentially result in widespread improved facility performance.

REFERENCES

1. Gannett, Fleming, Corddry and Carpenter, Harrisburg, Pennsylvania. Report prepared in partial fulfillment of EPA Contract No. 68-03-2223, U.S. Environmental Protection Agency, Cincinnati, Ohio.

2. Hegg, B. A., K. L. Rakness, and J. R. Schultz. A Demonstrated Approach for Improving Performance and Reliability of Biological Wastewater Treatment Plants. Report prepared in partial fulfillment of EPA Contract No. 68-03-2224, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1978.

3. Gilbert, Walter G. "Relation of Operation and Maintenance to Treatment Plant Efficiency," Journal Water Pollution Control Federation, 48, 1822 (1976).

LISTING OF SITE VISIT ONLY AND SITE VISIT PLUS PRELIMINARY SURVEY FACILITIES

STATE	TREATMENT FACILITY	
	SITE VISIT ONLY	SITE VISIT AND PRELIMINARY SURVEY
Colorado	Kittredge	Morrison
	Colorado Springs	Englewood
	Empire	Snowmass Village
	Georgetown	Aspen Metro
	Vail	Fort Morgan
	Brush	Elizabeth
	Victor	Elbert
	Cripple Creek	Berthoud
	Eaton	Autora
Iowa	Clarinda	Bedford
	Shenandoah	Elma
	Eldora	Cresco
	Iowa Falls	Reinbeck
	Osage	
	Tama	
Montana	Butte	Hillbrook Nursing Home, Clancy
	Kalispell	Helena
	Big Fork	Columbia Falls
	Yellow Bay Biological Sta.	Lolo
	Harlem	Missoula
		Havre
		Chinook
Nebraska	Elkhorn	Arlington
	Waterloo	West Point
	Scribner	Crete
	Norfolk	Gretna
	Platte Center	
	Waco	
	Sutton	
South Dakota		Chamberlain
		Mobridge
Utah	Granger Hunter District, Salt Lake City	Cottonwood Dist., Salt Lake City
		So. Davis N., Salt Lake City
		So. Davis S., Salt Lake City
Wyoming	Laramie	South Cheyenne
	Lusk	
	Rock Springs	
	Evanston	

APPENDIX B

EXAMPLE PRELIMINARY SURVEY INFORMATION SHEETS

The forms in this appendix were completed for each wastewater treatment facility where a preliminary survey was conducted. Detailed information in the areas of plant administration, maintenance, design and operation was collected through the use of these forms.

I. PLANT IDENTIFICATION

A. NAME AND LOCATION

NAME OF FACILITY ______

TYPE OF FACILITY ______

OWNER ______

ADMINISTRATIVE OFFICE: MAILING ADDRESS ______

______

______

______

TELEPHONE NO. ______

TREATMENT PLANT: MAILING ADDRESS ______

______

______

______

TELEPHONE NO. ______

PLANT LOCATION: LEGAL ______

GENERAL ______

______

B. RECEIVING STREAM AND CLASSIFICATION

RECEIVING WATER ______ CLASSIFICATION ______

TRIBUTARY TO ______ CLASSIFICATION ______

MAJOR RIVER BASIN ______

COMMENT:

I. PLANT IDENTIFICATION (Cont.)

C. PERMIT INFORMATION

PLANT CLASSIFICATION ASSIGNED BY STATE ______

DISCHARGE PERMIT REQUIREMENTS FROM PERMIT NUMBER ______

DATE PERMIT ISSUED ______

DATE PERMIT EXPIRES ______

EFFLUENT LIMITS AND MONITORING REQUIREMENTS:

PARAMETER	MAXIMUM MONTHLY AVERAGE	MAXIMUM WEEKLY AVERAGE	MONITORING FREQUENCY REQUIRED	SAMPLE TYPE REQUIRED
Flow - mgd				
BOD_5 - mg/l				
TSS - mg/l				
Fecal Coliform - #/100 ml				
Chlorine Residual - mg/l				

COMPLIANCE SCHEDULE:

OTHER TREATMENT REQUIREMENTS ANTICIPATED:

II. PLANT DESCRIPTION

A. PROCESS TYPE

TYPE ______

FLOWSHEET - In body of report

B. DESIGN FLOW

PRESENT DESIGN FLOW ______mgd x 3785 = ______cu m/day

C. UPGRADING AND/OR EXPANSION HISTORY - AGE

PLANT HISTORY (Original construction, date completed, plant upgrade, date completed)

D. SERVICE AREA

NUMBER OF TAPS ______

GENERAL DESCRIPTION:

III. DESIGN INFORMATION

A. INFLUENT CHARACTERISTICS

AVERAGE DAILY FLOW: DESIGN ______mgd x 3785 = ______cu m/day

CURRENT ______mgd x 3785 = ______cu m/day

MAXIMUM HOURLY FLOW: DEISGN ______mgd x 3785 = ______cu m/day

CURRENT ______mgd x 3785 = ______cu m/day

AVERAGE DAILY BOD_5: DESIGN ______lb x 0.454 ______kg

CURRENT ______lb x 0.454 ______kg

AVERAGE DAILY TSS: DESIGN ______lb x 0.454 = ______kg

CURRENT ______lb x 0.454 = ______kg

INFILTRATION/INFLOW:

SEASONAL VARIATION:

MAJOR INDUSTRIAL WASTES:

KNOWN INHIBITORY WASTES:

COLLECTION SYSTEM:

COMMENTS:

III. DESIGN INFORMATION (Cont.)

B. UNIT PROCESSES

PUMPING

FLOW STREAM PUMPED	NO. PUMPS	NAME	MODEL	HP	CAPACITY

COMMENTS: (Flow control, suitability of installed equipment, etc.):

COMMENTS:

COMMENTS:

III. DESIGN INFORMATION (Cont.)

B UNIT PROCESSES (Cont.)

FLOW MEASUREMENT

FLOW STREAM MEASURED ____________

CONTROL SECTION:

TYPE AND SIZE ____________

LOCATION ____________

COMMENTS: (Operational problems, maintenance problems, unique features, preventive maintenance procedures, etc.)

RECORDER:

NAME ____________ MODEL ____________

FLOW RANGE ____________

CALIBRATION FREQUENCY ____________

DATE OF LAST CALIBRATION ____________

LOCATION ____________

TOTALIZER ____________

COMMENTS: (Operation and design problems, unique features, etc.)

III. DESIGN INFORMATION (Cont.)

B. UNIT PROCESSES (Cont.)

PRELIMINARY TREATMENT

MECHANICAL BAR SCREEN:

NAME ____________

MODEL ____________ HORSEPOWER ____________

WITHIN BUILDING? ____________ HEATED? ____________

DESCRIPTION OF OPERATION.

SPARE PARTS INVENTORY:

HAND CLEANED BAR SCREEN:

WIDTH ____________

BAR SPACING ____________

CLEANING FREQUENCY ____________

WITHIN BUILDING? ____________ HEATED? ____________

COMMENTS:

SCREENINGS DISPOSAL:

III. DESIGN INFORMATION (Cont.)

B. UNIT PROCESSES (Cont.)

PRELIMINARY TREATMENT

COMMINUTOR:

NAME ____________

MODEL ____________ HORSEPOWER ____________

WITHIN BUILDING? ____________ HEATED? ____________

MAINTENANCE:

SPARE PARTS INVENTORY:

COMMENTS:

GRIT REMOVAL

DISPOSAL OF GRIT:

DESCRIPTION OF UNIT:

SPARE PARTS INVENTORY:

COMMENTS:

III. DESIGN INFORMATION (Cont.)

B. UNIT PROCESSES (Cont.)

PRIMARY TREATMENT

PRIMARY CLARIFIER:

NUMBER ________ SURFACE DIMENSIONS ________

WATER DEPTH (SHALLOWEST) ________ ft x 0.305 = ________ m

WATER DEPTH (DEEPEST) ________ ft x 0.305 = ________ m

WEIR LOCATION ________

WEIR LENGTH ________ ft x 0.305 = ________ m

TOTAL SURFACE AREA ________ ft^2 x 0.0929 = ________ m^2

TOTAL VOLUME ________ gal x 0.003785 = ________ cu m

FLOW (DESIGN) ________ mgd x 3785 = ________ cu m/day

(OPERATING) ________ mgd x 3785 ________ cu m/day

WEIR OVERFLOW RATE

(DESIGN) ________ gal/day/ft x 0.0124 = ________ cu m/day/m

(OPERATING) ________ gal/day/ft x 0.0124 = ________ cu m/day/m

SURFACE SETTLING RATE

(DESIGN) ________ gal/day/sq ft x 0.0408 = ________ cu m/day/sq m

(OPERATING) ________ gal/day/sq ft x 0.0408 = ________ cu m/day/sq m

HYDRAULIC DETENTION TIME (DESIGN) ________

(OPERATING) ________

COLLECTOR MECHANISM NAME ________

MODEL ________ HORSEPOWER ________

SCUM COLLECTION AND TREATMENT:

MAINTENANCE:

SPARE PARTS INVENTORY:

III. DESIGN INFORMATION (Cont.)

B. UNIT PROCESSES (Cont.)

SECONDARY TREATMENT

AERATION BASIN:

NO. BASINS ________ SURFACE DIMENSIONS ________

WATER DEPTH ________

FLOW (DESIGN) ________ mgd x 3785 = ________ cu m/day

(OPERATING) ________ mgd x 3785 = ________ cu m/day

SEWAGE DETENTION TIME (DESIGN) ________

(OPERATING) ________

BOD_5 LOADING

(DESIGN) ________ lb/1000 cu ft/day x 16.0 = ________ gm/cu m/day

(OPERATING) ________ lb/1000 cu ft/day x 16.0 = ________ gm/cu m/day

COVERED? ________

TOTAL VOLUME ________ gal x 0.003785 = ________ cu m

TYPE OF AERATION ________ NO. AERATORS ________

NAME ________ MODEL ________ HORSEPOWER ________

MODE OF OPERATION:

TYPE OF DIFFUSERS:

NUMBER COMPRESSORS ________ NAME ________

MODEL ________ HORSEPOWER ________

AIR CAPACITY (cfm) ________ LOCATION ________

MAINTENANCE:

SPARE PARTS INVENTORY:

COMMENTS:

III. DESIGN INFORMATION (Cont.)

B. UNIT PROCESSES (Cont.)

SECONDARY TREATMENT

AFB (Activated Bio Filter)

NAME ________ NO. CELLS ________

MODEL ________ FREEBOARD ________

SURFACE DIMENSIONS ________

TOTAL SURFACE AREA ________ ft^2 x 0.0929 ________ m^2

MEDIA DEPTH ________ ft x 0.305 = ________ m

TOTAL MEDAI VOLUME ________ ft^3 x 0.028 = ________ m^3

RECIRCULATION TANK: DIMENSIONS ________

VOLUME ________ gal x 0.003785 = ________ cu m

RECIRCULATION:

MAINTENANCE

COMMENTS:

III. DESIGN INFORMATION (Cont.)

B. UNIT PROCESSES (Cont.)

SECONDARY TREATMENT

ROTATING BIOLOGICAL CONTACTOR (RBC):

NO. SHAFTS ________ LENGTH OF SHAFTS ________ ft x 0.3048 = ________ m

NO. CELLS ________ CELL VOLUME ________ gal x 0.003785 = ________ cu m

NAME ________

DISC DIAMETER ________ ft x 0.3048 = ________ m

RPM ________

PERIPHERAL VELOCITY ________ ft/sec x 0.3048 = ________ m/sec

TOTAL SURFACE AREA ________ sq ft x 0.0929 = ________ sq m

PERCENT SUBMERGENCE ________

FLOW (DESIGN) ________ mgd x 3785 = ________ cu m/day

(OPERATING) ________ mgd x 3785 = ________ cu m/day

HYDRAULIC LOADING:

(DESIGN) ________ gpd/sq ft x 0.0408 = ________ cu m/day/sq m

(OPERATING) ________ gpd/sq ft x 0.0408 = ________ cu m/day/sq m

TEMPERATURE (DESIGN) ________ (OPERATING) ________

ORGANIC LOADING

(DESIGN) ________ lb BOD/day/1000 sq ft x 4.885

________ kg BOD/day/1000 sq m

(OPERATING) ________ lb BOD/day/1000 sq ft x 4.885

________ kg BOD/day/1000 sq m

TOTAL DETENTION TIME (DESIGN) ________ hr (OPERATING) ________ hr

COVERED? ________ HEATED? ________

MAINTENANCE:

SPARE PARTS INVENTORY:

COMMENTS:

III. DESIGN INFORMATION (Cont.)

B. UNIT PROCESSES (Cont.)

SECONDARY TREATMENT

CONTACT BASIN:

SURFACE DIMENSION ____________

WATER DEPTH ________ ft x 0.3048 = ________ m

VOLUME ________ gal x 0.003785 = ________ cu m

FLOW (DESIGN) ________ mgd x 3785 = ________ cu m/day

(OPERATING) ________ mgd x 3785 = ________ cu m/day

SEWAGE DETENTION TIME (DESIGN) ________ min (OPERATING) ________ min

COVERED? ____________

COMMENTS:

REAERATION BASIN:

SURFACE DIMENSION ____________

WATER DEPTH ________ ft x 0.3048 = ________ m

VOLUME ________ gal x 0.003785 = ________ cu m

HYDRAULIC DETENTION TIME AT 100% RETURN

(DESIGN) ________ hr (OPERATING) ________ hr

FLEXIBILITY TO OPERATE AS CONVENTIONAL ____________

COVERED? ____________

COMMENTS:

III. DESIGN INFORMATION (Cont.)

B. UNIT PROCESSES (Cont.)

SECONDARY TREATMENT

OXYGEN TRANSFER:

TYPE AERATION ________ NO. AERATORS ____ NAME ________

MODEL ________ HORSEPOWER ________

CAPACITY ________ cfm x 0.028 = ________ cu m/min

NO. COMPRESSORS ________ NAME ________ MODEL ________

HORSEPOWER ________ CAPACITY ________ cfm x 0.028 = ________ cu m/min

LOCATION ____________

SPARE PARTS INVENTORY:

MAINTENANCE:

COMMENTS:

III. DESIGN INFORMATION (Cont.)

B. UNIT PROCESSES (Cont.)

SECONDARY TREATMENT

TRICKLING FILTER:

NO. FILTERS ________ COVERED? ________

SURFACE DIMENSION ____________

MEDIA DEPTH ________ ft x 0.3048 = ________ m

SURFACE AREA ________ ft x 0.0929 = ________ m^2

MEDIA VOLUME ________ gal x 0.003785 = ________ cu m

FLOW (DESIGN) ________ mgd x 3785 = ________ cu m/day

(OPERATING) ________ mgd x 3785 = ________ cu m/day

ORGANIC LOADING (DESIGN) ________ lb/1000 cu ft x 16.0 =

________ gm/cu m

(OPERATING) ________ lb/1000 cu ft x 16.0 =

________ gm/cu m

HYDRAULIC LOADING (DESIGN) ________ gal/day/sq ft x 0.0408 =

________ cu m/day/sq m

(OPERATING) ________ gal/day/sq ft x 0.0408 =

________ cu m/day/sq m

RECIRCULATION:

MODE OF OPERATION.

MAINTENANCE:

SPARE PARTS INVENTORY:

COMMENTS:

III. DESIGN INFORMATION (Cont.)

B. UNIT PROCESSES (Cont.)

SECONDARY TREATMENT

SECONDARY CLARIFIERS:

NO. ________ DIMENSION(S) ____________

WATER DEPTH (SHALLOWEST) ________ ft x 0.305 = ________ m

(DEEPEST) ________ ft x 0.305 = ________ m

WEIR LOCATION ____________

WEIR LENGTH ________ ft x 0.305 = ________ m

SURFACE AREA ________ ft^2 x 0.0929 = ________ m^2

VOLUME ________ gal x 0.003785 = ________ cu m

FLOW (DESIGN) ________ mgd x 3785 = ________ cu m/day

(OPERATING) ________ mgd x 3785 = ________ cu m/day

WEIR OVERFLOW RATE (DESIGN) ________ gal/day/ft x 0.0124 =

________ cu m/day/m

(OPERATING) ________ gal/day/ft x 0.0124 =

________ cu m/day/m

SURFACE SETTLING RATE (DESIGN) ________ gal/day/sq ft x 0.0408 =

________ cu m/day/sq m

(OPERATING) ________ gal/day/sq ft x 0.0408 =

________ cu m/day/sq m

HYDRAULIC DETENTION TIME (DESIGN) ________ hr (OPERATING) ________ hr

COLLECTOR MECHANISM NAME ________ MODEL ________ HP ________

SCUM COLLECTION AND REMOVAL:

SPARE PARTS INVENTORY:

COMMENTS:

III. DESIGN INFORMATION (Cont.)

B. UNIT PROCESSES (Cont.)

DISINFECTION

CONTACT BASIN:

SURFACE DIMENSIONS ______

WATER DEPTH ______ ft x 0.3048 = ______ m

VOLUME ______ gal x 0.003785 = ______ cu m

DETENTION TIME (DESIGN) ______ min (OPERATING) ______ min

COMMENTS:

CHLORINATOR:

NAME ______ NUMBER ______

CAPACITY ______ lb/day x 0.454 = ______ kg/day

TYPE INJECTION ______

FEED RATE (OPERATING) ______ lb/day x 0.454 = ______ kg/day

DOSAGE (OPERATING) ______ mg/l

DIFFUSERS ______

SPARE PARTS INVENTORY:

MAINTENANCE:

COMMENTS:

III. DESIGN INFORMATION (Cont.)

B. UNIT PROCESSES (Cont.)

SLUDGE HANDLING

AEROBIC DIGESTION:

NO. BASINS ______ SURFACE DIMENSION(S) ______

WATER DEPTH ______ ft x 0.3048 = ______ m

VOLUME ______ gal x 0.003785 = ______ cu m

COVERED? ______ HEATED? ______

TYPE OF AERATION ______

NO. AERATORS ______ NAME ______

MODEL ______ HORSEPOWER ______

TYPE OF DIFFUSERS:

NO. COMPRESSORS ______ NAME ______

MODEL ______ HORSEPOWER ______

AIR CAPACITY ______ cfm x 0.028 = ______ cu m/min

LOCATION: ______

SPARE PARTS INVENTORY:

MAINTENANCE:

MODE OF OPERATION:

COMMENTS:

III. DESIGN INFORMATION (Cont.)

B. UNIT PROCESSES (Cont.)

SLUDGE HANDLING

ANAEROBIC DIGESTION:

NO. DIGESTERS ______ DIAMETER ______ ft x 0.3048 = ______ m

SIDEWALL DEPTH ______ ft x 0.3048 = ______ m

CENTER DEPTH ______ ft x 0.3048 = ______ m

TOTAL VOLUME ______ gal x 0.003785 = ______ cu m

FLOATING COVER? ______

FLOW (DESIGN) ______ mgd x 3785 = ______ cu m/day

(OPERATING) ______ mgd x 3785 = ______ cu m/day

DETENTION TIME (DESIGN) ______ days (OPERATING) ______ days

HEATING:

MIXING:

SUPERNATING CAPABILITY:

SPARE PARTS INVENTORY:

MAINTENANCE:

MODE OF OPERATION:

COMMENTS:

III. DESIGN INFORMATION (Cont.)

B. UNIT PROCESSES (Cont.)

SLUDGE HANDLING

SLUDGE DRYING BEDS:

NO. ______ SIZE ______

COVERED? ______ SUBNATANT DRAIN TO ______

DEWATERED SLUDGE REMOVAL:

MODE OF OPERATION:

COMMENTS:

OTHER DEWATERING UNIT(S):

III. DESIGN INFORMATION (Cont.)

C. OTHER DESIGN INFORMATION

STAND-BY POWER:

ALARM SYSTEMS:

MISCELLANEOUS:

III. DESIGN INFORMATION (Cont.)

D. PLANT AUTOMATION:

E. LABORATORY CAPABILITY:

LOCATION ____________ FLOOR DIMENSIONS ____________

COUNTER SPACE ________ ft = ________ m HOT WATER? ________

FILE CABINET? ____________ DESK? ____________

TESTS PERFORMED BY WHOM ____________

OPERATIONAL TESTS CONDUCTED (TSS, D.O., S.V.I., BOD, pH, & OTHERS) AND FREQUENCY:

MONITORING TESTS CONDUCTED (TSS, BOD, pH, FECAL COLIFORM, OTHERS) AND FREQUENCY:

QUALITY CONTROL:

COMMENTS:

IV. PLANT PERFORMANCE

A. SOURCES OF PLANT PERFORMANCE DATA:

B. DATA AND DISCUSSIONS:

V. OPERATION AND MAINTENANCE PROCEDURES

A. OPERATION CONTROL PROCEDURE:

B. MAINTENANCE:

SCHEDULING PROCEDURE FOR PREVENTIVE MAINTENANCE:

EMERGENCY MAINTENANCE:

C. O & M MANUAL, SHOP DRAWINGS, EQUIPMENT MANUALS, AS-BUILT PLANS, ETC.:

D. TECHNICAL GUIDANCE:

VI. ADMINISTRATION

A. ORGANIZATION:

GOVERNING BODY ______________________ NO. MEMBERS ____________

TERMS OF ELECTION ______________________________________

SCHEDULED MEETINGS ______________________________________

AUTHORITY AND RESPONSIBILITY:

HISTORY:

CHAIN OF RESPONSIBILITIES:

COMMENTS:

VI. ADMINISTRATION (Cont.)

B. PLANT PERSONNEL:

PERSONNEL CLASSIFICATION (TITLE, NUMBER, PAY SCALE, FRACTION OF TIME SPENT AT SEWAGE TREATMENT, CERTIFICATION GRADE):

COMMENTS:

C. PLANT COVERAGE:

WEEKDAYS ______________________________________

WEEKENDS & HOLIDAYS ______________________________________

VI. ADMINISTRATION (Cont.)

D. PLANT BUDGET:

REVENUE:

TYPE OF TAP	TAP FEE	USER FEE

CURRENT ASSESSED VALUATION ______________________________________

CURRENT MILL LEVY ______________________________________

CURRENT ANNUAL REVENUE FROM PROPERTY TAX ______________________

OTHER REVENUE SOURCES:

COMMENTS:

VI. ADMINISTRATION (Cont.)

D. PLANT BUDGET (Cont).

(Budget Year ______)

VI. ADMINISTRATION (Cont.)

D. PLANT BUDGET (Cont.)

EXPENDITURES (Cont.)

BOND TYPE	YEAR ISSUED	DURATION	INTEREST RATE	PROJECT FINANCED

COMMENTS:

VI. ADMINISTRATION (Cont.)

D. PLANT BUDGET (Cont.)

DISCUSSION OF EXPENDITURES:

BUDGET FOR:	DOLLAR AMOUNT	PERCENT OF TOTAL
SALARIES (INCL. FRINGES)	______	______
UTILITIES	______	______
SUPPLIES	______	______
CHEMICALS	______	______
TRANSPORTATION	______	______
TRAINING & EDUCATION	______	______
MISCELLANEOUS	______	______
OPERATIONS SUBTOTAL	______	______
CAPITAL OUTLAY (Incl. Bond Debt Retirement)	______	______
TOTAL	______	______

OPERATIONAL COST PER MILLION GALLONS (OPERATIONS SUBTOTAL ÷ YEARLY FLOW)

______ ÷ ______mg ÷ 10 = ______¢/1000 gal x 0.264

______¢/cu m

APPROXIMATE ANNUAL COST PER TAP (TOTAL ÷ NO. TAPS)

______ ÷ ______taps = $______/tap

DISCUSSION:

VI. ADMINISTRATION (Cont.)

D. PLANT BUDGET (Cont.)

ELECTRICAL COSTS

SOURCE OF INFORMATION ______

Month & Year	Days in Billing Period	KWH	Demand	Cost	¢/Kwh	Flow
______	______	______	______	______	______	______
______	______	______	______	______	______	______
______	______	______	______	______	______	______
______	______	______	______	______	______	______
______	______	______	______	______	______	______
______	______	______	______	______	______	______
______	______	______	______	______	______	______
______	______	______	______	______	______	______
TOTALS	______	______		______	______	______ mgd
					______	cu m/day

KWH/DAY ______ $/DAY ______

KWH/1000 gal ______ ¢/1000 gal ______

KWH/cu m ______ ¢/cu m ______

COST SUMMARY

	¢/cu m	¢/1000 gal
Electrical	______	______
Salaries	______	______
Total Operations	______	______
Total Cost	______	______

APPENDIX C

LISTING OF DESIGN INADEQUACIES OBSERVED

The following design problems were identified during the 63 plant site visits and 30 preliminary surveys. Problems listed have created unnecessary or excessive maintenance, difficult process control, inaccurate or excessive sampling and decreased performance. All problems listed are design oriented in that an alternative design could have prevented or minimized each problem observed.

- PLANT LAYOUT
- FLOW MEASUREMENT
- BAR SCREENS
- COMMINUTORS
- GRIT REMOVAL
- PRIMARY CLARIFIERS
- AERATION BASINS
- AERATORS
- TRICKLING FILTERS
- ABF TOWERS
- FINAL CLARIFIERS
- SLUDGE RETURNS
- POLISHING PONDS
- CHLORINATION
- WASTING CAPABILITY
- SLUDGE HOLDING FACILITIES
- AEROBIC DIGESTERS
- ANAEROBIC DIGESTERS
- SLUDGE DEWATERING & ULTIMATE DISPOSAL
- LABORATORY FACILITY
- MISCELLANEOUS

PLANT LAYOUT

- Covered basins prevent observation of processes
- Return sludge air compressors are located outside and repeatedly break down
- Plant with multiple units not having the flexibility to operate as parallel plants
- No flow splitting flexibility to parallel plants
- Bar screen located downstream from comminutor
- Freezing of influent sampler located outside
- Plant location inaccessible during inclement weather
- Excessive compressor noise
- Disinfection before polishing pond
- Parallel secondary treatment units not capable of being operated as one facility
- Inadequate piping flexibility requires shut down of one trickling filter if one clarifier is down
- One scraper drive for primary and final clarifiers requires operation of both when operation of one is desired
- Lack of bypasses on individual treatment units, like aeration basin, trickling filter, etc.

FLOW MEASUREMENT

- Discharge through a pipe rather than the control section for which the recorder is designed
- Downstream channel slope and geometry causes backup in Parshall flume throat
- Parshall flume oversized
- Flow measurement inaccurate due to upstream barminutor placement

- Level transmitting instrumentation not compatible with level receiving instrument
- During high river flows, Parshall flume on effluent submerged
- Flow recorder not calibrated
- Recycle flows (cooling water) included in plant flow measurement
- Roll-up flow chart requires removal to observe flow for more than the preceeding four hours
- Parshall flume filled with grit deposits
- Wires crossed in totalizer, resulting in wrong reading
- Flow measurement not adequately showing flow variations
- Humid influent structure causes problem with moisture sensitive level sensor
- Flow velocity too high in Kennison nozzel
- Liquid level sensing float feezes
- Downstream bar screen backs flow into flume throat as screen plugs

BAR SCREENS

- Bar spacing too narrow
- Backed up flow released after cleaning causes hydraulic surges through aeration basin and into clarifier
- Freezing problems with mechanical bar screen located outside

COMMINUTORS

- Bent teeth, no protective bar screen
- Plugging with rags
- Repeated mechanical failure of hydraulic drive type comminutor

GRIT REMOVAL

- Excess wear on grit screw center bearing because of exposure to grit
- Odors from organics settling out in grit channel
- Pump discharge to grit chamber directed at grit buckets, and washes grit from buckets
- Grit auger not functional

PRIMARY CLARIFIERS

- Overloaded by excessively large trickling filter humus return pump
- Overload due to trickling filter recirculation through primary
- Improper placement of valve limits scum pumping
- Short-circuiting due to inlet baffle construction
- Preaeration in center of clarifier reduces effective clarification area

AERATION BASINS

- Pipe outlet plugs with rags
- Lack of piping to operate as conventional, as well as step load or contact-stabilization activated sludge
- Receives hydraulic surges when the bar screen is cleaned
- Receives hydraulic surges from oversized return pump on a time clock
- Loss of solids due to flooding
- No bypass to final clarifier
- Action of aeration rotors and revolving bridge and configuration of basin creates swells and voids which result in wave-like stresses on bridge

AERATORS

- Surface mechanical aerators overheat and shut off under increased flows due to I/I
- With floating aerators, repeated breaking of cables when operated on intermittent basis
- With submerged turbine aerators, repeated down time due to bearing and shaft failure
- Inadequate freeboard for splashing with surface mechanical aerators
- Icing problems with surface mechanical aerators
- Rag accumulation on surface mechanical aerators

TRICKLING FILTERS

- Recirculation only through primary clarifier
- Inadequate capacity of trickling filter arms
- Leaking distributor seal causing ponding and short-circuiting
- Poor flow splitting to trickling filters

ABF TOWER

- Undersized pipe carrying tower underflow back to recirculation tank
- No flexibility to vary percent tower underflow returned to recirculation tank
- Sludge return and tower recycle flow are directed into the same pipe which limits their volume recycled

FINAL CLARIFIERS

- Poor flow splitting to clarifiers
- Poor development of surface area with weirs
- Sludge scraper mechanism directing counter-current to wastewater flow

- Freezing during cold weather
- Inlet and outlet on clarifier circumference. Problem compounded by large diameter clarifiers, large design overflow rate and failure to consider process recycle flows.
- Floating trash returned to aeration basin, no ultimate disposal of scum.
- A common scraper mechanism used in the primary and final clarifiers allows mixing between the clarifiers.
- Hydraulic restriction causes submerged overflow weirs.
- Short circuiting due to inlet baffle construction.
- Placement of trickling filter recirculation draw-off causes a hydraulic overload on the final clarifier.
- Weirs on single launder not balanced to pull evenly from each side.

SLUDGE RETURNS

- Constant speed centrifugal pumps used, difficult to adjust flow
- Return sludge flow not visible at any point
- No measurement
- With multiple clarifiers, balancing return flow was difficult
- Variable speed return pumps that were too large even at the lowest setting
- Plugging of telescoping valves at lower flows
- With multiple clarifiers, asymetrical piping causes inbalance of return sludge flows
- Sludge returned to a point near the outlet of the aeration basin
- Valve controlling air to air lift returns is shut-off type, not regulating type
- Measurement with 90^{o} V-notch weir not sensitive enough
- Oversized pump draws down final clarifier, then hydraulically overloads aeration basin

- Plugging of ball valve used for return control

- When return channel overflows, it overflows to the clarifier as well as the aeration basin due to channel construction

- Partial plugging with rags of butterfly valve used for return sludge flow control

POLISHING PONDS

- No pond bypass

- Sludge wasted to polishing pond

- Pond located after disinfection

- All ponds noted to contain large amounts of sludge, some of which was being discharged

CHLORINATION

- Chlorine diffuser located at center of contact tank rather than at the inlet

- Rotometer on chlorinator too large for present application

- Poor mixing

- Chlorine dosage paced by effluent flow, but filter backwash water removed from combined contact-backwash storage tank shuts off chlorination until it is again filled and discharging

- Inadequate contact time in outfall pipe

- Inadequate chlorination in final clarifiers

- No depth control device on contact tank results in inadequate contact time and short-circuiting

- Short-circuiting over baffles during high flows

- Short-circuiting due to inlet design

WASTING CAPABILITY

- No digester or sludge holding facility, inadequate drying beds
- Down time of exotic sludge treatment facility causes inadequate wasting
- Insufficient capacity
- No measurement
- None provided
- Partial plugging of waste pump prevents use of pumping rate to calculate waste volume

SLUDGE HOLDING FACILITIES

- Odors from unaerated, uncovered sludge storage
- Potential gas build-up problem with covered, unaerated sludge storage

AEROBIC DIGESTERS

- High groundwater and pressure relief valve prevents batch operation
- Inadequate air supply
- Inadequate supernating flexibility
- Undersized
- Pump used for sludge removal prevents thickening of sludge
- Small digesters and minimum freeboard make foam containment difficult
- Freezing problems
- Common wall with aeration basin structurally insufficient to allow batch operation

ANAEROBIC DIGESTERS

- Inadequate supernatant draw-offs
- With multiple units, inflexibility to waste to desired primary digester

- Water seal on recirculation pump loads digester with cold water
- Sludge pumping line from clarifier plugs which prevents digester loading at concentrations above about six percent
- No gas meters
- No mixing
- Uneven loading due to breakdown of time clock
- Temperature drop due to failure of automatic firing mechanism on boiler
- Cold digester produces poor supernatant
- Leaky cover requiring down time for repair
- Single gas meter for two digesters
- Uninsulated heating pipes outside

SLUDGE DEWATERING & ULTIMATE DISPOSAL

- Repeated maintenance on sludge incineration facilities
- Insufficient sludge drying lagoons
- Insufficient drying beds
- Drying bed subnatant line crushed by construction equipment

LABORATORY FACILITY

- Vibrations prevent use of scale
- Humidity difficult to work in and hard on equipment
- Noise limits useability
- Poor lighting
- Insufficient floor space

MISCELLANEOUS

- Stabilization of sludge with chlorine releases heavy metals to recycled supernatant
- Wooden gates in flow diversion structure swelled and could not be removed
- No automatic re-start after power outage
- Butterfly valve used between mixed liquor and final effluent leaked mixed liquor into effluent

APPENDIX D

PLANT EVALUATION SUMMARY WEIGHING AND RANKING TABLE AND DEFINITION OF TERMS

This appendix contains a plant evaluation summary that was developed for the research project to evaluate those factors limiting performance at wastewater treatment facilities studied. For each plant studied the second part of the summary, which consisted of the weighing table, was completed. Possible causes of less than optimum performance in the areas of administration, maintenance, design and operation were evaluated for each plant using the factors listed in this table. A point system was used to express the severity of problems noted at the facilities studied. The first part of the summary consists of a ranking table where those factors limiting plant performance were summarized and ranked according to magnitude of importance. A definition of the terms used in the plant evaluation summary is also included.

RANKING TABLE

PLANT NO. ______

PLANT TYPE:	
DESIGN FLOW:	
ACTUAL FLOW:	
YEAR PLANT BUILT:	
YEAR OF MOST RECENT UPGRADE:	
PLANT PERFORMANCE SUMMARY:	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

WEIGHTING TABLE (PART 2)

CATEGORY	PTS.	COMMENTS
A. ADMINISTRATION		
1. Plant Administrators		
a. Policies		
b. Familiarity with Plant Needs		
2. Plant Staff		
a. Manpower		
1. Number		
2. Plant Coverage		
b. Morale		
1. Motivation		
2. Pay		
3. Supervision		
4. Working Conditions		
c. Productivity		
d. Personnel Turnover		
3. Financial		
a. Insufficient Funding		
b. Unnecessary Expenditures		
c. Bond Indebtedness		
B. MAINTENANCE		
1. General		
a. Housekeeping		
b. Equipment Age		
c. Scheduling & Recording		
d. Manpower		
2. Preventive		
a. Lack of Program		
b. References Available		
c. Spare Parts Inventory		

WEIGHTING TABLE (PART 2)

CATEGORY	PTS.	COMMENTS
3. Emergency		
a. Staff Expertise		
b. Critical Parts Procurement		
c. Technical Guidance		
C. DESIGN		
1. Plant Loading		
a. Organic		
b. Hydraulic		
c. Industrial		
d. Toxic		
e. Seasonal Variation		
f. Infiltration/Inflow		
g. Return Process Streams		
2. Unit Design Adequacy		
a. Preliminary		
b. Primary		
c. Secondary		
1. Process Flexibility		
2. Process Controlability		
3. Aerator		
4. Clarifier		
d. Advance Waste Treatment		
1.		
2.		
3.		
4.		
5.		
e. Disinfection		
f. Sludge Wasting Capability		

WEIGHTING TABLE (PART 2)

CATEGORY	PTS.	COMMENTS
g. Sludge Treatment		
h. Ultimate Sludge Disposal		
3. Miscellaneous		
a. Plant Location		
b. Unit Process Layout		
c. Lack of Unit Bypass		
d. Hydraulic Profile		
1. Flow Backup		
2. Submerged Weirs		
3. Flow Proportioning to Units		
e. Alarm Systems		
f. Alternate Power Source		
g. Process Automation		
1. Monitoring		
2. Control		
h. Lack of Stand-by Units for Key Equipment		
i. Laboratory Space & Equipment		
j. Process Accessibility for Sampling		
k. Equipment Accessibility for Maintenance		
l. Plant Inoperability Due to Weather		
m.		
n.		
D. OPERATION		
1. Staff Qualifications		

WEIGHTING TABLE (PART 2)

CATEGORY	PTS.	COMMENTS
a. Ability		
1. Aptitude		
2. Level of Education		
b. Certification		
1. Level of Certification		
2. Training		
c. Sewage Treatment Under-standing		
d. Insufficient time on the Job (Green crew)		
2. Testing		
a. Performance Monitoring		
b. Process Control Testing		
3. Process Control Adjustments		
a. Operator Application of Concepts and Testing to Process Control		
b. Technical Guidance		
4. O & M Manual		
a. Adequacy		
b. Use by Operators		
5. Miscellaneous		
a. Equipment Malfunction		
b. Shift Staffing Adequacy (Operations)		
c.		
d.		
e.		
f.		

RANKING TABLE DEFINITION OF TERMS

Plant Number	This in an in-house identification and reference number assigned to plant by M & I, Inc. A numbering system is used rather than a specific plant name.
Plant Type	Specific description of type of plant (e.g. 2 stage trickling filter with anaerobic digestor or extended aeration activated sludge with polishing pond and without sludge digestion).
Design Flow	Plant design flow rate as of most recent upgrade.
Actual Flow	Sewage flow rate for current operating condition (e.g. for past 1 to 2 months). Also significant seasonal variation in flows will be noted.
Year Plant Built	Year initial units were put into operation that are still functioning.
Year of Most Recent Upgrade	Year last additional major units were put into operation (e.g. digester, chlorine contact chamber, etc.)
Plant Performance	Brief description of plant performance as related to present and anticipated treatment requirements.
Ranking Table	List in descending order the major causes that were detrimental to plant performance and reliability.
Ranking	Begin with the most critical cause of decreased plant performance and reliability.
Table Reference	Letter and number of causes as shown in the Weighting Table (Pages 2-7).
Cause	Name of cause as shown in the Weighting Table.
Point	Points given each cause as shown in the Weighting Table.

WEIGHTING TABLE

DESCRIPTION OF POINT SYSTEM

Point	Effect on Plant Performance
0	No significant effect on plant performance.
1	Minor effect on plant performance.
2	Minimum indirect effect on plant performance on continuous basis or major direct effect on plant performance on a periodic basis.
3	Major direct effect on plant performance.

WEIGHTING TABLE

DEFINITIONS FOR FACTORS LIMITING PERFORMANCE

CATEGORY	EXPLANATION
A. ADMINISTRATION	
1 Plant Administrators	
a. Policies	Do the appropriate staff members have the authority to make required decisions regarding operations (e.g., valve adjustment), maintenance (e.g., hire electrician), and/or administration (e.g., purchase critical piece of equipment) decisions or do the administration policies require a strict adherence to a "chain of command" that has caused critical decisions to be delayed which in turn affected plant performance and reliability? Does an established administrative policy limit plant performance?
b. Familiarity with Plant Needs	Do the administrators have a first hand knowledge of plant needs through plant visits, discussions with operators, etc. and if not has this been a cause of poor plant performance and reliability through poor budget decisions, poor staff morale, poor O & M procedures to be continued, poor design decisions to be made, etc.?
2. Plant Staff	
a. Manpower	
1 Number	Does a limited number of people employed have a detrimental effect on plant operation through not getting the necessary work done?
2. Plant Coverage	Does the time period of plant operation cause operational adjustments to be made when they shouldn't be made, or inefficient usage of the number of people on the staff

provided because the operators "get into each others way?"

b. Morale

1. Motivation — Is the plant staff motivated to do a good job by self satisfaction?

2. Pay — Does a low pay scale discourage more highly qualified persons from applying for operator positions or cause operators to leave after they are trained?

3. Supervisor — Does the plant superintendent and operator or supervisor and operator working relationship cause adverse operator incentive?

4. Working Conditions — Does a poor working environment create a condition for more "sloppy work habits" and lower operator morale?

c. Productivity — Does the plant staff conduct the daily operation and maintenance tasks in an efficient manner? is time used efficiently?

d. Personnel Turnover — Does a high personnel turnover rate cause operation and/or maintenance problems which affect process performance or reliability?

3. Financial

a. Insufficient Funding — Does the lack of available funds cause poor salary schedules, insufficient spare parts and equipment repair, insufficient capital outlay for improvements, etc?

b. Unnecessary Expenditures — Does the manner in which available funds are dispersed cause problems in obtaining needed equipment, staff, etc.? Is the money spent wisely?

c. Bond Indebtedness — Does the annual bond debt payment limit the amount of funds available for other needed items like equipment, staff, etc.? Does a disproportionate amount of the total budget go for bond debt retirement?

B. MAINTENANCE

1 General

a. Housekeeping — Has a lack of good housekeeping procedures (e.g., grit channel cleaning, bar screen cleaning, unkept, untidy, or cluttered working environment) caused an excessive equipment failure rate?

b. Equipment Age — Has the age or outdatedness of critical pieces of equipment causes excessive equipment down time and/or inefficient process performance and reliability (due to unavailability of replacement parts?)

c. Scheduling and Recording — Has the absence or lack of an effective maintenance scheduling and recording procedure created a condition for an erratic preventive maintenance program that has caused unnecessary equipment failure?

d. Manpower — Has the lack of adequate maintenance manpower caused prevented maintenance functions to not be completed to prevent equipment breakdown or emergency equipment repair to be delayed?

2. Preventive

a. Lack of Program — Has the absence of extreme lack of an effective maintenance program causes unnecessary equipment failures or excessive down time that has degraded plant performance or reliability?

b. Reference Available — Has the absence or lack of good equipment reference caused unnecessary equipment failure and/or down time for repair (includes maintenance portion of O & M manual)?

c. Spare Parts Inventory — Has a critically low or non-existent spare parts inventory caused unnecessary long delays in equipment repair which has caused degraded process performance?

3. Emergency

a. Staff Expertise — Does the plant staff have the necessary expertise to keep the equipment operating and to make smaller equipment repairs when necessary?

b. Critical Parts Procurement — Have delays in getting replacement parts causes extended periods of equipment down time?

c. Technical Guidance — If technical guidance for repairing or installing equipment is necessary to descrease equipment down time, it is retained?

C. DESIGN

1 Plant loading — Has the presence of "shock" loading characteristics over and above what the plant was designed for or over and above what is thought to be tolerable caused degraded process performance by one or more of the listed loadings (a-e)?

a. Organic

b. Hydraulic

c. Industrial

d Toxic

e. Seasonal Variation

f Infiltration/Inflow — Does excessive infiltration or inflow cause degraded process performance because the plant cannot handle the extra flow?

g. Return Process Stream — Does an excessive volume and/or a highly organic or toxic return process flow stream cause adverse affects on process performance, equipment problems, etc.?

2 Unit Design Adequacy

a. Preliminary Treatment — Do the design features of any preliminary treatment unit cause upsets in downstream processes or excessive downstream equipment wear and tear that has led to degraded plant performance?

b. Primary Treatment — Does the shape of the unit, or location of the unit lend to its accomplishing the task of primary treatment? Does the unit have any design problem area within it that has caused it to perform poorly?

c. Secondary Treatment

1 Process Flexibility — Does the non-availability of adequate valves, piping, etc. limit plant performance and reliability when other modes of operations of the existing plant could be utilized to improve performance (e.g. operate activated sludge plant in plug, step, or contact stabilization mode; operate trickling filter with constant hydraulic loading or recirculation ratio; discharge good secondary treatment effluent as opposed to a degraded "polishing pond" effluent; etc.)?

2. Process Controllability — Do the existing process control features provide adequate adjustment and measurement over the appropriate flows (e.g. return sludge) in the range necessary to optimize process performance, or, is the flow difficult to adjust, variable once adjusted, not measured and recorded, not easily measurable, etc.?

3. Aerator — Does the type, size, shape, or location of the aerator hinder its ability to adequately treat the sewage and provide for stable operation?

4. Clarifier — Does a deficient design cause poor sedimentation due to the size of the clarifier, placement of the weir, length of the weir, type of clarifier, or other miscellaneous problems?

d. Advanced Waste Treatment — Any process of wastewater treatment which upgrades water quality to meet specific effluent limits which cannot be met by conventional primary and secondary treatment process (i.e., nitrification towers, chemical treatment, multi-media filters). (Space has been allowed for in the table to accommodate all advanced processes encountered during the research project.)

e. Disinfection — Does the shape or location of the unit lend to its accomplishing disinfection of the wastewater? (i.e., Proper mixing, detention time, feeding rates proportional to flow, etc.)?

f Sludge Wasting Capability — Does the plant have sludge wasting facilities? If so can a known volume of sludge be wasted? Can sludge wasting be adequately controlled?

g. Sludge Treatment — Does the type of size of sludge treatment processes hinder sludge stabilization (once sludge has been removed from the wastewater treatment system) which in turn affects process operation (e.g., causes odor problems, causes limited sludge wasting, etc.)?

h. Ultimate Sludge Disposal — Are the ultimate sludge disposal facilities of sufficient size and type to adequately handle the sludge? Are there any specific areas that limit ultimate sludge disposal such as seasonal weather variations, crop harvesting, etc.?

3. Miscellaneous — The design miscellaneous section covers areas of design inadequacy not specified in the previous design categories. (Space has been allowed to accommodate additional items not listed.)

a. Plant Location — Does a poor plant location or poor roads leading into the plant cause it to be inaccessible during certain periods of the year (e.g. winter) for chemical or equipment delivery or for routine operation?

b. Unit Process Layout — Does the arrangement of the unit processes cause inefficient utilization of operator's time for checking various processes, collecting samples, making adjustments, etc.?

c. Lack of Unit Bypass — Does the lack of unit bypass cause plant up set and long term poor treatment when a short term bypass could have minimized pollutional load to the receiving waters; caused necessary preventive maintenance items to be cancelled or delayed; caused more than one unit to be out of service when maintaining only one unit?

d. Hydraulic Profile

1. Flow Backup — Does an insufficient hydraulic profile cause ground flooding or flooding of upstream units except clarifiers? Does periodic release of backed up flow cause hydraulic surge?

2. Submerged Weirs — Does an insufficient hydraulic profile cause flooding of clarifiers and submerged clarifier weirs?

3. Flow Proportioning to Units — Has inadequate flow proportion or flow splitting to duplicate units caused problems in partial unit overload which degraded effluent quality or hindered achieving optimum process performance?

e. Alarm System — Has the absense of inadequacy of a good alarm system for critical pieces of equipment causes unnecessary equipment failure or in any way caused degraded process performance?

f. Alternate Power Source — Does the absence of an alternate power source cause problems in plant operation and/or plant performance?

g. Process Automation

1. Monitoring — Has the lack of needed automatic monitoring devices (D.O. meter, pH meter, etc.) caused excessive operator time to watch for slug loads or process upset to occur because of slug loads? Has a breakdown or the improper workings of automated process monitoring features caused disruption of automated control features and subsequent degradation of process performance?

2. Control — Has the lack of a needed automatic control devices (time clock) caused excessive operator time to make process control changes or necessary changes to be cancelled or delayed? Has the breakdown or the improper workings of automatic control features caused degradation of process performance?

h. Lack of Stand-by Units for Key Equipment — Has the lack of stand-by units for key equipment caused degraded process performance during breakdown or necessary preventive maintenance items to be cancelled or delayed?

i. Laboratory Space and Equipment — Does the absence of an adequately equipped laboratory indirectly limit plant performance by the lack of operational testing and performance monitoring?

j. Process Accessibility for Sampling — Has the inaccessibility of various process flow streams (e.g., recycle streams) for sampling caused needed information to not be obtained?

k. Equipment Accessibility for Maintenance — Has the inaccessibility of various pieces of equipment caused extensive down time or difficulty in making needed repairs or adjustments.

l. Plant Inoperability Due to Weather — Are certain units in the plant extremely vulnerable to weather changes (e.g., cold temperature) and as such do not operate at all, or do not operate as efficiently as necessary to achieve the required performance?

D. OPERATION

1. Staff Qualifications

a. Ability

1. Aptitude — Has the lack of the capacity for learning or undertaking new ideas by staff members or critical staff members caused poor O & M decisions to be made which has caused poor plant performance or reliability?

2. Level of Education — Does a low level of education cause poor O & M decisions to be made? Does a high level of education but a lack of process understanding cause needed training to be overlooked?

b. Certification

1. Level of Certification — Does the lack of adequately certified operators cause poor process control decisions?

2. Training — Does the operators <u>non-attendance</u> of available training programs cause poor process control decisions?

c. Sewage Training Understanding — Has the operators' lack of understanding of sewage treatment in general been a factor in poor operational decisions and poor plant performance and reliability?

d. Insufficient Time on job (Green Crew) — Has a short time on the job caused improper process control adjustments to be made because of opening or closing a wrong valve, turning on or off a wrong pump, etc.?

2. Testing

a. Performance Monitoring — Are the required monitoring tests being completed in compliance with the discharge permit?

b. Process Control Testing — Has the absence or wrong type of process control testing caused improper operational control decisions to be made?

3. Process Control Adjustments

a. Operator Application of Concepts and Testing to Process Control — Has the operator been deficient in the application of his knowledge of sewage treatment and the interpretation of his process control testing, to process control adjustments?

b. Technical Guidance — Has false operational information received from an equipment supplier, or from a paid technical consultant, caused improper operation decisions to be continued? Has a technical person (design engineer, state engineer, etc.) failed to address obvious operational deficiencies while being in a position to correct the problem?

4. O & M Manual

a. Adequacy — Has a poor O & M Manual resulted in the operator making poor or improper operational decisions?

b. Use by the Operator — Has a good O & M Manual not used by the operator caused poor process control and poor treatment that could have been avoided?

5. Miscellaneous — The operations miscellaneous category deals with any pertinent operational information not covered in the previous operational sections. (Space has been allowed to accommodate additional items not listed.)

a.	Equipment Malfunction	Does malfunctioning equipment cause deteriorated process performance?
b.	Shift Staffing Adequacy (operations)	Has the improper distribution of adequate manpower caused process controls to not be made, or be made at inappropriate times which in turn has caused poor plant performance?

PLANT EVALUATION SUMMARY (RANKING TABLE) RESULTS FOR THIRTY-THREE PLANT SITE VISITS

Plant Evaluation Summary site visit results differ from the "preliminary survey" results because only a one-half day evaluation was made during the site visit, whereas a one-week evaluation was made during "preliminary surveys". Therefore, only the obvious factor limiting performance could be determined. Only those factors in the weighing table that were rated at least two and three points were listed. No factor was listed at one point.

PLANT EVALUATION SUMMARY

PLANT NO. 001

PLANT TYPE: Aerated Lagoon	
DESIGN FLOW: 15,140 cu m/day (4.0 mgd)	
ACTUAL FLOW: 11,350 cu m/day (3.0 mgd)	
YEAR PLANT BUILT: 1972	
YEAR OF MOST RECENT UPGRADE: -	

PLANT PERFORMANCE SUMMARY:

Plant effluent was not meeting permit standards on a consistent basis.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.c.3.	Aerator	3
2			
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PLANT EVALUATION SUMMARY

PLANT NO. 003

PLANT TYPE: Activated Sludge	
DESIGN FLOW: 1,140 cu m/day (0.3 mgd)	
ACTUAL FLOW: 570 cu m/day (0.15 mgd)	
YEAR PLANT BUILT: -	
YEAR OF MOST RECENT UPGRADE: -	

PLANT PERFORMANCE SUMMARY:

During the site visit the clarifiers were being repaired as a scheduled preventive maintenance procedure, and aeration basin effluent was being bypassed to the receiving stream. Prior to this situation, plant effluent quality frequently was "bad" according to the State Engineer, due to excessive solids in the plant effluent.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.f.	Sludge Wasting Capability	3
2	D.1.c.	Sewage Treatment Understanding	3
3	D.2.a.	Performance Monitoring	2
4	D.2.b.	Process Control Testing	2
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PLANT EVALUATION SUMMARY

PLANT NO. 004

PLANT TYPE: Trickling Filter	
DESIGN FLOW: 4,160 cu m/day (1.1 mgd)	
ACTUAL FLOW: 6,060 cu m/day (1.6 mgd)	
YEAR PLANT BUILT: 1954	
YEAR OF MOST RECENT UPGRADE: -	

PLANT PERFORMANCE SUMMARY:

Plant performance was not meeting permit standards.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.1.b.	Plant Loading (hydraulic)	3
2	A.1.a.	Administrative Policies	3
3	C.2.c.1.	Process Flexibility	2
4	C.2.g.	Sludge Treatment	2
5	C.2.c.3.	Aerator	2
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PLANT EVALUATION SUMMARY

PLANT NO. 005

PLANT TYPE: Activated Sludge	
DESIGN FLOW: 4,920 cu m/day (1.3 mgd)	
ACTUAL FLOW: 5,680 cu m/day (1.5 mgd)	
YEAR PLANT BUILT: -	
YEAR OF MOST RECENT UPGRADE: 1968	

PLANT PERFORMANCE SUMMARY:

Plant performance was not meeting permit standards and frequently raw sewage is bypassed to the river.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.3.d.1.	Flow Backup	3
2	D.3.b.	Technical Guidance	3
3	C.1.f.	Infiltration/Inflow	2
4	C.2.f.	Sludge Wasting Capability	2
5	D.1.c.	Sewage Treatment Understanding	2
6			
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PLANT EVALUATION SUMMARY

PLANT NO. 006

PLANT TYPE: Activated Sludge with Polishing Pond	
DESIGN FLOW: 230 cu m/day (0.06 mgd)	
ACTUAL FLOW: 150 cu m/day (0.04 mgd)	
YEAR PLANT BUILT: 1968	
YEAR OF MOST RECENT UPGRADE: 1974	
PLANT PERFORMANCE SUMMARY: Plant performance not meeting permit standards. Mechanical plant effluent appeared very poor.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	A.2.b.1.	Staff Motivation	3
2	C.2.f.	Sludge Wasting Capability	3
3	C.3.k.	Equipment Accessibility for Maintenance	2
4	C.2.c.1.	Process Flexibility	2
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PLANT EVALUATION SUMMARY

PLANT NO. 008

PLANT TYPE: Activated Sludge	
DESIGN FLOW: 113,500 cu m/day (30 mgd)	
ACTUAL FLOW: 75,700 cu m/day (20 mgd)	
YEAR PLANT BUILT: -	
YEAR OF MOST RECENT UPGRADE: 1973	
PLANT PERFORMANCE SUMMARY: Plant performance not consistently meeting permit standards.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.g.	Sludge Treatment	3
2	C.2.c.2.	Process Controllability	3
3	D.3.a.	Operator Application of Concepts on Testing to Process Control	2
4	C.1.g.	Return Process Streams	2
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PLANT EVALUATION SUMMARY

PLANT NO. 009

PLANT TYPE: Activated Sludge	
DESIGN FLOW: 230 cu m/day (0.06 mgd)	
ACTUAL FLOW: 115 cu m/day (0.03 mgd)	
YEAR PLANT BUILT: 1973	
YEAR OF MOST RECENT UPGRADE: -	
PLANT PERFORMANCE SUMMARY: Plant effluent has not consistently met permit standards.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.c.2.	Process Controllability	3
2	C.2.f.	Sludge Wasting Capability	3
3	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
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PLANT EVALUATION SUMMARY

PLANT NO. 010

PLANT TYPE: Activated Sludge Contact-Stab	
DESIGN FLOW: 950 cu m/day (0.25 mgd)	
ACTUAL FLOW: 1,900 cu m/day (0.5 mgd)	
YEAR PLANT BUILT: -	
YEAR OF MOST RECENT UPGRADE: -	
PLANT PERFORMANCE SUMMARY: Plant effluent was not meeting permit standards.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.1.f.	Infiltration/Inflow	3
2	A.1.a.	Administrative Policies	3
3	C.2.c.1.	Process Flexibility	2
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PLANT EVALUATION SUMMARY

PLANT NO. 011

PLANT TYPE: Activated Sludge	
DESIGN FLOW: 5,680 cu m/day (1.5 mgd)	
ACTUAL FLOW: 3,785 cu m/day (1.0 mgd)	
YEAR PLANT BUILT: 1964	
YEAR OF MOST RECENT UPGRADE: 1974	
PLANT PERFORMANCE SUMMARY:	Plant effluent was not consistently meeting permit standards.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.c.4.	Clarifier, Secondary	3
2	C.2.c.2.	Process Controllability	2
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PLANT EVALUATION SUMMARY

PLANT NO. 016

PLANT TYPE: Trickling Filter	
DESIGN FLOW: Unknown	
ACTUAL FLOW: 3,400 cu m/day (0.9 mgd)	
YEAR PLANT BUILT: 1965	
YEAR OF MOST RECENT UPGRADE: -	
PLANT PERFORMANCE SUMMARY:	Plant effluent sometimes does not meet permit standards.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.1.c.	Industrial Loadings	3
2			
3			
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PLANT EVALUATION SUMMARY

PLANT NO. 017

PLANT TYPE: Activated Sludge	
DESIGN FLOW: 260 cu m/day (0.07 mgd)	
ACTUAL FLOW: 230 cu m/day (0.06 mgd)	
YEAR PLANT BUILT: -	
YEAR OF MOST RECENT UPGRADE:	
PLANT PERFORMANCE SUMMARY:	Plant effluent was not meeting permit standards.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	B.2.a.	Lack of Preventive Maintenance Program	3
2	A.1.a.	Administrative Policies	3
3	C.1.f.	Sludge Wasting Capabilities	2
4	C.3.a.	Plant Location	2
5	C.3.1.	Plant Inoperable due to Weather	2
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PLANT EVALUATION SUMMARY

PLANT NO. 018

PLANT TYPE: Activated Sludge	
DESIGN FLOW: 570 cu m/day (0.15 mgd)	
ACTUAL FLOW: 950 cu m/day (0.25 mgd winter) 260 cu m/day (0.07 mgd summer)	
YEAR PLANT BUILT: 1969	
YEAR OF MOST RECENT UPGRADE: 1969	
PLANT PERFORMANCE SUMMARY:	Plant effluent was not meeting permit standards.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.1.f.	Infiltration/Inflow	3
2	C.3.e.	Plant Inoperability due to Weather	2
3			
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PLANT EVALUATION SUMMARY

PLANT NO. 023

PLANT TYPE: Activated Sludge
DESIGN FLOW: 32,170 cu m/day (8.5 mgd)
ACTUAL FLOW: 24,980 cu m/day (6.6 mgd)
YEAR PLANT BUILT: 1969
YEAR OF MOST RECENT UPGRADE: -
PLANT PERFORMANCE SUMMARY: Plant effluent had not been meeting permit standards because of discharge of sludge to creek. Also, fecal coliform density has been high.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.1.g.	Sludge Treatment	3
2	C.1.e.	Disinfection	2
3			
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PLANT EVALUATION SUMMARY

PLANT NO. 025

PLANT TYPE: Activated Bio Filter
DESIGN FLOW: 10,220 cu m/day (2.7 mgd)
ACTUAL FLOW: 6,430 cu m/day (1.7 mgd)
YEAR PLANT BUILT: -
YEAR OF MOST RECENT UPGRADE: 1974
PLANT PERFORMANCE SUMMARY: Plant effluent not meeting permit standards (Water Quality Limited discharge 10 BOD, 20 TSS).

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.c.3.	Aerator	3
2	C.1.f.	Infiltration/Inflow	3
3	C.1.g.	Sludge Treatment	2
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PLANT EVALUATION SUMMARY

PLANT NO. 030

PLANT TYPE: Trickling Filter
DESIGN FLOW: 870 cu m/day (0.23 mgd)
ACTUAL FLOW: 490 cu m/day (0.13 mgd)
YEAR PLANT BUILT: 1963
YEAR OF MOST RECENT UPGRADE: -
PLANT PERFORMANCE SUMMARY: Plant meeting standards most of the time.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.c.3.	Aerator	2
2			
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PLANT EVALUATION SUMMARY

PLANT NO. 031

PLANT TYPE: Activated Sludge with Phosphorus removal and filters
DESIGN FLOW: 120 cu m/day (0.033 mgd)
ACTUAL FLOW: 11 cu m/day (0.003 mgd winter) 60 cu m/day (0.015 mgd summer)
YEAR PLANT BUILT: 1973
YEAR OF MOST RECENT UPGRADE: 1973
PLANT PERFORMANCE SUMMARY: Plant effluent sometimes does not meet permit standards.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	A.1.a.	Administrative Policies	3
2	A.2.a.1.	Staff Number	2
3	C.1.e.	Seasonal Variation	2
4			
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PLANT EVALUATION SUMMARY

PLANT NO. 033

PLANT TYPE: Activated Sludge
DESIGN FLOW: 760 cu m/day (0.2 mgd)
ACTUAL FLOW: 380 cu m/day (0.1 mgd)
YEAR PLANT BUILT: 1949
YEAR OF MOST RECENT UPGRADE: -
PLANT PERFORMANCE SUMMARY: Plant effluent does not consistently meet permit standards.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.g.	Sludge Treatment	3
2	C.2.c.2.	Process Control Lability	3
3	B.1.a.	Housekeeping	2
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PLANT EVALUATION SUMMARY

PLANT NO. 037

PLANT TYPE: Trickling Filter with Polishing Ponds
DESIGN FLOW: 30,280 cu m/day (8 mgd)
ACTUAL FLOW: 25,740 cu m/day (6.8 mgd)
YEAR PLANT BUILT: 1957
YEAR OF MOST RECENT UPGRADE: 1976
PLANT PERFORMANCE SUMMARY: Plant effluent sometimes does not meet permit standards. Coliform standards are frequently violated.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.c.3.	Aerator	3
2	C.2.e.	Disinfection	3
3	C.2.c.1.	Process Flexibility	2
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PLANT EVALUATION SUMMARY

PLANT NO. 038

PLANT TYPE: Activated Sludge
DESIGN FLOW: 17,030 cu m/day (4.5 mgd)
ACTUAL FLOW: 13,250 cu m/day (3.5 mgd)
YEAR PLANT BUILT: -
YEAR OF MOST RECENT UPGRADE: 1976
PLANT PERFORMANCE SUMMARY: Plant effluent was not consistently meeting permit standards.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.a.	Operator Application of Concepts and Testing to Process Control	3
2	C.1.g.	Sludge Treatment	2
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PLANT EVALUATION SUMMARY

PLANT NO. 042

PLANT TYPE: Trickling Filter
DESIGN FLOW: 2,270 cu m/day (0.6 mgd)
ACTUAL FLOW: 2,500 cu m/day (0.66 mgd)
YEAR PLANT BUILT: 1954
YEAR OF MOST RECENT UPGRADE: -
PLANT PERFORMANCE SUMMARY: Plant effluent was sometimes not meeting standards.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.c.3.	Aerator	2
2	C.1.f.	Infiltration/Inflow	2
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PLANT EVALUATION SUMMARY

PLANT NO. 043

PLANT TYPE: Trickling Filter	
DESIGN FLOW: 3,970 cu m/day (1.05 mgd)	
ACTUAL FLOW: 3,030 cu m/day (0.8 mgd)	
YEAR PLANT BUILT: 1965	
YEAR OF MOST RECENT UPGRADE: -	
PLANT PERFORMANCE SUMMARY: Plant effluent was not meeting standards.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.1.c.	Industrial	3
2	D.3.a.	Operator Application of Concepts and Testing to Process Control	3
3			
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PLANT EVALUATION SUMMARY

PLANT NO. 044

PLANT TYPE: Trickling Filter	
DESIGN FLOW: 1,510 cu m/day (0.4 mgd)	
ACTUAL FLOW: 1,400 cu m/day (0.37 mgd)	
YEAR PLANT BUILT: 1935	
YEAR OF MOST RECENT UPGRADE: -	
PLANT PERFORMANCE SUMMARY: Plant effluent met standards most of the time.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.1.f.	Infiltration/Inflow	2
2			
3			
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PLANT EVALUATION SUMMARY

PLANT NO. 045

PLANT TYPE: Trickling Filter	
DESIGN FLOW: 3,030 cu m/day (0.8 mgd)	
ACTUAL FLOW: 2,650 cu m/day (0.7 mgd)	
YEAR PLANT BUILT: 1962	
YEAR OF MOST RECENT UPGRADE:	
PLANT PERFORMANCE SUMMARY: Plant effluent violated standards some of the time.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.1.f.	Infiltration/Inflow	3
2	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
3			
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PLANT EVALUATION SUMMARY

PLANT NO. 046

PLANT TYPE: Activated Sludge Contact Stab. with Polishing Pond	
DESIGN FLOW: 2,840 cu m/day (0.75 mgd)	
ACTUAL FLOW: 1,140 cu m/day (0.3 mgd)	
YEAR PLANT BUILT: 1975	
YEAR OF MOST RECENT UPGRADE: -	
PLANT PERFORMANCE SUMMARY: Plant effluent meeting permit standards most of the time (note: performance records are suspect).	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.c.1.	Process Flexibility	2
2	D.2.a.	Performance Monitoring	2
3	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
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PLANT EVALUATION SUMMARY

PLANT NO. 049

PLANT TYPE: Activated Sludge	
DESIGN FLOW: 1,890 cu m/day (0.5 mgd)	
ACTUAL FLOW: 2,840 cu m/day (0.75 mgd)	
YEAR PLANT BUILT: 1975	
YEAR OF MOST RECENT UPGRADE: -	
PLANT PERFORMANCE SUMMARY:	
Plant effluent was not meeting standards on a consistent basis.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.5.a.	Equipment Malfunction	3
2	C.1.f.	Infiltration/Inflow	3
3	C.1.c.	Industrial	3
4			
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PLANT EVALUATION SUMMARY

PLANT NO. 051

PLANT TYPE: Activated Sludge	
DESIGN FLOW: 1,060 cu m/day (.28 mgd)	
ACTUAL FLOW: 570 cu m/day (.15 mgd)	
YEAR PLANT BUILT: 1975	
YEAR OF MOST RECENT UPGRADE: -	
PLANT PERFORMANCE SUMMARY:	
Plant effluent met standards, but plant is fairly new.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
2			
3			
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PLANT EVALUATION SUMMARY

PLANT NO. 052

PLANT TYPE: Activated Sludge	
DESIGN FLOW: 260 cu m/day (0.07 mgd)	
ACTUAL FLOW: Unknown	
YEAR PLANT BUILT: 1970	
YEAR OF MOST RECENT UPGRADE: -	
PLANT PERFORMANCE SUMMARY:	
Plant effluent periodically violated standards.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.1.c.	Sewage Treatment Understanding	3
2			
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PLANT EVALUATION SUMMARY

PLANT NO. 054

PLANT TYPE: Trickling Filter	
DESIGN FLOW: 570 cu m/day (0.15 mgd)	
ACTUAL FLOW: 190 cu m/day (0.05 mgd)	
YEAR PLANT BUILT: Primary 1966	
YEAR OF MOST RECENT UPGRADE: 1971	
PLANT PERFORMANCE SUMMARY:	
Plant effluent has not met standards.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.3.1.	Plant Inoperability due to Weather	3
2	C.2.c.3.	Aerator	3
3	C.1.f.	Infiltration/Inflow	2
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PLANT EVALUATION SUMMARY

PLANT NO. 056

PLANT TYPE: Activated Sludge	
DESIGN FLOW: 14,000 cu m/day (3.7 mgd)	
ACTUAL FLOW: 8,330 cu m/day (2.2 mgd)	
YEAR PLANT BUILT: 1970	
YEAR OF MOST RECENT UPGRADE: -	
PLANT PERFORMANCE SUMMARY: Plant Effluent was not meeting standards.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.1.c.	Industrial Loading	3
2	C.2.c.1.	Process Flexibility	2
3	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
4			
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PLANT EVALUATION SUMMARY

PLANT NO. 057

PLANT TYPE: Activated Sludge	
DESIGN FLOW: 110 cu m/day (.03 mgd)	
ACTUAL FLOW: 150 cu m/day (.04 mgd)	
YEAR PLANT BUILT: -	
YEAR OF MOST RECENT UPGRADE: -	
PLANT PERFORMANCE SUMMARY: Plant effluent has not met standards.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.a.	Operator Application of Concepts and Testing to Process Control	3
2	C.1.f.	Infiltration/Inflow	2
3	C.1.h.	Ultimate Sludge Disposal	2
4			
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PLANT EVALUATION SUMMARY

PLANT NO. 058

PLANT TYPE: Activated Sludge	
DESIGN FLOW: 130 cu m/day (0.034 mgd)	
ACTUAL FLOW: 50 cu m/day (0.014 mgd)	
YEAR PLANT BUILT: 1960	
YEAR OF MOST RECENT UPGRADE: -	
PLANT PERFORMANCE SUMMARY: Plant effluent has not met standards.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.1.c.	Sewage Treatment Understanding	3
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PLANT EVALUATION SUMMARY

PLANT NO. 059

PLANT TYPE: Activated Sludge	
DESIGN FLOW: 450 cu m/day (0.12 mgd)	
ACTUAL FLOW: 640 cu m/day (0.17 mgd)	
YEAR PLANT BUILT: 1938	
YEAR OF MOST RECENT UPGRADE:	
PLANT PERFORMANCE SUMMARY: Plant effluent has not met standards.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.c.2.	Process Controlability	3
2	C.3.1.	Plant Inoperability due to Weather	2
3	C.1.f.	Infiltraion/Inflow	2
4	C.1.g.	Sludge Treatment	2
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PLANT EVALUATION SUMMARY

PLANT NO. 062

PLANT TYPE: Activated Sludge
DESIGN FLOW: 1,290 cu m/day (0.34 mgd)
ACTUAL FLOW: 760 cu m/day (0.2 mgd)
YEAR PLANT BUILT: 1968
YEAR OF MOST RECENT UPGRADE: 1977
PLANT PERFORMANCE SUMMARY: Plant effluent was not meeting standards.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.a.	Operator Application of Concepts and Testing to Process Control	3
2	C.2.c.2.	Process Controllability	2
3	C.2.f.	Sludge Wasting Capability	2
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PLANT EVALUATION SUMMARY (RANKING TABLE) RESULTS FOR THIRTY "PRELIMINARY SURVEY" FACILITIES

The "preliminary survey" ranking tables include the ranking of all factors that received two and three points. The factors that received one point were not ranked at individual facilities, but were included in the overall ranking of factors discussed in the body of this report.

PLANT EVALUATION SUMMARY

PLANT NO. 002

PLANT TYPE: Activated Sludge (Extended Aeration) with Waste Sludge Pond

DESIGN FLOW: 3,028 cu m/day (0.8 mgd) Total - 2 Parallel Plants 1,514 cu m/day (0.4 mgd) each

ACTUAL FLOW: 1,628 cu m/day (0.43 mgd)

YEAR PLANT BUILT: 1969

YEAR OF MOST RECENT UPGRADE: 1974

PLANT PERFORMANCE SUMMARY:

Plant effluent quality was not monitored prior to the preliminary survey. The operator said the plant effluent had looked better during the survey than many times before. During the survey one of the two parallel plants met minimum secondary treatment standards, the other did not. The plant probably would not have consistently met standards if it had been monitored.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.c.4.	Secondary Clarifier Design	3
2	D.1.c.	Sewage Treatment Understanding	3
3	D.1.a.1.	Staff Aptitude	2
4	A.1.b.	Administration - Familiarity with Plant Needs	2
5	D.3.b.	Technical Guidance	2
6	C.2.c.2.	Process Controllability	2
7	D.2.b.	Process Testing	2
8	A.2.b.2.	Staff Pay	2
9	C.3.1.	Inoperability due to weather	2
10	A.2.a.2.	Staff Coverage	2
11	A.2.a.1.	Staff Number	2

PLANT EVALUATION SUMMARY

PLANT NO. 007

PLANT TYPE: Oxidation Ditch with Sludge Drying Beds

DESIGN FLOW: 265 cu m/day (0.07 mgd)

ACTUAL FLOW: 151 cu m/day (0.04 mgd)

YEAR PLANT BUILT: 1968

YEAR OF MOST RECENT UPGRADE: 1973

PLANT PERFORMANCE SUMMARY:

Plant has not met discharge standards because of excessive solids loss over the clarifier weir.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.1.c.	Sewage Treatment Understanding	3
2	C.2.f.	Sludge Wasting Capability	3
3	D.2.b.	Process Control Testing	2
4	C.3.d.1.	Hydraulic Profile - Flow Back-up	2
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PLANT EVALUATION SUMMARY

PLANT NO. 012

PLANT TYPE: Trickling Filter with Contact Stabilization and Anaerobic Sludge Digestion

DESIGN FLOW: 45,420 cu m/day (12 mgd)

ACTUAL FLOW: 30,659 cu m/day (8.1 mgd)

YEAR PLANT BUILT: 1953

YEAR OF MOST RECENT UPGRADE: 1972

PLANT PERFORMANCE SUMMARY:

The plant has not been able to consistently meet permit standards. When standards are met they are barely met. When standards are exceeded they are barely exceeded.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.1.g.	Plant Loading - Return Process Streams	3
2	C.2.h.	Ultimate Sludge Disposal	3
3	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
4	C.2.c.3.	Unit Design Adequacy - Aerator	2
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PLANT EVALUATION SUMMARY

PLANT NO. 013

PLANT TYPE: Activated Sludge with Polishing Pond and Aerobic Digestion

DESIGN FLOW: 3,028 cu m/day (0.8 mgd)

ACTUAL FLOW: 3,028 cu m/day (0.8 mgd)

YEAR PLANT BUILT: 1967

YEAR OF MOST RECENT UPGRADE: 1970

PLANT PERFORMANCE SUMMARY:

Activated sludge plant effluent would not have met minimum secondary treatment standards if discharged. Pond effluent did not meet minimum secondary treatment standards with respect to TSS.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.b.	Technical Guidance	3
2	D.3.a.	Operator Application of Concepts and Testing to Process Control	3
3	C.3.d.3.	Hydraulic Profile - Flow Proportioning	2
4	D.1.c.	Sewage Treatment Understanding	2
5	C.2.c.1.	Process Flexibility	2
6	C.2.c.2.	Process Controllability	2
7	A.1.b.	Administration - Familiarity with Plant Needs	2
8	D.2.b.	Process Control Testing	2
9	C.2.c.4.	Clarifier, Secondary	2
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PLANT EVALUATION SUMMARY

PLANT NO. 014

PLANT TYPE: Activated Sludge with Polishing Pond and Aerobic Digestion	
DESIGN FLOW: 7,570 cu m/day (2 mgd)	
ACTUAL FLOW: 5,410 cu m/day (1.43 mgd)	
YEAR PLANT BUILT: 1969	
YEAR OF MOST RECENT UPGRADE: 1974	
PLANT PERFORMANCE SUMMARY: During the survey the activated sludge plant effluent and polishing pond effluent did not meet the minimum secondary treatment standards. Plant records show that the standards were met for the four previous months.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.a.	Operators Application of Concepts and Testing to Process Control	3
2	C.2.c.1.	Process Flexibility	3
3	D.3.b.	Technical Guidance	2
4	C.2.c.2.	Process Controllability	2
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PLANT EVALUATION SUMMARY

PLANT NO. 015

PLANT TYPE: High - Rate, Two-Stage Trickling Filter with Anaerobic Digestion and Sludge Lagoons	
DESIGN FLOW: 13,600 cu m/day (3.6 mgd)	
ACTUAL FLOW: 6,240 cu m/day (1.65 mgd)	
YEAR PLANT BUILT: 1954	
YEAR OF MOST RECENT UPGRADE: 1972	
PLANT PERFORMANCE SUMMARY: This plant has met permit effluent standards which are presently higher than secondary requirements and achieves high percentage removals but does not meet secondary effluent limits.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.1.c.	Industrial Loading	3
2	A.2.b.3.	Supervision	2
3	A.2.c.	Productivity	2
4	B.2.a.	Lack of Preventive Maintenance Programs	2
5	D.1.c.	Sewage Treatment Understanding	2
6	A.2.b.2.	Pay	2
7			
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PLANT EVALUATION SUMMARY

PLANT NO. 019

PLANT TYPE: Activated Sludge (Extended Aeration) with Pond	
DESIGN FLOW: 246 cu m/day (0.065 mgd)	
ACTUAL FLOW: 132 cu m/day (0.035 mgd)	
YEAR PLANT BUILT: 1972	
YEAR OF MOST RECENT UPGRADE: 1972	
PLANT PERFORMANCE SUMMARY: Activated sludge plant and pond marginally meeting BOD standards and not meeting TSS standards.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.f.	Sludge Wasting Capability	3
2	C.2.c.1.	Process Flexibility	3
3	C.3.b.	Unit Process Layout	3
4	C.2.c.2.	Process Controllability	2
5	D.2.b.	Process Control Testing	2
6	D.3.b.	Technical Guidance	2
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PLANT EVALUATION SUMMARY

PLANT NO. 020

PLANT TYPE: Activated Sludge (Extended Aeration) with Pond	
DESIGN FLOW: 95 cu m/day (0.025 mgd)	
ACTUAL FLOW: 26 cu m/day (0.007 mgd)	
YEAR PLANT BUILT: 1974	
YEAR OF MOST RECENT UPGRADE: 1974	
PLANT PERFORMANCE SUMMARY: Activated sludge plant effluent would not have met minimum secondary effluent standards. Pond effluent was significantly poorer than activated sludge plant effluent and did not meet permit standards.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.f.	Sludge Wasting Capability	3
2	D.1.c.	Sewage Treatment Understanding	3
3	C.2.c.1.	Process Flexibility	3
4	C.3.1.	Plant Inoperability Due to Weather	2
5	C.3.b.	Unit Process Layout	2
6	D.2.b.	Process Control Testing	2
7	C.2.c.4.	Clarifier Design	2
8	C.2.c.2.	Process Controllability	2
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PLANT EVALUATION SUMMARY

PLANT NO. 021

PLANT TYPE: Activated Sludge (Oxidation Ditch) with Drying Beds	
DESIGN FLOW: 3,400 cu m/day (0.9 mgd)	
ACTUAL FLOW: 2,200 cu m/day (0.59 mgd)	
YEAR PLANT BUILT: 1963	
YEAR OF MOST RECENT UPGRADE: 1973	

PLANT PERFORMANCE SUMMARY:

Plant has met permit standards except for infrequent periods of sludge bulking.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.f.	Sludge Wasting Capability	3
2	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
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PLANT EVALUATION SUMMARY

PLANT NO. 022

PLANT TYPE: Activated Sludge (Extended Aeration) with Polishing Pond and no Sludge Wasting.	
DESIGN FLOW: 56.8 cu m/day (0.015 mgd)	
ACTUAL FLOW: 45.4 cu m/day (0.012 mgd)	
YEAR PLANT BUILT: 1972	
YEAR OF MOST RECENT UPGRADE: 1972	

PLANT PERFORMANCE SUMMARY:

Activated sludge plant effluent was of poor quality due to bulking solids. Pond effluent met minimum effluent standards but was anaerobic and diluted with spring water. If dilution factor was accounted for, pond effluent would not have met standards.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.b.	Technical Guidance	3
2	C.2.f.	Sludge Wasting Capability	3
3	D.1.c.	Sewage Treatment Understanding	3
4	C.2.c.2.	Process Controllability	2
5	D.2.b.	Process Control Testing	2
6	C.3.i.	Lab Space and Equipment	2
7	D.1.d.	Insufficient Time on Job	2
8	D.1.b.2.	Training	2
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PLANT EVALUATION SUMMARY

PLANT NO. 024

PLANT TYPE: Activated Bio-Filter with Chemical Sludge Oxidation and Sludge Drying Lagoons	
DESIGN FLOW: 22,700 cu m/day (6 mgd)	
ACTUAL FLOW: 18,500 cu m/day (4.9 mgd)	
YEAR PLANT BUILT: 1960	
YEAR OF MOST RECENT UPGRADE: 1975	

PLANT PERFORMANCE SUMMARY:

Secondary standards for BOD_5 had been met only one month of the first 18 months of operation. Suspended solids removal has been consistently better than BOD_5 removal. Effluent standards are now being met (past 2 months). Achievement of the 85 percent removal standards is marginal.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.b.	Technical Guidance	3
2	D.3.a.	Operator Application of Concepts and Testing to Process Control	3
3	C.2.c.3.	Aerator	3
4	C.2.c.2.	Process Controllability	2
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PLANT EVALUATION SUMMARY

PLANT NO. 026

PLANT TYPE: Extended Aeration Activated Sludge w/Multi-Media Filters	
DESIGN FLOW: 1,892 cu m/day (0.50 mgd)	
ACTUAL FLOW: 568 cu m/day (0.15 mgd)	
YEAR PLANT BUILT: 1970	
YEAR OF MOST RECENT UPGRADE: 1970	

PLANT PERFORMANCE SUMMARY:

The plant was bypassed for extended periods of time from 1970 - 1975 while modifications to the plant were being completed. Very high-quality effluent has been produced for the last 15 months, easily meeting permit limits.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.3.b.	Unit Process Layout	2
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PLANT EVALUATION SUMMARY

PLANT NO. 027

PLANT TYPE: Conventional Activated Sludge with Anaerobic Digestion	
DESIGN FLOW: 37,850 cu m/day (10 mgd)	
ACTUAL FLOW: 26,495 cu m/day (5.5 mgd)	
YEAR PLANT BUILT: 1963	
YEAR OF MOST RECENT UPGRADE: 1976	
PLANT PERFORMANCE SUMMARY: Plant has not met minimum secondary treatment standards since recent (1 year) start up after completion of secondary facilities.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.5.a.	Equipment Malfunction	3
2	C.2.c.4.	Clarifier Design	3
3	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
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PLANT EVALUATION SUMMARY

PLANT NO. 028

PLANT TYPE: Activated Sludge (Contact Stabilization) with a Polishing Pond, an Aerobic Digester, and Sludge Drying Beds	
DESIGN FLOW: 946 cu m/day (0.25 mgd)	
ACTUAL FLOW: 568 cu m/day (0.15 mgd)	
YEAR PLANT BUILT: 1971	
YEAR OF MOST RECENT UPGRADE: 1971	
PLANT PERFORMANCE SUMMARY: Activated sludge plant effluent quality was better than pond effluent quality. Pond effluent was just barely meeting minimum secondary treatment standards.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.c.1.	Process Flexibility	3
2	C.2.h.	Ultimate Sludge Disposal	3
3	C.2.c.2.	Process Controllability	2
4	C.2.e.	Disinfection	2
5	C.2.g.	Sludge Treatment	2
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PLANT EVALUATION SUMMARY

PLANT NO. 029

PLANT TYPE: Activated Sludge with Aerobic Digestion and Sludge Lagoon	
DESIGN FLOW: 6,800 cu m/day (1.8 mgd)	
ACTUAL FLOW: 4,900 cu m/day (1.3 mgd)	
YEAR PLANT BUILT: 1949	
YEAR OF MOST RECENT UPGRADE: 1975	
PLANT PERFORMANCE SUMMARY: Plant has not been consistently meeting effluent permit standards (minimum secondary treatment standards).	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.a.	Operator Application of Concepts and Testing to Process Control	3
2	C.2.c.2.	Process Controllability	2
3	C.2.e.3.	Aerator	2
4	C.2.c.1.	Process Flexibility	2
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PLANT EVALUATION SUMMARY

PLANT NO. 032

PLANT TYPE: Trickling Filter with Anaerobic Sludge Digestion	
DESIGN FLOW: 1,890 cu m/day (0.5 mgd)	
ACTUAL FLOW: 850 cu m/day (0.224 mgd)	
YEAR PLANT BUILT: 1948	
YEAR OF MOST RECENT UPGRADE: 1948	
PLANT PERFORMANCE SUMMARY: Historically, the plant effluent quality would not have met minimum secondary treatment standards. During the survey the standards (fecal coliform not tested) were met, but was a favorable time of the year for trickling filter performance (summer months).	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.c.1.	Process Flexibility	3
2	D.1.c.	Sewage Treatment Understanding	3
3	C.2.e.	Disinfection	3
4	C.3.d.1	Hydraulic Profile - Flow Backup	2
5	D.1.a.1.	Operator Aptitude	2
6	D.2.a.	Performance Monitoring	2
7	D.2.b.	Process Control Testing	2
8			
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PLANT EVALUATION SUMMARY

PLANT NO. 034

PLANT TYPE: Trickling Filter with Anaerobic Digestion	
DESIGN FLOW: 30,280 cu m/day (8 mgd)	
ACTUAL FLOW: 20,820 cu m/day (5.5 mgd)	
YEAR PLANT BUILT: -	
YEAR OF MOST RECENT UPGRADE: -	
PLANT PERFORMANCE SUMMARY: Plant effluent was not meeting discharge permit requirements.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.a.	Operator Application of Concepts and Testing to Process Control	3
2	C.2.c.3.	Trickling Filter	3
3	C.2.f.	Sludge Wasting Capability	2
4	C.2.c.1.	Process Flexibility	2
5	C.2.c.4.	Secondary Clarifier	2
6	C.2.e.	Disinfection	2
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PLANT EVALUATION SUMMARY

PLANT NO. 035

PLANT TYPE: Single-Stage Low-Rate Trickling Filter	
DESIGN FLOW: 20,200 cu m/day (5.35 mgd)	
ACTUAL FLOW: 19,900 cu m/day (5.25 mgd)	
YEAR PLANT BUILT: 1962	
YEAR OF MOST RECENT UPGRADE: 1966	
PLANT PERFORMANCE SUMMARY: Plant meets permit effluent limits of 25 mg/l BOD and TSS. Coliform limits are not consistently met.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	A.1.a.	Policies	3
2	C.2.e.	Disinfection	2
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PLANT EVALUATION SUMMARY

PLANT NO. 036

PLANT TYPE: Two-Stage, Low-Rate Trickling Filter Operating as Single-Stage	
DESIGN FLOW: 10,700 cu m/day (2.84 mgd)	
ACTUAL FLOW: 6,400 cu m/day (1.68 mgd)	
YEAR PLANT BUILT: 1962	
YEAR OF MOST RECENT UPGRADE: 1964	
PLANT PERFORMANCE SUMMARY: The plant meets permit effluent limits of 25 mg/l BOD_5 and TSS. Coliform limits are not met.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	A.1.a.	Policies	3
2	C.2.e.	Disinfection	2
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PLANT EVALUATION SUMMARY

PLANT NO. 039

PLANT TYPE: Oxidation ditch with polishing pond & sludge drying beds.	
DESIGN FLOW: 1,550 cu m/day (0.41 mgd)	
ACTUAL FLOW: 795 cu m/day (0.21 mgd)	
YEAR PLANT BUILT: 1952	
YEAR OF MOST RECENT UPGRADE: 1976	
PLANT PERFORMANCE SUMMARY: Plant effluent was meeting secondary treatment standards during the survey. However, the plant was approaching the point of bulking sludge solids. The plant was recently upgraded and was just started up about 3 months prior to the survey.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.1.c.	Sewage Treatment Understanding	3
2	C.2.f.	Sludge Wasting Capability	2
3	D.3.b.	Technical Guidance (Process Control)	2
4	A.1.b.	Administration Familiarity with Plant Needs	2
5	D.3.a.	Operators Application of Concepts and Testing to Process Control	2
6	D.2.b.	Process Control Testing	2
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PLANT EVALUATION SUMMARY

PLANT NO. 040

PLANT TYPE: Rotating Biological Surface (RBS)	
DESIGN FLOW: 2,380 cu m/day (0.63 mgd)	
ACTUAL FLOW: 1,450 cu m/day (0.384 mgd)	
YEAR PLANT BUILT: 1959	
YEAR OF MOST RECENT UPGRADE: 1976	
PLANT PERFORMANCE SUMMARY:	

There is little monitoring data available since startup of the secondary. That available indicates the plant is not meeting permit and design standards.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.c.3.	Aerator	3
2	D.1.a.1.	Aptitude	2
3	D.3.b.	Technical Guidance	2
4	D.1.c.	Sewage Treatment Understanding	2
5	D.2.b.	Process Control Testing	2
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PLANT EVALUATION SUMMARY

PLANT NO. 041

PLANT TYPE: Second stage trickling filter with anaerobic digestion	
DESIGN FLOW: Unknown	
ACTUAL FLOW: 530 cu m/day (0.13 mgd)	
YEAR PLANT BUILT: 1936	
YEAR OF MOST RECENT UPGRADE: 1958	
PLANT PERFORMANCE SUMMARY:	

Plant is performing at about "secondary treatment" performance level except there is no disinfection at the facility.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.c.4.	Clarifier (secondary)	3
2	A.1.a.	Administration policies	2
3	C.2.c.1.	Process Flexibility	2
4	D.3.b.	Operation Technical Guidance	2
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PLANT EVALUATION SUMMARY

PLANT NO. 047

PLANT TYPE: Activated Sludge, extended aeration with polishing pond	
DESIGN FLOW: 237 cu m/day (0.0627 mgd)	
ACTUAL FLOW: 189 cu m/day (0.05 mgd)	
YEAR PLANT BUILT: 1967	
YEAR OF MOST RECENT UPGRADE: 1967	
PLANT PERFORMANCE SUMMARY:	

Activated sludge plant bulked solids every day during survey and according to the plant operator has done so quite often. Pond was an estimated 80 percent to 90 percent filled with sludge.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.b.	Technical Guidance	3
2	D.1.e.	Sewage Treatment Understanding	3
3	C.2.f.	Sludge Wasting	3
4	C.2.c.4.	Clarifier	2
5	C.2.c.1.	Process Flexibility	2
6	C.3.a.	Plant Location	2
7	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
8			
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PLANT EVALUATION SUMMARY

PLANT NO. 048

PLANT TYPE: Activated Sludge with Aerobic Digestion	
DESIGN FLOW: 1,440 cu m/day (0.38 mgd)	
ACTUAL FLOW: 1,290 cu m/day (0.34 mgd)	
YEAR PLANT BUILT: 1971	
YEAR OF MOST RECENT UPGRADE: 1971	
PLANT PERFORMANCE SUMMARY:	

According to the operator the plant has bulked solids typically from one to six days per week since start up. A high quality effluent is discharged when not bulking.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.a.	Operator Application of Concepts and Testing to Process Control	3
2	D.3.b.	Technical Guidance	3
3	C.1.f.	Infiltration/Inflow	2
4	D.2.b.	Process Control Testing	2
5	C.2.c.2.	Process Controllability	2
6	D.2.a.	Performance Monitoring	2
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PLANT EVALUATION SUMMARY

PLANT NO. 050

PLANT TYPE: Activated Sludge or extended aeration	
DESIGN FLOW: 680 cu m/day (0.18 mgd)	
ACTUAL FLOW: 640 cu m/day (0.17 mgd)	
YEAR PLANT BUILT: 1975	
YEAR OF MOST RECENT UPGRADE: 1975	

PLANT PERFORMANCE SUMMARY:

Meets design secondary performance when not bulking sludge. Sludge bulks fairly frequently. Current more stringent standards cannot be consistently met with present design.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.a.	Operator Application of Concepts and Testing to Process Control	3
2	C.2.f.	Sludge Wasting Capability	2
3	C.2.c.2.	Process Controllability	2
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PLANT EVALUATION SUMMARY

PLANT NO. 053

PLANT TYPE: Extended Aeration Activated Sludge	
DESIGN FLOW: 625 cu m/day (0.165 mgd)	
ACTUAL FLOW: 428 cu m/day (0.113 mgd)	
YEAR PLANT BUILT: 1976	
YEAR OF MOST RECENT UPGRADE: N/A	

PLANT PERFORMANCE SUMMARY:

Alternate periods of good performance and poor performance due to sludge bulking.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.b.	Technical Guidance	3
2	C.3.b.	Unit Process Layout	3
3	D.1.c.	Sewage Treatment Understanding	2
4			
5			
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9			
10			

PLANT EVALUATION SUMMARY

PLANT NO. 055

PLANT TYPE: Activated Sludge Extended Aeration	
DESIGN FLOW: 2,176 cu m/day (.575 mgd)	
ACTUAL FLOW: 1,128 cu m/day (.298 mgd)	
YEAR PLANT BUILT: Primary 1964 Secondary 1973	
YEAR OF MOST RECENT UPGRADE: -	

PLANT PERFORMANCE SUMMARY:

The secondary system was performing well. The anaerobic digester was providing little digestion due to the manner in which it had been operating.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.1.c.	Sewage Treatment Understanding	3
2	D.3.a.	Operator Application	2
3	A.2.b.3.	Supervision	2
4	A.1.a.	Policies	2
5	D.3.b.	Technical Guidance	2
6	C.2.g.	Sludge Treatment	2
7	C.1.g.	Return Process Streams	2
8	D.2.b.	Process Control Testing	2
9	B.1.a.	Housekeeping	2
10	D.4.a.	O & M Manual Adequacy	2

PLANT EVALUATION SUMMARY

PLANT NO. 060

PLANT TYPE: First Stage Trickling Filter-Second Stage ABF With Vacuum Filter	
DESIGN FLOW: 3974 cu m/day (1.05 mgd)	
ACTUAL FLOW: 1855 cu m/day (0.49 mgd)	
YEAR PLANT BUILT: 1974	
YEAR OF MOST RECENT UPGRADE: 1974	

PLANT PERFORMANCE SUMMARY:

Plant not meeting permit standards of 30 mg/l, TSS, and BOD_5.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.c.3.	Aerator	3
2	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
3	C.2.g.	Sludge Treatment	2
4	D.3.b.	Technical Guidance	2
5	B.1.d.	Maintenance Manpower	2
6	C.2.c.1.	Process Flexibility	2
7			
8			
9			
10			

PLANT EVALUATION SUMMARY

PLANT NO. 061

PLANT TYPE: Activated Sludge Contact Stabilization (2 plants)	
DESIGN FLOW: 1892 cu m/day (0.50 mgd)	
ACTUAL FLOW: 643 cu m/day (0.17 mgd)	
YEAR PLANT BUILT: 1967	
YEAR OF MOST RECENT UPGRADE: 1976	
PLANT PERFORMANCE SUMMARY: One of the two plants was meeting secondary limits, the other was not.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.a.	Operation Application of Concepts and Testing to Process Control	3
2	C.2.g.	Sludge Treatment	2
3	D.2.b.	Process Control Testing	2
4	C.3.b.	Unit Process Layout	2
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10			

PLANT EVALUATION SUMMARY

PLANT NO. 063

PLANT TYPE: Activated Sludge	
DESIGN FLOW: 5680 cu m/day (1.5 mgd)	
ACTUAL FLOW: 2650 cu m/day (0.7 mgd)	
YEAR PLANT BUILT: 1963	
YEAR OF MOST RECENT UPGRADE: 1963	
PLANT PERFORMANCE SUMMARY: Plant effluent exceeded discharge standards about 40% of the time.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.1.e.	Sewage Treatment Understanding	3
2	D.3.a.	Operator Application of Concepts and Testing to Process Control	3
3	D.2.b.	Process Control Testing	2
4			
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COST INFORMATION FOR VARIOUS TYPES AND SIZES OF FACILITIES SURVEYED

TABLE G-1. (1 of 2) COST INFORMATION FOR 0-380 CU M/DAY (0-0.1 MGD) SUSPENDED GROWTH FACILITIES

PLANT IDENTITY	007		019		020	
FLOW (mgd)*	0.041		0.035		0.007	
CATEGORY	$	¢/1000 GAL.	$	¢/1000 GAL.	$	¢/1000 GAL.
Salary	3540	23.5	5191	40.6	2500	97.8
Utilities	2700	17.9	1200	9.4	450	17.6
Supplies	3300	21.9	1450	11.4	300	11.7
Chemicals	300	2.0	500	3.9	150	5.9
Transportation	100	0.7	0	0	0	0
Training & Education	0	0	0	0	0	0
Miscellaneous	1185	7.9	2500	19.6	1340	52.5
Operations Subtotal	11125	73.9	10841	84.9	4740	185.5
Capital Outlay	20600	136.7	19250	150.7	3600	140.9
Total	31725	210.6	30091	235.6	8340	326.4

* mgd x 3785 = cu m/day

TABLE G-1. (2 of 2) COST INFORMATION FOR 0-380 CU M/DAY (0-0.1 MGD) SUSPENDED GROWTH FACILITIES

PLANT IDENTITY	022		047	
FLOW (mgd)*	0.012		0.05	
CATEGORY	$	¢/1000 GAL.	$	¢/1000 GAL.
Salary	Information Not Available		3132	17.2
Utilities			1498	8.2
Supplies			297	1.6
Chemicals			50	0.3
Transportation			0	0
Training & Education			12	0.1
Miscellaneous			223	1.2
Operations Subtotal			5212	28.6
Capital Outlay			3245	17.8
Total			8457	46.4

* mgd x 3785 = cu m/day

TABLE G-2. (1 of 3) COST INFORMATION FOR 380-3800 CU M/DAY (0.1-1.0 MGD) SUSPENDED GROWTH FACILITIES

PLANT IDENTITY	002		013		021		026	
FLOW (mgd)*	0.43		0.50		0.59		0.15	
CATEGORY	$	¢/1000 GAL.	$	¢/1000 GAL.	$	¢/1000 GAL.	$	¢/1000 GAL.
Salary	28685	18.3	34164	18.7	17878	8.3	18186	33.2
Utilities	11000	7.0	22000	12.1	6800	3.2	2000	3.7
Supplies	14000	8.9	7000	3.8	8595	4.0	4000	7.3
Chemicals	1000	0.6	1500	0.8	1200	0.6	800	1.5
Transportation	3000	1.9	2500	1.4	4500	2.1	0	0
Training & Education	500	0.3	1000	0.5	100	0.05	0	0
Miscellaneous	46203	29.4	11000	6.0	9300	4.3	6700	12.2
Operations Subtotal	104388	66.4	79164	43.3	48373	22.5	31686	57.9
Capital Outlay	58600	37.3	312000	171.0	31005	14.4	38000	69.4
Total	162988	103.7	391164	214.3	79378	36.9	69686	127.3

* mgd x 3785 = cu m/day

TABLE G-2. (2 of 3) COST INFORMATION FOR 380-3800 CU M/DAY (0.1-1.0 MGD) SUSPENDED GROWTH FACILITIES

PLANT IDENTITY	028		039		048		050	
FLOW (mgd)*	0.15		0.21		0.34		0.17	
CATEGORY	$	¢/1000 GAL.	$	¢/1000 GAL.	$	¢/1000 GAL.	$	¢/1000 GAL.
Salary	9610	17.6	Information Not Available		18470	14.9	7717	12.3
Utilities	12100	22.1			13500	10.9	14891	23.7
Supplies	1000	1.8			7900	6.4	1784	2.8
Chemicals	1000	1.8			1000	0.8	648	1.0
Transportation	1200	2.2			150	0.1	120	0.2
Training & Education	0	0			100	0.1	153	0.2
Miscellaneous	14850	27.1			0	0	225	0.4
Operations Subtotal	39760	72.6			41120	33.2	25538	40.6
Capital Outlay	2000	3.7			21000	16.9	9332	14.9
Total	41760	76.3			62120	50.1	34870	55.5

* mgd x 3785 = cu m/day

TABLE G-2. (3 of 3) COST INFORMATION FOR 380-3800 CU M/DAY (0.1-1.0 MGD) SUSPENDED GROWTH FACILITIES

PLANT IDENTITY	053		055		061		063	
FLOW (mgd)*	0.11		0.30		0.17		0.70	
CATEGORY	$	¢/1000 GAL.	$	¢/1000 GAL.	$	¢/1000 GAL.	$	¢/1000 GAL.
Salary	13400	32.5	4992	4.6	10300	16.6	57148	22.4
Utilities	4870	11.8	13961	12.8	12800	20.6	17107	6.7
Supplies	1300	3.2	3323	3.1	3400	5.5	5241	2.1
Chemicals	100	0.2	0	0	3900	6.3	1078	0.4
Transportation	650	1.6	0	0	60	0.1	4965	1.9
Training & Education	40	0.1	0	0	100	0.2	0	0
Miscellaneous	330	0.8	2945	2.7	2800	4.5	576	0.2
Operations Subtotal	20690	50.2	25221	23.2	33360	53.8	86115	33.7
Capital Outlay	0	0	7000	6.4	10400	16.8	0	0
Total	20690	50.2	32221	29.6	43760	70.6	86115	33.7

* mgd x 3785 = cu m/day

TABLE G-3. COST INFORMATION FOR 380-3800 CU M/DAY (0.1-1.0 MGD) FIXED FILM FACILITIES

PLANT IDENTITY	032		040		041		060	
FLOW (mgd)*	0.22		0.38		0.13		0.49	
CATEGORY	$	¢/1000 GAL.	$	¢/1000 GAL.	$	¢/1000 GAL.	$	¢/1000 GAL.
Salary	3780	4.7	13316	9.5	15755	33.2	36500	20.4
Utilities	4000	5.0	2050	1.5	2500	5.3	13000	7.3
Supplies	3600	4.5	6130	4.4	8000	16.9	3000	1.7
Chemicals	1000	1.2	2300	1.6	200	0.4	25000	14.0
Transportation	0	0	300	0.2	200	0.4	1800	1.0
Training & Education	0	0	150	0.1	200	0.4	500	0.3
Miscellaneous	0	0	130	0.1	825	1.7	700	0.4
Operations Subtotal	12380	15.4	24376	17.4	27680	58.3	80500	45.1
Capital Outlay	100	0.1	19200	13.7	5090	10.7	15000	8.4
Total	12480	15.5	43576	31.1	32770	69.0	95500	53.5

* mgd x 3785 = cu m/day

TABLE G-4. (1 of 2) INFORMATION FOR 3800-38000 CU M/DAY (1.0-10.0 MGD) FIXED FILM FACILITIES

PLANT IDENTITY	012		015		024		034	
FLOW (mgd)*	8.1		1.7		4.9		5.5	
CATEGORY	$	¢/1000 GAL.	$	¢/1000 GAL.	$	¢/1000 GAL.	$	¢/1000 GAL.
Salary	189970	6.4	Information Not Available		84141	4.7	87917	4.4
Utilities	62657	2.1			19800	1.1	13920	0.7
Supplies	15575	0.5			7100	0.4	7000	0.3
Chemicals	20000	0.7			30000	1.7	23976	1.2
Transportation	3400	0.1			1000	0.1	50	0.002
Training & Education	300	0.01			2400	0.1	73	0.004
Miscellaneous	5098	0.2			63100	3.5	41360	2.1
Operations Subtotal	297000	10.0			207541	11.6	174296	8.7
Capital Outlay	82700	2.8			98900	5.5	120000	6.0
Total	379700	12.8			306441	17.1	294296	14.7

* mgd x 3785 = cu m/day

TABLE G-4. (2 of 2) INFORMATION FOR 3800-38000 CU M/DAY (1.0-10.0 MGD) FIXED FILM FACILITIES

PLANT IDENTITY	035		036	
FLOW (mgd)*	5.3		2.5	
CATEGORY	$	¢/1000 GAL.	$	¢/1000 GAL.
Salary	54162	2.8	49746	5.5
Utilities	17660	0.9	7586	0.8
Supplies	13961	0.7	10742	1.2
Chemicals	4200	0.2	3655	0.4
Transportation	2000	0.1	2000	0.2
Training & Education	245	0.01	183	0.02
Miscellaneous	11085	0.6	11024	1.2
Operations Subtotal	103313	5.3	84936	9.3
Capital Outlay	86024	4.4	79545	8.7
Total	189337	9.7	164481	18.0

* mgd x 3785 = cu m/day

TABLE G-5. COST INFORMATION FOR 3800-38,000 CU M/DAY (1.0-10.0 MGD) SUSPENDED GROWTH FACILITIES

PLANT IDENTITY	014		027		029	
FLOW (mgd)*	1.0		1.4		5.5	
CATEGORY	$	¢/1000 GAL.	$	¢/1000 GAL.	$	¢/1000 GAL.
Salary	50000	13.7	118782	5.9	51732	10.3
Utilities	20000	5.5	53228	2.7	25400	5.1
Supplies	8000	2.2	300	0.01	4000	0.8
Chemicals	12000	3.3	16625	0.8	5000	1.0
Transportation	0	0	2000	0.1	300	0.1
Training & Education	0	0	750	0.04	750	0.1
Miscellaneous	10850	3.0	86178	4.3	9000	1.8
Operations Subtotal	100850	27.7	277863	13.8	96182	19.2
Capital Outlay	145000	39.7	182465	9.1	13000	2.6
Total	245850	67.4	460328	22.9	109182	21.8

* mgd x 3785 = cu m/day

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-79-034	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE EVALUATION OF OPERATION AND MAINTENANCE FACTORS LIMITING MUNICIPAL WASTEWATER TREATMENT PLANT PERFORMANCE		5. REPORT DATE June 1979 (Issuing Date) 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Bob A. Hegg, Kerwin L. Rakness, and James R. Schultz		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS M & I, Inc., Consulting Engineers 4710 South College Avenue Fort Collins, Colorado 80525		10. PROGRAM ELEMENT NO. 1BC821; SOS 2; Task A1 11. CONTRACT/~~GRANT~~ NO. 68-03-2224
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15. SUPPLEMENTARY NOTES See also EPA-600/2-79-035,"A Demonstrated Approach for Improving Performance and Reliability of Biological Wastewater Treatment Plants" and EPA-600/2-79-078,"Evaluation of Operation and Maintenance Factors Limiting Biological Wastewater Treatment Plant Performance"; Contact: Francis L. Evans, III (513) 684-7610

16. ABSTRACT

A significant number of wastewater treatment plants constructed with Federal monies have not met design or NPDES permit standards. The emphasis of this research study was to identify, quantify and rank the causes of this poor performance. Research objectives were accomplished by conducting comprehensive evaluations at thirty wastewater treatment facilities. The two highest ranking factors identified were inadequate operator application of concepts and testing to process control and sewage treatment understanding. Many operators were not trained as evidenced by a lack of sewage treatment understanding, but even trained operators did not apply concepts of operation to process control. The third highest ranking factor identified was improper technical guidance from authoritative sources. These sources have dramatically affected the capability of existing operations personnel. Also, six of the ten highest ranking factors were related to improper plant design. Existing correction programs which address specific performance limiting factors were found to be limited in their ability to achieve the desired performance from an individual facility. A supplemental program to improve facility performance was developed and demonstrated. The program has potential of reducing plant construction costs as well as improving plant effluent quality.

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