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

Phase II

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

Phase II

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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 problem.

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 communication link between the researcher and the user community.

Many of the country's wastewater treatment plants do not meet design expectations and NPDES permit standards. A research project was initiated to identify, quantify and rank the causes of this poor performance by comprehensive evaluations of 50 plants in nine western states. The identified highest ranking causes of limited plant performance reflect an inability of in-plant personnel to optimize process control and the performance of existing facilities. Deficiencies in design features also ranked high. The performance of each plant is typically limited by a unique combination of problems which require individual identification and elimination. The Composite Correction Program (CCP) was introduced and demonstrated. This approach to improving the performance of existing facilities was conducted at selected facilities. Areas of special evaluation include aerator and clarifier design, sludge production in activated sludge plants, aerobic digester operation, reference materials used in treatment plants, operator time and tasks before and after a CCP, and the effects of toxic substances on well-operated treatment facilities.

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ABSTRACT

Many of the country's wastewater treatment plants do not meet design expectations and NPDES permit standards despite vastly increased spending and numerous improvement programs initiated in recent years. A two-phased research project was initiated to identify, quantify and rank the causes of this poor performance. Phase I of the project included comprehensive evaluations of 30 plants in seven western states. In Phase II, the data base was expanded to 50 plants in nine states. The identified highest ranking causes of limited plant performance reflect an inability of in-plant personnel to optimize process control and the performance of existing facilities. Many design features also ranked high among performance-limiting factors and reflect the construction of many incomplete and marginally operable facilities. Inadequate design and the high ranking of improper technical guidance concerning process control by design engineers, regulatory personnel, equipment manufacturers, training personnel and other authoritative sources indicate the plant performance problem is not a uniquely local problem but rather industry-wide.

Findings indicate the performance of each plant is typically limited by a unique combination of problems which require individual identification and elimination. The Composite Correction Program (CCP) was introduced and demonstrated in Phase I as a recommended approach to improve the performance of existing facilities (EPA-600/2-79-034). These programs were conducted in Phase II at selected facilities to demonstrate improved performance and to further illustrate the implementation of this approach.

Areas of special evaluation in the Phase II effort include aerator and clarifier design, sludge production in activated sludge plants, aerobic digester operation, reference materials used in treatment plants, operator time and tasks before and after a CCP, and the effects of toxic substances on well-operated treatment facilities.

This report was submitted in partial fulfillment of Contract No. 68-03-2572 by M&I, Inc., under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period October 1, 1977 to April 1, 1979 and the work was completed November 1979.

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ACKNOWLEDGEMENT

Appreciation is expressed to all managers, operators and other personnel of the various wastewater treatment facilities who participated in the research effort. Appreciation is also expressed to all state and EPA regulatory agency personnel who developed the various lists of possible research facilities and who actively participated in various phases of the study.

The direction provided and assistance given by Mr. John Smith, Mr. Ben Lykins and Mr. Francis Evans, III, of the Environmental Protection Agency, Office of Research and Development, Cincinnati, Ohio, are greatly appreciated.

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, the 1973, 1974 and 1975 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 addition to these reports other sources have documented the plant performance problem (1, 2). In response to these findings, EPA's Office of Research and Development initiated a three and one-half year research program with the objective to identify, quantify and rank the factors causing poor wastewater treatment plant performance.

Two consultants were selected to perform the research effort. Initially, two 24-month contracts were awarded (Phase I), one to an Eastern U.S. Contractor and one to the Western U.S. Contractor. Separate reports were prepared describing Phase I findings (3,4,5). The work was continued through subsequent 17-month contracts (Phase II) to the two firms in order to expand the data base and research additional areas of special interest.

The objective of the research effort was to identify and rank the major factors which limit biological wastewater treatment plant performance. This objective was accomplished by conducting comprehensive evaluations of selected wastewater treatment facilities. Plants were carefully selected rather than chosen randomly because of the nature of the problem that prompted the study. Recently constructed facilities (designed to be adequate for 20 years) were expected to be operable without overwhelming design inadequacies or other obvious problems that would preclude achievement of good performance. This group of facilities were chosen for study to determine the performance limiting factors. Facilities that were obviously overloaded, were inoperable due to equipment problems or were incomplete because of inadequate process design were not studied. The obvious nature of the problem in these facilities are indeed performance limiting and must be addressed, but the more subtle causes of continued poor performance in operable facilities was the emphasis of this research. In this category, facilities that met and did not meet treatment requirements were studied. Evaluations of selected plants in nine western states were conducted, thirty during Phase I and twenty during Phase II. The study area for the Western U. S. contractor is shown in Figure 1.

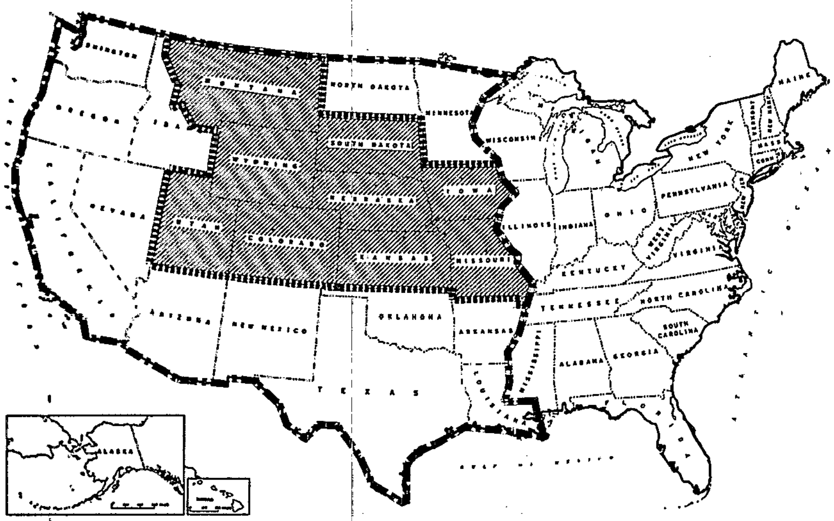


Figure 1. Study area of the western U.S. contractor.

A special research approach was developed to identify the causes of poor plant performance. As the causes were identified, it became obvious that a complex interrelationship existed between the problems in POTW's and the potential solutions to those problems. An illustrative tool called the "Unified Concept for Achieveing Optimum Plant Performance" was developed and used to explain why a large number of POTW's do not achieve desired performance. The "Unified Concept" also formed the illustrative basis for an approach which can lead to improved performance from POTW's. The approach termed a Composite Correction Program, focuses on all the problems at an individual plant, and its effectiveness was demonstrated at six facilities. In addition to the overall evaluation, several areas typically felt to be specific causes of poor performance were evaluated including: reference material, toxic substances, sludge production, clarifier design, aerator loadings, aerobic digesters, and operator activities.

This report documents findings of the Western U.S. Contractor for both Phase I and Phase II activities. Data collected in Phase I (5) have been incorporated into this report so that the entire data base for the fifty facilities could be used to develop the conclusions and recommendations. A separate report describing the results for the Eastern United States has been prepared by the eastern area contractor (3).

SECTION 2

CONCLUSIONS

1. Performance limiting factors at publicly owned wastewater treatment facilities were identified and ranked by conducting comprehensive evaluations at 50 plants.

   A. Through a formal screening process, inoperable plants with major hydraulic or organic overloads, heavy industrial loadings, excessively poor maintenance, or major administrative limitations were eliminated from study.

   B. Of the factors evaluated, improper operator application of concepts and testing to process control received the highest ranking. Inadequate sewage treatment understanding was ranked second. Additional training needs were indicated, but restructured training activities are necessary.

   C. Improper technical guidance was ranked third and occurred in half of the plants evaluated. A general re-evaluation of the approach taken to the dissemination of operations oriented information, especially that relating to process control, is necessary and must include increased accountability for guidance given by "authoritative" sources.

   D. Inadequate design features comprised six of the top ten performance limiting factors. Additional emphasis to provide better designed wastewater treatment plants is required.

   E. Performance limiting factors at fixed film facilities were more design oriented, with inadequate capability to convert soluble BOD_5 to a settleable solid being the leading problem. Operation oriented problems were more frequent at suspended growth plants.

2. Thirty-seven of 50 facilities evaluated did not consistently meet Federally defined secondary treatment standards.

   A. The inability of these plants to meet standards was not related to loading since no plant exceeded its design loading. The mean hydraulic loading was 66 percent of design.

   B. Twenty-seven of 37 plants could potentially meet standards by addressing major performance-limiting operations oriented factors, and minor administration, maintenance and design factors.

C. Ten of 37 plants violating standards have major design problems that must be corrected through plant expansion or upgrading. Of these ten facilities, nine were fixed film facilities.

D. Suspended growth plants could be brought into compliance without major capital improvements, but somewhat higher O & M costs may be necessary primarily due to increased sludge handling needs.

3. Relating specific factors to plant performance resulted in only limited correlations being established.

A. Larger staff size, higher staff salaries, and higher total operations costs did not correlate with good plant performance.

B. A higher level of certification by the chief operator did promote better plant performance, but only 40 percent of the "A" and "B" certified operators' plants met standards.

4. A "Unified Concept for Achieving Optimum Plant Performance" was developed to describe the interrelationship of performance-limiting factors and the methods used to improve plant capabilities.

A. Two different categories of programs using distinctly different approaches to achieving desired plant performance were described.

1) Individual correction programs are implemented with the purpose of addressing and eliminating specific factors or groups of factors at a large number of facilities and do not address the unique combination of factors at various individual facilities.

2) A Composite Correction Program is implemented at a single facility with the purpose of identifying and eliminating all limiting factors to achieve a desired level of performance.

B. Major factors limiting performance in the design, maintenance and administration areas tend to cause a plant to be incapable of meeting performance objectives. These plants must achieve an operable status in order to pursue the goal of optimum performance. Operation problems represent the remaining step between an operable facility and the goal of a good, economical plant effluent.

C. Adoption of the basic principals described in the "Unified Concept" would allow a coordinated and directed effort to be developed for the groups that influence plant performance. (i.e. operating personnel, municipal officials, regulatory agency personnel, engineering consultants, equipment suppliers, etc.)

5. If properly implemented, the Composite Correction Program (CCP) approach can achieve an improvement in plant effluent quality at many treatment facilities without major capital expenditures.

A. Implementation of four CCPs during the research project resulted in a dramatic improvement in plant effluent quality.

B. Significant potential for improving performance through implementation of CCP's exists. Without major facility modifications, 27 of 37 plants found violating standards could be brought into compliance. Additionally, the BOD_5 and TSS discharged to receiving streams by 38 plants could be reduced by 1020 metric tons/year (1120 ton/year) and 1190 metric tons/year (1315 tons/year), respectively.

C. The CCP approach can reduce the improper technical guidance factor noted if personnel conducting a CCP are held accountable in attaining the objective of a CCP: namely to achieve desired performance at a particular facility.

D. Further incentives (i.e., enforcement) are necessary to encourage administrators to investigate the CCP approach. Presently, a negative incentive for good performance exists in that poor performing plants are "rewarded" with substantial construction grant funds to build new facilities.

6. A special evaluation was made for aerators and a positive correlation between aerator loading and plants meeting standards was noted.

A. Conservative aerator loading for suspended growth facilities helps to improve plant performance, but is not a guaranteed solution nor is it cost effective.

B. The performance of activated sludge plants violating standards could be improved significantly through better operation and often could adequately treat additional wastewater without major capital improvements.

C. Fixed film plants with low aerator organic loadings had a better performance record, while more heavily organically loaded facilites could not achieve good performance without major capital improvements.

7. A special evaluation of secondary clarifiers indicated that significant additional capacity remains in existing units. Some design and operational factors were observed to limit or enhance utilization of this capacity.

A. Inadequate utilization of the clarifier surface for overflow with resulting hydraulic limitations was noted in many clarifiers.

B. At some small facilities a clarifier sludge scraper mechanism was not provided and inadequate sludge removal occurred. Better operation priorities and/or major design modifications are necessary at these plants.

C. Deep final clarifiers [4.5 m (15 ft)] were observed to aid plant performance and process control capability.

D. Clarifiers with separate rapid withdrawal return sludge mechanisms and a scraper used to feed sludge to a hopper bottom were advantageous in allowing partial separation of activated sludge and heavier solids for plants without primary clarifiers.

8. A special evaluation was made of sludge production in activated sludge plants without primary clarifiers.

A. Documented sludge production ratios for single aeration and two stage aeration activated sludge plants varied from 0.6 kg TSS/kg BOD_5 to 1.1 kg TSS/kg BOD_5 removed, and were highest for two stage aeration (contact stabilization) plants.

B. Documented sludge production ratios did not change significantly with varying mean cell residence times, food to microorganism ratios, wastewater detention times in the aerator or aeration basin organic loadings.

C. Most sludge handling systems were grossly undersized because design sludge production values were severely underestimated.

9. A special evaluation was made of aerobic digesters at activated sludge plants.

A. Aerobic digester sludge solids were frequently recycled back to the activated sludge treatment process.

B. None of the aerobic digester automatic supernating devices performed satisfactorily.

C. Batch operation of aerobic digesters provided the best control over operation and performance. At some plants batch operation was difficult because of inadequate structural integrity of digester walls.

D. Inadequate aerobic digester size was noted repeatedly. Inadequately sized digesters caused increased operations activities in the form of frequent supernating requirements, digester foaming problems, and additional efforts for removing undigested sludge for ultimate sludge disposal.

E. Final effluent quality of operating facilities with inadequately sized digesters can be improved by hauling partially digested sludge.

10. A special evaluation was made of the availability and usage of plant reference literature.

A. Plant specific O & M manuals were the most available and widely used reference source. Despite their use, only 30 percent of those plants met standards indicating that O & M manuals are limited in their ability to provide a basis for the operator to improve plant performance.

B. Other publications used ranked in the following order: New York Manual, Sacramento Course, WPCF MOP5, Texas Manual, and WPCF Studybook for Wastewater Operator Certification. The highest ranking process specific publication used was Operation Manual, Anaerobic Sludge Digesters (EPA 430/9 - 76-001).

C. Other specific areas of highest reference usage were as follows:
Lab Reference - Standard Methods
Management Reference - Safety in Wastewater Works
Periodical Publication - WPCF "Highlights"

11. A special evaluation was made of operator time and tasks at two plants prior to and after plant standards were consistently met.

A. Adequate manpower is required but without proper training and usage of the manpower good performance will not occur.

B. Increased operator time for process control activities at two smaller activated sludge plants was required to improve plant performance.

12. A special evaluation was made of the effects of toxics on biological wastewater treatment process performance at two facilities where CCP's were conducted.

A. A short term effect of toxics was that plant effluent quality deteriorated. A long term effect was that poor sludge characteristics developed and were slow to recover because of the long time associated with biological system response.

B. Many problems with plant operations associated with poor process control are unjustifiably blamed on toxics.

C. When a true toxic problem exists, finding and eliminating the source should receive a high priority from plant administrators and staff.

SECTION 3

RECOMMENDATIONS

1. Improve design of wastewater treatment facilities, with special consideration to the high ranking design features observed.

   A. Consider conservative organic loading rates in the design of fixed film biological reactors.

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

   C. Include flow rate measurement and control features in the design of return activated sludge flow systems.

   D. Improve secondary clarifier design by considering features which optimize surface area development, provide for greater sludge storage and compaction (i.e. depth), and provide separate return and waste sludge removal mechanisms.

   E. Include adequately designed sludge handling facilities in all plants. Use realistic sludge production estimates as a basis for design.

   F. Design aerobic digesters for batch operation and eliminate in-tank automatic supernating devices.

   G. Recognize that ultimate sludge disposal can directly affect effluent quality. Design alternatives and flexibility into ultimate disposal systems.

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

   A. Recognize that on-site training is the most effective way to develop an operator's capability to properly apply wastewater treatment concepts to process control. Seek to develop operators' skills through technical guidance at their respective facilities.

   B. Encourage operating personnel to improve sewage treatment understanding through budget support for off-site training and certification.

   C. Expand training of design and review engineers in plant operations and process control through classroom training plus guided inplant operations experience.

D. Use persons thoroughly aware of wastewater treatment process requirements to review and correct inaccurate, incomplete and misleading training information.

E. Improve qualifications and training of private and governmental persons providing operations technical assistance, in order to avoid the frequent occurrence of improper technical guidance. Training should include in-plant operations experience where personnel are in a position to be held accountable for process oriented recommendations.

3. Implement the composite correction program (CCP) approach on a broad scale to improve the performance of wastewater treatment facilities.

   A. Develop an awareness of the broad range of factors (i.e., administrative, design, operation and maintenance) that can limit POTW performance. Realize that all these problems must be addressed at an individual plant to achieve optimum performance.

   B. Recognize that many factors limiting plant performance are beyond the plant operator's control (i.e., design and administrative factors).

   C. Verify performance potential of existing facilities by requiring a comprehensive evaluation which assesses performance problems from the basis of a thorough understanding of process requirements. Implement a CCP to develop full plant potential.

   D. Require extended and process oriented technical assistance services at new or upgraded facilities with the objective of achieving desired performance.

   E. Implement incentives such as enforcement to encourage improved performance at facilities not achieving design or permit standards.

SECTION 4

RESEARCH APPROACH

PRELIMINARY PLANT SELECTION

Plants selected for evaluation had to meet general criteria stipulated for the research effort, such as: geographical area, biological wastewater treatment facilities in the 0-37,850 cu m/day (0-10 mgd) size range, plants not severely overloaded, plants which had all major units operable, and plants not involved in enforcement action. To find facilities which met the selection criteria, several screening steps were used. The plant selection procedure is depicted in Figure 2.

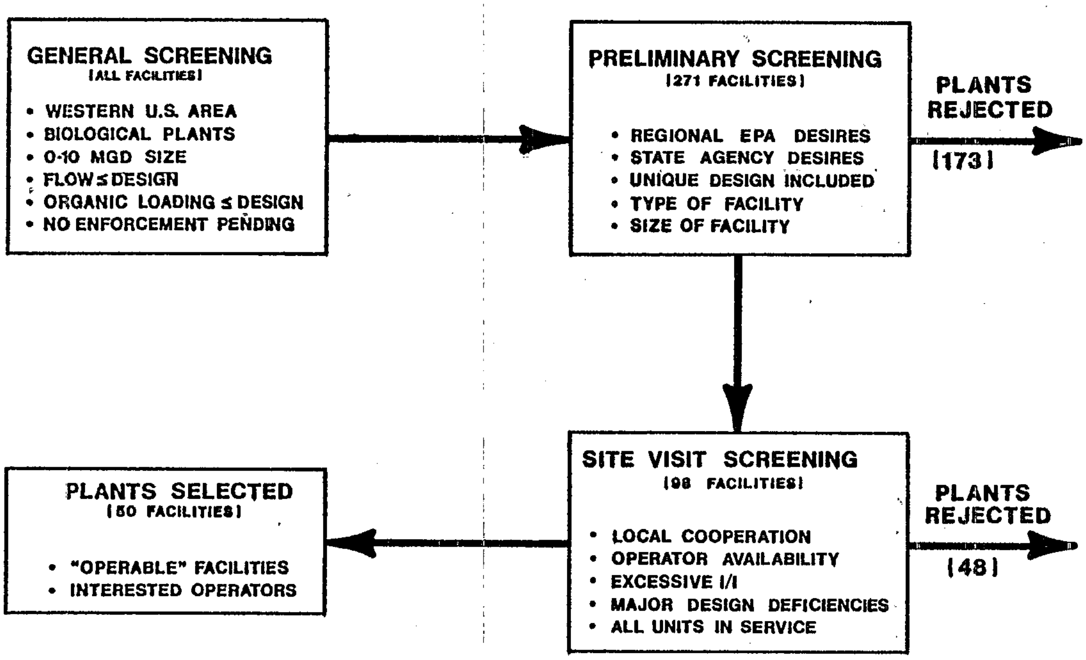


Figure 2. Plant selection procedure.

Personnel in EPA Regions VII and VIII and in nine state regulatory agencies were informed of the general screening criteria and asked to provide suggested plants for study. A total of 271 plants were suggested. Using telephone discussions and considerations of location, size, type of process, and plant loading, 173 of these facilities were eliminated from further consideration.

SITE VISITS

Site visits were made at 98 facilities. Typically, half-day visits were made by two sanitary engineers with experience in identifying performance-limiting factors. Based on the site visit findings, 48 facilities were elminated from further study. Problems which caused the elimination of facilities included such factors as inoperability of the facility, equipment problems and extreme overloading problems. A few facilities were eliminated because town officials or plant personnel expressed a desire to not participate in the study. Some very small facilities were rejected because plant personnel were not available. Some facilities were rejected because facilities of that type and size had been previously evaluated.

The scope of the site visits included formal documentation of general information (design flow, population served, receiving stream, etc.), process description (wastewater and sludge flow schematic) and plant operation and maintenance characteristics (number of operators, lab facilities available, plant maintenance completed, etc.). An investigation checklist used for site visits is included in Appendix B. Additional documentation included factors which were noted to limit performance and the reasons the plant was not selected for further study. Plants for which a site visit was conducted are referenced in Appendix A.

COMPREHENSIVE SURVEYS

Using the plant selection procedures outlined, fifty facilities were identified for comprehensive evaluations. A list of facilities surveyed is included in Appendix A. Each evaluation was typically conducted with one and one-half to two man-weeks of effort over a four to ten-day period. Persons conducting the surveys were sanitary engineers with experience in plant operations. The evaluation team worked with plant personnel to temporarily address obvious and controllable performance limiting problems at the plant so other less apparent problems could be identified. Each evaluation was followed by a written report which explained the problems identified during the survey. Factors which limited performance were discussed under four general topics: administration, maintenance, design and operation. The discussion in the text of the reports was limited to areas in which conclusions and recommendations were made. Implementation of recommendations made to the city or sanitation district were completely voluntary.

Two appendices were included in all survey reports. One appendix consisted of Survey Information Sheets, which were used to provide a common data base and a thorough documentation of diverse information about each facility. An example copy of these sheets is included in Appendix B. The second appendix in the preliminary survey reports consisted of a completed EPA Inspection Form 7500-5. Copies of each 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.

Plants chosen for preliminary surveys represented a cross-section of facility types and sizes within the desired plant flow range of 0-37,850 cu m/day (0-10 mgd). Research was limited to this flow range because the majority of POTW's in the United States falls within this range. Results obtained from evaluations of plants within this size range were expected to have broad applicability. Additionally, it was the intent of the research project to identify the reasons why many recently upgraded facilities were not in compliance with current treatment requirements (1, 2). Facilities chosen for comprehensive evaluations were "operable" facilities selected to meet these requirements. Results for the comprehensive evaluations are thus biased away from obvious performance limiting factors such as hydraulic and organic overloading.

A more extensive discussion of the research approach, including an example survey, was presented in the Phase I report (5).

SECTION 5

CAUSES OF LIMITED PLANT PERFORMANCE

An in-depth evaluation was made at each facility to determine what factors were limiting performance. Results of each evaluation were documented on Plant Evaluation Summary Forms. A copy of these forms along with a definition of terms used is included in Appendix C. The Plant Evaluation Summary was developed as part of the research effort and consisted of two parts, a weighing table and a ranking table. The weighing table included seventy different factors that could possibly limit plant performance. This list of factors was composed of items from various inspection forms, troubleshooting lists and other sources. To achieve a high degree of consistency and objectivity for the research, each factor was specifically defined. During the plant evaluations each factor was evaluated and assigned a numerical weight according to the schedule in Table 1.

TABLE 1. POINT SYSTEM FOR PLANT EVALUATION SUMMARY WEIGHING TABLE

Weighing Points	Adverse Effect of 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 second part of the Plant Evaluation Summary, the ranking table, was used to put the factors which received points in priority ranking. Only factors which received two or three points were included in the ranking table. Ranking tables for all facilities evaluated during Phase II are included in Appendix D and E. Ranking tables for facilities evaluated during Phase I have been previously published (5).

The Plant Evaluation Summary was originally developed to quantify and rank the factors limiting performance only at the facilities where comprehensive surveys were conducted. However, because it was found that a meaningful amount of information especially for obvious performance-limiting problems, could be obtained during the half-day site visits, the Plant Evaluation Summary was also completed for the 48 facilities where site visits were conducted.

SITE VISIT FACILITIES

Site visits were conducted at 98 facilities as part of the plant selection process. Fifty of these facilities were selected for comprehenisve evaluations. Results from the 48 site visited facilities differed from the comprehensive evaluation results due to limited time that was spent for each visit, and the nature of the plant selection criteria. Whereas, more of the subtle factors were determined during the week-long comprehensive surveys, only the more obvious factors were documented during the site visits. Therefore, only the factors that warranted a weight of two or three points were listed. The ranking table completed for each site visit facility is included in Appendix D.

The combined ranking of performance limiting factors for all site visit facilities is shown in Table 2. Thirty-three different factors which were given two or three points are included. Each factor was ranked according to the cumulative number of points received for the 48 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.

Each site visit typically included discussions with plant administrators as well as in-plant personnel. During such discussions responsiveness to plant needs was assessed. Plants with unresponsive administrators were eliminated from further study. In this manner, administrative policies received a high ranking in site visit facilities (ranked number 8), but was not nearly as prevalent in facilities where comprehensive evaluations were conducted.

The design aspects of each plant were evaluated based on unit sizes, control features and process completeness. Nineteen of the top 33 factors were design oriented. It was concluded that for many site visited facilities major and/or minor design modifications were required before an operable plant could be provided.

Some site visit facilities had serious equipment malfunction problems or lacked preventive maintenance and housekeeping programs to the point that operability of the facility was questionable. Site visits were often too short to identify if these obvious problems were actually a result of administrative or in-plant operator problems. However, the inoperable condition of these facilities eliminated them from further evaluation.

An evalution of the operation of many site visit facilities showed an obvious lack of application of even basic concepts and test results to process control. However, there was not sufficient time to evaluate other more subtle

TABLE 2. RANKING OF FACTORS LIMITING PERFORMANCE OF 48 SITE VISITED FACILITIES

Ranking	Weighing Table Reference*	Factor Limiting Performance	No. of Times Factor Occurred	No. of Plants Factor Ranked #1	Point Breakdown 3pt	Point Breakdown 2pt	Total Points
1	D.3.a.	Operator Application of Concepts and Testing to Process Control	19	6	5	14	43
2	C.1.f.	Infiltration/Inflow	17	7	8	9	42
3	C.2.c.3.	Aerator	14	8	5	9	33
4	C.2.c.2.	Process Controllability	12	2	5	7	29
5	C.2.g.	Sludge Treatment	10	5	4	7	26
6	C.2.c.1.	Process Flexibility	13	1	1	11	25
7	C.2.f.	Sludge Wasting Capability	9	2	4	5	22
8	A.1.a.	Administrative Policies	6	3	5	1	17
9	C.1.c.	Industrial Loading	4	3	4	0	12
10	D.1.c.	Sewage Treatment Understanding	4	1	3	1	11
11	C.2.c.4.	Clarifier	4	1	3	1	11
12	D.2.b.	Process Control Testing	5	0	0	5	10
13	C.3.1.	Plant Inoperability Due to Weather	4	1	1	3	9
14	D.3.b.	Technical Guidance	3	0	2	1	8
14	D.5.a.	Equipment Malfunction	3	2	2	1	8
16	A.2.b.1.	Motivation (Staff)	2	2	2	0	6
16	C.2.h.	Ultimate Sludge Disposal	3	0	0	3	6
18	C.2.e.	Disinfection	2	0	1	1	5
18	A.1.b.	Familiarity With Plant Needs	2	1	1	1	5
20	D.2.a.	Performance Monitoring	2	0	0	2	4
21	B.2.a.	Lack of Maintenance Program	1	1	1	0	3
21	C.1.b.	Hydraulic Loading	1	1	1	0	3
21	C.3.d.1.	Flow Back-Up	1	1	1	0	3
24	A.2.a.1.	Staff Number	1	0	0	1	2
24	B.1.a.	Housekeeping	1	0	0	1	2
24	C.1.e.	Seasonal Variation	1	0	0	1	2
24	C.1.g.	Return Process Streams	1	0	0	1	2
24	C.3.a.	Plant Location	1	0	0	1	2
24	C.3.k.	Equipment Accessibility for Maintenance	1	0	0	1	2
24	C.3.1.	Laboratory Space and Equipment	1	0	0	1	2
24	A.2.b.5.	Safe Working Conditions	1	0	0	1	2
24	C.1.d.	Toxic Loading	1	0	0	1	2
24	B.3.a.	Staff Expertise (Emergency Maintenance)	1	0	0	1	2

* A = Administrative, B = Maintenance, C = Design, D = Operations Factor

operations related factors such as improper technical guidance, inadequate operator aptitude, inadequate training, etc.

It was concluded that the performance of site visit facilities was limited by obvious design, administration and maintenance factors that hindered those facilities from obtaining an operable status. In these facilities, evaluation of performance was limited and further study under the scope of this research was not warranted.

COMPREHENSIVE SURVEY FACILITIES

The results for the comprehensive surveys represent reliable and in-depth insight into the problems which prevent many operable facilities from achieving desired levels of performance. This is true because of the nature of the research approach, the length of time spent at each facility and the experience possessed by the persons conducting the research. Additionally, comprehensive survey facilities were selected plants and the problems identified represent in-depth types of factors that might not have been as predominantly exhibited by plants randomly chosen.

The factors which ranked highest for Phase I did vary somewhat from those factors which ranked highest in Phase II. The ten highest ranking factors for the two phases are as follows:

Phase I (30 plants)	Phase II (20 plants)
1. Operator Application of Concepts ...	1. Operator Application of Concepts ...
2. Sewage Treatment Understanding	2. Infiltration/Inflow
3. Technical Guidance	3. Sludge Wasting Capability
4. Process Control Testing	4. Technical Guidance
5. Sludge Wasting Capability	5. Process Controllability
6. Process Flexibility	6. Aerator
7. Process Controllability	7. Sewage Treatment Understanding
8. Clarifier	8. Process Control Testing
9. Sludge Treatment	9. Process Flexibility
10. Aerator	10. Ultimate Sludge Disposal

In the Phase II results infiltration/inflow and ultimate sludge disposal ranked in the top ten in place of clarifier and sludge treatment. Eight factors were included in the top ten for both phases, however, the relative ranking of these factors varied from the first phase to the second. Operator application of concepts and testing to process control ranked first in both phases. Operator, as used here, represents the person or persons in responsible charge of process adjustments within the plant.

The most significant change between Phase I and Phase II results appears to be the high ranking of Infiltration/Inflow in Phase II. Infiltration/Inflow ranked only eighteenth in Phase I, but ranked second in Phase II. Probably the greatest factor influencing the higher ranking of I/I was that Phase II research was concentrated more in the eastern portion of the study area. In these states the collection systems were typically older and precipitation is significantly greater than in the states in the western portion of the study area.

For purposes of this report, the results from the Plant Evaluation Summaries for Phase I and for Phase II were combined for all fifty facilities at which comprehensive surveys were conducted. An average of thirteen and a range four to thirty performance-limiting factors were identified at individual facilities. As was concluded in the Phase I research effort, it is not believed that the actual ranking of individual factors is particularly important. The interrelationship among factors are believed more important, as well as the understanding that at least four performance limiting factors were identified at each facility studied, including those that met secondary treatment standards. The ranking of performance-limiting factors for all fifty facilities is shown in Table 3. Sixty-two of the 71 factors evaluated received at least one point in at least one plant.

The highest ranking factor limiting performance at facilities surveyed was inadequate operator application of concepts and testing to process control. This factor was identified in 48 of fifty facilities surveyed and was the leading cause of poor performance in fifteen facilities. Improper operator application of concepts was ranked when incorrect control adjustments and/or incorrect control test interpretation occurred. This factor was ranked number one in some facilities which had major design problems also. Thus, proper application of concepts required that an operator recognize when the plant design legitimately limited his capability to apply basic fundamentals of wastewater treatment to process control. At some plants, operator ingenuity was observed to overcome minor plant design limitations and 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 system.

The second highest ranking performance limiting factor was a general lack of sewage treatment understanding. This factor was identified in 28 of fifty facilities surveyed and was the leading cause of poor performance at six facilities. The two leading causes of poor plant performance, operator application of concepts and sewage treatment understanding, are similar, but differentiate between levels of operator abilities. Sewage treatment understanding refers to a lack of general knowledge concerning sewage treatment.

The high rankings of inadequate operator application of concepts and testing to process control and inadequate sewage treatment understanding indicate that present efforts toward accomplishing the goal of developing operators with desired capabilities are not being achieved. These findings suggest that a change may be necessary in the approach to operator development before significant improvement in plant performance will occur.

Improper technical guidance was the third highest ranking performance limiting factor occurring at 25 of the fifty plants surveyed and was the leading cause of poor performance in six facilities. Improper technical quidance

TABLE 3. RANKING OF FACTORS LIMITING PERFORMANCE FOR FIFTY COMPREHENSIVE 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 pt.	3 pt.	Total Points
1	D.3.a	Operator Application of Concepts and Testing to Process Control	48	15	17	14	17	96
2	D.1.c.	Sewage Treatment Understanding	28	6	11	7	10	55
3	D.3.b.	Technical Guidance	25	6	4	13	8	54
4	C.2.f.	Sludge Wasting Capability	26	4	10	7	9	51
5	D.2.b.	Process Control Testing	32	0	17	15	0	47
5	C.2.c.2.	Process Controllability	32	0	17	15	0	47
7	C.2.c.1.	Process Flexibility	24	3	9	9	6	45
8	C.2.c.3.	Aerator	17	4	5	6	6	35
8	C.1.f.	Infiltration/Inflow	24	1	17	3	4	35
10	C.2.c.4.	Clarifier (Secondary)	16	2	7	6	3	28
11	C.2.h.	Ultimate Sludge Disposal	19	1	14	2	3	27
12	C.2.g.	Sludge Treatment	19	0	14	5	0	24
13	A.1.b.	Familiarity with Plant Needs (Administrators)	11	1	4	5	2	20
14	D.2.a.	Performance Monitoring	16	0	14	2	0	18
15	A.1.a.	Policies (Administrators)	10	2	5	3	2	17
15	C.3.i.	Laboratory Space and Equipment	16	0	15	1	0	17
15	C.2.e.	Disinfection	11	0	6	4	1	17
18	A.2.a.2	Plant Converage	15	0	14	1	0	16
19	C.3.b.	Unit Process Layout	7	1	1	4	2	15
19	C.2.a.	Preliminary (Design)	15	0	15	0	0	15

(Continued)

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 pt.	3 pt.	Total Points
21	D.5.a.	Equipment Malfunction	8	1	4	3	1	13
21	C.2.f.	Alternate Power Source	13	0	13	0	0	13
21	C.3.e.	Alarms Systems	13	0	13	0	0	13
24	A.2.b.1.	Motivation (Operators)	12	0	12	0	0	12
24	A.2.a.1.	Number (Staff)	11	0	10	1	0	12
26	B.1.c.	Scheduling and Recording (Maintenance)	11	0	11	0	0	11
26	D.4.a.	Adequacy (O & M Manual)	10	0	9	1	0	11
26	A.2.c.	Productivity (Operators)	9	0	7	2	0	11
26	D.1.a.1.	Aptitude (Operators)	8	0	5	3	0	11
30	C.1.g.	Return Process Streams	7	1	5	1	1	10
30	D.1.b.2.	Training Operators	9	0	8	1	0	10
32	C.1.c.	Industrial (Loading)	6	1	4	1	1	9
32	A.3.a.	Insufficient Funding	9	0	9	0	0	9
32	B.1.a.	Housekeeping	8	0	7	1	0	9
32	A.2.b.2.	Pay (Operators)	7	0	5	2	0	9
36	C.3.1.	Plant Inoperability due to Weather	6	0	4	2	0	8
36	A.2.b.4.	Plant Esthetics	8	0	8	0	0	8
38	C.3.c.	Lack of Unit Bypass	7	0	7	0	0	7
38	C.3.d.3.	Flow Proportioning to Units	6	0	5	1	0	7
38	A.b.3.	Supervision	5	0	3	2	0	7
41	D.1.b.1.	Level of Certification	6	0	6	0	0	6

(Continued)

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 pt.	3 pt.	Total Points
41	B.1.b.	Equipment Age	6	0	6	0	0	6
41	D.1.d.	Insufficient Time on Job	5	0	4	1	0	6
41	B.2.a.	Lack of Program (Maintenance)	5	0	4	1	0	6
41	B.1.d.	Manpower (Maintenance)	5	0	4	1	0	6
41	A.2.b.5	Safe Working Conditions	4	0	2	2	0	6
47	A.3.b.	Unnecessary Expenditures	5	0	5	0	0	5
47	B.2.c.	Spare Parts Inventory	5	0	5	0	0	5
47	C.3.d.1.	Flow Backup	3	0	1	2	0	5
50	A.2.a.3.	Plant Management	2	1	1	0	1	4
50	C.3.a.	Plant Location	3	0	2	1	0	4
52	C.1.b.	Hydraulic (Loading)	3	0	3	0	0	3
53	C.1.d.	Toxic (Loading)	2	0	2	0	0	2
53	C.1.e.	Seasonal Variation (Loading)	2	0	2	0	0	2
53	C.3.j.	Process Accessibility for Sampling	2	0	2	0	0	2
53	C.3.h.	Lack of Stand-By Units for Key Equipment	2	0	2	0	0	2
53	C.3.g.2.	Process Automation Control	2	0	2	0	0	2
53	D.4.b.	O & M Manual, Use by Operators	2	0	2	0	0	2
59	C.3.m.	Quality of Equipment	1	0	1	0	0	1
59	D.1.a.2.	Level of Education	1	0	1	0	0	1
59	C.1.a.	Organic (Loading)	1	0	1	0	0	1
59	C.d.2.	Submerged Weirs	1	0	1	0	0	1

(Continued)

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 pt.	3 pt.	Total Points
59	A.2.d.	Personnel Turnover	1	0	1	0	0	1
64	A.3.c.	Bond Indebtedness	0	0	0	0	0	0
64	B.2.b.	References Available	0	0	0	0	0	0
64	B.3.a.	Staff Expertise (Emergency Maintenance)	0	0	0	0	0	0
64	B.3.b.	Critical Parts Procurement	0	0	0	0	0	0
64	B.3.c.	Technical Guidance (Emergency Maintenance)	0	0	0	0	0	0
64	C.2.b.	Unit Design Adequacy, Primary	0	0	0	0	0	0
64	C.3.g.1.	Process Automation, Monitoring	0	0	0	0	0	0
64	C.3.k.	Equipment Accessiblity for Maintenance	0	0	0	0	0	0
64	D.5.b.	Shift Staffing Adequacy	0	0	0	0	0	0

* A = Administrative, B = Maintenance, C = Design, D = Operations Factor

was strongly suspected in additional facilities, but was not documented as a problem unless the specific source of the misinformation was determined. Misinformation was provided by authoritative sources including design engineers, state and federal regulatory agency personnel, equipment suppliers, operator training staff and other plant operators. A detailed evaluation of each source of improper technical guidance was developed in the Phase I report (5).

A general observation that applies to each source 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. 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.

Another important aspect of the improper technical guidance factor is that it extends the source of poor plant performance beyond the plant operations staff. Authoritative sources have limited the capability of operators to attain adequate sewage treatment understanding by providing misinformation. Additionally, misinformation is harmful in that it sidetracks the search for a legitimate solution to a plant performance problem.

Inadequate sludge wasting capability was the fourth highest ranking factor and was documented in 26 facilities. Sludge wasting capability was rated as having a major impact on plant performance (i.e., 3 points) at nine facilities. Lower ratings of one or two points were assigned at seventeen facilities where waste capacity was marginal or sludge flow measurement and/or control were inadequate. Because of the high ranking of this factor, sludge production for small activated sludge plants is given special consideration in Section 8.

Inadequate Process Control Testing and inadequate Process Controllability tied for fifth among the performance limiting factors. Each was documented in 32 facilities, but neither was considered to have a major direct effect on plant performance (i.e., given 3 points) and neither was ranked as the number one performance limiting factor at any facility. Inadequate process control testing was never considered a leading cause of poor performance because it was usually interpreted as a secondary factor to an operator's ability to understand and/or apply treatment concepts to process control.

Inadequate control and measurement of return activated sludge flow was the most frequent reason for rating the process controllability factor. Only six of 36 activated sludge plants surveyed had both good measurement and control of return sludge flow rates. These findings indicate a general misunderstanding of the importance of return sludge flow control.

The seventh ranked factor limiting plant performance was inadequate process flexibility. Process flexibility is 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. Inadequate process flexibility limited performance at twenty-four plants surveyed and was the leading cause of poor performance at three facilities. At these three plants a dramatic improvement in plant effluent quality could have been achieved with improved process flexibility.

Deficient aerators and infiltration/inflow tied for the eighth and ninth ranking performance limiting factors. Aerator, as used in this evaluation, means the facility used 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. Performance limiting aerators were found in seventeen facilities surveyed and were the number one cause of limited performance in four facilities. Twelve of the seventeen facilities for which an indequate aerator was noted as a factor limiting performance were fixed film facilities, including trickling filters, rotating biological contactors and activated bio-filter systems. The other five facilities were activated sludge plants exhibiting a variety of aerator deficiencies. These included inadequate oxygen transfer capability, under-sized aeration basins and incomplete or inadequate separation of contact and reaeration compartment in contact stabilization plants.

Excessive I/I was documented to be a performance-limiting factor in twenty-four facilities surveyed. I/I caused short-term operating and performance problems in many facilities, but was not considered the most critical factor limiting performance relative to the numerous design and/or process control related factors which were observed to be causing serious performance problems on a continuous long-term basis. I/I problems remain as a periodic factor limiting plant performance and must continue to be addressed.

The tenth ranked factor was inadequately designed secondary clarifiers. Performance limiting clarifiers were documented in sixteen facilities, and were the most significant performance limiting factor in two facilities surveyed. 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. Clarifier design is discussed in greater detail in Section 8.

MISCELLANEOUS EVALUATIONS

Fixed Film Versus Suspended Growth Facilities

An evaluation was made of the major performance-limiting factors (received 2's or 3's) for the two general types of facilities surveyed: suspended growth and fixed film. Activated sludge facilities and all facilities using modifications of the conventional activated sludge process were classified as suspended growth facilities. Trickling filter, rotating biological contactor and activated bio-filter facilities were classified as fixed film facilities. For each plant type the percentages of performance limiting factors was determined for the categories of administration, maintenance, design and operation. The results of this evaluation are illustrated in Figure 3.

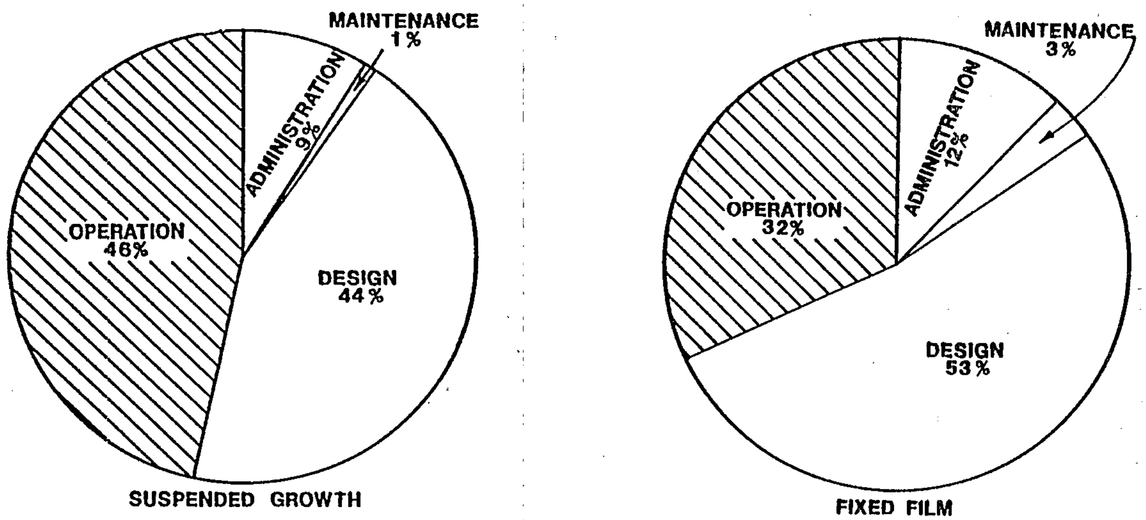


Figure 3. Categories of major performance-limiting factors.

At fixed film facilities the majority of performance limiting factors identified were design oriented. Within the design category, inadequate aerator capability occurred most often. Generally, fixed film facilities which had very low organic loadings consistently met standards. Those that had intermediate and higher loadings generally did not meet standards even with good operation. Approximately one third of the major factors limiting fixed film facility performance were operations oriented. Most prevalent among these was operator application of concepts and testing to process control. Operational changes could improve the performance of these facilities.

At suspended growth facilities, operations problems were more prevalent than design problems. Together these categories accounted for 90 percent of the factors identified. In the operations category, the factors of improper operator application of concepts, inadequate sewage treatment understanding and improper technical guidance were most common. Most common among the design problems were inadequate design for I/I, inadequate process flexibility and controllability, and inadequate design of sludge wasting and disposal facilities. Most design problems identified were closely related to providing process control capability. Inadequate operations understanding by designers and regulatory review personnel. These same persons were repeatedly identified as sources of improper technical guidance.

Maintenance factors received a low ranking for both suspended growth and fixed film facilities. This low ranking was expected since facilities with obvious poor maintenance were not selected for evaluation. Also, many operators possessed better maintenance than process control skills. Additionally, maintenance has been given priority since a maintenance problem is more obvious.

Performance versus Secondary Treatment Standards

An evaluation was made to determine if the facilities surveyed met secondary treatment standards as defined in CFR 38-159. A facility was considered to be meeting standards even with isolated violations of the limits for BOD_5 and TSS, if it was believed the violations were a legitimate exception to normal performance. For example, a facility that averaged 12 mg/l for effluent BOD_5 and 17 mg/l for effluent TSS for the year, but recorded monthly averages in the thirties for one or two months was considered to be meeting standards. On the other hand, a facility that produced an otherwise excellent effluent but bulked solids only two afternoons a week was not considered to be meeting standards.

Thirty-seven of the fifty facilities evaluated did not meet minimum secondary treatment standards even though the mean hydraulic loading for these plants was 66 percent of design flow. Apparently the ability of plants to meet secondary standards was not generally related to plant loading.

It should be noted that performance-limiting factors were identified in facilities that met standards since many of these facilities were not being operated at their optimum performance levels. In the thirteen plants that met standards consistently, an average of 2.8 major factors per plant were identified. In the 37 plants that did not meet standards consistently, an average of 5.2 major factors per plant were identified. The important observation was that a combination of factors existed in each plant.

The performance evaluation included an estimation of the improvement in effluent quality that could be achieved by eliminating all factors which would not require major capital expenditures. The results for individual facilities are included in Appendix H. The projected improvement would allow many facilities which are currently in violation to meet secondary standards. Individual facilities that meet secondary standards, facilities that could meet secondary standards without major capital improvements and facilities that would likely require major capital improvements to meet secondary standards are identified in Table 4.

Thirty-seven of fifty plants surveyed did not meet secondary standards. Of these, 27 were limited primarily by factors that could be eliminated by addressing administration, maintenance and process control problems. These 27 plants could potentially meet secondary standards without a major design and construction effort. Ten facilities would require a major plant expansion to meet secondary standards. Most of these would also require improved operations. This evaluation indicated that performance could be improved significantly at existing treatment facilities.

TABLE 4. PERFORMANCE EVALUATION OF 50 COMPREHENSIVE SURVEY FACILITIES

Plant No.	Date	Plant Type***	Actual Flow cu m/day	Actual Flow mgd	Actual Flow % Design	Secondary Treatment Standards Met	Secondary Treatment Standards Not Met (Operation)	Secondary Treatment Standards Not Met (Design & Operation)
002	1975	ASEA	1,628	0.43	54		X	
007	1976	ODEA	155	0.041	59		X	
012	1976	TF/CS	30,660	8.1	68			X
013	1976	AS	1,892	0.5	63		X	
014	1976	AS	3,785	1.0	50		X	
015	1976	TF	6,434	1.7	47			X
019	1976	ASEA	132	0.035	54		X	
020	1976	ASEA	26	0.007	28		X	
021	1976	ODEA	2,233	0.59	66	X		
022	1976	ASEA	45	0.012	80		X	
024	1976	ABF	18,550	4.9	69			X
026	1976	ASEA	568	0.15	30	X		
027	1976	AS	20,820	5.5	55		X	
028	1976	ASCS	568	0.15	60		X	
029	1976	AS	5,185	1.37	78		X	
032	1976	TF	833	0.22	50			X
034	1976	TF	20,820	5.5	68			X
035	1976	TF	20,060	5.3	98	X		
036	1976	TF	6,056	1.6	87	X		
038	1978	AS	11,880	3.14	70		X	
039	1976	ODEA	795	0.21	51		X	
040	1976	RBC	1,438	0.38	60			X
041	1977	TF	492	0.13	33	X		
047	1976	ASEA	189	0.05	80		X	
048	1976	AS	1,287	0.34	89		X	
050	1977	ASEA	643	0.17	96		X	
051	1977	ASEA	795	0.21	75			X
052	1977	ASEA	170	0.045	60	X		
053	1977	ASEA	416	0.11	68		X	
055	1977	ASEA	1,136	0.30	52	X		
060	1977	ABF	1,855	0.49	47			X
061	1977	ASCS	643	0.17	34		X	
062	1977	ODEA	757	0.20	59		X	
063	1977	AS	2,650	0.7	47	X		
065	1977	ASCS	492	0.13	87		X	
066	1977	AS(2)	2,687	0.71	76	X		
068	1978	AS	20,440	5.4	98		X	
069	1978	TF	303	0.08	114		X	
070	1978	TF	4,164	1.10	101	X		
074	1978	AS	1,136	0.30	86		X	
075	1978	AS	21,950	5.8	64	X		
077	1978	AS	908	0.24	78		X	
080	1978	AS	946	0.25	60	X		
082	1978	ASCS/TF	314	0.083	69		X	
085	1978	ODAS	3,179	0.84	86		X	
086	1978	ASEA	1,817	0.48	48		X	
092	1978	AS	11,910	3.12	57	X		
093	1978	RBC	8,327	2.2	44			X
095	1978	TF	4,542	2.1	48			X
097	1978	ASCS	3,179	0.84	84		X	

*Standards not met primarily because of operations oriented problems which would not require major capital expenditures to correct.

**Standards not met because of facility limitations that would require a major designed plant expansion to correct.

***ASEA = Activated Sludge Extended Aeration; ODEA = Oxidation Ditch extended Aeration; TF = Trickling Filter; CS = Contact Stabilization; AS = Activated Sludge; ABF = Activated Biofilter; RBC = Rotating Biological Contactor.

Operations Costs

An evaluation was made of the operational costs for wastewater treatment. Cost information for individual facilities is shown in Appendix G. The average for each cost category is shown in Figure 4. All costs to the user are included except general taxes which are paid to state and federal governments and partially returned in the form of grants for construction. These costs were not identifiable. Costs shown include capital investments paid directly by the city or sanitation district, primarily bond debt retirement. Two-fifths of the total 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 administration policies, construction grant funding opportunities, plant age, bond interest rates, etc. Capital improvement cost therefore are not included in the following cost comparisons.

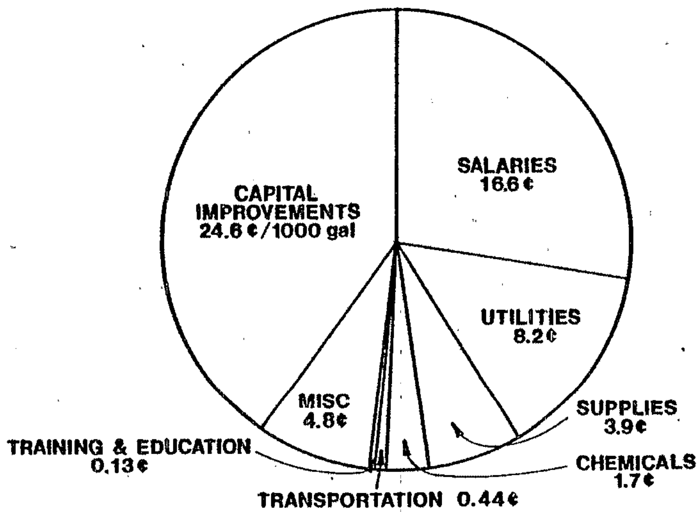


Figure 4. Average costs for wastewater treatment in fifty facilities surveyed.

A summary of cost information for various types and sizes of facilities is shown in Table 5. Salaries accounted for the greater share of the costs at facilities surveyed; training and education of staff members accounted for the smallest portion. Costs varied so significantly from plant to plant that a general increase for inflation was not recognizable over the 2-1/2 year data collection period.

Figure 5 illustrates the range and the overall O & M costs for different types and sizes of facilities surveyed. The average cost per unit of flow was greater for smaller facilities than for larger facilities; the average O & M cost for suspended growth facilities was more than for fixed film facilities. However, fixed film facilities have historically had higher capital costs than suspended growth facilities. In addition, of the ten facilities which could not meet secondary treatment standards without major capital improvements nine were fixed film facilities. Of the fixed film facilities, only trickling

TABLE 5. SUMMARY OF COST INFORMATION BY TYPE AND SIZE OF FACILITY

	Suspended Growth			Fixed Film		
Number of Facilities	7*	22*	7	1	4	9*
Size Range (mgd)**	0–0.1	0.1–1.0	1.0–10.0	0–0.1	0.1–1.0	1.0–10.0
Salary (¢/k gal)***	39.3	15.6	12.9	27.4	17.0	6.4
Utilities (¢/k gal)	15.1	11.1	5.0	2.9	4.8	1.9
Supplies (¢/k gal)	10.5	3.1	2.8	0.3	6.9	1.1
Chemicals (¢/k gal)	2.3	1.3	1.7	2.2	4.3	1.2
Transportation (¢/k gal)	0.2	0.7	0.3	0.3	0.4	0.2
Training and Education (¢/k gal)	0.02	0.2	0.05	0.1	0.2	0.05
Miscellaneous****(¢/k gal)	15.8	5.1	1.5	0.5	0.6	1.3
Total – O & M Costs (¢/k gal)	83.3	37.2	24.1	33.7	34.2	12.0

* One plant not included in cost summary; information not available.
** mgd x 3785 = cu m/day
*** ¢/k gal x 0.264 = ¢/m^3
**** This category includes costs such as testing by private laboratories, repair services, plant insurance, computer service and consulting services.

filters which were loaded conservatively were found to meet standards consistently. This suggests that even larger construction costs may be required for fixed film facilities to meet standards with an acceptable degree of reliability.

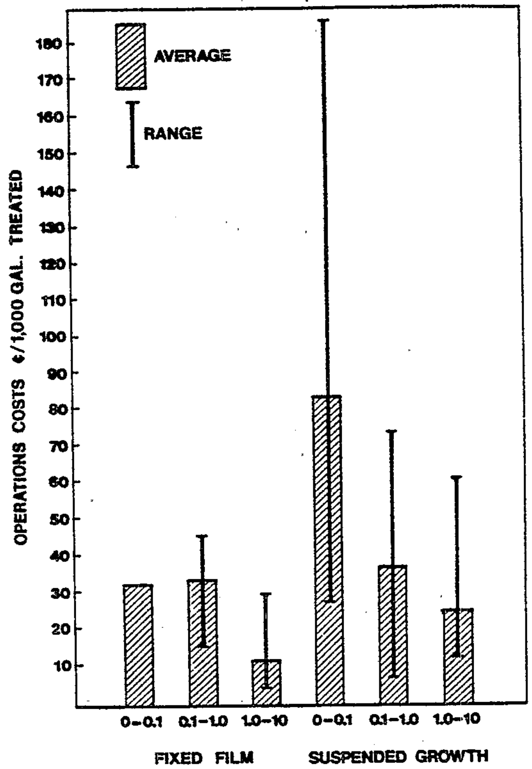


Figure 5. Plant operations costs for major plant types and selected flow ranges (¢/1000 gal x 0.264 = ¢/cu m).

Nine of 36 suspended growth facilities studied met secondary standards. All but one of these facilities could meet standards without major construction expenditures if administration, maintenance, operation and minor design limitations were properly addressed. The overall cost of treatment for these plants, if all were brought within compliance, would be greater than the costs presented in Figure 5. The reason for this increase in O & M cost would primarily be increased sludge handling. Presently, these solids are lost in the final effluent.

Electrical Energy

Electrical energy consumption was evaluated, although at some facilities the condition of records and the availability of city personnel time was not conducive to obtaining the desired information. Electrical usage data for individual plants is presented in Table 6. The unit cost of electrical power varied from 1.17¢/kwh to 6.13¢/kwh, including power demand and power factor charges. Power costs varied considerably from one geographic location to another. Data was collected over a period of 2-1/2 years and there appeared to be some cost increase from the first to last plants surveyed. Power costs averaged 2.43¢/kwh for Phase I and 3.06¢/kwh for Phase II. The increase is

TABLE 6. POWER USAGE FOR 50 COMPREHENSIVE SURVEY FACILITIES

Plant No.	Date	Plant Type	Actual Flow cu m/day	mgd	% Design	KWH/1000 gal*	¢/KWH	¢/1000 gal **
002	1975	ASEA	1,628	0.43	54	3.0	1.53	4.6
007	1976	ODEA	155	0.041	59	3.2	3.06	9.8
012	1976	TF/CS	30,660	8.1	68	0.83	2.28	1.9
013	1976	AS	1,892	0.5	63	2.7	2.23	6.0
014	1976	AS	3,785	1.0	50	2.4	1.89	4.5
015	1976	TF	6,434	1.7	47	1.0	1.50	1.5
019	1976	ASEA	132	0.035	54	4.3	2.20	9.5
020	1976	ASEA	26	0.007	28	-	-	-
021	1976	ODEA	2,233	0.59	66	0.87	3.54	3.1
022	1976	ASEA	45	0.012	80	-	-	-
024	1976	ABF	18,550	4.9	69	0.43	1.37	0.6
026	1976	ASEA	568	0.15	30	-	-	-
027	1976	AS	20,820	5.5	55	1.3	1.26	1.6
028	1976	ASCS	568	0.15	60	2.1	2.49	5.2
029	1976	AS	5,185	1.37	78	2.7	1.17	3.2
032	1976	TF	833	0.22	50	0.40	3.28	1.3
034	1976	TF	20,820	5.5	68	-	-	-
035	1976	TF	20,060	5.3	98	0.52	1.96	1.0
036	1976	TF	6,056	1.6	87	0.61	2.36	1.4
038	1978	AS	11,880	3.14	70	1.3	2.15	2.9
039	1976	ODEA	795	0.21	51	2.3	3.85	8.9
040	1976	RBC	1,438	0.38	60	0.72	1.51	1.1
041	1977	TF	492	0.13	33	1.1	2.87	3.2
047	1976	ASEA	189	0.05	80	3.1	3.24	10.0
048	1976	AS	1,287	0.34	89	4.3	2.56	11.0
050	1977	ASEA	643	0.17	96	2.7	3.58	9.7
051	1977	ASEA	795	0.21	75	2.6	2.64	7.0
052	1977	ASEA	170	0.045	60	7.1	3.40	24.3
053	1977	ASEA	416	0.11	68	4.2	2.96	12.4
055	1977	ASEA	1,136	0.30	52	-	-	-
060	1977	ABF	1,855	0.49	47	2.3	3.31	7.6
061	1977	ASCS	643	0.17	34	5.8	2.35	13.6
062	1977	ODEA	757	0.20	59	2.8	3.68	10.5
063	1977	AS	2,650	0.7	47	-	-	-
065	1977	ASCS	492	0.13	87	2.6	2.00	5.3
066	1977	AS(2)	2,687	0.71	76	3.2	3.44	11.1
068	1978	AS	20,440	5.4	98	-	-	-
069	1978	TF	303	0.08	114	0.50	6.13	3.1
070	1978	TF	4,164	1.10	101	0.45	2.45	1.1
074	1978	AS	1,136	0.30	86	11.7	2.73	31.9
075	1978	AS	21,950	5.8	64	2.4	2.71	3.2
077	1978	AS	908	0.24	78	2.9	3.75	10.8
080	1978	AS	946	0.25	60	0.97	2.00	2.0
082	1978	ASCS/TF	314	0.083	69	3.3	4.20	13.7
085	1978	ODAS	3,179	0.84	86	1.1	2.09	2.4
086	1978	ASEA	1,817	0.48	48	3.2	2.44	7.8
092	1978	AS	11,910	3.12	57	-	-	-
093	1978	RBC	8,327	2.2	44	0.81	2.00	1.7
095	1978	TF	4,542	2.1	48	1.0	3.47	3.6
097	1978	ASCS	3,179	0.84	84	1.3	3.71	4.5

*KWH/1000 gal X 0.264 = KWH/m^3
**¢/1000 gal X 0.264 = ¢/m^3

believed to be due to both inflation and the geographic location of plants studied.

A more meaningful comparison of energy costs was made using kilowatt hours per thousand gallons of wastewater treated. In this analysis the energy usage was independent of survey dates or local unit energy costs and more dependent on such things as plant loading relative to design or the type of aeration used. Electrical energy consumption varied from a low of 0.1 kwh/cu m (0.4 kwh/1000 gal) in several fixed film facilities to a high of 3.1 kwh/cu m (11.7 kwh/1000 gal) in a recently constructed plant using a modification of the activated sludge process. Suspended growth facilities averaged 0.84 kwh/cu m (3.2 kwh/1000 gal) treated and fixed film facilities averaged 0.22 kwh/cu m (0.82 kwh/1000 gal) treated. The potential energy savings of many fixed film facilities are reflected in these energy requirements. However, the initial investment may be higher for these facilities because of the apparent need for a more conservative design.

Staffing Considerations

In the Phase I research effort a considerable effort was made to correlate plants displaying good performance with a single or group of common parameters. Plant costs, operator certification, operator manpower, operator aptitude and aerator loadings were evaluated. The only correlation which appeared to have significance was aerator loading. Aerator loadings are discussed in Section 8 as a topic of special consideration. Other evaluations were expanded to include information from Phase II plants and are presented here.

An analysis of staffing costs 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 7 presents a summary of staff size and cost for each of the fifty plants. 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.

Table 7 shows three selected units costs to present staffing information on a common basis. Large differences existed in calculated unit costs. The specific staff size ranged from 0.2 my/1000 cu m/day to 9.8 my/1000 cu m/day (0.8 to 37 my/mgd). The adjusted staff salary cost ranged from $8,700/my to $19,300/my. The specific staff cost ranged from 0.74 ¢/cu m to 26¢/cu m (2.8¢/1000 gal to 98¢/1000 gal).

Staff size, staffing costs, and total operations cost were given special consideration by graphically plotting the selected parmeter against plant flow rates. Staff size versus plant flow rate is presented in Figure 6. Each data point represents a plant surveyed. Those plants that met secondary standards consistently are depicted with shaded dots; plants that did not meet standards are depicted with open circles. Large variations in the number of staff persons were observed for any given flow range. For example, for the seven plants whose actual flow ranged from 760 cu m/day (0.2 mgd) to 1140 cu m/day

TABLE 7. STAFF SIZE AND COST FOR 50 COMPREHENSIVE SURVEY FACILITIES

							Budget		Unit Relationships		
Plant No.	Date	Plant Type	Actual Flow cu m/day	Actual Flow mgd	Actual Flow % Design	Staff Man-Years	Staffing Costs	% of Operations Budget	Specific Staff Size*	Adjusted Salary**	Specific Staff Cost***
002	1975	ASEA	1,628	0.43	54	3.0	28,685	28	7.0	9,500	18
007	1976	ODEA	155	0.041	59	0.30	3,540	17	7.3	11,800	24
012	1976	TF/CS	30,660	8.1	68	12	189,970	64	1.5	15,800	6.4
013	1976	AS	1,892	0.5	63	0.5	34,164	43	6.0	11,400	19
014	1976	AS	3,785	1.0	50	5.0	50,000	50	5.0	10,000	14
015	1976	TF	6,434	1.7	47	3.0	30,312	43	1.8	10,100	4.9
019	1976	ASEA	132	0.035	54	0.6	5,191	23	17	8,700	41
020	1976	ASEA	26	0.007	28	0.26	2,500	53	37	9,600	98
021	1976	ODEA	2,233	0.59	66	1.5	17,878	37	2.5	11,900	8.2
022	1976	ASEA	45	0.012	80	0.3	3,600(est)	50(est)	25	12,000	82
024	1976	ABF	18,550	4.9	69	7.3	84,141	40	1.5	11,500	4.7
026	1976	ASEA	568	0.15	30	1.6	18,186	57	11	11,400	33
027	1976	AS	20,820	5.5	55	7.5	118,782	43	1.4	15,800	5.9
028	1976	ASCS	568	0.15	60	0.88	9,610	42	5.9	10,900	18
029	1976	AS	5,185	1.37	78	4.0	51,732	47	2.9	12,900	10
032	1976	TF	833	0.22	50	0.35	3,780	30	1.6	10,800	4.7
034	1976	TF	20,820	5.5	68	7.0	87,917	50	1.3	12,600	4.4
035	1976	TF	20,060	5.3	98	4.2	54,162	52	0.8	12,900	2.8
036	1976	TF	6,056	1.6	87	3.8	49,746	59	1.5	13,100	5.5
038	1978	AS	11,880	3.14	70	7.0	96,368	65	2.2	13,800	8.4
039	1976	ODEA	795	0.21	51	1.0	10,000	25	4.8	10,000	13
040	1976	RBC	1,438	0.38	60	1.3	13,316	55	3.4	10,200	9.6
041	1977	TF	492	0.13	33	1.5	15,755	57	12	10,500	33
047	1976	ASEA	189	0.05	80	0.30	3,132	60	6.0	10,400	17
048	1976	AS	1,287	0.34	89	1.9	18,470	45	5.6	9,700	15
050	1977	ASEA	643	0.17	96	0.57	7,717	30	3.4	13,500	12
051	1977	ASEA	795	0.21	75	0.60	6,200	46	2.9	10,300	8.1
052	1977	ASEA	170	0.045	60	0.50	4,951	40	11	9,900	30
053	1977	ASEA	416	0.11	68	0.73	13,400	65	6.6	18,500	33
055	1977	ASEA	1,136	0.30	52	0.50	4,992	19	1.7	10,000	4.6
060	1977	ABF	1,855	0.49	47	3.0	36,500	45	6.1	12,200	20
061	1977	ASCS	643	0.17	34	0.80	10,296	31	4.7	12,900	17
062	1977	ODEA	757	0.20	59	0.43	5,300	38	2.2	12,200	7.3
063	1977	AS	2,650	0.7	47	4.0	57,148	66	5.7	14,300	22
065	1977	ASCS	492	0.13	87	0.55	6,900	61	4.2	12,500	14
066	1977	AS(2)	2,687	0.71	76	2.8	39,060	33	3.9	14,000	15
068	1978	AS	20,440	5.4	98	14.0	245,000	67	2.6	17,500	12
069	1978	TF	303	0.08	114	0.5	7,987	81	6.2	16,000	27
070	1978	TF	4,164	1.10	101	2.8	38,633	64	2.5	14,000	9.6
074	1978	AS	1,136	0.30	86	1.8	34,700	43	6.0	19,300	32
075	1978	AS	21,950	5.8	64	11.8	137,500	41	2.0	11,700	6.5
077	1978	AS	908	0.24	78	0.43	3,800	23	1.8	8,800	4.3
080	1978	AS	946	0.25	60	0.49	4,260	60	2.0	8,700	4.7
082	1978	ASCS/TF	314	0.083	69	0.75	8,100	53	9.0	10,800	27
085	1978	ODAS	3,179	0.84	86	2.3	25,831	56	2.7	11,200	8.4
086	1978	ASEA	1,817	0.48	48	1.6	18,880	46	3.3	11,400	11
092	1978	AS	11,910	3.12	57	26	373,700	54	8.3	14,400	33
093	1978	RBC	8,327	2.2	44	3.7	41,600	44	1.7	11,200	5.2
095	1978	TF	4,542	2.1	48	3.8	42,800	52	3.2	11,300	9.8
097	1978	ASCS	3,179	0.84	84	4.0	74,900	66	4.8	18,700	24

* Specific staff size – man years per mgd x 0.264 = my/1000 cu m/day
** Adjusted salary cost – $ per man year
*** Specific staff cost – ¢ per 1000 gallons treated x 0.264 = ¢/cu m

(0.3 mgd), the total number of man-years used to operate the facilities varied from 0.35 to 1.8. If a large staff size was a prerequisite for good performance, then a majority of shaded dots should be above the line of best fit. This was not the case. A large staff does not necessarily promote good plant performance.

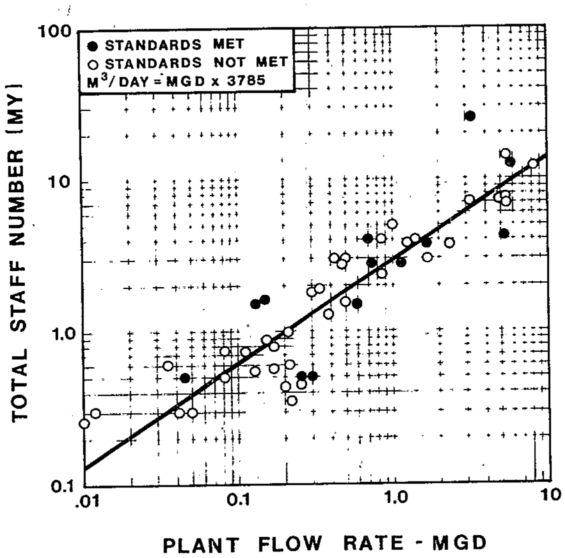


Figure 6. Correlation of total staff size with performance.

A similar evaluation was made to determine if higher salaries correlated with good performance by attracting more highly qualified personnel. Figure 7 shows the relationship between staff salary and plant flow rate. Staff salary includes base pay plus fringe benefits. Part time salaries were developed on a basis of one man for one year. Salaries within a narrow range varied considerably from plant to plant throughout the range of plant sizes studied. A positive correlation between higher staff salaries and good plant performance would be indicated by a significant fraction of the shaded does above the line of best fit. Eight of the thirteen plants which met standards were operated by personnel with below average salaries indicating no positive correlation between higher salaries and good performance. It was observed that persons with more ability and potential were needed at many facilities. However, securing a more qualified operator by offering a higher salary did not by _itself_ appear to promote better performance.

Total plant operations costs were evaluated to determine if a positive correlation existed with good performance. This data is presented in Figure 8. Plants which met standards were dispersed throughout the data points. Facilities with high total operations budgets did not meet standards with any more consistency than did facilities with lower budgets. Clearly, improved treatment plant performance was not indicated by higher operating budgets.

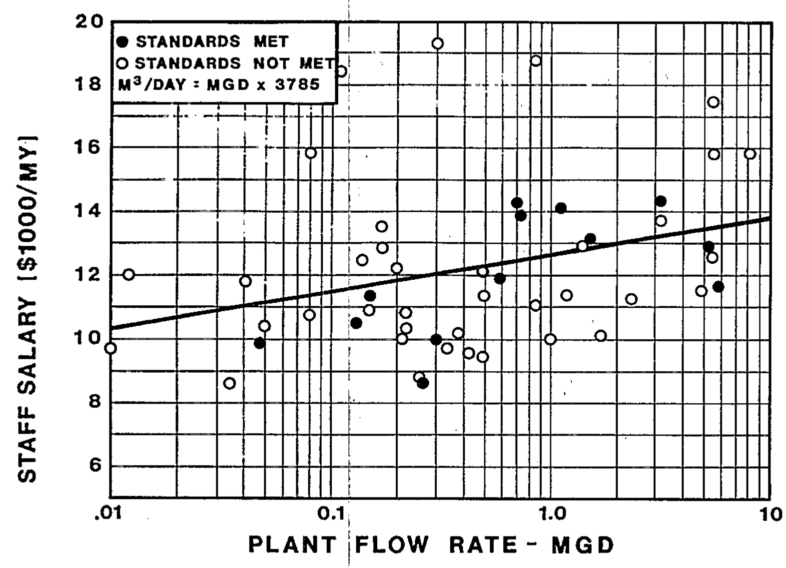


Figure 7. Correlation of salaries with performance.

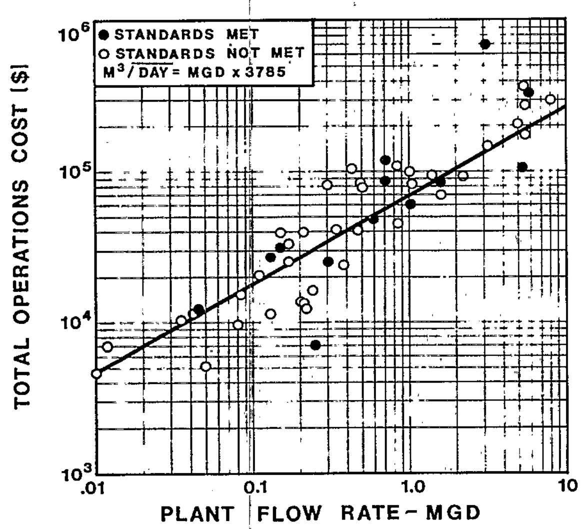


Figure 8. Correlation of total operations costs with performance.

Operator Certification

The relationship between operator certification and plant performance i summarized in Table 8. "A" is the highest certification rating and "D" is th lowest. In some states a Class I through Class IV rating system was used ar an appropriate conversion to the "A" through "D" system was necessary.

TABLE 8. CORRELATION OF OPERATOR CERTIFICATION WITH PERFORMANCE

Certification Class of Chief Operator	Number of Facilities Surveyed	Secondary Treatment Standards		
		Met	Violated	% Met
"A"	15	6	9	40
"B"	10	4	6	40
"C"	9	1	8	11
"D"	9	1	8	11
None	7	1	6	14

In fifteen of the fifty facilities, the chief operator had an "A" certification. Six of those facilities met secondary treatment standards. Ten facilities had "B" operators and four met secondary standards. Nine facilities had "C" operators, nine had "D" and seven facilities were operated by operators who were not certified at all. One plant in each of these categories met secondary standards.

Forty percent of the facilities which had "A" and "B" certified operators were found to be meetng secondary effluent standards. This was a higher percentage than for other facilities, but significantly less than desired. It was concluded that certification programs promote better plant performance, but do not singularly qualify persons to produce a high percentage of compliance.

SUMMARY

Identification of the causes of limited wastewater treatment plant performance in fifty facilities showed that no facilities were limited by a single factor. Each facility, even those meeting secondary treatment requirements were limited by several factors which affected the achievement of optimum performance. In addition to multiple factors, each facility had a combination of problems which were unique to that facility. The evaluation of specific items normally believed to be major problem/solution areas (i.e. staffing, certification, operations budgets, operator salaries, etc.) did not lead to positive correlations with good performance. The ranking and evaluation of the most critical performance-limiting factors for all plants did not provide a clear approach to improving the performance of existing facilities. However, the high ranking of improper technical guidance provided by design engineers, equipment suppliers, regulatory agency personnel and other operator trainers, along with the high ranking of many process control oriented design features, indicates the problem stems from a much broader base than with just local plant administrators and operators. The findings clearly indicate the need for an alternative to the conventional efforts for improving biological wastewater treatment plant performance.

SECTION 6

THE UNIFIED CONCEPT

To better describe the plant performance problem a "Unified Concept for Achieving Optimum Plant Performance" was presented in the Phase I report (5). The concept was used to describe the interrelationships among the factors limiting performance and the programs implemented to address these factors. From the understanding provided by the concept, a recommended approach (i.e. Composite Correction Program) for addressing a specific facility's performance problem was developed. The Unified Concept will be used in this report to explain the differences in the problem areas that existed in site-visit plants versus the comprehensive evaluation plants. A discussion regarding implementation of the Composite Correction Program is also presented.

The Unified Concept for Achieving Optimum Plant Performance is illustrated in Figure 9. As shown, the goal is to obtain optimum performance from a given treatment plant. The horizontal line represents a given plant's position with respect to optimum performance. Factors limiting performance tend to move the plant further away from the goal. The number of performance limiting factors is indicated by the number of arrows pointing downward. The relative severity of the various problems is indicated by the length of the downward arrows. A large number of factors and/or a few severe factors would cause a facility to be far removed from optimum performance. Finally, the length of the horizontal line represents the degree of less than optimum performance.

The elimination of factors through use of a correction program would tend to move a plant's position closer toward optimum performance as indicated by the arrows pointing upward. The term correction program is used to describe any public or private activity; national, regional or local in scope that eliminates the effects of adverse factors. The length and number of upward arrows indicates the number and relative

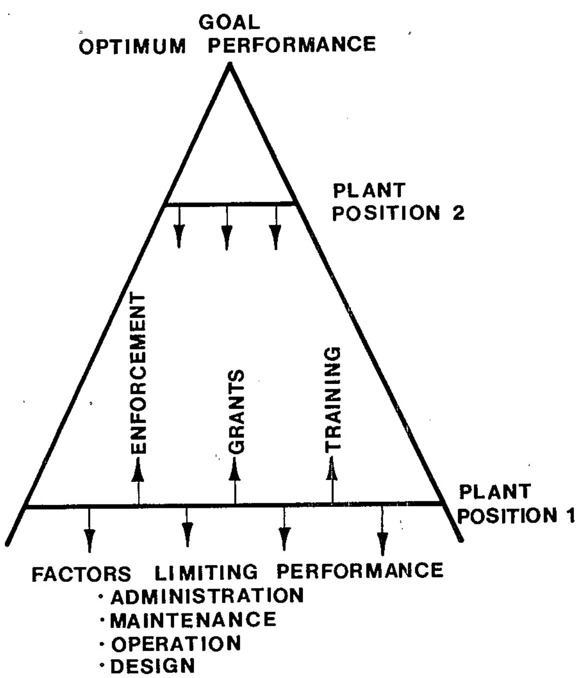


Figure 9. The unified concept for achieving optimum plant performance.

influence of correction programs applied to a given treatment facility. Correction programs are many and varied, probably because the performance limiting factors are so diverse. As factors limiting performance are corrected, the plant's position moves closer toward optimum performance and the length of the horizontal line becomes shorter, indicating a better performance level.

To achieve the desired performance goal, all of the factors limiting performance must be addressed.

INDIVIDUAL CORRECTION PROGRAMS

A popular approach to improving plant performance has been to develop programs with the purpose of addressing performance-limiting factors or groups of factors at a large number of facilities. Three example programs of this type are the construction grants program, the NPDES permit enforcement program, and the operator training program. 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 all municipal 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 programs focus on specific factors or groups of factors limiting performance at many treatment facilities. Because of this emphasis these programs have been labelled Individual Correction Programs to point out the emphasis on individual factors the programs are intended to address.

Since PL 92-500 was enacted in 1972 the major emphasis 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, most facilitites are not performing well (1,2,5). One of the reasons for only moderate success of these programs is the manner in which they have been implemented. Most 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 <u>specific</u> facility must be eliminated before that facility wil achieve optimum performance. Individual Correction Programs cannot address the unique combination of performance limiting factors at an individual plant.

The role of Individual Correction Program in the Unified Concept theory is demonstrated using an example. Consider a facility with two major and other minor factors limiting performance. Assume the major factors are hydraulic overload due to a large volume of inflow, and improper operator application of concepts and testing to process control. With these two major factors limiting performance the plant could be far removed from optimum performance at Plant Position 1 as shown in Figure 9. Using a construction grant (Individual Correction Program), a holding pond could be constructed to equalize peak storm flows and thus address the hydraulic overload problem. However, the construction grant and associated activities may not address the operator application of concepts and testing to process control factor. This factor then becomes prominent in the facility's ability to achieve desired performance. This example facility would then be at Plant Position 2 as shown in Figure 9.

This example illustrates why many upgraded facilities have not achieved desired performance. Individual Correction Programs do not eliminate all the factors limiting performance at a particular facility. 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. It should be recognized, however, that programs of this type are limited in their ability directly to achieve optimum performance at an individual plant.

COMPOSITE CORRECTION PROGRAM

An approach called a Composite Correction Program (CCP) was developed during the Phase I effort. The objective of this approach was to identify and eliminate all the factors which limit performance at a specified plant. This qpproach is illustrated in Figure 10. As shown, all factors at an individual plant are systematically identified and eliminated and the plant achieves the goal of optimum performance (Position 2).

A CCP can only be completed when desired changes are implemented to achieve optimum performance at a particular facility. Therefore, it can be concluded that an overall improvement in effluent quality must occur if CCP's are properly implemented on a broad scale. Broad scale implementation of CCP's is limited by the availability of qualified personnel to direct such programs. This conclusion is supported by the high ranking of the improper technical guidance factor which was discussed earlier.

The achievement of improved performance through the CCP approach may lag significantly behind the elimination of performance-limiting factors. For example, in a facility in which fifteen factors are identified, eight or ten may have to be eliminated before a measureable improvement in effluent quality is achieved. If only six factors are eliminated and no further work is pursued, the effort could be judged fruitless even though each individual effort to eliminate a problem may have been exactly correct. Because incremental improvement in effluent quality does not typically occur with the elimination of each factor, the plant administrative staff may

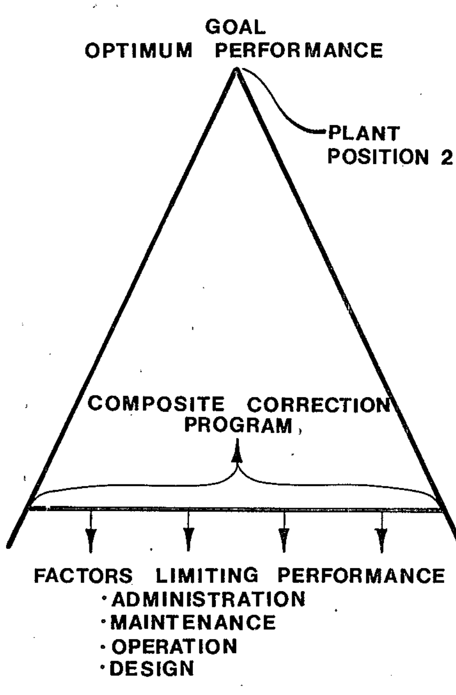


Figure 10. The role of the composite correction program (CCP) in the unified concept.

misinterpret or falsely judge the value of the accomplishments and prematurely stop the program. A similar situation exists in assessing the value of Individual Correction Programs and accounts for some of the confusion concerning the value of these programs.

The lack of incremental improvement in effluent quality may make it difficult for plant administrators to distinguish between the misdirected efforts of unqualified personnel and the appropriate efforts of qualified personnel. When improvement in performance does not occur, unqualified technical personnel may falsely claim that desired performance cannot be achieved unless other factors are addressed. Many administrative personnel are not in a position to evaluate the technical merit of the recommendations made. However, CCP implementation should be able to overcome this difficulty because the objective is to provide a desired plant performance level in the most economical manner. Both the performance and cost aspect of this objective can be measured, therefore providing a straightforward endpoint that can be evaluated. If measureable progress is not achieved, the plant administration should not abandon the concept of the CCP approach, but should consider continuing the program with other persons. In so doing, the improper technical guidance factor noted during this research can be eliminated since only successful personnel will be able to continue in business.

UNIFIED CONCEPT - SITE VISIT VERSUS COMPREHENSIVE EVALUATIONS

During plant selection, facilities that were totally inoperable, excessively overloaded and/or inadequately staffed, were excluded from further study. Performance limiting factors were identified at facilities in which a site visit only (1/2 day visit) was made and facilities for which a comprehensive evaluation (4-7 days) was completed. The results from these plant visits were different as discussed in Section 5 of this report. In general, the site visit plants had more design and maintenance problems and the comprehensive evaluation plants had more operational problems. Two reasons are given for the difference in these results. Many site visit plants which had design and/or maintenance problems were excluded from a comprehensive evaluation, thus performance-limiting factors for site visit facilities were more heavily weighted toward these problems. Secondly, the site visit plants were not extensively evaluated and only the more obvious problems were observed. The more obvious problems were typically design and maintenance oriented.

The site visit facility problems were de-emphasized relative to the discussion of performance-limiting factors for plants in which a comprehensive evaluation was completed. Yet, the major design, maintenance and other severe problems that existed at the site visit facilities are important. However, these problems reflect a different level or magnitude of factors limiting performance. To describe these different levels of problems a modification of the Unified Concept was developed as shown in Figure 11.

Major performance-limiting factors contribute to a facility that is considered inoperable as depicted Figure 11. Many of the site visit plants which were excluded from further research were at the position 1 level with major I/I problems, extensive overload problems, staffing problems and or equipment inoperability problems. These types of factors had been corrected at the comprehensive evaluation facilities. The plants where comprehensive evaluations were conducted were considered to be operable facilities and located at position 2 in Figure 11. The application of better process control (operation) procedures would have allowed these plants to achieve the goal indicated, which is a good quality, economically produced effluent. Indeed, major design, maintenance and other severe problems must be addressed to obtain an operable plant. Then, as plants achieve "operable" status the problems documented by this research will become more paramount in the plant's inability to achieve a desired level of performance. In this manner the Unified Concept can be used to describe the relative position, with respect to optimum performance, of the problems documented for the site visit facilities and the comprehensive evaluation plants described in this report.

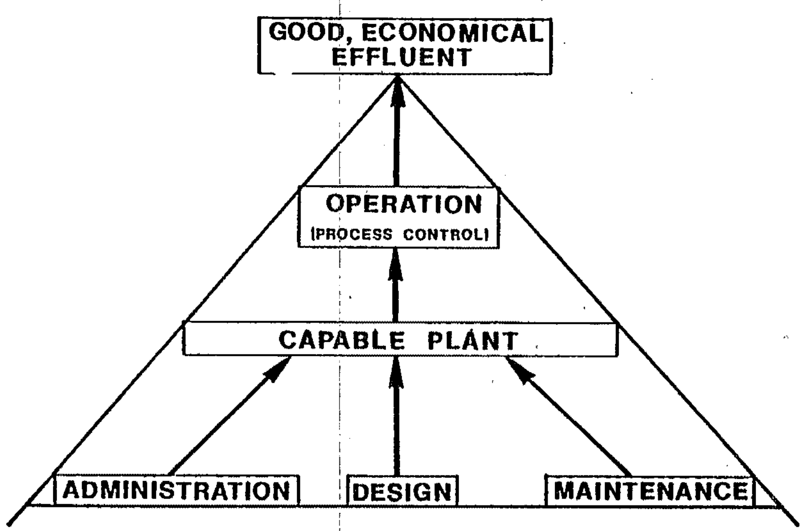


Figure 11. A relationship of major types of performance-limiting factors.

IMPLEMENTATION OF A COMPOSITE CORRECTION PROGRAM

The approach that should be taken for implementing a CCP is best illustrated in Figure 11. As shown, the step between an operable facility and a good economical plant effluent (optimum performance) is plant operation (i.e. process control). It is from the process control position that a determination must be made as to whether the plant performance problem is due to improper operations or due to an inoperable plant. If the problem is operations, process control is improved and desired performance is achieved. If the problem is with an inoperable plant, then recommendations for corrective action must be provided and implemented.

An example approach to implementing a CCP will be discussed. Initially, a plant is assumed to be operable and process control procedures are initiated to attempt to improve performance. If problems arise in the design, maintenance and/or administration areas, an effect on process control occurs and recommendations to eliminate the effect are implemented. Assume that the CCP reaches an impasse in terms of improving performance because the plant is found to be organically overloaded. In this case the plant is not operable because as it exists it cannot properly treat the wastewater. Conduct of the CCP would require completion of construction to allow the plant to become operable. After construction CCP activities could continue until the desired performance level was achieved. The important aspects from this example are that the CCP was continued until the performance objective was reached, and an Individual Correction Program (i.e. plant construction) was not abandoned but effectively utilized. To accomplish the steps outlined in this example the CCP implementor must not only have expertise in plant operation, but also must be knowledgeable in design, administration and maintenace aspects of plant performance.

During Phase I (4,5) it was established that CCP's must be implemented over a long period of time to: determine if the problem is with operations or with an inoperable facility; be compatible with the time required for biological system response (i.e. months); and transfer the ability to maintain a desired performance level to the plant staff.

From an independent contractor basis, the long time frame can best be utilized by periods of on-site involvement where the consultant assumes the responsibility for major aspects of process control and periods of off-site non-involvement when the plant staff must re-assume this role. This approach is graphically illustrated in Figure 12.

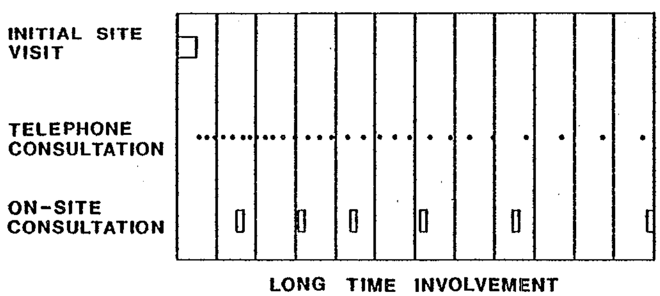


Figure 12. Implementation of a CCP.

During the initial consultation period, the consultant becomes well-aquainted with facilities, personnel, operations procedures and other items that influence process control. A common testing procedure is established to serve as a basis for communication to recommend and implement changes in plant operations. Apparent factors limiting performance are identified and appropriate corrective actions are recommended and implemented. Plant specific operator training is initiated by explaining process control strategies and requirements. Finally, a basis is established to implement on-going consultation activities.

The on-going consultation activities spans the long time involvement required. Periodic site visits are completed to verify benefits of changes made, establish priorities for other possible changes, enhance operator training, and identify and implement corrective action to solve other plant performance limiting factors that typically evolve. Additionally, telephone consultation is used so that the consultant can stay abreast of plant operation status, recommend process control modifications, identify optimum times for site visits, and provide guidance so that as more and more of the process control responsibility can be transferred to plant personnel.

Reporting is used to provide sketches for minor plant modifications, provide data for budget and staffing plans, provide information for regulatory agencies and describe project status. A final report is prepared to describe the plant status, document project results and define plant capabilities. It is not intended that reporting be used to recommend actions. Actions are intended to be completed as the CCP progresses.

Benefits of a properly implemented CCP include: technical consultant accountablity since action on recommendations are part of the CCP; long-time involvement is achieved yet the client costs are minimized because the technical consultant is not working at the facility 100 percent of the time, yet is involved and accountable 100 percent of the time; operator training is enhanced because it is directed to the achievement of better process control and performance at the operator's plant; process control capability is transferred to plant personnel; slow biological system response is addressed through long-time involvement; the program is action oriented not report oriented and the objective of good performance is established and pursued until it is achieved.

During both Phases of the research effort, six CCP's were implemented. However, the primary objective of the research effort was to document performance-limiting factors and not the conduct of CCP's. As such, a modified level of effort was expended in the conduct of the CCP's. The results obtained from the CCP's that were implemented are discussed in the next section of this report.

SECTION 7

COMPOSITE CORRECTION PROGRAM DEMONSTRATIONS

The CCP approach was demonstrated and documented at Plants 029 and 050 during Phase I (4,5). The resources necessary to achieve successful CCP demonstrations during Phase II were limited due to budget constraints and the original research objectives. However, because of the potential applicability of the CCP approach on a national basis, further demonstrations were felt to be necessary. Therefore, five wastewater treatment plants were selected to demonstrate the CCP approach when implemented at a level of effort compatible with the EPA research contract.

The comprehensive evaluations involved in-plant operations assistance similar to that requied in a typical CCP. Therefore, when surveys were initiated, most plants were considered to be potential candidates for demonstrations. The potential of each plant was evaluated based on the nature of the performance-limiting problems determined. The resources available for implementing CCPs were limited to the initial one-week on-site involvement and to follow-up telephone consultation and data analysis assistance. In one case, a half-day return visit was possible because of other work in the same vicinity. This level of effort is typically substantially less than required to satisfactorily implement the CCP approach. As such, plants selected usually had adequate staffing and basically operable facilities. Another important criteria was the plant administrator's and staff's willingness to work with the research personnel. This support was necessary because in several facilities increases in manpower and minor design modifications were required to show improved performance. In one of the plants where improved performance was achieved, this effluent quality was not expected to continue for an indefinite length of time because of inadequate sludge handling capacity. Many facilities evaluated were not selected even though a large potential for improvement was identified. At these facilities a CCP was applicalbe but more time and effort than was available would have been required to gain the confidence and support of the plant personnel and administrators.

In the remainder of this section, the results of the five CCP demonstrations that were implemented during Phase II are presented. Also, a discussion is included on the potential for improved performance at all fifty facilities.

CCP AT PLANT 086

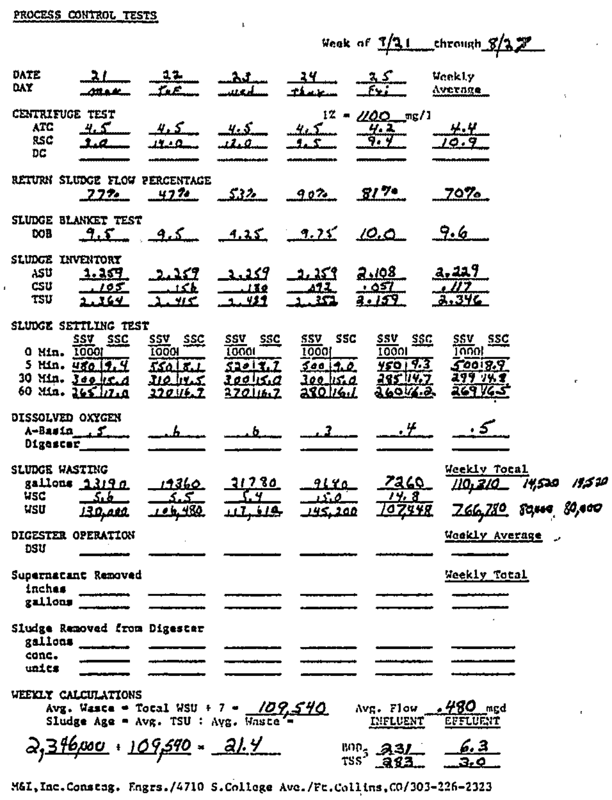
Plant 086 is a newly constructed, extended aeration activated sludge facility designed for an average flow of 3785 cu m/day (1.0 mgd). Actual flow recieved during the last eight months of 1978 was 1700 cu m/day (0.46 mgd). Wastewater is mostly domestic in nature with some light industrial and commercial wastes. On occasions, storm water inflow substantially increases wastewater flow to several times the daily average. This problem was addressed in design by preserving an existing lagoon for excess storm water treatment. At the time of the evaluation and follow-up work, the plant was receiving about three-fourths the design organic loading. Only one of two aeration basins was in operation and aeration basin loading was approximately 224 gm/day/cu m (14 lb/day/1000 ft^3). Both clarifiers were loaded at about 8 cu m/day/sq m (190 gal/day/sq ft).

Prior to the comprehensive survey, effluent quality periodically violated permit requirements. The reason for poor effluent quality was limited sludge wasting which resulted in poor sludge character and periodic, excessive solids loss from the final clarifiers. The superintendent had requested help from the city engineer and from the state regulatory agency in establishing a sludge wasting program. The superintendent had been referred to technical publications which he felt were of little help. Additionally, the superintendent had quit attending training courses because he could not get help with the problems at his facility.

Plant 086 was chosen for a CCP demonstration because the operator was very supportive, the city administrators were actively interested, and design limitations of the facility were not critical at current loadings. Finally, it was anticipated that significantly improved plant performance could be demonstrated.

CCP Implementation

The CCP was initiated in conjunction with the in-plant comprehensive evaluation. The superintendent's previous concern for establishing a sludge wasting program coincided very closely with the process needs of the plant. Process control equipment, testing procedures and calculations were demonstrated as an integral part of the initial activities. By the end of the week the plant staff were wasting a desired mass of sludge. Survey recommendations were used to inform the plant administrators of the accomplishments of the week and to obtain support for purchasing equipment needed to continue the process control program. The results of process control tests were sent to the contractor on a weekly basis on a sheet that was provided (Figure 13.) Assistance in making process control decisions was provided by telephone for a 10-month period following the initial survey.



PROCESS CONTROL TESTS

Week of 7/21 through 8/27

DATE	21	22	23	24	25	Weekly
DAY	mon	tue	wed	thur	Fri	Average
CENTRIFUGE TEST (1% = 1100 mg/l)						
ATC	4.5	4.5	4.5	4.5	4.2	4.4
RSC	9.0	11.0	12.0	9.5	9.4	10.9
DC						
RETURN SLUDGE FLOW PERCENTAGE	77%	47%	53%	90%	81%	70%
SLUDGE BLANKET TEST DOB	9.5	9.5	9.25	9.75	10.0	9.6
SLUDGE INVENTORY						
ASU	2.259	2.259	2.259	2.259	2.108	2.229
CSU	.105	.156	.130	.093	.051	.117
TSU	2.364	2.415	2.489	2.352	2.159	2.346

SLUDGE SETTLING TEST

	SSV	SSC	SSV	SSC	SSV	SSC	SSV	SSC	SSV	SSC	SSV	SSC
0 Min.	1000		1000		1000		1000		1000		1000	
5 Min.	480	9.4	550	8.1	520	8.7	500	9.0	450	9.3	500	8.9
30 Min.	300	15.0	310	14.5	300	15.0	300	15.0	285	14.7	299	14.8
60 Min.	265	17.0	270	16.7	270	16.7	280	16.1	260	16.2	269	16.5

DISSOLVED OXYGEN						
A-Basin	.5	.6	.6	.3	.4	.5
Digester						
SLUDGE WASTING						Weekly Total
gallons	23190	19360	21780	9680	7260	110,210 14,520 19,520
WSC	5.6	5.5	5.4	15.0	14.8	
WSU	130,000	106,480	117,612	145,200	107,448	766,780 80,000 80,000
DIGESTER OPERATION						Weekly Average
DSU						
Supernatant Removed						Weekly Total
inches						
gallons						
Sludge Removed from Digester						
gallons						
conc.						
units						

WEEKLY CALCULATIONS

Avg. Waste = Total WSU ÷ 7 = 109,540 Avg. Flow .480 mgd

Sludge Age = Avg. TSU ÷ Avg. Waste =

2,346,000 ÷ 109,540 = 21.4

	INFLUENT	EFFLUENT
BOD_5	231	6.3
TSS	283	3.0

M&I,Inc.Consltg. Engrs./4710 S.College Ave./Ft.Collins,CO/303-226-2323

Figure 13. Process control summary sheet used at Plant 086.

Site visits which are normally a part of a CCP were not possible within the scope of the research effort.

Factors Limiting Performance

The obvious factor limiting performance of Plant 086 was the inability to apply concepts of process control. This limitation was addressed by implementing a process control program. Through documentation developed during the survey week and by explaining how testing fit into the process control program, the mayor, city administrator, and a councilman agree to provide the needed testing equipment. With proper testing equipment and guidance in making process control decisions, activated sludge mass control was no longer a significant problem. The factors that limited performance included: improper operator application of concepts and testing to process control, improper technical guidance and inadequate process control testing. Each of these factors was addressed.

As process control was implemented design related problems became apparent. Among these were inadequte process controlability and inadequate sludge wasting capability. Process contollability was limited by return sludge flow rate control. No return sludge flow measurement was provided, and control adjustments in the desired range resulted in unacceptable variations and plugging. It was determined that a constant, higher return sludge flow rate would be acceptable, although not optimum. If site visits had been possible, the advantages of closer return sludge flow control could have been evaluated further and techniques for improving adjustments of return sludge flow may have been successfully applied to the problem.

Inadequate sludge wasting capability was a another design related factor identified during the survey. No waste sludge flow measurement was provided with the plant and the waste sludge flow rate had to be estimated using the drawndown rate in a final clarifier. Although not convenient, this method worked adequately for present plant loadings. A greater problem contributing to inadequate sludge wasting capability was the limited size of the sludge lagoons. These were the only sludge handling facilities provided. Design documents made no mention of additional ultimate sludge disposal methods.

Following the initial evlauation good effluent quality was maintained. Very good documentation of sludge wasting requirements was also developed indicating that an average of 251 kg (553 lb) of sludge was wasted per day (approximately 7400 gpd). Since no method of removing supernatant or sludge from the lagoons had been provided, it was estimated that this wasting rate would completely fill both lagoons in less than a year. To avoid a serious sludge handling problem, the superintendent, with the help of research personnel, convinced the city administrators of the need to obtain a sludge truck so sludge could be removed from the lagoons on a periodic basis. The state agreed to reopen the city's contruction grant and provide the needed truck. Thus, a major performance-limiting, design-oriented factor was eliminated. Other problems may limit sludge wasting capability, such as inadequate manpower to operate the truck, production of odors from the sludge storage lagoons or inadequate land available for ultimate sludge disposal. If these problems occur they must also be identified and corrected if good performance is expected to continue.

Other factors which were determined to limit plant performance to a lesser extent were inhibitory industrial wastes and infiltration/inflow. Slug loads of inhibitory wastes had been received periodically and had degraded effluent quality. The superintendent had isolated the probable source and was waiting to obtain a sample for identification and verification of the source of the problem.

Infiltration/inflow continues to be a minor problem on a periodic basis. The I/I problem requires that faster settling sludge which is more easily contained and controlled during high I/I flows be maintained in late winter in preparation for spring rains and runoff. Daily flows as high as 9800 cu m (2.6 mg) have been treated successfully in the plant by maintaining faster settling sludge. The sacrifice is a 5 to 10 mg/l increase in effluent TSS and BOD_5 on a continuous basis while the faster settling sludge is maintained. This slight degradation will be necessary every year during high potential I/I flow periods, and will be a continuing factor limiting plant performance.

Performance

Performance of Plant 086 improved dramatically. Plant 086's recorded effluent results for the time prior to the CCP did not reflect excessive solids loss that was known to occur. Therefore, actual effluent quality was estimated. Recorded and estimated effluent TSS and BOD_5 concentrations are presented in Figure 14. The amount of TSS lost due to the uncontrolled mass prior to the CCP was estimated by determining the amount of activated sludge wasted after good process control and associated sludge wasting had been implemented. This value was compared with the amount of sludge wasted previously. Typically the amount of BOD_5 lost during excessive solids loss is less than the amount of TSS lost. During comprehensive surveys at five plants, separate samples were collected during observed solids-loss periods, and these samples were analyzed for BOD_5 and TSS concentrations. The average BOD_5 to TSS ratio for these samples was 0.5. This ratio was used to estimated the average BOD_5 concentration prior to the CCP. Estimated effluent BOD_5 and TSS concentrations before initiation of the CCP were 90 mg/l and 150 mg/l, respectively. For the remaining eight months of 1978, excessive solids loss did not occur and recorded results are

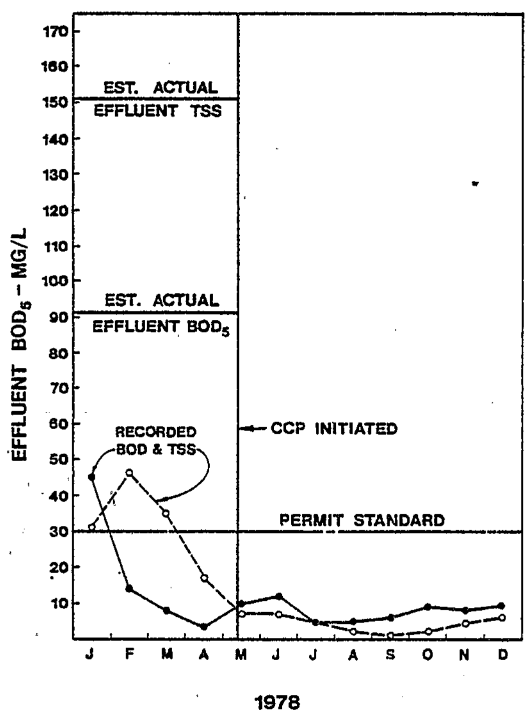


Figure 14. Effluent BOD_5 and TSS at Plant 086.

believed to accurately reflect effluent quality. During this period, BOD_5 averaged 7.8 mg/l, and TSS averaged 3.9 mg/l.

Discussion

The CCP demonstration at Plant 086 was highly successful because of the nature of the most important performance-limiting problems and because of enthusiastic involvement of city personnel throughout the project. Although paid below average, the plant superintendent possessed above average aptitude. Atributes which were of particular value were his ability to learn to implement process control concepts and his ability to work with and solicit support from the city administration. When a superintendent involved with a CCP does not excell in these qualities, site visits are necessary for both training of in-plant personnel and for increasing administrators' familiarity with plant needs.

CCP AT PLANT 065

Plant 065 is a contact stabilization activated sludge plant with aerobic sludge digestion, and ultimate sludge disposal by land application. Design flow is 568 cu m/day (0.15 mgd), and wastewater flow during 1978 averaged 454 cu m/day (0.12 mgd), or 80 percent of design. The plant received primarily domestic wastes; however, several slugs of inhibitory petroleum wastes were received during the year. Wastewater strength in 1978 averaged 208 mg/l and 190 mg/l for BOD_5 and TSS respectively resulting in an organic loading on the aeration basin (contact and reaeration) of 464 mg/day/cu m (29 lb/day/1000 ft^3). The final clarifier is operating at a surface settling rate of 21 cu m/day/sq m (512 gal/day/sq ft).

CCP Implementation

The comprehensive survey provided time to initiate CCP activities at Plant 065. Plant 065 was basically an operable facility in that all required processes were provided in the plant design, and all necessary equipment was operable. The operator expressed a sincere desire to improve his operation and made signifiant improvements during the survey week. Initial efforts were directed at operator training in process control. Nearly all necessary testing equipment was available at the plant. Equipment which was not initially available, was obtained during or shortly after the initial survey. Process control testing, calculations and trend graphs were initiated on a daily basis.

As a portion of the CCP activities process control results were sent to research personnel on a bi-weekly basis. Telephone consultation was used extensively over a one-year period. Additionally, a half-day site visit was possible because of other related work in the area.

Most of the effort within the CCP was directed at improving the operator's ability to apply the basic concepts of plant operation and process control. The operator had been performing nearly all necesary testing and operations tasks prior to the initiation of CCP activities. However, test results were not used properly to make process control decisions. A new process control program was established to maintain the total sludge inventory at preselected levels chosen to produce desired sludge characteristics. Additionally, the operator was taught how to adjust the return sludge flow rate to obtain optimum distribution of sludge.

Factors Limiting Performance

The most important performance-limiting factor was improper operator application of concepts and testing to process control. Neither return activated sludge flow control nor activated sludge mass control had been applied correctly at the plant. The return rate had been maintained at a high level (over 150 percent), which contributed to excessive solids loss over the clarifier weirs as well as poor sludge distribution within the plant. Sludge mass control was completely inadequate in that only a small fraction of the sludge produced was intentionally wasted to the aerobic digester. The remainder was discharged in the plant effluent during peak flows of the day. In addition, partially digested sludge was frequently returned to the reaeration basin via the digester supernating mechanism.

The problem of improper operator application of concepts was compounded through improper technical guidance from the state district engineer and the town's consulting engineer. The state engineer had recommended that specific MLSS values be maintained in the contact and reaeration basins because "it looked like the best treatment achieved in the past had occurred at those values." Because of the long time associated with changing sludge characteristics, such cause and effect assumptions are almost always incorrect. The town's consulting engineer was preparing a facilities plan before and during the period that the CCP activities were implemented. A requirement for grant funding is to consider optimizing operation of existing facilities. Yet, very little was being done in the plant to meet this requirement.

Initiation of the new process control program resulted in the identification of several secondary factors limiting plant performance. The aerobic digester was shown to be too small to provide adequate stabilization and volume reduction of sludge prior to land application. Also, available land for sludge application was inaccessible for long periods due to inclement weather or crop conditions. Finally, the plant operator was expected to help with other city utilities which did not allow the time required for sludge disposal tasks. Typically, when secondary factors such as these begin limiting a plant's perfromance, a site visit is conducted to explain the situation and alternatives to plant administrators. This was not possible and the operator was forced to work alone with plant administrators that had been convinced that they needed a new plant. Consequently, their general attitude was to do as little as necessary with the existing facilities. After several months of discussion, the operator succeeded in getting approval to haul sludge to a more distant site owned by the town. Prior to this approval, some relief occurred in the sludge handling situation from a modification that was made in the source of waste sludge. A minor modification allowing wasting from the return sludge line resulted in a desired mass of sludge being wasted with less volume.

Another secondary performance limiting factor was uncovered when optimum distribution of sludge was attempted within the system. It was discovered that the steel wall between the contact and reaeration basins was designed to be movable and that it allowed significant leakage to occur between the two basins. As a result, the return sludge concentration was substantially higher than the reaeration basin concentration due to back mixing of the mixed liquor from the contact basin area into the reaeration basin. The result was inadequate sludge distribution control and a plant which was operating somewhere between the contact stabilization and conventional activated sludge modes. As such, a loading condition existed which was not characteristic of either process mode. Modifications to seal the wall or provide piping for operation as conventional activated sludge could have improved controllability of the plant at very little cost; however, because of the attitude of the administration, no steps were taken to improve this situation.

Slug discharges of a petroleum product were received at the plant periodically throughout the last several months of the CCP. A deterioration of effluent quality at this time was believed to be caused by the repeated oil discharges. The operator had found the probable source by the end of the CCP and intended to work with those responsible to eliminate the problem.

Performance

As a result of the CCP, substantially improved performance resulted. However, several factors continued to limit plant performance and prevented standards from being met consistently. Quantitative measure of improved performance could not be determined since prior to the CCP, samples were not collected during periods of excessive solids loss. Estimates of effluent TSS and BOD_5 quality were made based on actual sludge production documented during the CCP and estimates of previous wasting. This approach was similar to that outlined at Plant 086. Effluent BOD_5 and TSS before the CCP were estimated to be 70 mg/l and 140 mg/l, respectively. While the CCP was in progress, effluent BOD_5 averaged 29 mg/l and effluent TSS averaged 15 mg/l.

Discussion

The major objectives of the CCP were to optimize plant performance and to transfer the capability to the operator to maintain this performance. Significant improvement in performance and the operator's process understanding and control capabilities were achieved. However, sludge character was never completely controlled at an optimum. The unavailability of resources to conduct required site visits contributed to this partial success. Normally site visits are made when observations or results do not follow the expected pattern. Additionally, the lack of support of the plant administrators encouraged by the apparent need of a new facility hindered the success of this CCP.

CCP AT PLANT 074

Plant 074 is a newly constructed activated sludge plant. Effluent from the plant is discharged to two aerated lagoons, a non-aerated polishing pond and a chlorine contact basin. The plant was designed for an average flow of 1320 cu m/day (0.35 mgd), and a peak hydraulic flow of 5700 cu m/day

(1.5 mgd). The facility is designed such that wastewater volume in excess of the activated sludge plant's capabilities can be automatically directed to the aerated lagoons. Waste sludge from the activated sludge plant is discharged to the aerated lagoons. Plant 074 receives wastewater from a single, significant industrial waste producer, a cannery. The plant is operated by a plant superintendent, an operator, and a third city employee who checks the plant on some weekends. The plant superintendent has the highest grade certification in the state, is active in the state pollution control association and attends short courses and operator schools.

CCP Implementation

During the comprehensive survey, alternative process control tests and calculations were demonstrated. By the end of the survey plant personnel decided to implement the test procedures, calculations and data evaluation methods. Thus a good basis was developed for communication between research and plant personnel. A weekly operations report was prepared as a method of maintaining communication. Process control decisions were discussed by telephone. This type of assistance was provided for a 7-month period.

Factors Limiting Performance

Several design and operations oriented factors significantly limited the performance of Plant 074. The design oriented problems were quite critical and could not be addressed within the scope of the CCP, however, it was believed that the potential for improved performance could be demonstrated by addressing the operations oriented factors.

The most obvious operations oriented problem was improper operator application of concepts and testing to process control. At the time of the survey, the operator was trying to build the MLSS concentration to a previously obtained level of about 7000 mg/l - 8000 mg/l. However, the MLSS could not be raised above about 2500 mg/l due to solids loss over the final clarifier weirs. Intentional wasting had been discontinued, and the return sludge flow rate had been increased in attempts to build the MLSS concentration. This strategy failed, and the entire sludge mass was "dumped" to eliminate the filamentous organisms that were thought to be dominant in the system. The sludge mass had been rebuilt to the 2500 mg/l level when the survey was initiated. The superintendent had planned to dump the sludge mass a second time and disinfect the entire system. However, during the initial survey several changes were made and the operator was convinced to look at other alternatives. The major changes were: implementing a more complete sludge monitoring program; reducing the return sludge flow rate; wasting daily to control the sludge inventory and sludge mass was increased more slowly to allow sludge character to develop with the changing sludge inventory.

A design oriented problem was the method of ultimate sludge disposal. The plant was designed so that the final effluent passes through two aerated lagoons. Additionally, sludge wasted from the activated sludge plant was designed to be discharged from the return sludge line to the aerated lagoons. Disposing of sludge in this manner will eventually degrade the final effluent as more and more sludge builds up in the lagoons. During the CCP, very good sludge production data was compiled. It was documented that 0.82 kg of sludge was produced in the activated sludge plant for every 1.0 kg of BOD_5 removed by the activated sludge plant. At design BOD_5 loading this would result in the production of 500 kg (1100 lb) of sludge per day to be discharged to the lagoons.

Process Flexibility was also a critical design factor in that no flexibility existed to bypass the aerated polishing lagoons. The activated sludge plant, when operated properly, produced a higher quality effluent than was often attainable from the lagoons. In fact, repeated effluent violations occurred because of extensive algal growth in the lagoons. Presently, only secondary treatment is required, however, the wasteload allocation plan developed for the river indicated that nitrification will also be required. Ammonia concentrations from the ponds will be almost impossible to control, whereas almost complete nitrification has been documented in the activated sludge plant. The ability to discharge clarifier effluent through the lagoon when desired would still be a valuable operational tool during mechanical breakdown or periods of poor sludge character, but the present inability to bypass the ponds is felt to be a serious limitation.

A third factor which could limit plant performance in the future is the design organic loading on the aerator of 1300 gm BOD_5/cu m/day (81 lb $BOD_5/1000\ ft^3$/day). This is an extremely high loading at which to retain control of sludge settling characteristics. Presently, wastewater strength has been considerably less than design at about 500 gm BOD_5/cu m/day (31 lb $BOD_5/1000\ ft^3$/day).

Performance

The objective of the CCP demonstration was to demonstrate the potential improved performance that could be achieved if design modifications would have been included in the CCP. Demonstrated improved effluent quality would require the addition of a pond bypass. Effluent quality for the 22-week period during which the CCP was implemented is presented in Table 9. This data shows that the activated sludge plant can produce considerably better effluent quality than the ponds . Clarifier effluent BOD_5, TSS and ammonia were all less than half the corresponding values for pond effluent.

Discussion

At Plant 074 important performance-limiting factors were eliminated, specifically, inadequate operator application of concepts and testing to process control and improper technical guidance. However, another major factor, inadequate process flexibility to bypass the ponds, was not addressed. Using the "Unified Concept" present in Section 6, the position of Plant 074 would have been a considerable distance away from the goal of optimum performance, because several major design factors existed as well as operations factors. Elimination of the operations factors moved Plant 074's position closer to the goal of optimum performance. However, plant effluent quality was not improved. Regardless of how well the mechanical plant is operated, the final plant effluent quality will not improve until the major design factors are addressed.

TABLE 9. SECONDARY CLARIFIER AND FINAL EFFLUENT QUALITIES FOR PLANT 074

Week 1978	Clarifier Effluent BOD_5 (mg/l)	Clarifier Effluent TSS (mg/l)	Clarifier Effluent NH_3 (mg/l)	Final Effluent BOD_5 (mg/l)	Final Effluent TSS (mg/l)	Final Effluent NH_3 (mg/l)
6/25 - 7/1	10	30	--	43	46	--
7/2 - 7/8	17	17	--	43	55	--
7/9 - 7/15	10	15	--	24	52	--
7/16 - 7/22	--	19	--	--	51	--
7/27 - 7/29	--	14	--	17	41	--
7/30 - 8/5	10	12	--	12	46	--
8/13 - 8/19	8	11	--	9	32	--
8/20 - 8/26	11	9	--	17	39	--
8/27 - 9/2	7	8	0.0	--	30	0.0
9/3 - 9/9	12	17	0.0	32	49	0.2
9/10 - 9/16	6	11	0.0	23	36	0.2
9/17 - 9/23	8	18	0.0	26	28	0.4
9/24 - 9/30	5	13	0.0	15	28	0.0
10/1 - 10/7	5	19	0.0	14	25	0.0
10/8 - 10/14	6	18	0.0	14	30	0.0
10/15- 10/21	11	23	0.0	15	31	0.0
10/22- 10/28	8	16	0.5	14	29	0.8
10/29- 11/4	8	16	0.8	14	29	1.2
11/4 - 11/11	8	16	0.9	14	30	1.5
11/12- 11/18	7	12	0.5	12	33	1.9
11/19- 11/25	6	13	0.8	11	33	2.3
Average	8.5	16	0.3	20	38	0.7

This example points out the importance of addressing all performance-limiting factors when conducting a CCP. In the case of Plant 074 additional requirements of the CCP would have been to make the plant administrators aware of the needed improvements for the treatment facility and to gain their support to complete the required modifications.

CCP AT PLANT 097

Plant 097 is a contact stabilization activated sludge facility designed to treat an average daily flow of 3785 cu m (1 mgd). Recent wastewater flow has averaged 1890 cu m/day (0.5 mgd). The present organic loading on the contact and reaeration tanks is approximately 350 g/day/cu m (22 lb/day/-1000 cu ft). Based on daily average plant flows, the surface settling rate on the clarifier is 13 cu m/day/sq m (315 gal/day/sq ft). Sufficient capacity exists to easily treat the design flow if process control is practiced. Chlorine disinfection facilities are provided but not utilized since current state regulations do not require disinfection. Stabilization of wasted sludge occurs in an aerobic digester, and a combination gravity/pressure filter is used for concentration of digested sludge prior to ultimate disposal.

Historical records on effluent quality indicated that standards were met in most cases; however, occasional violations were documented. Inspection of the receiving stream revealed significant deposits of sludge. According to plant personnel, periodic infiltration/inflow caused hydraulic overloading of the secondary process to the point where substantial solids washout occurred. It was felt that conducting a CCP would result in improvement in maintaining a high quality effluent.

CCP Implementation

During the initial survey the plant director provided most of the information. However, additional information was obtained through conversations with the plant operators. It became apparent during the evaluation that some conflicts existed among the plant staff. The city had recently hired a new plant director creating ill feelings among existing personnel. However, since the director's appointment, some needed improvements had occurred at the plant; consequently, the city's decision to change the staffing situation appeared to be beneficial. However, the plant personnel problems became more paramount as the CCP progressed.

Several potential areas existed where plant performance could be improved, including process control for the activated sludge and aerobic digester systems. An alternative control method was introduced, and the plant staff was trained in this new approach. Operation of the sludge dewatering equipment was also investigated and potential areas for cost savings became apparent. Continued operational assistance was discussed with the plant director who agreed that continued operational assistance would be beneficial. Assistance was continued through monitoring process control records and telephone consultation.

Factors Limiting Performance

Several changes were implemented with respect to process control of the activated sludge and aerobic digester systems. Prior to the survey, sludge was wasted from the return sludge line on a daily basis for a selected period of time. With the implementation of a controlled sludge inventory, a selected mass of sludge was wasted each day by measuring the waste sludge concentration and volume.

Operation of the aerobic digester was also modified. Supernatant was removed from the digester on a regular basis; however, the digester basin level would always equalize with the aeration basin level within a few hours. Through the assistance of the plant design engineer, it was determined that an open valve existed between these two basins. To allow independent operation of the digester and aeration basin, this valve was permanently closed. The digester was then operated in the draw-and-fill mode. Supernatant was pumped from the digester to the aeration basin on a daily basis, and the digester concentraion gradually increased to approximately twice the original level. The draw-andfill operation also affected sludge dewatering. Prior to the survey the sludge dewatering equipment had been operated on an almost day-to-day basis, requiring a significant amount of operator time and expenditures for sludge conditioning chemicals. Once normal digester operation was established, operation of the dewatering equipment was decreased to one to two times per week, substantially reducing sludge handling cost.

As the CCP effort progressed, other factors began to limit performance. Previously, the digester was actually operated as part of the aeration system. By closing the valve the sludge mass in the activated sludge system was reduced approximately 40 percent. This sudden change in system mass induced a change to poorer settling sludge The poorer concentration sludge caused the sludge blanket level in the final clarifier to increase. An attempt was made to return to desired characteristics by maintaining close process control. A problem developed with respect to sludge distribution among the contact, reaeration and clarifier basins. An opening was provided to allow the reaeration basin sludge to enter the contact tank. However, mixing occurred in both directions thus diluting the reaeration basin contents and making mass distribution control difficult. To effectively change sludge characteristics, an overflow gate was needed between the contact and reaeration basins. This minor design change was discussed with the plant director, but no progress was made. The director was more concerned about the blanket level in the clarifier. It is noted that the sludge blanket level had never been measured prior to the CCP. A scum layer, which had developed on the final clarifier, was also a serious concern of the director since the plant was being considered for a state award. Site visits would have been required to discuss these items with the director and to continue the CCP activities in an effective manner.

Performance

During the two-month CCP effort BOD_5 and TSS concentrations in the effluent averaged 8 mg/l and 4 mg/l, respectively. The recorded respective BOD_5 and TSS levels for a 7-month period prior to the survey averaged 26 mg/l and 38 mg/l. However, these concentrations were suspected to be higher than reported since significant deposits of sludge were noted at the plant outfall. Improved sludge handling also resulted from the CCP effort. Operation of the sludge concentrator was reduced from seven days per week to 2-3 days per week. The reduced manpower, chemicals and power requirements substantially decreased the sludge handling cost, although no data was collected on the magnitude of this cost reduction.

Discussion

Since significant transfer of capability to plant personnel was not achieved, sustained high quality effluent is not anticipated. The plant director was more interested in the esthetics of the treatment facility than in achieving long-term process stability. Site visits should have been conducted to involve city administrators to the point that more authority over training of the plant staff could be achieved. The involvement of the state regulatory agency would also have been beneficial so that the importance of long-term stability could have been discussed. This is expecially important since the state was planning on giving an award to Plant 097.

CCP AT PLANT 085

Plant 085 is an oxidation ditch activated sludge facility designed to treat an average flow of 3785 cu m/day (1 mgd). The average flow to the plant is 85 percent of design; however, infiltration/inflow often constitutes a significant portion of the wastewater volume. Wastewater detention time in the oxidation ditch was designed at 30 hours. At design flow a surface settling rate of 23 cu m/day/sq m (550 gpd/ft^2) would exist in the peripheral feed final clarifier. A chlorine contact basin is provided for disinfection. Provisions are made for wasting sludge from the return sludge line to two storage lagoons. Prior to the research survey the plant personnel had experienced problems with containing the sludge solids within the activated sludge system. Because of the conservative plant design, it was felt that increased process control would result in stable performance.

CCP Implementation

During the initial survey, process control procedures were implemented to provide the basis for control strategies. Both plant operators had limited experience in the wastewater treatment; therefore, it was necessary to extablish modified process control procedures. The capabilities of performing the control tests and recording the associated data were developed, but the ability to interpret the results and implement process changes required further development. Operational assistance through telephone consultation was implemented to continue operator training and to obtain plant stability. Plant personnel also completed a weekly summary of process control results for research personnel.

Factors Limiting Performance

At Plant 085 operator application of concepts and testing to process control was the highest ranking factor limiting performance. This factor was addressed by providing operator training and implementing a process control program. Mass control in the activated sludge system was developed to control solids loss from the final clarifier.

Maintaining a selected mass in the activated sludge system required regular wasting to the storage lagoons. Because of the limited capacity of these facilities, sludge wasting capability was noted as the second highest factor limiting performance. The city engineer was made aware of the limited capacity and preliminary investigations were made into alternative sludge handling methods. No definite decisions were made. Toward the end of the CCP activities, the sludge lagoons approached capacity, and the plant personnel made the decision to reduce the wasting from the activated sludge system. This approach provided a short-term solution to the sludge handling problem, but degraded effluent quality is expected in the future.

Prior to the survey a considerable amount of operator time was being spent in the laboratory. With the addition of process control testing the laboratory work load became overwhelming. An evaluation of all tests performed at the plant was made in an attempt to determine the need for each test. The state regulatory agency was contacted, and the tests required by the NPDES permit for monitoring and operation were determined. Many of the tests being conducted were not necessary and the laboratory schedule was revised. As a result, operator time in the laboratory was minimized, permit testing requirements were achieved, and process control tests were incorporated into the schedule.

The results of the BOD_5 test indicated a poorer quality effluent than noted by visual inspection. The suspicion of the BOD_5 results was further supported by the relatively good quality of TSS concentrations in the plant effluent. An evaluation of the BOD_5 testing procedures showed that the results were obtained inaccurately. Reliable BOD_5 results were finally obtained, but much of the data prior to and during the CCP was questionable in value.

Performance

Historical records showed that the plant typically met effluent standards, but plant personnel reported that solids loss from the final clarifier had occurred on a frequent basis. When operated properly, Plant 085 produced a good quality effluent. However, with the limited sludge handling facilities, degraded effluent quality was expected to resume in the future.

Discussion

To conduct a completely successful CCP, a higher level of effort would be required than that expended during the research project. A major effort was directed towards improving operator application of concepts and testing to process control. However, because of the limited experience of the plant operators, the required degree of training was not possible. Consequently, the operational capability of the plant staff is still limiting performance.

The lack of adequate sludge handling facilities let to the termination of sludge wasting. Since no provision for achieving required wasting in the future was pursued, effluent quality is expected to deteriorate. Plant operators and administrators will require incentives other than those provided by the CCP demonstrations before they will pursue expanded sludge handling capabilities.

CCP APPLICATION TO THE 50 RESEARCH FACILITIES

The CCP approach was implemented with varying levels of success at seven facilities during Phases I and II. In several of these plants, performance limiting factors still remained preventing achievement of desired plant performance. While the CCP approach was still applicable, a higher level of effort would have been necessary to eliminate all of the factors. In almost all of these demonstrations additional time was needed for such efforts as site visits, evaluation of design limitations, additional operator training, and meetings with state and federal regulatory personnel, plant design engineers and plant administrators. Despite the limitations of the CCP demonstrations conducted under the scope of this research significant improvements in plant performance were documented. Based on these results, an evaluation of the potential impact of the CCP approach on the fifty facilities studied under this research was completed. The individual facility evaluations are included in Appendix H. Only thirteen of the fifty facilities studied consistently met secondary treatment standards. Using the CCP approach and excluding the option of a major design modification, forty of the fifty facilities evaluated could consistently meet secondary standards. Table 10 presents a summary of this evaluation. An additional 27 plants could consistently meet secondary treatment standards without major facility modifications.

TABLE 10. PERFORMANCE OF 50 PLANTS EVALUATED VERSUS SECONDARY TREATMENT STANDARDS

	Prior to Research	Potential After CCP
Standards Frequently Violated	37	10*
Standards Consistently Met	13	40

*Major facility modifications would be required for these facilities to consistently meet secondary treatment standards (9 of 10 of these facilities were trickling filters - See Appendix H).

The dramatic impact of the potential improved performance is supported by further evaluation of all facilities (See Appendix H). This evaluation indicated that the performance of 38 facilities could be improved using the CCP approach. The potential reduction of BOD_5 and TSS being discharged to receiving streams was estimated to be 1020 metric tons/year (1120 tons/year) and 1190 metric tons/year (1315 tons/year), respectively.

The potential improvement in effluent quality from existing wastewater treatment facilities warrants the consideration of implementing the CCP approach on a broad scale. However, implementation of CCPs requires qualified personnel and incentives to encourage the program's use (4, 5). Personnel who implement CCPs must be able to recognize performance limiting factors in the broad areas of design, operation, maintenance and administration. These people must then be able to implement programs over a long enough time period to insure that desired performance is achieved and maintained. It is not intended that present programs be eliminated and replaced with the CCP program. A properly implemented CCP would utilize existing programs, as necessary, to correct the unique combination of factors limiting performance at a particular facility. The CCP is then more of an overall coordination effort implemented by technically competent individuals.

Two recent articles summarize workshop and committee activities of groups developed to address the plant performance problem (6, 7). A major emphasis of these efforts was to describe the roles of each of the various categories of individuals involved with wastewater treatment plant performance. Categories of individuals included: operators, plant managers, consultants, municipal officials, regulatory personnel, equipment manufacturers, training personnel, and the public. Role definition for each group was very difficult. If an overall objective like CCP implementation is adopted, the coordinated effort of all these groups can be better developed. Limited examples of roles for operating personnel, plant managers and municipal officials, regulatory agency personnel, equipment suppliers and consultants are presented:

Operating Personnel

- Improve sewage treatment understanding through training and certification.
- Develop an awareness of the broad range of factors that can limit performance such as design and administrative problems, and seek technical assistance in addressing these problems (i.e. CCP).
- Accept operations assistance that is provided during a CCP as a learning experience that will improve qualifications rather than view it as a reflection of poor capabilities.

Plant Managers and Municipal Officials

- Verify performance potential of existing facilities.
- If a CCP is warranted, require that it be conducted by qualified personnel.
- Provide an environment for operating personnel to improve sewage treatment understanding through budget support for training and certification.
- Recognize that on-site training is the most effective way to develop an operator's capability to properly apply wastewater treatment concepts to process control.
- Realize that a well trained operator is an investment in the success of a facility's performance and strive to retain this investment through an adequate salary and benefit schedule.

Regulatory Agency Personnel

- Expand enforcement of NPDES Permits to provide incentives for implementing CCPs at facilities which do not meet standards.
- Require that the performance potential of an existing facility is adequately assessed before construction of new or modified facilities are implemented.
- Structure information dissemination and training programs to emphasize the higher ranking factors limiting plant performance defined in this research.
- Improve qualifications of personnel to avoid frequent occurrence of improper technical guidance.

Equipment Suppliers

- Provide flexibility and controllability in equipment and associated processes that are marketed.
- Present realistic assessments of operation and maintenance requirements for equipment and associated processes.
- Expand qualifications of personnel for start-up services to avoid the occurrence of improper technical guidance concerning wastewater treatment.

Engineering Consultants

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

- Improve qualifications of personnel to avoid frequent occurrence of improper technical guidance. Training should include in-plant operations experience where personnel are in a position to be held accountable for their recommendations.
- Develop capabilities to implement Composite Correction Programs.

SECTION 8

SELECTED EVALUATIONS

Special evaluations were made regarding specific groupings of factors limiting performance. Some of these evaluations were made because they were specificlly requested by EPA, and others were made to address major performance-limiting factors determined in this research. Presentation of these evaluations is not intended to imply that significant improvement in plant performance will occur by addressing these factors. Each topic presented may represent only a portion of the overall problems at a particular plant.

AERATORS

Inadequate aerator capability was the ninth highest ranking factor limiting performance. The term aerator refers to the facility utilized for the conversion of soluble and colloidal organic matter into settleable organic matter. The aerator factor was ranked when size of the aerator was adversely affecting plant performance. The data has been separated into three different categories: activated sludge aeration basins preceeded by clarifiers, activated sludge aeration basins not preceeded by clarifiers, and fixed film aerators.

Activated Sludge Aeration Basin Preceeded by Clarifier

Six of the 36 activated sludge facilities in which a comprehensive evaluation was made had primary clarifiers preceeding the activated sludge process. A summary of the aeration basin organic loading for these facilities is shown in Table 11.

TABLE 11. AERATION BASIN ORGANIC LOADING AT ACTIVATED SLUDGE PLANTS WITH PRIMARY CLARIFIERS

Plant No.	Plant Type	Actual Flow		lb BOD/day/1000 cu ft**		Standards Met	Standards Not Met
		mgd*	% Design	Operating	Design		
027	AS	5.5	55	24	--		X
038	AS	3.14	70	34	62		X
066	AS	0.71	76	20	41	X	
068	AS	5.4	98	31	52		X
075	AS	5.8	64	31	56	X	
092	AS	3.12	57	36	45	X	

*mgd X 3785 = cu m/day; **lb/day/1000 ft^3 X 16.0 = gm/day/cu m

As shown, activated sludge facilities with primary clarifiers had an average flow of 14,950 cu m/day (3.95 mgd). One facility had a wastewater flow rate less than 3,785 cu m/day (1 mgd). The average operating organic loading was 460 gm/day/cu m (29 lb/day/1000 ft^3) which was 60 percent of the average design loading. The average organic loading for those plants meeting standards was the same as the loading for those plants that violated standards. Therefore, no correlation between aeration basin loading and improved performance existed.

<u>Activated Sludge Aeration Basin Not Preceeded by Clarifier</u>

The remaining 30 of 36 activated sludge plants evaluated did not use primary clarifier prior to the activated sludge process. Sixteen of these thirty plants were extended aeration, five were contact stabilization, and nine were activated sludge categorized as conventional. A summary of the organic loading for these thirty facilities is shown in Table 12. For contact stabilization plants both the reaeration and contact tanks were included in the calculation of aerator volume.

The average aeration basin organic loading for this category of plants was 290 g/day/cu m (18 lb/day/1000 ft^3), which was about 64 percent of the average design loading. The average operating flow rate was 1250 cu m/day (0.33 mgd). Organic loading versus plant flow rate is shown in Figure 15. Considerable scatter exists in the plotted data, but aerator loading appears to slightly increase with increased flow rate.

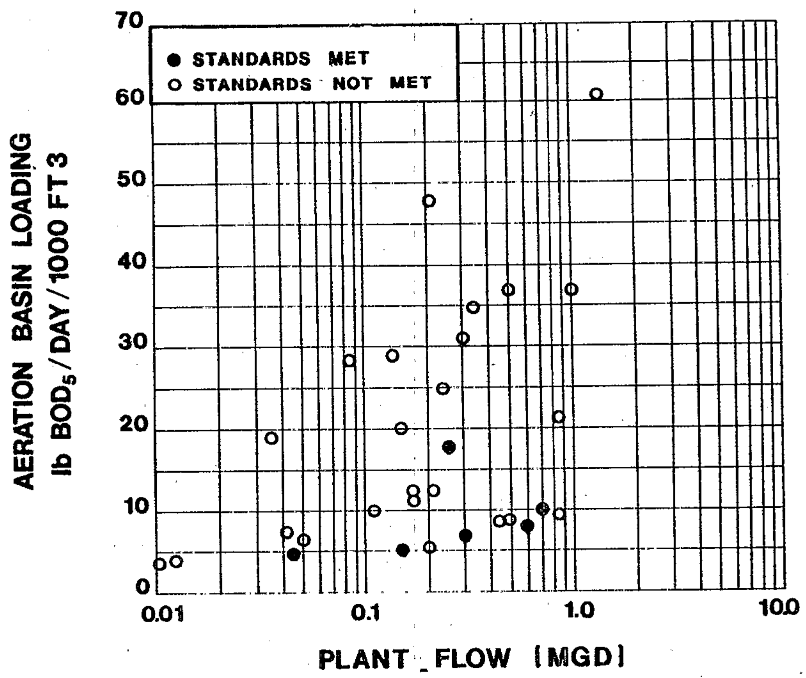


Figure 15. Organic loading of activated sludge plants without primary clarifiers (lb/day/1000 ft^3 x 16 = gm/day/cu m).

TABLE 12. ORGANIC LOADING AT ACTIVATED SLUDGE PLANTS WITHOUT PRIMARY CLARIFIERS

Plant No.	Plant Type	Actual Flow mgd*	Actual Flow % Design	lb BOD/day/1000 cu ft** Operating	lb BOD/day/1000 cu ft** Design	Standards Met	Standards Not Met
002	ASEA	0.43	54	8.8	13		X
007	ODEA	0.041	59	7.4	15		X
013	AS	0.5	63	37	46		X
014	AS	1.0	50	37	47		X
019	ASEA	0.035	54	19	--		X
020	ASEA	0.007	28	3.5	12		X
021	ODEA	0.59	66	8.3	--	X	
022	ASEA	0.012	80	4.0	7.2		X
026	ASEA	0.15	30	5.2	--	X	
028	ASCS	0.15	60	20	--		X
029	AS	1.37	78	61	74		X
039	ODEA	0.21	51	13	--		X
047	ASEA	0.05	80	6.4	--		X
048	AS	0.34	89	35	--		X
050	ASEA	0.17	96	11	14		X
051	ASEA	0.21	75	48	18		X
052	ASEA	0.045	60	5	--	X	
053	ASEA	0.11	68	10	14		X
055	ASEA	0.30	52	7	14	X	
061	ASCS	0.17	34	12	34		X
062	ODEA	0.20	59	5.6	12	X	
063	AS	0.70	47	10	--		X
065	ASCS	0.13	87	29	32		X
074	AS	0.30	86	31	81		X
077	AS	0.24	78	25	38		X
080	AS	0.25	60	18	36	X	
082	ASCS	0.083	69	28	--		X
085	ODEA	0.84	86	9.7	11		X
086	ASEA	0.48	48	8.9	15		X
097	ASCS	0.84	84	22	35		X

*mgd X 3785 = cu m/day; **lb/day/1000 ft^3 X 16.0 = gm/day/c um.

In Figure 15, plants that met standards are denoted by the shaded points. A definite correlation exists between a low aerator loading and plants meeting standards. Except for one plant with a loading of 290 gm/day/cu m (18 lb/day/1000 ft^3), the six plants that met standards had organic loadings of less than 160 gm/day/cu m (10 lb/day/ 1000 ft^3). Conversely, nine plants that violated standards also had aerator loadings less than 160 gm/day/cu m (10 lb/day/1000 ft^3). Conservative aerator loadings appear to aid in improvement of plant performance, but are neither a guaranteed solution nor cost effective.

The highest loaded activated sludge plant evaluated had an aerator loading of 976 gm/day/cu m (61 lb/day/1000 ft^3). At the time of the comprehensive evaluation this plant was not consistently meeting standards. Through a CCP the plant was brought into compliance and now consistently meets standards with an average effluent BOD_5 and TSS concentration of about 10 to 15 mg/l (4). This improvement occurred without a major facility upgrade and indicates that aerator loading was probably not the factor limiting performance of the other activated sludge plants that were violating standards. These plants could probably be brought into compliance without major capital expenditures for aeration capacity. It also suggests that many plants may have a tremendous reserve capacity in terms of aeration capability and probably could handle additional wastewater flow without major capital improvements. Thus, through better plant operation, plant effluent quality can be improved and capital cost savings can be realized.

Fixed Film Facilities

Fixed film facilities evaluated included two using rotating biological contactors, two using activated bio-filters, and ten using trickling filters. A summary of aerator organic loading for these facilities is shown in Table 13. The rotating biological contactor facilities (RBC) were separated from the other plants, because the organic loading for RBC units is more accurately expressed as mass per unit surface area.

TABLE 13. ORGANIC LOADING AT FIXED FILM TREATMENT PLANTS

Plant No.	Plant Type	Actual Flow mgd*	Actual Flow % Design	lb BOD/day/1000 cu ft** Operating	lb BOD/day/1000 cu ft** Design	Standards Met	Standards Not Met
012	TF/CS	8.1	68	71	92		X
015	TF	1.7	47	29	---		X
024	ABF	4.9	82	90	147		X
032	TF	0.22	50	31	---		X
034	TF	5.5	68	19	27		X
035	TF	5.3	98	12	12	X	
036	TF	1.6	87	11	31	X	
041	TF	0.13	33	12	---	X	
060	ABF/TF	0.49	47	61	94		X
069	TF	0.08	114	13	---		X
070	TF	1.10	100	9.6	12	X	
095	TF	1.2	48	29	72		X
				lb BOD/DAY/1000 sq. ft.***			
040	RBC			3.7	4.3		X
093	RBC			1.4	4.4		X

*mgd x 3785 = cu m/day; **lb/day/1000 ft^3 x 16 = g/day/cu m;
***lb/day/1000 sq ft x 4.885 = Kg/day/1000 sq m

The two RBC facilities had dramatically different loadings but at the time of the evaluation neither facility consistently met standards. The more lightly loaded facility exceeded standards because of problems with aerator loading. Subsequent to the evaluation this plant had better experience with the shafts on the RBC unit and permit standards were met. At the more heavily loaded facility permit standards were continually violated. Both RBC facilities were operating at organic loadings less than design values, at 86 percent for the more heavily loaded plant and 32 percent for the other facility. From this limited data, it appears that a more thorough evaluation of RBC capabilities and design loadings is warranted.

At the other fixed film facilities the wastewater flow averaged 9,575 cu m/day (2.5 mgd) and the average organic loading was 510 gm/day/cu m (32 lb/day/1000 ft^3). A graph of organic loading versus flow for these plants is shown in Figure 16. The shaded points indicate plants that met standards. As shown, only four plants met standards on a consistent basis. These plants were operating at the lower organic loading rates. Only one plant that was operating at a similar loading violated standards. Further evaluation of this facility indicated that poor performance was associated with inadequate sludge removal from the secondary clarifier, inadequate recirculation capability, and trickling filter freezing problems during the winter.

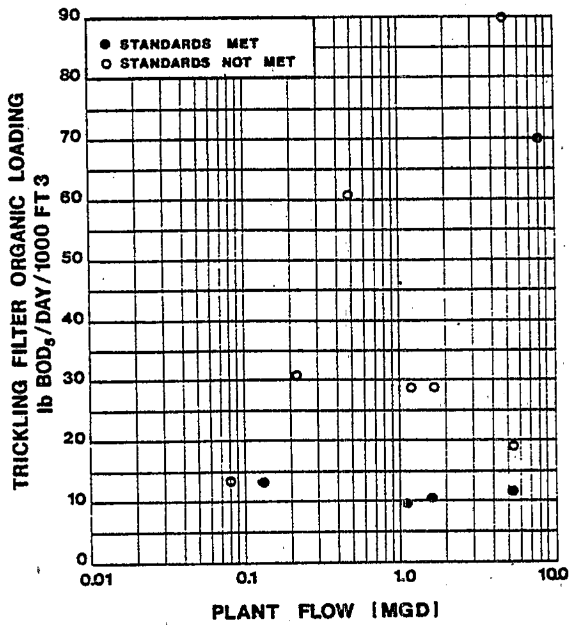


Figure 16. Organic loading of fixed film facilities (lb/day/1000 ft^3 x 16 = gm/day/cu m).

The results indicate that conservatively designed fixed film aerators are necessary to meet permit standards. However, the extent of this conservative design is not necessarily related directly to the specific low organic loading values shown in Figure 16. Other performance limiting factors exist, as evidenced by the lightly loaded trickling filter plant that violated standards. Therefore, some of the more heavily loaded facilities may be able to meet standards if other performance-limiting factors were corrected. Each facility must be individually evaluated but the trend for better performance for conservatively loaded fixed film plants was apparent.

Overall Aerator Evaluation

The aerator represents a key aspect in a system's capability for meeting standards. The results from this evaluation indicated that most plants that met standards had lower levels of organic loading. The results for the fixed film systems were more conclusive in relating aerator loading to plant performance, in that all fixed film plants that met standards had lower organic loadings. The suspended growth systems showed that most of the plants that met standards had a low aerator organic loading, but at the same time, many lightly loaded suspended growth plants violated standards. The conclusion from these results, coupled with field observation, was that fewer operational problems existed for fixed film facilities which enabled them to meet standards when they had a low loading rate. More operational problems existed for the suspended growth facilities, as evidenced by the fact that quite a few activated sludge plants violated standards even though they had a low loading rate. The overall conclusion was that low organic loading of the aerator tends to "mask" other performance-limiting problems and allows these plants to meet standards. However, low organic loading does not guarantee a good plant effluent nor is it cost effective.

For fixed film systems with higher organic loadings, permit violations are more apt to occur. For these systems major capital improvements would be requried to allow consistent compliance. For suspended growth systems improved operations could significantly improve plant performance. Furthermore, additional plant capacity could be achieved. Thus, improved plant operations could improve existing plant performance and save expenditure for unrequired capital improvements.

CLARIFIER DESIGN

Sixteen of 50 facilities evaluated during Phase I and II were limited to some degree by inadequate secondary clarifier design. As such, secondary clarifier was the tenth highest ranking factor and warrants further discussion.

Characteristics of the secondary clarifiers for the 50 facilities evaluated are shown in Table 14. About 75 percent of the plants used circular clarifiers. The majority of these clarifiers (80 percent) were of the center-feed type. Typically, rectangular clarifiers were found in small extended aeration, activated sludge plants.

In general, conservative clarifier overflow rates existed. For suspended growth plants, the average clarifier overflow rate was 14.5 cu m/day/sq m (355 gal/day/ft^2). For the fixed film plants the average overflow rate was 19.4 cu m/day/sq m (475 gal/day/ft^2). These overflow rates are considerably less than a reasonable design overflow rate of 24 cu m/day/sq m (600 gpd/ft^2). The conservative values indicate that with good operational control significant capacity should be available in existing clarifiers.

Design Limitations

Despite conservative overflow rates, several hydraulic problems limited performance at some facilities. The most critical problem was inadequate development of the clarifier surface area with effluent launders. Of seven facilities identified with this problem, six were rectangular clarifiers with effluent launders located at one end. In these facilities, excessively high upflow velocities in the area of the weirs caused washout of sludge solids. This situation could have been improved by additional weirs to enlarge the upflow area.

One recently constructed circular clarifier was a 27.4 m (90 feet) diameter peripheral-feed/peripheral withdrawal unit. Excessive solids washout due to shortcircuiting occurred in this clarifier even when good sludge settling characteristics existed and a low blanket depth was measured near the center

TABLE 14. CHARACTERISTICS OF SECONDARY CLARIFIERS AT THE 50 COMPREHENSIVE SURVEY FACILITIES

Plant No.	Survey Date	Plant Type	Actual Flow cu m/day	Actual Flow mgd	Actual Flow % Design	Clarifier* Type	Clarifier Overflow Rate gpd/ft²** Operating	Clarifier Overflow Rate gpd/ft²** Design
002	1975	ASEA	1,628	0.43	54	R	190	350
007	1976	ODEA	155	0.041	59	CPF	270	460
012	1976	TF/CS	30,660	8.1	68	CCF	520	760
013	1976	AS	1,892	0.5	63	R	770	740
014	1976	AS	3,785	1.0	50	CCF	370	520
015	1976	TF	6,434	1.7	47	CPF	340	730
019	1976	ASEA	132	0.035	54	R	100	190
020	1976	ASEA	26	0.007	28	R	60	200
021	1976	ODEA	2,233	0.59	66	CPF	250	380
022	1976	ASEA	45	0.012	80	R	190	240
024	1976	ABF	18,550	4.9	69	CCF	560	800
026	1976	ASEA	568	0.15	30	N/A	600	2000
027	1976	AS	20,820	5.5	55	CPF	860	790
028	1976	ASCS	568	0.15	60	CCF	350	580
029	1976	AS	5,185	1.37	78	CCF	350	460
032	1976	TF	833	0.22	50	CCF	310	710
034	1976	TF	20,820	5.5	68	R & CCF	560	810
035	1976	TF	20,060	5.3	98	CCF	590	610
036	1976	TF	6,056	1.6	87	CCF	170	280
038	1978	AS	11,880	3.14	70	CPF	440	640
039	1976	ODEA	795	0.21	51	CPF	300	580
040	1976	RBC	1,438	0.38	60	CCF	300	500
041	1977	TF	492	0.13	33	R	1000	1000
047	1976	ASEA	189	0.05	80	R	250	314
048	1976	AS	1,287	0.34	89	CCF	480	540
050	1977	ASEA	643	0.17	96	CCF	300	310
051	1977	ASEA	795	0.21	75	R	250	330
052	1977	ASEA	170	0.045	60	R	230	390
053	1977	ASEA	416	0.11	68	R	180	270
055	1977	ASEA	1,136	0.30	52	CCF	310	600
060	1977	ABF	1,855	0.49	47	CCF	300	650
061	1977	ASCS	643	0.17	34	CCF	180	530
062	1977	ODEA	757	0.20	59	CCF	280	240
063	1977	AS	2,650	0.7	47	CPF	280	600
065	1977	ASCS	492	0.13	87	CCF	510	590
066	1977	AS(2)	2,687	0.71	76	CCF	360	480
068	1978	AS	20,440	5.4	98	CCF	670	680
069	1978	TF	303	0.08	114	R	630	560
070	1978	TF	4,164	1.10	101	CCF	750	690
074	1978	AS	1,136	0.30	86	CCF	210	250
075	1978	AS	21,950	5.8	64	CCF	300	500
077	1978	AS	908	0.24	78	CCF	380	510
080	1978	AS	946	0.25	60	CCF	310	520
082	1978	ASCS/TF	314	0.083	69	R & CCF	440	560
085	1978	ODAS	3,179	0.84	86	CPF	480	550
086	1978	ASEA	1,817	0.48	48	CCF	190	400
092	1978	AS	11,910	3.12	57	CCF	350	550
093	1978	RBC	8,327	2.2	44	CCF	280	650
095	1978	TF	4,542	2.1	48	CCF	380	790
097	1978	ASCS	3,179	0.84	84	CCF	530	630

*R = Rectangular; CPF = Circular Peripheral Feed; CCF = Circular Center Feed.
**gpd/ft^2 x 0.0408 = cu m/day/sq m.

of the clarifier. Installation of additional weirs and effluent launders at incremental intervals toward the center of the clarifier would have improved performance of this unit.

In several plants using circular, center-feed clarifiers, short-circuiting from the center inlet baffle to the peripheral effluent weirs was observed. An opening in the inlet baffle which was designed to allow for the escape of floating materials and scum from the center ring of the clarifier allowed this shortcircuiting to occur. Solids loss with this design arrangement was not critical with a relatively well settling sludge in the system, but was critical and allowed abnormally high effluent TSS concentrations when activated sludge settling characteristics were slower than desired. At Plant 029 (4) the problem was solved by closing up the scum outlet port and removing the accumulated scum manually.

In several small activated sludge and trickling filter plants mechanical sludge collecting mechanisms were not provided. The intent was to have the plant operator aid sludge removal by manually scraping down the hoppered bottoms of these clarifiers on a daily basis. A problem was observed when sufficient manpower was not available or provided to complete this task. As a result, effluent quality deteriorated because of sludge build-up in the clarifier. To solve this problem either major design modifications would be necessary or better operations priorities established.

Design Innovations

Some facilities surveyed had clarifiers that were particularly conducive to achieving good plant performance. An advantageous design was final clarifiers with a side water depth of 4.5 meters (15 ft) or greater. During peak flow periods these deep clarifiers demonstrated an ability to absorb a high solids loading and associated increased sludge blanket level without allowing a degraded plant effluent quality. In addition, less stringent operational control was necessary because the need for close return sludge flow control was minimized. Another advantage occurred when bulky sludge conditions existed. In this case, a thick return sludge concentration would normally be difficult to maintain, but with deep clarifiers a reasonably thick return sludge concentration could be maintained due to sludge build-up and additional time for sludge thickening.

Another advantageous design arrangement was noted for clarifiers that had separate clarifier return sludge and waste sludge removal mechanisms. For these clarifiers, a rapid withdrawal sludge collection mechanism was used to return sludge to the aeration basin, and waste sludge was taken from a center hopper that was fed by scrapers on the sludge removal mechanism. This arrangement was particularly useful at plants that did not have primary clarifiers since rags, strings, and other solids would be scraped to the center hopper and wasted as opposed to being recycled in the return sludge. Also, the presence of the center hopper for wasting sludge allowed for a higher concentration of waste sludge than could be obtained from the return sludge line. Typically, the waste sludge concentration was found to be two to four times greater than the return sludge concentration allowing a desired mass of sludge to be wasted using only one-half to one-fourth of the volume that would have been required if return sludge had been wasted.

SLUDGE PRODUCTION IN ACTIVATED SLUDGE PLANTS WITHOUT PRIMARY CLARIFIERS

The most significant group of performance-limiting factors identified were those associated with sludge production and wasting requirements in activated sludge plants. Three design factors, inadequate sludge wasting capability, inadequate ultimate sludge disposal and inadequate sludge treatment facilities, ranked very high as performance-limiting factors in many facilities. Yet, these design problems were secondary to a more fundamental problem represented by some higher ranking operations oriented factors: inadequate operator application of concepts, inadequate sewage treatment understanding, improper technical guidance and inadequate process control testing. Regardless of the physical facility limitations observed, the available facilities at most plants were not being used to their capacity. Based on the design and operations problems observed, it was concluded that much confusion exists concerning sludge production and sludge wasting. The following statements, obtained during the project, further illustrate this widespread problem.

> "All activated sludge plants bulk solids periodically - there's nothing you can do about it." -- Plant Superintendent and former full-time instructor at an operator training school.

> "I realized that things weren't just right (referring to daily bulking), but I was told to keep the MLSS concentration up, even higher than what it is now." --Plant Operator

> "The engineer said I'd only have to draw sludge (waste) once or twice a year." --Plant Operator

> "When the plant was being built, the guy putting in the equipment said I probably won't have to remove sludge at all because each time it rains excess solids will be washed out." --Plant Operator

> "I've asked the town's engineer and the state for help in setting up a wasting program, but nobody seems to know how to go about it." --Plant Operator.

> "Hardly any of the small plants waste sludge on a regular basis. I don't even mention it unless I have a special request to provide operational assistance." --State District Engineer

Activated Sludge Mass Control

The fundamental principles governing performance of activated sludge plants are universal regardless of size of facility or type of activated sludge process. In the activated sludge process total sludge mass will increase naturally as microogranisms metabolize organic matter in the wastewater. Whether or not the total activated sludge mass in the system increases, decreases or remains constant depends on how much sludge is removed voluntarily or involuntarily from the system in relation to the amount grown. Graphs indicating the relationship of sludge mass and wasting are shown in Figure 17. Time in days is plotted on the X-axis. The mass of activated sludge wasted and the mass of sludge in the activated sludge system are plotted on the Y-axis. System mass and mass wasted are plotted together to show their close interdependence. System mass is determined by mass wasted and can be adjusted by changing wasting rates.

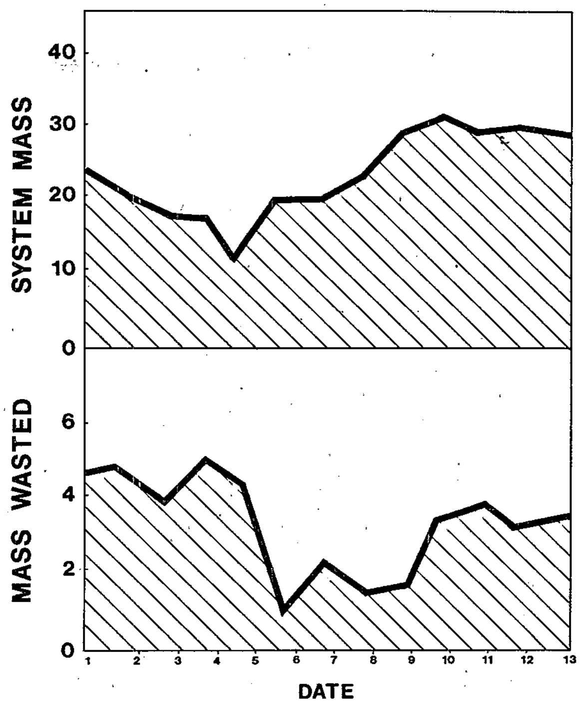


Figure 17. Typical activated sludge mass control data.

Figure 18 shows a conceptual relationship between sludge mass and sludge wasting. The naturally occurring daily variations shown in Figure 17 were smoothed out and the more important aspect of system trends is emphasized. In the first time period shown a high level of wasting resulted in a decrease in the total activated sludge mass. In this case, wasting exceeded sludge growth. If wasting is decreased to a level below sludge growth, as shown in the second time frame, the total sludge inventory increases. In every plant, for current loading and growth conditions, some level of wasting will hold a relatively constant total sludge inventory, as shown in the last time frame of Figure 18.

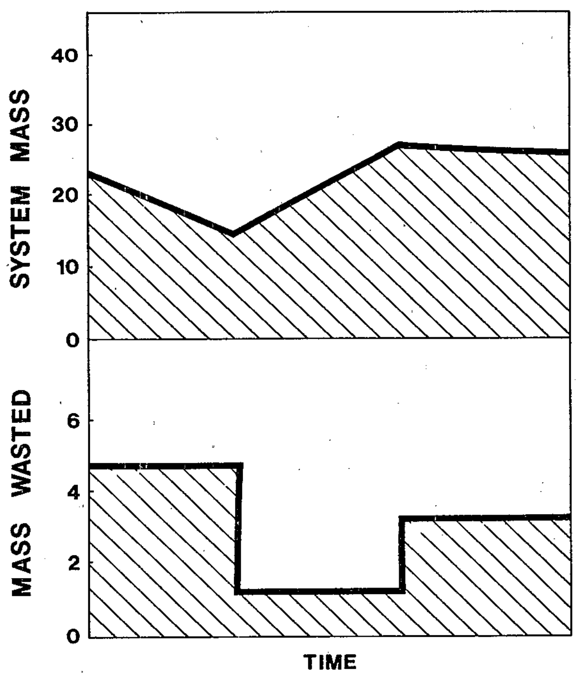


Figure 18. Activated sludge mass control.

Although the basic concept is quite simple, mass control was inadequate in most activated sludge plants surveyed.

Sludge Production

Reliable information on sludge production was obtained from seven activated sludge plants surveyed. The data presented is supplemented with data from four plants with which research personnel are involved on a private consultant-client basis.

Sludge growth and wasting commonly fluctuate for a given plant; therefore, sludge production data is presented only for facilities with which close contact was maintained for a minimum of three months. The eleven plants evaluated were located in four states and all were activated sludge plants without primary clarifiers.

Sludge production data is shown in Table 15. Data was collected for a total of 3,234 operating days for the eleven facilities. Effluent BOD_5 varied from 1.2 mg/l to 31 mg/l and effluent TSS varied from 1.9 mg/l to 24 mg/l. The average effluent BOD_5 and TSS values were 13 mg/l and 11 mg/l, respectively, indicating good plant performance.

TABLE 15. SLUDGE PRODUCTION DATA

Facility	Plant Type	Actual mgd*	Flow % of Design	Days of Data Collection	Effluent BOD_5 mg/l	Effluent TSS mg/l
Reinbeck, IA	Extended Aeration	0.14	78	122	8.3	5.5
Berthoud, CO	Oxidation Ditch	0.55	61	228	4.0	5.5
East Canon S.D., CO	Contact Stabilization	0.43	142	210	7.9	17
Marshfield, MO	Extended Aeration	0.46	46	231	7.8	3.9
Grimes, IA	Conventional	0.25	85	182	8.5	14
Upper Eagle Valley S.D., CO	Contact Stabilization	0.91		215	15	13
Akron, IA	Contact Stabilization	0.12	81	364	29	15
Upper Thompson S.D., CO	Conventional	0.50	33	644	31	24
Cresco, IA	Conventional	0.50	133	92	15	7
S. Fort Collins S.D., CO	Conventional with filters	0.51	34	216	1.2	1.9
Havre, MT	Conventional	1.29	72	730	14	16
			Total	3234 Average	13	11

*mgd x 3785 = cu m/day

To compare sludge production for plants of various sizes and types, a common basis for documenting sludge produced was necessary. The single characteristic of domestic wastewater which has typically been used to describe the amount of sludge which will result from biological secondary treatment is the BOD_5 removed in the process. Thus, sludge production has been correlated with BOD_5 removed to calculate a sludge production ratio. The units are kilograms of total suspended solids (sludge) produced per kilogram of BOD_5 removed. Because primary clarifiers were not provided, waste sludge from the secondary system included both net cell production and nondegradable primary type solids.

In calculating sludge production three components were included: sludge intentionally wasted, sludge lost as effluent suspended solids, and changes in the sludge inventory within the activated sludge system. Over a period of many months of stable operating conditions, the change in sludge inventory was usually insignificant compared to waste and effluent sludge. However, when calculating sludge production on a monthly or shorter basis, changes in sludge inventory became very significant.

When comparing sludge production values, it was desirable to include effluent suspended solids since varying effluent qualities could have introduced an unnecessary variable into the evaluation. Accounting for effluent sludge does lend consistency to sludge production calculations but does not accurately describe actual sludge wasting requirements. Therefore, a second sludge to BOD_5 ratio, called the sludge wasting ratio, was determined. The sludge wasting ratio is always less than the sludge production ratio in proportion to the amount of sludge solids lost in the plant effluent. Sludge production and sludge wasting ratios are listed in Table 16 and are graphically shown in Figure 19. The sludge production ratios averaged 0.81 and the sludge wasting ratios averaged 0.75.

TABLE 16. SLUDGE PRODUCTION - Kg TSS PER Kg BOD_5 REMOVED

Facility	Plant Type	Sludge Production Ratio*	Sludge Wasting Ratio**
Reinbeck, IA	Extended Aeration	0.80	0.78
Berthoud, CO	Oxidation Ditch	0.60	0.55
East Canon S.D., CO	Contact Stabilization	0.95	0.84
Marshfield, MO	Extended Aeration	0.65	0.63
Grimes, IA	Conventional	0.82	0.76
Upper Eagle Valley S.D., CO	Contact Stabilization	1.14	1.01
Akron, IA	Contact Stabilization	1.11	1.03
Upper Thompson S.D., CO	Conventional	0.79	0.67
Cresco, IA	Conventional	0.73	0.70
S. Fort Collins S.D., CO	Conventional	0.70	0.69
Havre, MT	Conventional	0.66	0.60
	Averages	0.81	0.75

*Includes effluent TSS
**Does not include effluent TSS

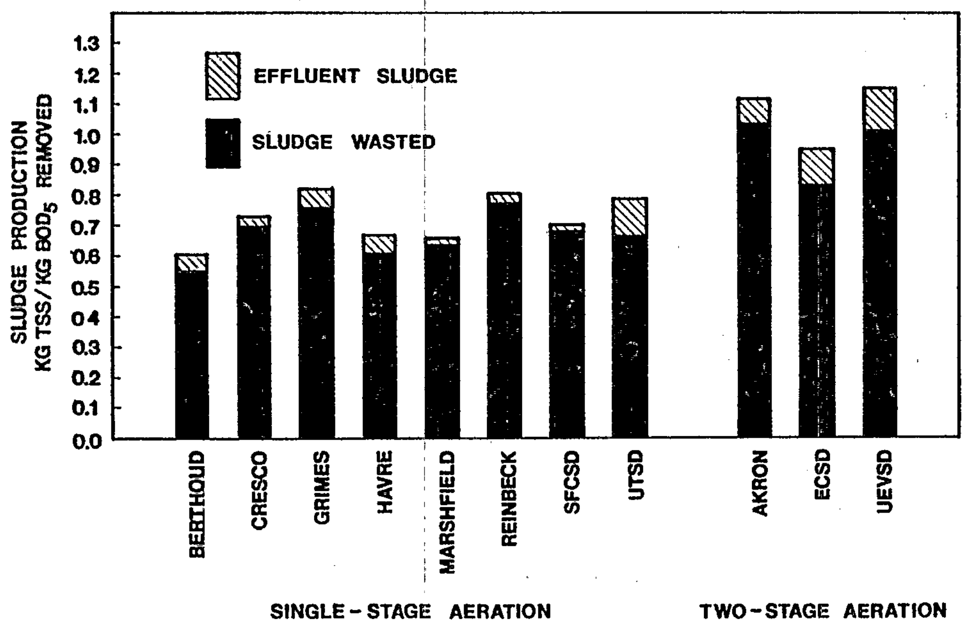


Figure 19. Sludge production at selected wastewater treatment facilities.

Sludge production ratios varied from 0.60 to 1.14. The highest sludge production ratios were found at contact stabilization (two-stage aeration) plants. Sludge production for the three contact stabilization plants averaged 1.07 kilograms of TSS produced per kilogram of BOD_5 removed. The single-stage aeration facilities averaged 0.71 kilograms of TSS produced per kilogram of BOD_5 removed. The limited data available strongly indicates that a significantly greater amount of sludge is produced in two-stage aeration systems. If additional data supports this conclusion, increased sludge handling capability will be necessary when designing contact stabilization plants.

<u>Evaluation of Factors Affecting Sludge Production</u>

Historically, sludge yield has been predicted based on mean cell residence time (MCRT), food to microorganism ratios (F/M) or other parameters which indicate the amount of endogenous respiration which will likely occur in the system. Efforts were made to correlate sludge production ratios with four parameters: MCRT, F/M, wastewater detention time in the aerator ($WWDT_A$), and volumetric organic loading (gm BOD_5/m^3/day). These parameters are summarized in Table 17. The correlation between these parameters and sludge production ratios were analyzed graphically. Sludge production ratios for twostage aeration systems were included on the graphs, but not included in the statistical data analysis.

Sludge production ratios versus MCRT are shown in Figure 20. The least squares line of best fit indicates a lower sludge production ratio for a higher mean cell residence time. The correlation coefficient (r) indicates the strength of the linear relationship between the two variables. An exact correlation would be indicated by a value of ± 1.00 while no correlation would be indicated by a value of zero. The correlation coefficient between the sludge production ratio and MCRT was -0.60. Thus, the linear correlation between sludge production and MCRT appears to be only fair. The negative value indicates that as MCRT increases, the expected sludge production ratio decreases.

TABLE 17. AVERAGE OPERATING PARAMETERS DURING SLUDGE PRODUCTION EVALUATION

Facility	Aerator Type	Sludge Production Ratio	MCRT	F/M*	WWDTA	gm BOD_5/day/m^3**
Reinbeck, IA	Extended Aeration	0.80	22	0.058	29	190 (12)
Berthoud, CO	Oxidation Ditch	0.60	63	0.025	25	93 (5.8)
East Canon S.D., CO	Contact Stabilization	0.95	21	0.053	10.5	290 (18)
Marshfield, MO	Extended Aeration	0.65	37	0.042	26	220 (14)
Grimes, IA	Conventional	0.82	23	0.061	12.2	510 (32)
Upper Eagle Valley S.D., CO	Contact Stabilization	1.14	34	0.030	10.6	240 (15)
Akron, IA	Contact Stabilization	1.11	14	0.079	11.7	420 (26)
Upper Thompson S.D., CO	Conventional	0.79	10	0.147	13.2	460 (29)
Cresco, IA	Conventional	0.73	15	0.10	10	500 (31)
S. Fort Collins S.D., CO	Conventional with filters	0.70	34	0.041	19	140 (8.9)
Havre, MT	Conventional	0.66	7.7	0.21	6.8	1100 (69)

* Based on MLSS, not MLVSS
** Values in parantheses are equivalent loadings in lb BOD_5/day/1000 ft^3.

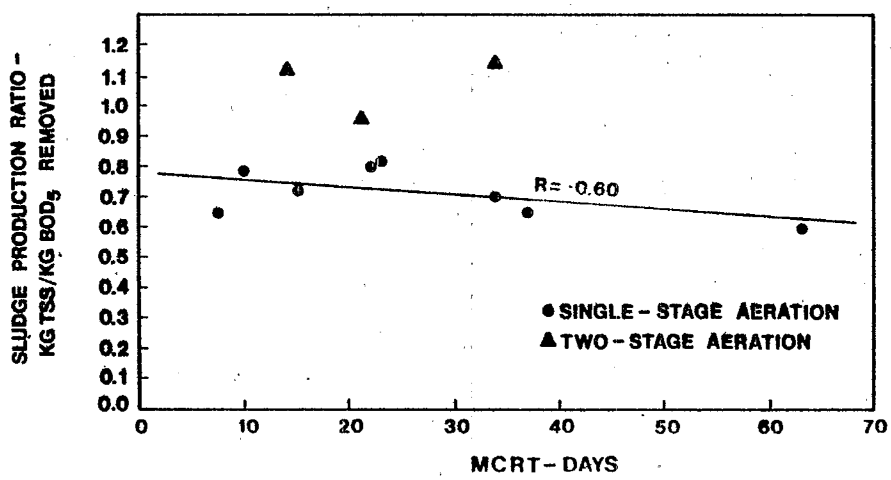


Figure 20. Influence of mean cell residence time on sludge production.

The correlation between F/M and sludge production is presented in Figure 21. Routine MLVSS data was not collected at most facilities so the F/M presented is based on kg BOD_5/day/kg MLSS. The linear line of best fit between

F/M and sludge production slopes upward indicating a greater sludge production ratio at a higher F/M. However, very little difference in sludge production is indicated over the range of F/M values studied. Furthermore, the correlation coefficient was only 0.10 indicating no significant correlation between the F/M and sludge production ratios.

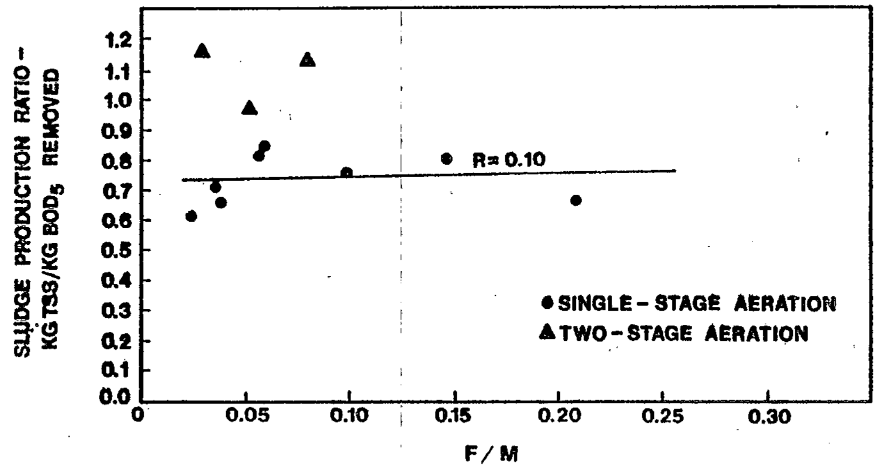


Figure 21. Influence of food to microorganisms ratio on sludge production.

Sludge production ratio versus the $WWDT_A$ is shown in Figure 22. Values for $WWDT_A$ were determined by dividing the total aeration volume by the average daily flow. The linear relationship between $WWDT_A$ and sludge production slopes in the expected direction. However, the poor correlation coefficient indicates an insignificant correlation between these values.

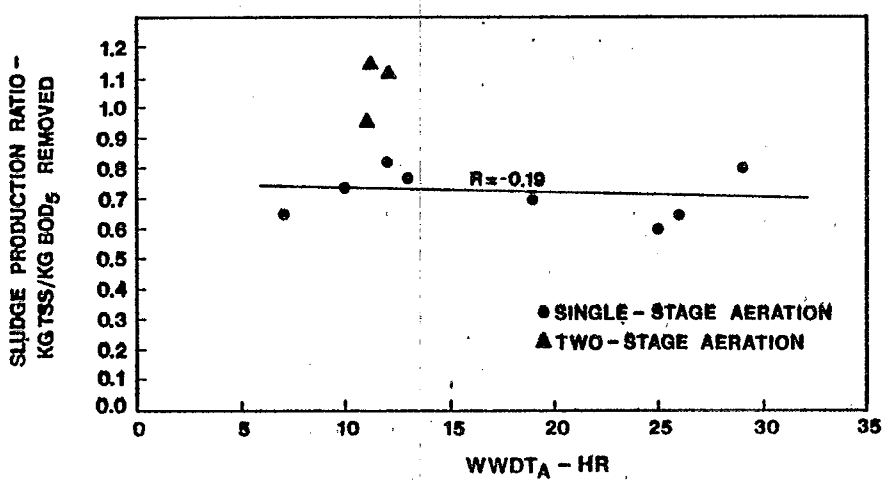


Figure 22. Influence of wastewater detention time in the aerator on sludge production.

Sludge production ratios versus aeration basin organic loading are presented in Figure 23. The linear correlation coefficient of only 0.07 indicates almost no correlation exists.

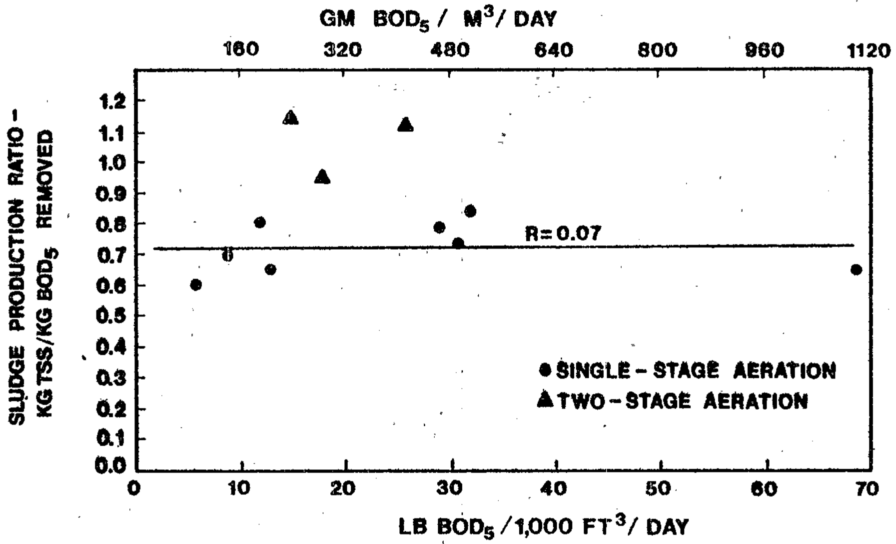


Figure 23. Influence of aeration basin organic loading on sludge production.

The most important observation from the attempts to correlate sludge production with common operating parameters was that sludge production was not significantly less for the variety of plants studied. However, in practice typical design sludge yield values vary from 0.65 kg of TSS produced per kg of BOD_5 removed for conventionally loaded activated sludge plant to 0.15 kg of TSS produced per kg of BOD_5 removed for extended aeration plants (8,9). Actual sludge production documented indicates that all facilities would have undersized sludge handling capability if designed with these typical values. It was concluded that a sludge production ratio of approximately 0.75 kg of TSS produced per pound of BOD_5 removed represents a more realistic value for providing adequate sludge handling facilities.

Required Sludge Wasting Capacity

Wasting variations were evaluated to determine the effect on wasting requirements. This information is plotted in Figure 24, indicating how short-term wasting requirements can vary by as much as 100 percent of the long-term average. Obviously, sludge treatment facilities must be capable of handling the short-term peaks as well as the long-term average if good activated sludge mass control and high quality effluent are to be maintained. Therefore, realistic sludge production estimates form only the basis for providing adequate sludge wasting capability.

Many of the performance-limiting factors identified related to the general area of sludge production and wasting requirements. Evaluation has shown that actual sludge production is several times greater than the amount commonly projected for small activated sludge facilities. As such, adequate sludge handling capability must be provided before optimum performance of many existing wastewater treatment plants can be achieved.

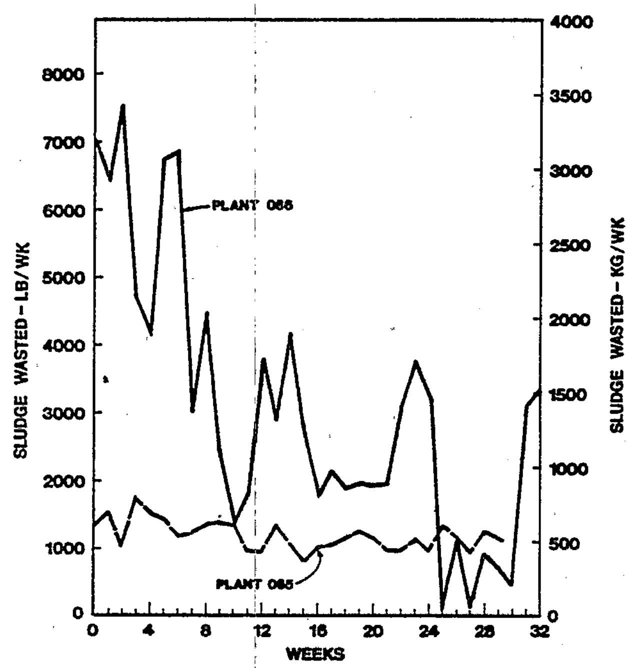


Figure 24. Variations in sludge wasted to maintain process control.

AEROBIC DIGESTERS

Aerobic digesters were used in fourteen of 36 of the activated sludge plants in which a comprehensive evaluation was completed. In the other 22 activated sludge plants, eleven had no sludge treatment, four had anaerobic digesters, and seven had other types of sludge treatment. Aerobic digestion was not used at any of the fixed film facilities evaluated. During the project many improper applications of aerobic digester design and operation were noted.

The performance-limiting factor of improper operator application of concepts and testing to process control was very apparent in aerobic digester operation. The fundamental concept that sludge solids wasted to the digester should not be returned to the wastewater treatment process was frequenly violated at facilities evaluated. Another common misconception was that in order for an aerobic digester to work, it must be loaded at a controlled rate. To address this misconception, the relationship between the aerobic digester sludge treatment process and activated sludge wastewater treatment process must be established. To achieve optimum wastewater effluent quality, the amount of sludge wasted should be based on the requirements of the activated sludge process, and not on the organic loading considerations of the aerobic digester. Misconceptions concerning these points dramatically affected the operation and performance of aerobic digesters. Problem areas noted were improper use of digesters, inadequate supernating capabilities and practices, and insufficient digester size.

Flagrant misuse of aerobic digesters was observed most often in activated sludge package plants incorporating the contact stabilization mode of operation. These facilities were typically designed so that return activated sludge from the bottom of the clarifier was air-lifted to a reaeration basin. Sludge wasting was accomplished by either directing the return sludge flow to the aerobic digester or by air-lifting sludge from the reaeration basin to the digester. Within the digester an automatic supernating device was constructed to recycle supernatant back to the reaeration basin for treatment. A schematic diagram of a typical automatic supernating device is shown in Figure 25. Typically, the automatic supernating device was ineffective and digester solids were recycled into the activated sludge process. Consequently, sludge was only removed from the system when hauled to ultimate disposal (typically land application). Unfortunately, sludge was normally lost over the final clarifier weirs in the plant effluent. Even when excessive solids loss of this nature was not occurring, a turbid, poor quality effluent was discharged because the activated sludge process was not properly controlled. At facilities where this type of digester operation was encountered, use of the continuous supernating devices was stopped, and the digester was operated on a batch basis. To convert to a batch mode of operation, draw-off lines or a portable pump were used to remove clear supernatant after the air supply to the digeser was shut-off and the digester contents were allowed to settle. Supernating capability which had adjustable draw-off levels was most desirable.

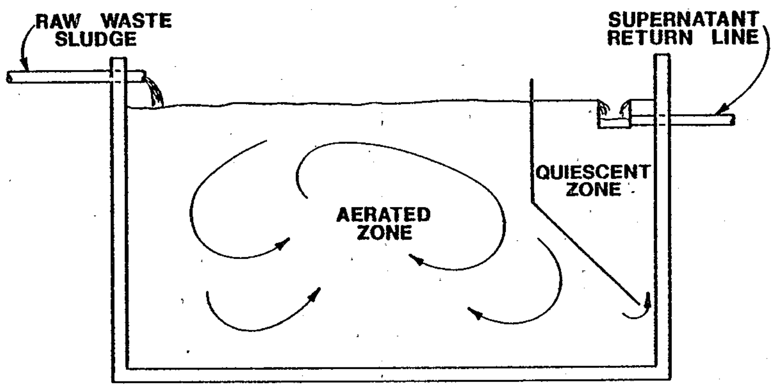


Figure 25. Automatic supernating device.

The batch operation approach allowed the operator to reserve capacity in the digester so that activated sludge wasting could be completed as necessary. When clear supernatant could not be obtained and removed to achieve this capacity the operator was instructed to remove sludge from the digester to the ultimate sludge disposal site. Another advantage of the batch operation approach was that the operator was able to monitor the quality of supernatant to insure that excessive quantities of digested sludge solids were not recycled to the activated sludge process.

At some facilities, problems were encountered when attempting to operate the digester in a batch mode of operation because the digester walls were not designed with sufficient structural integrity. Many of these plant were built with all unit processes (i.e. aeration basin,clarifier and digester) contained in a large concrete structure which had steel walls to separate the basins. These walls were not designed to allow significant liquid level variations between adjacent basins. When one unit required dewatering, the liquid level in all units had to be lowered simultaneously. In most of these facilities the difference between liquid levels in adjacent basins could not be greater than about one meter (three feet) without risking structural failure. This constraint limited the effectiveness of batch digester operation since an increased frequency of supernating was required which resulted in increased operational requirements and decreased sludge digestion time.

In many facilities the aerobic digesters were undersized and caused increased operational requirements and considertions. The small sized digesters were felt to be a result of inadequate sludge production values used in the original design calucations (see previous section). The primary problem with undersized digesters was that increased frequency of supernating was required and decreased sludge digestion occurred. In a few cases limited digestion resulted and partially digested sludge that would not settle was produced. In these facilities, increased resources to transport the sludge to ultimate disposal sites was necessary.

Although sludge digestion was less than desired because of short detention time in the digester, this operational approach was considered a better solution than allowing large quantities of sludge to be discharged to the receiving stream.

In general, aerobic digesters were not being effectively utilized and were found to be contributing to the plant performance problem. In many instances it was not understood that activated sludge solids wasted to the digester are <u>not</u> to be returned to the wastewater treatment processes. Additionally, it was not understood that aerobic digester performance should not dictate the amount of sludge wasted from the wastewater treatment process. As such the aerobic digester must be viewed as an intermediary unit between the activated sludge process and the ultimate disposal system. If the digester does not have the required capacity to serve this purpose, ultimate sludge disposal capabilities must be expanded in order to maintain high effluent quality from the wastewater treatment process. Additionally, adequate aerobic digester capacity is generally not available to handle the sludge produced by wastewater treatment processes. Until sludge treatment facilities are designed based on realistic values for sludge production plant performance will continue to be adversely affected.

PLANT REFERENCE LITERATURE

Numerous technical publications and periodicals are published for wastewater treatment personnel by government agencies, training schools and technical societies. The availability and useage of this material by treatment plant operators has not been established. The lack of technical literature at treatment facilities has been thought to be a cause of poor facility performance. This is evidenced by the emphasis in recent years by regulatory and/or reviewing agencies to make available plant specific operator oriented literature (i.e. operation and maintenance manuals) at newly constructed wastewater treatment facilities.

A special study was implemented to determine the type of reference material available and the level of usage of this material. A standard form listing selected references was used to obtain information on availability of a variety of literature sources. Space was provided on the form for an evaluation of the level of usage. Reference usage was assigned points using the following: 0) available but not used, 1) read through once, 2) used occasionally, or 3) used regularly. A compilation of the available literature and its usage at 48 facilities surveyed is shown in Table 18. This evaluation was initiated during Phase II, and the 48 facilities shown represent facilities where either site visits or comprehensive evaluations were conducted. The reference items were divided by topic among four categories; operation and maintenance, laboratory, management and periodicals.

The reference items were ranked according to the total number of usage point received. Usage was that by the chief plant operator or the person in charge of making the process control decisions. The ranking of each reference item within the four broad topic categories is also shown in Table 18.

Operation and Maintenance References

Twenty-four reference items are included in the operation and maintenance category. These items varied from general (i.e., Operation of Wastewater Treatment Plants) to specific (i.e., the plant specific Operation and Maintenance Manual). The reference with the most usage points was the plant Operation and Maintenance manual. Despite the regular usage of plant specific O & M manuals only about 30 percent of the surveyed facilities were meeting secondary effluent standards. This data does not indicate that information provided by a plant O & M manual is inadequte nor unnecessary. However, it does indicate that an O & M manual may be limited in its ability to provide a basis for the operator to improve plant performance.

The second highest ranking factor limiting plant performance identified in this research was sewage treatment understanding. The high ranking of references such as: the Sacramento Course, New York Manual, Texas Manual, Studybook for Wastewater Operator Certification and the Operation of Wastewater Treatment Plants support this research finding. These manuals cover a wide range of basic wastewater topics and their use indicates that the operators recognize the need for more basic understanding of the sytems they are asked to control. Plant operators also indicated that these sources provided a good basis of study for preparing to take operator certification exams. The application of these reference items to plant performance problems is somewhat limited because of their general nature. The first literature source that was indicated by the operators to be used to aid in addressing a specific plant operational problem was the Operations Manual Anaerobic Sludge Digestion.

TABLE 18. AVAILABILITY AND USAGE OF PLANT REFERENCE LITERATURE

Category	Rank	Reference	No. of Plants Reference Available	Level of Usage* 0	1	2	3	Total Pts
A. Operation and Maintenance References								
	1	Plant O & M Manual	45	5	1	21	18	97
	2	New York Manual	36	3	3	16	14	77
	3	Sacramento Course	29	0	2	16	11	67
	4	Operation of Wastewater Treatment Plants-WPCF MOP 5	29	2	8	8	11	57
	5	Texas Manual	21	3	1	9	8	43
	6	Studybook for Wastewater Operator Certification-WPCF	21	3	3	9	6	39
	7	Operations Manual Anaerobic Sludge Digestion (EPA 430/9-76-001)	18	5	5	5	3	33
	8	Literature from Local and/or State Training Schools	9	0	1	1	7	24
	9	Package Treatment Plants, Operations Manual (EPA 430/9-77-005)	10	1	2	5	2	18
	10	Aeration in Wastewater Treatment WPCF MOP 3	11	1	5	4	1	16
	11	Procedural Manual for Evaluating the Performance of Wastewater Treatment Plants - EPA	8	2	1	3	2	13
	12	Operational Control Procedures for the Activated Sludge Process (West)	6	1	1	1	3	12
	13	A Planned Maintenance Management System for Municipal Wastewater Treatment Plants(EPA-600/2-73-004)	5	1	0	3	2	12
	14	Process Control Manual for Aerobic Biological Wastewater Treatment Facilities (EPA-430/9-77-006	9	2	4	3	0	10
	15	Start-Up of Municipal Wastewater Treatment Facilities (EPA-430/9-74-008)	7	2	2	2	1	9
	16	Sludge Dewatering-WPCF MOP 20	6	0	4	1	1	9

(Continued)

TABLE 18. (CONTINUED)

Category	Rank	Reference	No. of Plants Reference Available	Level of Usage* 0	1	2	3	Total Pts
	17	Maintenance Management Systems for Municipal Wastewater Facilities (EPA-430/9-74-004)	5	0	0	4	0	8
	18	Chlorination of Waste-Water-WPCF MOP 4	7	3	1	3	0	7
	19	Technical Books	3	0	1	1	1	6
	20	Utilization of Municipal Wastewater Sludge-WPCF MOP 2	5	2	2	1	0	4
	21	Paints and Protective Coatings for Wastewater Treatment Facilities-WPCF MOP 17	3	0	2	1	0	4
	22	Sludge Treatment and Disposal-EPA Technology Transfer	2	0	1	1	0	3
	23	Units of Expression for Wastewater Treatment-WPCF MOP 6	1	0	1	0	0	1
	24	Upgrading Existing Waste-Water Treatment Plants EPA Technology Transfer	1	0	1	0	0	1
B. Laboratory References								
	1	Standard Methods for Examination of Water and Wastewater-APHA,AWWA,WPCF	43	4	5	16	18	91
	2	Simplified Laboratory Procedures for Wastewater Examination-WPCF MOP 18	33	3	5	16	9	64
	3	Analytical Quality Control EPA Technology Transfer	3	0	0	1	2	8
	4	Methods for Chemical Analysis of Water and Wastes-EPA Technology Transfer	5	1	1	2	1	7
	5	Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities (EPA)	4	1	0	2	1	7
	6	Monitoring Industrial Wastewater-EPA Technology Transfer	4	0	2	1	1	7
C. Management References								
	1	Safety in Wastewater Works WPCF MOP 1	14	1	4	8	1	23

(Continued)

TABLE 18. (CONTINUED)

Category	Rank	Reference	No. of Plants Reference Available	Level of Usage* 0	1	2	3	Total Pts
	2	Regulation of Sewer Use-WPCF MOP 3	12	6	1	5	0	12
	3	Emergency Planning for Municipal Wastewater Treatment Facilities(EPA-430/9-74-013)	4	0	0	3	1	9
	4	Estimating Staffing for Municipal Wastewater Treatment Facilities(EPA)	3	1	0	2	0	4
	5	Safety Practices for Water Utilities - AWWA M3	1	0	0	1	0	2
	6	Tailgate Safety Lectures-AWWA M16	1	0	0	1	0	2
	7	Uniform System of Accounts for Wastewater Utilities-WPCF MOP 10	2	0	2	0	0	2
	8	Financing and Charges for Wastewater Systems - APWA, ASCE, WPCF	1	0	1	0	0	1
	9	Public Relations for Water Pollution Control - WPCF	2	1	1	0	0	1
D. Periodical Publications								
	1.	Water Pollution Control Federation Highlights	23	1	8	8	6	42
	2	Journal Water Pollution Control Federation	25	3	8	12	2	38
	3	Water and Wastes Engineering	26	3	13	6	4	37
	4	Public Works	22	1	10	10	1	33
	5	Regulatory Agency Newsletter	6	0	5	0	1	8
	6	American City and County	2	0	0	2	0	4
	7	Engineering News-Record	1	0	0	1	0	2
	8	Water and Sewage Works	1	0	1	0	0	1

* 0 = Available but not used.
1 = Read through once.
2 = Used Occasionally.
3 = Used regularly.

Laboratory References

Six items were included in the laboratory category. Standard Methods for the Examination of Water and Wastewater was utilized most often for conducting laboratory analyses, and Simplified Laboratory Procedures for Wastewater Examination was the second most used reference. The manual, Methods for Chemical Analysis of Water and Wastes, did not have widespread use among the facilities surveyed. Other references, which were used on a less frequent basis, dealt with quality control, industrial monitoring and laboratory needs.

Management References

Nine different reference items were included in the plant management category. Safety in Wastewater Works was the most utilized reference followed by Regulation of Sewer Use. Usage of these references was mostly on a read through once or used occasionally basis. Other literature in this category was available at only a few of the facilities surveyed.

Periodical Publications

Periodical publications were a common source of technical information for plant personnel. The Water Pollution Control Federation Highlights received the highest ranking in this category. This publication is specifically oriented toward plant operations personnel. Other periodicals that were ranked high among the plant personnel include the Journal Water Pollution Control Federation, Water and Wastes Engineering, and Public Works.

Relationship Between Reference Material and Plant Performance

An evaluation was conducted to determine if a relationship existed between references utilized by plant personnel and a facilities' ability to meet secondary treatment standards. Table 19 shows the total usage points per plant for the reference materials evaluated. Plants meeting standards on a consistent basis are denoted. A definite trend does not exist between high usage of references (high total points) and plant performance. However, the average points, with respect to reference usage, for those plants meeting standards was 25, while the average points for those plant not meeting standards was 18. It is not known if this difference in usage is significant, but the trend of better performance associated with increased use of references indicated by this data is encouraging.

Overall conclusions on the use of references and plant performance were difficult to develop with the data available from this analysis. However, it was concluded that, without additional guidance, the majority of present plant operators cannot apply wastewater treatment concepts presented in most literature sources to the operation of their facilities.

OPERATOR TIME AND TASKS

Plant staffing is an important consideration in achieving the desired performance in any wastewater treatment facility. However, adequate manpower

TABLE 19. RELATIONSHIP OF REFERENCE MATERIAL USAGE AND PLANT PERFORMANCE

Plant Identity	Level of Usage 0	1	2	3	Total Pts.	Secondary Standards Met	Type* of Survey
063	0	0	6	15	57	yes	CS
073	2	4	15	6	52	no	SV
088	0	2	6	12	50	yes	SV
067	2	5	11	4	39	yes	SV
040	0	0	6	8	36	no	CS
072	2	2	9	5	35	yes	SV
014	0	0	5	8	34	no	CS
097	1	1	2	8	31	no	CS
024	0	0	6	6	30	no	CS
092	0	4	7	4	30	yes	CS
068	3	4	8	3	29	no	CS
029	0	0	11	2	28	no	CS
070	1	8	10	0	28	yes	CS
047	0	1	7	4	27	no	CS
093	0	3	1	7	26	no	CS
064	0	8	7	1	25	yes	SV
090	1	2	2	6	24	no	SV
094	3	6	6	2	24	no	SV
034	1	10	7	0	24	no	CS
013	0	4	5	3	23	no	CS
096	1	3	3	4	21	no	SV
021	0	2	8	1	21	yes	CS
061	0	3	2	4	19	no	CS
027	3	3	8	0	19	no	CS
084	1	0	4	3	17	yes	SV
048	1	5	4	1	16	no	CS
060	2	4	4	1	15	no	CS
028	3	4	2	2	14	no	SV
041	1	0	7	0	14	yes	CS
032	0	3	5	0	13	no	CS
085	1	3	0	3	12	no	CS
036	1	2	2	2	12	yes	CS
052	5	0	4	1	11	yes	CS
015	0	2	3	1	11	no	CS
035	2	5	1	1	10	yes	CS
002	1	0	0	3	9	no	CS
083	0	0	0	3	9	no	SV
039	2	1	1	2	9	no	CS
086	2	2	2	1	9	no	CS
025	2	5	2	0	9	no	SV
079	0	2	3	0	8	no	SV
065	4	1	3	0	7	no	CS
055	0	3	2	0	7	yes	CS
022	4	0	3	0	6	no	CS
077	0	0	3	0	6	no	CS
062	1	2	0	1	5	no	CS
050	1	0	2	0	4	no	CS
069	10	0	0	1	3	no	CS

*SV = Site Visit; CS = Comprehensive Survey is like adequate design, adequate testing equipment or operating budgets; it provides one of the base level requirements from which to build a plant toward optimum performance. Therefore, providing adequate manpower should not be expected to produce good plant performance without proper training, a good plant design and other essential elements.

During the research project, CCP's were demonstrated in selected facilities. An evaluation was made of the effect of the CCP on operator time and tasks for two of these facilities. The objective was to document changes in time and tasks and to relate these changes to operator activities in other facilities. The facilities selected were a 570 cu m/day (0.15 mgd) contact stabilization, package-type plant and a 3800 cu m/day (1.0 mgd) extended aeration activated sludge plant. These facilities, in addition to being suitable for implementation of limited CCP's, were representative of a large number of other plants evaluated in terms of size, type and operator coverage.

Plant 065

Plant 065, a small contact stabilization activated sludge plant was operated on a part-time basis by one city employee. The operator was also assigned duties associated with other city utilities. The operator was certified and attended operator seminars periodically. Before the CCP was implemented, the operator was not properly applying process controls nor was he aware of which operational adjustments or tasks most significantly influenced plant performance. Solids loss occurred repeatedly resulting in frequent violations of NPDES permit standards. The CCP was implemented over a 12 month period. The operator's process control capability was improved considerably as evidenced by improved sludge characteristics and associated improved effluent quality. The overall effluent quality averaged less than 30 mg/l for BOD_5 and TSS, but the monthly averages exceeded secondary treatment standards during three months of the year.

Operator time spent at various tasks before and after the CCP are presented in Table 20. As shown, time spent on the categories of administration, staff development, maintenance and inspection, and compliance monitoring was not effected by the CCP. Time and tasks expended for process control were affected by implementation of the CCP. The Process Control category includes all tasks associated with activated sludge process control testing, decision making and implementation. Before the CCP was initiated, approximately 9 1/2 hours per week were devoted to these tasks. After the CCP, about 17 1/2 hours per week were required. Increased time was required for operational testing to develop and maintain the desired sludge characteristics. The main control of sludge character implemented was adequate sludge mass control, which required increased time for the utilization of the available aerobic digester and for removing the digester contents to the land application site. Total Plant operating time requirements increased from 25 hours per week to 33 hours per week.

Plant 086

Plant 086, a 3800 cu m/day (1.0 mgd) extended aeration plant was operated by a superintendent and operator at the initiation of the CCP. Shortly before

TABLE 20. OPERATOR TIME AND TASKS AT PLANT 065

	Before CCP hr/wk	After CCP hr/wk
ADMINISTRATION		
Coordination, scheduling	2.5	2.5
STAFF DEVELOPMENT		
Seminars, literature review	1	1
MAINTENANCE & INSPECTION		
Preventive and emergency maintenance, rag removal, weekend inspections, yards, housekeeping	7	7
COMPLIANCE MONITORING		
Tests, reports	4	4
PROCESS CONTROL		
Tests, calculations, graphs return adjustments, wasting, sludge hauling, supernating	9.5	17.5
TOTAL PLANT WORK	25*	33*

*The balance of the operator's time was spent on assigned duties associated with other city utilities.

the research, the plant had been operated by the superintendent and by a laboratory technician. The laboratory technician had quit and the operator was hired. During the course of the CCP, a third person was hired to fill the position of laboratory technician under the CETA program. Both before and after the CCP the superintendent and operator worked part time maintaining the wastewater collection system.

The superintendent of Plant 086 was certified but had quit attending short-courses because he could not find satisfactory help in setting up a sludge wasting program. Before the CCP, sludge wasting was completed only periodically. For several months before the CCP, wasting had been discontinued altogether, resulting in several permit violations. Daily sludge wasting was implemented as part of a complete process control program and good effluent quality was achieved. Additionally, the superintendent's process control capabilities and understanding were improved. Effluent qualilty averaged 8 mg/l for BOD_5 and 4 mg/l for TSS for the eight months of the CCP.

Operator time spent at various tasks before and after the CCP are presented in Table 21. The majority of increased time was required for expanded process control activities. To support the need for additional time

TABLE 21. OPERATOR TIME AND TASKS AT PLANT 086

	Before CCP hr/wk	After CCP hr/wk
ADMINISTRATION		
Coordination with city, scheduling filing, visitors, coffee	17	17
STAFF DEVELOPMENT		
Seminars, certification study, literature review	2	8
MAINTENANCE & INSPECTION		
Preventive and emergency maintenance, yards, inspection, grit & rag removal, housekeeping	36	35
COMPLIANCE MONITORING		
Tests, reports	6	6
PROCESS CONTROL		
Tests, calculations, graphs, return adjustments, discussions, wasting, supernating	6	32
TOTAL PLANT WORK	67	98
NON-PLANT WORK BY OPERATORS		
Lift stations, lines, taps Miscellaneous city work	13	28
TOTAL	80	126

a person for line maintenance was hired. Available time in excess of that used for needed line work and increased process control was used for staff development (i.e., studying for certification).

Discussion

Operator time and tasks were evaluated for two facilities; in both the need for additional operator time for process control was documented. In the smaller facility, a 32 percent increase in total operator time was needed to achieve an acceptable level of process control. However, this increase represented eight hours per week. In the larger facility the need for increased manpower for process control required that a third operator be hired. The result was a 46 percent increase in manpower used at the plant. Despite this large percentage increase, the difference in operator time required between virtually no process control and excellent process control was 26 hours per week.

Large percentage increases in operator requirements were documented. Yet, for these relatively small facilities the percentage increases represent rather minor increases in time on a per week basis. It was concluded that relatively small amounts of operator time spent on meaningful process control activities could lead to dramatic improvement in plant performance. Although not evaluated, it was felt that for larger facilities no additional staff would be necessary. A shift in priorities would allow these operators to address process needs.

EFFECTS OF TOXICS ON PLANT PERFORMANCE

The term toxics is used to describe a multitude of compounds and elements which are present in some wastewaters in concentrations large enough to inhibit biological wastewater treatment processes. Toxics found in publicly owned wastewater collection systems are normally associated with industrial wastewaters. One of the plant selection criteria was that facilities treat primarily domestic wastes. As a result, the majority of plants studied did not have problems with toxic substances. Five of the 50 facilities studied had documented occasional severe problems with toxics. Some detrimental effects of lower levels of toxic elements were suspected but not documented at four additional plants.

The survey facilities affected by toxics are identified in Table 22. Trickling filter plants 035 and 095 reportedly received slug discharges of toxics sufficient to "kill off" a large fraction of the biomass on the filters. Plant 035 reportedly received sufficient acid to render a toxic pH at the plant. Plant 095 did not identify the compound, but received periodic slugs of a yellow precipitate which reportedly hindered performance.

Plants 065 and 077 were both small contact stabilization activated sludge plants which received periodic slugs of petroleum products in the raw wastewater. At Plant 077 the problem was found to be diesel fuel from the city power plant.

Plant 065

Plant 065 is a small contact stabilization activated sludge plant which was the subject of a CCP demonstration (Section 7). At plant 065, a railroad tank car washing operation was highly suspected as the source of toxic chemicals, but the probable source was later located at the school bus garage. Crankcase oil from the buses was drained directly to the sanitary sewer.

The periodic presence of an inhibitory compound was apparent in the results from the process control testing initiated as part of the CCP. When inhibitory slugs of oil were received, the sludge compacted significantly greater in the centrifuge analysis indicating an apparent loss of sludge from the system. A drop of between 25 and 50 percent of the total sludge mass in

TABLE 22. IMPACT OF TOXIC SUBSTANCES ON 50 COMPREHENSIVE SURVEY FACILITIES

Plant No.	Date	Plant Type	Actual Flow cu m/day	mgd**	% Design	No Problem	Problem Suspected	Problem Documented
002	1975	ASEA	1,628	0.43	54	X		
007	1976	ODEA	155	0.041	59	X		
012	1976	TF/CS	30,660	8.1	68		X	
013	1976	AS	1,892	0.5	63	X		
014	1976	AS	3,785	1.0	50	X		
015	1976	TF	6,434	1.7	47	X		
019	1976	ASEA	132	0.035	54	X		
020	1976	ASEA	26	0.007	28	X		
021	1976	ODEA	2,233	0.59	66	X		
022	1976	ASEA	45	0.012	80	X		
024	1976	ABF	18,550	4.9	69	X		
026	1976	ASEA	568	0.15	30	X		
027	1976	AS	20,820	5.5	55	X		
028	1976	ASCS	568	0.15	60	X		
029	1976	AS	5,185	1.37	78	X		
032	1976	TF	833	0.22	50	X		
034	1976	TF	20,820	5.5	68	X		
035	1976	TF	20,060	5.3	98	X		
036	1976	TF	6,056	1.6	87			X
038	1978	AS	11,880	3.14	70	X		
039	1976	ODEA	795	0.21	51	X		
040	1976	RBC	1,438	0.38	60	X		
041	1977	TF	492	0.13	33	X		
047	1976	ASEA	189	0.05	80	X		
048	1976	AS	1,287	0.34	89	X		
050	1977	ASEA	643	0.17	96	X		
051	1977	ASEA	795	0.21	75	X		
052	1977	ASEA	170	0.045	60	X		
053	1977	ASEA	416	0.11	68	X		
055	1977	ASEA	1,136	0.30	52	X		
060	1977	ABF	1,855	0.49	47	X		
061	1977	ASCS	643	0.17	34	X		
062	1977	ODEA	757	0.20	59	X		
063	1977	AS	2,650	0.7	47	X		
065	1977	ASCS	492	0.13	87			X
066	1977	AS(2)	2,687	0.71	76	X		
068	1978	AS	20,440	5.4	98		X	
069	1978	TF	303	0.08	114	X		
070	1978	TF	4,164	1.10	101		X	
074	1978	AS	1,136	0.30	86	X		
075	1978	AS	21,950	5.8	64	X		
077	1978	AS	908	0.24	78			X
080	1978	AS	946	0.25	60	X		
082	1978	ASCS/TF	314	0.083	69	X		
085	1978	ODAS	3,179	0.84	86	X		
086	1978	ASEA	1,817	0.48	48			X
092	1978	AS	11,910	3.12	57	X		
093	1978	RBC	8,327	2.2	44		X	
095	1978	TF	4,542	2.1	48			X
097	1978	ASCS	3,179	0.84	84	X		
				TOTAL FACILITIES		41	4	5

the plant was indicated. Immediate changes in activated sludge characteristics also resulted. The sludge exhibited faster settling and turbid supernatant characteristics. The period during which slugs of oil was received coincided exactly with a significant reduction in plant performance. For the 5-month period prior to receiving the oil, effluent BOD_5 and TSS averaged 20 mg/l and 8 mg/l, respectively. For the 5-month period during which the oil slugs were received, effluent quality averaged 54 mg/l for BOD_5 and 24 mg/l for TSS.

Lack of adequate process control can often be the cause of poor plant performance. In fact, it has been observed that toxic substances are blamed for this less than optimum condition. However, in the case of Plant 065, the slugs of oil were felt to be the singular most direct cause of poor performance since good process control had been established for a 5-month period prior to the plant receiving oily wastes.

The long time associated with developing desirable activatd sludge characteristics was documented during Phase I (4). This long time requirement helps explain why a relatively minor yet periodic problem with toxic substances can create a long-term continuous performance problem. In Plant 065 two to four weeks of time was available between each slug of oil. This was not sufficient for the sludge quality to recover. As a result, poor performance occurred over a long period of time. This problem will persist until the oil source is removed.

Plant 086

Plant 086 is a 3800 cu m/day (1 mgd) activated sludge plant which was the subject of a CCP demonstration (Section 7). The plant superintendent reported several instances of a "tomato juice smell" at the plant headworks. Several of these instances were recorded without apparent detrimental effects on effluent quality. After several months, another typical "tomato juice smell" was detected along with a yellow precipitate in the plant influent. In several days the mixed liquor appeared gray and the effluent was highly turbid.

The sludge inventory in the plant and the sludge wasted to maintain that inventory are presented in Figure 26. The "tomato juice smell" and gray mixed liquor occurred during Week 4. As shown, the sludge inventory dropped radically the next two weeks. In response to the loss of sludge growth, wasting was reduced to a minimum starting with Week 6. By adjusting the wasting to a level below the decreased sludge growth rate, the sludge inventory was gradually returned to the desired level. Sludge production remained at a minimum for a seven-week period (weeks 5 through 11), before activity in the sludge returned and near normal sludge production was experienced. The duration of this recovery period indicates the long time period associated with biological system response.

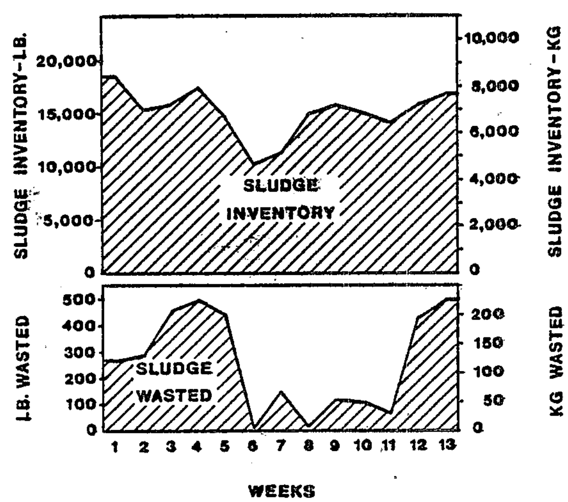


Figure 26. Impact of toxics on sludge activity at Plant 086.

Effluent quality during the same (13-week) period is presented in Figure 27. Effluent BOD_5 and TSS averaged 9.0 mg/l and 8.1 mg/l respectively, for the first six weeks. Effluent quality degraded approximately three weeks after the major slug load of toxics was received at the plant. No permit violations were experienced as effluent BOD_5 peaked at 27 mg/l.

At this writing, a metal plating industry was suspected to be the source of the toxics in the plant influent and samples had been obtained for analysis. Low levels of chromium, zinc and cyanide were found, but conclusive evidence concerning the exact amounts and concentrations which caused the plant operations problem was not available.

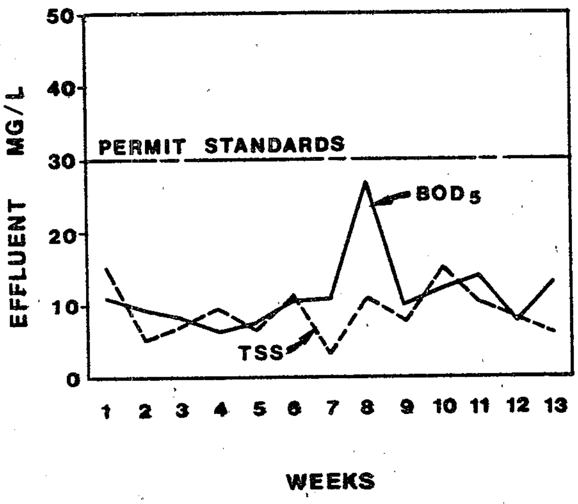


Figure 27. Impact of toxics on effluent quality at Plant 086.

Discussion

The effects of toxic substances on the performance of biological wastewater treatment processes were documented at two facilities. Periodic slug loads of oil were the suspected cause of degraded effluent quality in Plant 065. Due to the inherent long time necessary for activated sludge characteristics to recover, the periodic slug loads resulted in consistent, long-term degraded effluent quality.

Plant 086 was an underloaded extended aeration activated sludge plant. Toxics substances received at this plant resulted in a long-term (7-week) reduction in sludge activity, but only caused minor problems with plant effluent quality. Optimum sludge characteristics maintained before the toxic substances were received and quick operational response to changed wasting requirements were instrumental in minimizing the effect on plant performance. A larger slug dose may have caused considerably more severe problems.

Toxics were not identified as an overall major performance-limiting factor for the fifty plants studied. However, plants with known toxicity problems were excluded from study. In evaluating the effect of toxic substances on biological processes, it should be recognized that the symptoms of a toxicity problem are often similar to problems associated with improper process control. Toxic problems were identified at two facilities where improved process control had been established. Since improved process control was attained first, the true impact of the toxicity problems was felt to be demonstrated. It was concluded that when a true toxicity problem is indicated, finding and eliminating the source of the substance should receive a high priority.

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APPENDIX A

LOCATION OF FACILITIES AND TYPE OF EVALUATION CONDUCTED

TREATMENT FACILITY LOCATION

STATE	SITE VISIT	COMPREHENSIVE EVALUATION
Colorado	Kittredge	Morrison
	Colorado Springs	Englewood
	Empire	Snowmass Village
	Georgetown	Aspen Metro
	Vail	Fort Morgan
	Brush	Elizabeth
	Victor	Elbert
	Cripple Creek	Berthoud
		Aurora
		Eaton
Iowa	Clarinda	Bedford
	Shenandoah	Elma
	Eldora	Cresco
	Iowa Falls	Reinbeck
	Osage	Akron
	Tama	Cherokee
	Mason City	Marshalltown
	Oskaloosa NE	Melbourne
	Oskaloosa SW	Grinnell
	Ankeny	Grimes
Montana	Butte	Hillbrook Nursing Home, Clancy
	Kalispell	Helena
	Big Fork	Columbia Falls
	Yellow Bay Biological Sta.	Lolo
	Harlem	Missoula
		Havre
		Chinook
Nebraska	Fremont	Arlington
	Scribner	West Point
	Norfolk	Crete
	Platte Center	Gretna
	Waco	Elkhorn
	Sutton	Waterloo

APPENDIX A (Cont.)

LOCATION OF FACILITIES
AND
TYPE OF EVALUATION CONDUCTED

TREATMENT FACILITY LOCATION

STATE	SITE VISIT	COMPREHENSIVE EVALUATION
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 Lusk Rock Springs Evanston	South Cheyenne Cheyenne Dry Creek
Kansas	Ottawa Gypsum Herington Newton Haysville Anthony	Lawrence Osage City Hillsboro Colwich
Missouri	Newberg Rolla Festus/Crystal Eureka Saline County Sewer Company, Fenton Columbia Flat Branch Warrensburg Lee's Summit	Bolivar Marshfield St. Charles MO R. Kirkesville Sedalla Belton

APPENDIX B

INFORMATION SHEETS FOR SITE VISITS AND COMPREHENSIVE SURVEYS

The forms in this appendix were completed for each wastewater treatment facility where a survey was conducted. The site visit form was completed to provide general information about the treatment facility. The comprehensive evaluation forms were used to provide detailed information in the broad areas of plant administration, maintenance, design and operation.

SITE VISIT FORM

Operator ______________________________

Person to Call for Information ______________________________

Telephone No. ______________________________

Type Plant ______________________________

Year Built ______________________________

Design Flow ______________________________

Present Flow ______________________________

I/I Problems ______________________________

Industrial Loads ______________________________

Separate Sewers ______________________________

Population Served ______________________________

Receiving Stream ______________________________

Water Quality Limited ______________________________

Effluent Limits ______________________________

Current Effluent Quality ______________________________

Monitoring Tests Conducted ______________________________

____

____

____

Operational Tests Conducted ______________________________

____

____

Spare Parts Inventory ______________________________

No. Operators & Certification ______________________________

____

Plant Coverage - Weekdays ______________________________

Weekends & Holidays ______________________________

Preventive Maintenance Schedule ______________________________

Emergency Maintenance Records ______________________________

COMPREHENSIVE EVALUATION 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:

APPENDIX B (Cont.)

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 = _____ c/1000 gal x 0.264 = _____ c/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	c/Kwh	Flow
TOTALS						mgd
						cu m/day

KWH/DAY _____ $/DAY _____
KWH/1000 gal _____ c/1000 gal _____
KWH/cu m _____ c/cu m _____

COST SUMMARY

	c/cu m	c/1000 gal
Electrical		
Salaries		
Total Operations		
Total Cost		

APPENDIX C

PLANT EVALUATION SUMMARY FORMS

Plant Evaluation Summary forms were developed for the project to determine and rank the factors limiting performance at wastewater treatment facilities. Part 2 of the Summary (the weighing table) was used to note the causes of less than optimum performance in the areas of administration, maintenance, design and operation. A point system was used to express the severity of problems noted. Part 1 of the Summary (the ranking table) was used to rank the performance-limiting factors noted as severe according to their magnitude of importance. Definitions of the terms used in the Plant Evaluation Summary are 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			

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 (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		
3. Plant Management		
b. Morale		
1. Motivation		
2. Pay		
3. Supervision		
4. Plant Esthetics		
5. Safe 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		

WEIGHTING TABLE (PART 2)

CATEGORY	PTS	COMMENTS
b. References Available		
c. Spare Parts Inventory		
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 Controllability		
3. Aerator		
4. Clarifier		
d. Advance Waste Treatment		
1.		
2.		
3.		
4.		
5.		

WEIGHTING TABLE (PART 2)

CATEGORY	PTS	COMMENTS
e. Disinfection		
f. Sludge Wasting Capability		
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. Quality of Equipment		
n.		

WEIGHTING TABLE (PART 2)

CATEGORY	PTS	COMMENTS
D. OPERATION		
1. Staff Qualifications		
a. Ability		
1. Aptitude		
2. Level of Education		
b. Certification		
1. Level of Certification		
2. Training		
c. Sewage Treatment Understanding		
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.		

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?"

3. **Plant Management** — Do formal personnel development programs exist? Are formal "Annual Reports" issued? Is there written evidence of Planning, Organizing, Staffing, Delegation and Controls?

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. **Plant Esthetics** — Does a poor working environment create a condition for more "sloppy work habits" and lower operator morale?

5. **Safe Working Conditions** — Are safety statistics kept and reported? Are there regular safety meetings or posted safety guides? Do unsafe working conditions cause operators to avoid taking measures to control the plant?

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 caused 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 or extreme lack of an effective maintenance program caused 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 caused extended periods of equipment down time?

c. **Technical Guidance** — If technical guidance for repairing or installing equipment is necessary to decrease equipment down time, is it 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 <u>of the existing plant</u> 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 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 or size of sludge treatment processes hinder sludge stabilization (once sludge has been removed from the wastewater treatment system) which in turn effects 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 upset 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 absence or inadequacy of a good alarm system for critical pieces of equipment caused 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 water 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 device (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?

m. Quality of Equipment — Has the poor quality of plant equipment resulted in excessive repairs and maintenance?

B. 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 Treatment Understanding — Has the opertors' 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?

APPENDIX D

PLANT EVALUATION SUMMARY FOR SITE VISIT FACILITIES (PHASE II)

Plant Evaluation Summarizes for plants where site visits were conducted differ from the comprehensive evaluation results because only a one-half day evaluation was made, whereas a one-week evaluation was made at comprehensively evaluated facilities. Therefore, only the more obvious factors limiting performance were determined during site visits. The Plant Evaluation Summary results for the Phase I site visits have been previously reported (5).

PLANT NO. 064

PLANT TYPE:	Conventional activated sludge with roughing filters
DESIGN FLOW:	39,740 cu m/day (10.5 mgd)
ACTUAL FLOW:	15140 cu m/day (4 mgd)
YEAR PLANT BUILT:	1967
YEAR OF MOST RECENT UPGRADE:	1974

PLANT PERFORMANCE SUMMARY:

Standard secondary treatment required. Effluent BOD reported as 15 mg/1. No solids loss problems reported.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.f.	Sludge Treatment	2
2	C.2.c.3.	Aerators	2
3	C.2.c.1.	Process Flexibility	2
4	C.2.h.	Ultimate Sludge Disposal	2
5			
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PLANT NO. 067

PLANT TYPE:	Trickling Filter/Activated Sludge
DESIGN FLOW:	24,600 cu m/day (6.5 mgd)
ACTUAL FLOW:	16,275 cu m/day (4.3 mgd)
YEAR PLANT BUILT:	1962
YEAR OF MOST RECENT UPGRADE:	1975

PLANT PERFORMANCE SUMMARY:

Plant records of operation indicate very good performance with BOD_5 and TSS values generally less than 5 mg/1 and ammonia less than 1 mg/1.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
2			
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PLANT NO. 071

PLANT TYPE:	Single-Stage Trickling Filter w/Storage Lagoon
DESIGN FLOW:	3785 cu m/day (1 mgd)
ACTUAL FLOW:	3785 cu m/day (1 mgd)
YEAR PLANT BUILT:	—
YEAR OF MOST RECENT UPGRADE:	1973

PLANT PERFORMANCE SUMMARY:

Plant has consistently met secondary standards, but is being replaced to meet new more stringent standards.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.c.3.	Aerator	2
2	C.1.f.	Infiltration/Inflow	2
3			
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PLANT NO. 072

PLANT TYPE:	Activated Sludge
DESIGN FLOW:	3028 cu m/day (0.8 mgd)
ACTUAL FLOW:	3028 cu m/day (0.8 mgd)
YEAR PLANT BUILT:	1973
YEAR OF MOST RECENT UPGRADE:	No Upgrade

PLANT PERFORMANCE SUMMARY:

Appeared to meet secondary standards.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
2	C.2.c.3.	Aerator	2
3	C.2.c.2.	Process Flexibility	2
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PLANT NO. 073

PLANT TYPE:	Activated Sludge
DESIGN FLOW:	4542 cu m/day (1.2 mgd)
ACTUAL FLOW:	5678 cu m/day (1.5 mgd)
YEAR PLANT BUILT:	1975
YEAR OF MOST RECENT UPGRADE:	No Upgrades

PLANT PERFORMANCE SUMMARY:

Plant has met secondary standards in recent months following a period of non-compliance.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.5.a.	Equipment Malfunction	3
2	C.2.c.3.	Aerator	2
3	C.2.c.1	Process Flexibility	2
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PLANT NO. 076

PLANT TYPE:	Contact Stabilization Activated Sludge
DESIGN FLOW:	6435 cu m/day (1.7 mgd)
ACTUAL FLOW:	4920 cu m/day (1.3 mgd) up to 10,220 cu m/day (2.7) in wet weather
YEAR PLANT BUILT:	1929
YEAR OF MOST RECENT UPGRADE:	1951

PLANT PERFORMANCE SUMMARY:

Plant records indicate secondary treatment is met or nearly met, but the operator bypasses primary effluent up to 1 mgd during rain and reports solids loss for periods of an hour or so every 15 to 20 days.

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	3
3	C.2.c.4.	Clarifier	3
4	C.2.c.1.	Flexibility	2
5	C.2.c.2.	Controllability	2
6	D.2.b.	Process Control Testing	2
7			
8			
9			
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PLANT NO. 078

PLANT TYPE:	Imhoff Tank/Trickling Filter
DESIGN FLOW:	300 cu m/day (0.08 mgd)
ACTUAL FLOW:	190 cu m/day (0.05 mgd)
YEAR PLANT BUILT:	1961
YEAR OF MOST RECENT UPGRADE:	None

PLANT PERFORMANCE SUMMARY:

Does not meet secondary standards consistently. Bypasses during high infiltration.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.g.	Sludge Treatment	3
2	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
3	C.1.f.	Infiltration/Inflow	2
4	C.2.c.3.	Aerator	2
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PLANT NO. 079

PLANT TYPE:	Activated Sludge w/Polishing Lagoon
DESIGN FLOW:	1890 cu m/day (0.5 mgd)
ACTUAL FLOW:	1135 cu m/day (0.3 mgd)
YEAR PLANT BUILT:	--
YEAR OF MOST RECENT UPGRADE:	1969

PLANT PERFORMANCE SUMMARY:

Violated standards frequently.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.f.	Sludge Wasting Capability	3
2	D.3.b.	Technical Guidance	3
3	D.1.c.	Sewage Treatment Understanding	3
4	C.1.f.	I/I	3
5	C.2.c.4.	Clarifier	3
6	C.2.c.2.	Process Controllability	2
7	C.2.c.1.	Process Flexibility	2
8			
9			
10			

PLANT NO. 081

PLANT TYPE: Two-Stage Trickling Filter	
DESIGN FLOW: 9460 cu m/day (2.5 mgd)	
ACTUAL FLOW: 3030 cu m/day (0.8 mgd)	
YEAR PLANT BUILT: 1952	
YEAR OF MOST RECENT UPGRADE: 1977	
PLANT PERFORMANCE SUMMARY: Has met standards consistently.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.c.3.	Aerator	2
2	C.2.g.	Sludge Treatment	2
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PLANT NO. 083

PLANT TYPE: Contact Stabilization and Trickling Filter	
DESIGN FLOW: 1890 cu m/day; 570 cu m/day (0.5 mgd/0.15 mgd)	
ACTUAL FLOW: 1515 cu m/day; 300 cu m/day (0.4 mgd/0.08 mgd)	
YEAR PLANT BUILT: --	
YEAR OF MOST RECENT UPGRADE: 1965	
PLANT PERFORMANCE SUMMARY: The trickling filter performs quite well in summer, but does not meet standards in winter. The contact stabilization plant usually meets standards; however, solids loss was reported.	

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	2
3	C.2.g.	Sludge Treatment	2
4	D.2.b.	Process Control Testing	2
5			
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PLANT NO. 084

PLANT TYPE: Oxidation Ditch	
DESIGN FLOW: 3785 cu m/day (1 mgd)	
ACTUAL FLOW: 1135 cu m/day (0.3 mgd)	
YEAR PLANT BUILT: 1935	
YEAR OF MOST RECENT UPGRADE: 1977	
PLANT PERFORMANCE SUMMARY: Plant consistently meets effluent standards.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.1.3.a.	Operator Application of Concepts and Testing to Process Control	2
2	D.1.2.b.	Process Control Testing	2
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PLANT NO. 087

PLANT TYPE: Activated Sludge (Contact Stabilization)	
DESIGN FLOW: Unknown	
ACTUAL FLOW: Est. 300 cu m/day (80,000 gpd)	
YEAR PLANT BUILT: 1966	
YEAR OF MOST RECENT UPGRADE: --	
PLANT PERFORMANCE SUMMARY: Reported problems with meeting permit standards. The City is currently working with the State and the equipment manufacturer to work out problems.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	A.1.a.	Policies	3
2			
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PLANT NO. 088

PLANT TYPE:	Activated Sludge and Parallel Trickling Filter
DESIGN FLOW:	6813 cu m/day (1.8 mgd) and 3785 cu m/day (1.0 mgd)
ACTUAL FLOW:	Dry Weather: 10600 cu m/day (2.8 mgd), Wet 17030 cu m/day (4.5 mgd)
YEAR PLANT BUILT:	TF - 1953 AS - 1973
YEAR OF MOST RECENT UPGRADE:	1973
PLANT PERFORMANCE SUMMARY:	Meets standards consistently according to plant records.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.1.f.	Infiltration/Inflow	2
2	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
3	C.2.c.2.	Process Controllability	2
4	C.1.d.	Toxics	2
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PLANT NO. 089

PLANT TYPE:	Activated Sludge (Contact Stabilization)
DESIGN FLOW:	3860 cu m/day (1.0 mgd)
ACTUAL FLOW:	5680 cu m/day (1.5 mgd)
YEAR PLANT BUILT:	1965
YEAR OF MOST RECENT UPGRADE:	None
PLANT PERFORMANCE SUMMARY:	Plant does not meet standards on consistent basis.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	A.2.b.1.	Motivation	3
2	A.1.b.	Familiarity w/plant needs	2
3	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
4	C.2.c.2.	Process Controllability	2
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PLANT NO. 090

PLANT TYPE:	Contact Stabilization w/Polishing Lagoon
DESIGN FLOW:	1890 cu m/day (0.5 mgd)
ACTUAL FLOW:	Dry 1890 cu m/day (0.5 mgd); Wet as high as 17,000 cu m/day (4.5 mgd)
YEAR PLANT BUILT:	1970
YEAR OF MOST RECENT UPGRADE:	None
PLANT PERFORMANCE SUMMARY:	30/30 standards are exceeded the majority of the time. Clarifier effluent is generally better than pond effluent except when solids are lost due to I/I.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.1.f.	I/I	3
2	C.2.c.1.	Process Flexibility	3
3	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
4	D.2.b.	Process Control Testing	2
5	C.2.c.2.	Process Controllability	2
6	C.2.f.	Sludge Wasting Capability	2
7			
8			
9			
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PLANT NO. 091

PLANT TYPE:	Contact Stabilization
DESIGN FLOW:	2840 cu m/day (0.75 mgd)
ACTUAL FLOW:	Est. 1700 cu m/day (Est. 0.45 mgd)
YEAR PLANT BUILT:	1976
YEAR OF MOST RECENT UPGRADE:	None
PLANT PERFORMANCE SUMMARY:	Reportedly good, but lack of appreciation for process control and especially sludge handling indicate periodic solids loss. Performance poor during survey due to clarifier scraper failure and lack of control.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	A.1.b.	Familiarity w/Plant Needs	3
2	D.3.a.	Operator Application of Concepts and Testing to Process Control	3
3	C.2.c.2.	Process Controllability	3
4	C.3.i.	Lab Space and Equipment	2
5	D.5.a.	Equipment Malfunction	2
6	B.3.a.	Emergency Mtc. Staff Expertise	2
7	C.2.h.	Ultimate Sludge Disposal	2
8	A.2.b.5.	Unsafe Working Conditions	2
9			
10			

PLANT NO. 094

PLANT TYPE: Conventional Activated Sludge	
DESIGN FLOW: 7570 cu m/day (2.0 mgd)	
ACTUAL FLOW: 6060 cu m/day (1.6 mgd)	
YEAR PLANT BUILT: 1941	
YEAR OF MOST RECENT UPGRADE: No major upgrades	
PLANT PERFORMANCE SUMMARY: Plant appeared to be meeting standards based on plant records and reports from the operators. BOD_5 fluctuated from about 5 to 30 mg/l. High flows are bypassed to another plant downstream which does not meet standards.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	A.1.a.	Policies	2
2	C.2.c.2.	Process Controllability	2
3	C.2.c.1.	Process Flexibility	2
4	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
5	C.2.f.	Sludge Wasting Capability	2
6			
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9			
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PLANT NO. 096

PLANT TYPE: Extended Aeration Activated Sludge	
DESIGN FLOW: 6330 cu m/day (1.7 mgd)	
ACTUAL FLOW: 5680 cu m/day (1.5 mgd)	
YEAR PLANT BUILT: 1977	
YEAR OF MOST RECENT UPGRADE: None	
PLANT PERFORMANCE SUMMARY: Meets standards during normal operation according to plant records, but reports of "solids washout" indicate standards are violated periodically.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
2	C.2.f.	Sludge Wasting Capability	2
3	C.2.c.4.	Clarifier	2
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PLANT NO. 098

PLANT TYPE: Three-cell Aerated Lagoon	
DESIGN FLOW: 7570 cu m/day (2 mgd)	
ACTUAL FLOW: Unknown, est. approximately 3785 cu m/day (1 mgd)	
YEAR PLANT BUILT: 1977	
YEAR OF MOST RECENT UPGRADE: --	
PLANT PERFORMANCE SUMMARY: Reportedly meets BOD standard and occasionally exceeds SS standard.	

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.c.3.	Aerator	3
2			
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APPENDIX E

PLANT EVALUATION SUMMARY FOR COMPREHENSIVE EVALUATION FACILITIES (PHASE II)

The Plant Evaluation Summaries for plants where comprehensive evaluations were conducted are included in this appendix. The summaries include the ranking of only the factors that were more severely affecting performance (i.e., those factors that received two and three points). The Plant Evaluation Summary Results for the Phase I comprehensive evaluations have been previously reported (5).

PLANT NO. 038

PLANT TYPE:	Conventional Activated Sludge w/Anaerobic Digesters
DESIGN FLOW:	17,030cu m /day (4.5 mgd)
ACTUAL FLOW:	12,700cu m/day (3.35 mgd)
YEAR PLANT BUILT:	1976
YEAR OF MOST RECENT UPGRADE:	None
PLANT PERFORMANCE SUMMARY:	Plant effluent periodically violated permit standards.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	A.2.a.3.	Plant Management	3
2	D.3.a.	Operator Application of Concepts and Testing to Process Control	3
3	C.2.f.	Sludge Wasting Capability	2
4	A.1.b.	Familiarity With Plant Needs	2
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9			
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PLANT NO. 051

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PLANT TYPE:	Extended Aeration Activated Sludge
DESIGN FLOW:	1060 cu m/day (0.28 mgd)
ACTUAL FLOW:	795 cu m/day (0.21 mgd)
YEAR PLANT BUILT:	1975
YEAR OF MOST RECENT UPGRADE:	No Upgrades

PLANT PERFORMANCE SUMMARY:

Limited historical monitoring data indicates the final effluent has met secondary standards. Reports of past solids loss and information obtained during the survey indicate standards have been violated repeatedly because of excessive solids discharged.

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 & Testing to Process Control	3
3	A.1.b.	Familiarity with Plant Needs	2
4	C.2.c.4.	Clarifier	2
5	C.1.f.	Infiltration/Inflow	2
6	C.1.c.	Industrial Loading	2
7	C.2.c.2.	Process Controllability	2
8	C.2.h.	Ultimate Sludge Disposal	2
9	D.1.c.	Sewage Treatment Understanding	2
10	D.3.b.	Technical Guidance	2

PLANT NO. 052

Page 1 of 5

PLANT TYPE:	Activated Sludge Extended Aeration
DESIGN FLOW:	280 cu m/day (0.075 mgd)
ACTUAL FLOW:	170 cu m/day (0.045 mgd)
YEAR PLANT BUILT:	1954
YEAR OF MOST RECENT UPGRADE:	1971

PLANT PERFORMANCE SUMMARY:

Plant usually meets secondary treatment (permit) standards. Occasionally some solids are unnecessarily lost to the effluent.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.1.c.	Sewage Treatment Understanding	2
2			
3			
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PLANT NO. 062

Page 1 of 5

PLANT TYPE:	Extended Aeration Oxidation Ditch
DESIGN FLOW:	1290 cu m/day (0.34 mgd)
ACTUAL FLOW:	760 cu m/day (0.20 mgd)
YEAR PLANT BUILT:	1968
YEAR OF MOST RECENT UPGRADE:	1977

PLANT PERFORMANCE SUMMARY:

Plant has met standards on a consistent basis since upgrade.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.a.	Operator Application of Concepts & Testing to Process Control	2
2	D.1.c.	Sewage Treatment Understanding	2
3	D.5.a.	Equipment Malfunction	2
4			
5			
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8			
9			
10			

PLANT NO. 065

PLANT TYPE: Contact Stabilization Activated Sludge
DESIGN FLOW: 568 cu m/day (0.15 mgd)
ACTUAL FLOW: 492 cu m/day (0.13 mgd)
YEAR PLANT BUILT: 1967
YEAR OF MOST RECENT UPGRADE: None
PLANT PERFORMANCE SUMMARY: Records of operation indicate BOD_5 and TSS monthly averages fluctuate from about 25 mg/l to 45 mg/l. The plant operator also reported that excessive solids loss has occurred on a somewhat regular basis for as long as he had been there, and is not monitored in the above values.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D. 3. a.	Operator Application of Concepts and testing to Process Control	3
2	A. 1. b.	Familiarity with Plant needs	3
3	C. 2. g.	Sludge Treatment	2
4	D. 3. b.	Technical Guidance	2
5	C. 2. c. 4.	Clarifier	2
6	A. 2. b. 5.	Safe Working Conditions	2
7	D. 5. a.	Equipment Malfunction	2
8			
9			
10			

PLANT NO. 066

PLANT TYPE: Two - Stage Activated Sludge
DESIGN FLOW: 3560 cu m /day (0.94 mgd)
ACTUAL FLOW: 2700 cu m /day (0.71 mgd)
YEAR PLANT BUILT: 1975
YEAR OF MOST RECENT UPGRADE:
PLANT PERFORMANCE SUMMARY: Plant occasionally violates discharge permit water quality standards of 10 mg/l BOD, 20 mg/l SS, and 3 mg/l NH_3.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D. 3. a.	Operator Application of Concepts &	
2		testing to Process Control	3
3	D. 3. b.	Technical Guidance	2
4	C. 2. c. 2.	Process Controllability	2
5			
6			
7			
8			
9			
10			

PLANT NO. 068

PLANT TYPE: Activated Sludge
DESIGN FLOW: 20,800 cu m/day (5.5 mgd)
ACTUAL FLOW: 20,400 cu m/day (5.4 mgd)
YEAR PLANT BUILT: 1940
YEAR OF MOST RECENT UPGRADE: 1976
PLANT PERFORMANCE SUMMARY: Plant historically exceeds BOD, TSS and ammonia limits, but met BOD_5 and TSS limits during the survey.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.c.1.	Process Flexibility	3
2	C.2.f.	Sludge Wasting Capability	3
3	C.1.f.	Infiltration/Inflow	3
4	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
5	C.3.b.	Unit Process Layout	2
6	C.2.c.2.	Process Controllability	2
7	C.2.c.3.	Aerator	2
8			
9			
10			

PLANT NO. 069

PLANT TYPE: Imhoff Tank/Trickling Filter
DESIGN FLOW: 380 cu m/day (0.1 mgd)
ACTUAL FLOW: 250 cu m/day (0.065 mgd)
YEAR PLANT BUILT: 1948
YEAR OF MOST RECENT UPGRADE: No Upgrade
PLANT PERFORMANCE SUMMARY: Plant does not meet secondary standards consistently, and is presently going through a 201 study.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.1.c.	Sewage Treatment Understanding	3
2	D.3.a.	Operator Application of Concepts and	
3	—	Testing to Process Control	2
4	C.1.f.	Infiltration/Inflow	2
5	C.2.c.3.	Aerator	2
6			
7			
8			
9			
10			

PLANT NO. 070

PLANT TYPE: Single stage trickling filter with recirculation
DESIGN FLOW: 4160 cu m/day (1.1 mgd)
ACTUAL FLOW: 4125 cu m/day (1.09 mgd)
YEAR PLANT BUILT: 1952
YEAR OF MOST RECENT UPGRADE: No upgrade
PLANT PERFORMANCE SUMMARY:

Plant consistently meets secondary standards when not bypassing, but is being replaced to meet more stringent stream standards and to correct I/I.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.1.f	Infiltration/Inflow	3
2	C.2.c.1	Process Flexibility	2
3			
4			
5			
6			
7			
8			
9			
10			

PLANT NO. 074

PLANT TYPE: Activated Sludge w/Polishing Lagoons
DESIGN FLOW: 1320 cu m/day (0.35 mgd)
ACTUAL FLOW: 1140 cu m/day (0.30 mgd)
YEAR PLANT BUILT: 1975
YEAR OF MOST RECENT UPGRADE: None
PLANT PERFORMANCE SUMMARY:

Plant has not met TSS standards from either the polishing ponds or from the clarifiers about 50 percent of the time.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.h.	Ultimate Sludge Disposal	3
2	D.3.b.	Technical Guidance	3
3	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
4	C.2.C.1.	Process Flexibility	2
5			
6			
7			
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9			
10			

PLANT NO. 075

PLANT TYPE: Activated Sludge
DESIGN FLOW: 34,100 cu m/day (9.0 mgd)
ACTUAL FLOW: 22,000 cu m/day (5.8 mgd)
YEAR PLANT BUILT: 1967
YEAR OF MOST RECENT UPGRADE: 1976
PLANT PERFORMANCE SUMMARY:

Plant has met standards consistantly, but has not operated at optimum.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.b.	Technical Guidance	2
2			
3			
4			
5			
6			
7			
8			
9			
10			

PLANT NO. 077

PLANT TYPE: Activated Sludge with Aerobic Digester
DESIGN FLOW: 1165 cu m/day (0.31 MGD)
ACTUAL FLOW: 910 cu m/day (0.24 MGD)
YEAR PLANT BUILT: 1965
YEAR OF MOST RECENT UPGRADE: None
PLANT PERFORMANCE SUMMARY:

Consistent solids loss from plant due to uncontrolled sludge mass and infiltration/inflow.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	A.1.b.	Familiarity with Plant Needs	3
2	C.1.f.	Infiltration/Inflow	3
3	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
4	C.2.c.3.	Aerator	2
5	C.2.f.	Sludge Wasting Capability	2
6			
7			
8			
9			
10			

PLANT NO. 080

PLANT TYPE:	Activated Sludge With Aerobic Digester
DESIGN FLOW:	1590 cu m/day (0.42 MGD)
ACTUAL FLOW:	950 cu m/day (0.25 MGD)
YEAR PLANT BUILT:	1968
YEAR OF MOST RECENT UPGRADE:	None

PLANT PERFORMANCE SUMMARY:

Plant has historically violated permit requirements. Increased operations has improved plant performance.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.a.	Operator Application of Concepts and Testing to Process Control	2
2	C.2.h.	Ultimate Sludge Disposal	2
3	C.2.f.	Sludge Wasting Capability	2
4	C.2.c.3.	Aerator	2
5			
6			
7			
8			
9			
10			

PLANT NO. 082

PLANT TYPE:	Contact Stabilization/Trickling Filter
DESIGN FLOW:	450 cu m/day (0.12 mgd)
ACTUAL FLOW:	310 cu m/day (0.083 mgd)
YEAR PLANT BUILT:	1957
YEAR OF MOST RECENT UPGRADE:	1967

PLANT PERFORMANCE SUMMARY:

Plant effluent violates standards about 50 percent of the time.

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.2.b.	Process Control Testing	2
3	A.2.b.5.	Safe Working Conditions	2
4			
5			
6			
7			
8			
9			
10			

PLANT NO. 085

PLANT TYPE:	Activated Sludge (Oxidation Ditch)
DESIGN FLOW:	3700 cu m/day (0.98 mgd)
ACTUAL FLOW:	3530 cu m/day (0.93 mgd)
YEAR PLANT BUILT:	1974
YEAR OF MOST RECENT UPGRADE:	None

PLANT PERFORMANCE SUMMARY:

Plant has experienced occasional solids loss resulting in Permit violations.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.a.	Operator Application of Concepts and	
2	—	Testing to Process Control	3
3	C.2.f.	Sludge Wasting Capability	3
4	A.2.c.	Productivity	2
5	D.3.b.	Technical Guidance	2
6			
7			
8			
9			
10			

PLANT NO. 086

PLANT TYPE:	Activated Sludge Extended Aeration with I/I ponds
DESIGN FLOW:	3780 cu m/day (1.0 mgd)
ACTUAL FLOW:	1820 cu m/day (0.48 mgd)
YEAR PLANT BUILT:	1976
YEAR OF MOST RECENT UPGRADE:	None

PLANT PERFORMANCE SUMMARY:

Plant effluent quite often violated permit standards due to excessive solids loss.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.a.	Operator Application of Concepts and	
2	—	Testing to Process Control	3
3	D.3.b.	Technical Guidance	3
4	C.2.f.	Sludge Wasting Capability	2
5	C.2.c.2.	Process Controllability	2
6			
7			
8			
9			
10			

PLANT NO. 092

PLANT TYPE:	Conventional Activated Sludge with Carbon Filters
DESIGN FLOW:	20,800 cu m/day (5.5 mgd)
ACTUAL FLOW:	
YEAR PLANT BUILT:	1970 Primary Clarification
YEAR OF MOST RECENT UPGRADE:	1975 Secondary Treatment
PLANT PERFORMANCE SUMMARY:	Plant effluent from carbon tower met plant's secondary treatment standards, but effluent from secondary process would not have met standards.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.a.	Operator Application of Concepts and	
2		Testing to Process Control	2
3			
4			
5			
6			
7			
8			
9			
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PLANT NO. 093

PLANT TYPE:	Rotating Biological Media
DESIGN FLOW:	18,925 cu m/day (5 mgd)
ACTUAL FLOW:	8330 cu m/day (2.2 mgd)
YEAR PLANT BUILT:	1976
YEAR OF MOST RECENT UPGRADE:	None
PLANT PERFORMANCE SUMMARY:	Permit requirements have been violated since plant start-up. Effluent quality does show improvement during warmer months.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.c.3.	Aerator	3
2	D.5.a.	Equipment Malfunction	2
3			
4			
5			
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9			
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PLANT NO. 095

PLANT TYPE:	Plastic Media Trickling Filter
DESIGN FLOW:	9500 cu m/day (2.5 mgd)
ACTUAL FLOW:	4500 cu m/day (1.2 mgd)
YEAR PLANT BUILT:	1949
YEAR OF MOST RECENT UPGRADE:	1966
PLANT PERFORMANCE SUMMARY:	The plant has met standards the majority of the time but not consistently.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	C.2.c.3.	Aerator	3
2	A.1.a.	Policies	2
3	C.2.c.1.	Process Flexibility	2
4			
5			
6			
7			
8			
9			
10			

PLANT NO. 097

PLANT TYPE:	Activated Sludge - Contact Stabilization
DESIGN FLOW:	3785 cu m/day (1.0 mgd)
ACTUAL FLOW:	3400 cu m/day (0.9 mgd)
YEAR PLANT BUILT:	1975
YEAR OF MOST RECENT UPGRADE:	None
PLANT PERFORMANCE SUMMARY:	Violated standards periodically.

RANKING TABLE (PART 1)

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	D.3.a.	Operator Application of Concepts and	
2		Testing to Process Control	3
3	C.1.f.	Infiltration/Inflow	3
4	D.2.b.	Process Control Testing	2
5			
6			
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APPENDIX F

DESIGN INADEQUACIES OBSERVED

The following design problems were identified during the evaluation of 98 facilities for both Phase I and II of the project. Problems listed have created unnecessary or excessive maintenance, difficult process control, inaccurate or excessive sampling and decreased performance.

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

PLANT LAYOUT

- Lack of interconnection requires operation of three separate activated sludge plants as one facility
- 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 required 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.
- Overflow from septic tank to plant effluent
- Both trickling filter and activated sludge processes in very small plant causes excessive operational requirements

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
- No flow recorder
- Excessive upstream velocity causes turbulent flow through Parshall flume.
- Control section not accessible for inspection and maintenance
- 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
- 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 freezes
- Downstream bar screen backs flow into flume throat as screen plugs
- Control section as overflow from aerated grit chamber

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

COMMUNITORS

- 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
- Grit auger too low for disposal in truck

PRIMARY CLARIFIERS

- Overloaded by excessively large trickling filter humus return pump
- Overload due to trickling filter recirculation through primary clarifier
- 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 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

- Leakage betwen contact and reaeration basins due to moveable wall design.

- No wall between contact and reaeration areas

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

- Inadequate dissolved oxygen control

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
- Hydraulicly connected clarifiers not of the same elevation causes unequal flow splitting
- Freezing during cold weather
- Inlet and outlet on circumference, a large diameter, large design overflow rate, and failure to consider process recycle flows caused problems with hydraulic washout of solids.
- Floating trash returned to aeration basin, no ultimate disposal of scum
- Combined primary and final clarifier unit allows mixing of two with scraper mechanism
- Hydraulic restriction causes submerged overflow weirs
- Short-circuiting due to inlet baffle construction
- Placement of trickling filter recirculation draw-off, overloads final clarifier
- Weirs on single launder not balanced to pull evenly from each side
- No skimming device

RETURN SLUDGE FLOWS

- 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 imbalance 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° V-notch weir not sensitive enough

- Oversized pump draws down final clarifier, then hydraulically overloads aeration basin

- Waste piping and appurtenances requires excess return rate to accomplish wasting

- Stilling box ahead of V-notch weir too small

- Location of return measurement requires operator to walk out on narrow wall over basins

- Sludge return from clarifiers controlled by plug valve into wetwell. Excess operator time required to match variable speed pump with valve controlled rate.

- Return adjustment requires alternate operation of pump from first clarifier, second clarifier and both clarifiers to set desired total return

- 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

- Chlorine diffuser located at outlet of contact tank

- 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
- Residual chlorine analyzer for automatic adjustment of chlorine feed rate never worked

WASTING CAPABILITY

- No digester or sludge holding facility, inadequate drying beds
- Down time of exotic sludge treatment facility causes inadequate wasting
- Wasting capability only from mixed liquor requires excessive waste volume
- Insufficient capacity
- Sludge lagoons undersized
- No measurement
- None provided
- Partial plugging of waste pump prevents use of pumping rate to calculate waste volume
- Valve choice for directing return sludge to waste requires excess operator time
- Undersized waste pump

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
- Provide with automatic supernating device which does not work

ANAEROBIC DIGESTERS

- Inadequate supernatant draw-offs
- With multiple units, inflexibility to waste to desired primary digester
- Plugging problem between bottom of primary digester and second-stage 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

- Truck ramp too steep for use during winter
- Repeated maintenance on sludge incineration facilities
- Insufficient sludge drying lagoons
- Disposal of sludge in polishing lagoon
- Truck capacity too small
- Insufficient drying beds
- Drying bed subnatant line crushed by construction equipment
- Land application not possible during certain times of the year - no alternate disposal or storage

LABORATORY FACILITIES

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

MISCELLEANOUS

- 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
- Undersized raw lift pumps

APPENDIX G

WASTEWATER TREATMENT COST INFORMATION

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

PLANT IDENTITY	052		082**	
FLOW (mgd)*	0.045		0.083	
CATEGORY	$	¢/1000 GAL.	$	¢/1000 GAL.
Salary	4951	30.1	8100	26.7
Utilities	3974	24.2	4100	13.5
Supplies	1000	6.1	3050	10.1
Chemicals	291	1.8	0	0
Transportation	18	0.1	150	0.5
Training & Education	0	0	0	0
Miscellaneous	2230	13.6	0	0
Operations Subtotal	12464	75.9	15400	50.8
Capital Outlay	0	0	13100	43.2
Total	12464	75.9	28500	94.0

*mgd x 3785 = cu m/day

** Included both a fixed film and suspended growth facility; however, the majority of the wastewater was treated by the suspended growth facility.

TABLE G-2. (1 of 1) COST INFORMATION FOR 0-380 CU M/DAY (0-0.1 MGD)
FIXED FILM FACILITIES - PHASE II

PLANT IDENTITY		069
FLOW (mgd)*		0.08
CATEGORY	$	¢/1000 GAL.
Salary	7987	27.4
Utilities	840	2.9
Supplies	75	0.3
Chemicals	650	2.2
Transportation	100	0.3
Training & Education	24	0.1
Miscellaneous	150	0.5
Operations Subtotal	9826	33.7
Capital Outlay	0	0
Total	9826	33.7

*mgd x 3785 = cu m/day

TABLE G-3. (1 of 4) COST INFORMATION FOR 380-3800 CU M/DAY (0.1-1.0 MGD) SUSPENDED GROWTH FACILITIES - PHASE II

PLANT IDENTITY	051		062		065	
FLOW (mgd)*	0.21		0.20		0.13	
CATEGORY	$	¢/1000 GAL.	$	¢/1000 GAL.	$	¢/1000 GAL.
Salary	6200	8.1	5260	7.2	6900	14.5
Utilities	5600	7.3	5500	7.5	2400	5.1
Supplies	500	0.6	800	1.1	1000	2.1
Chemicals	500	0.6	1800	2.5	300	0.6
Transportation	300	0.4	200	0.3	500	1.1
Training & Education	0	0	300	0.4	300	0.6
Miscellaneous	500	0.7	100	0.1	0	0
Operations Subtotal	13600	17.7	13960	19.1	11400	24.0
Capital Outlay	8900	11.6	6675	9.1	0	0
Total	22500	29.3	20635	28.2	11400	24.0

*mgd x 3785 = cu m/day

TABLE G-3. (2 of 4) COST INFORMATION FOR 380-3800 CU M/DAY (0.1-1.0 MGD)
SUSPENDED GROWTH FACILITIES - PHASE II

PLANT IDENTITY	066		074		077	
FLOW (mgd)*	0.71		0.30		0.24	
CATEGORY	$	¢/1000 GAL.	$	¢/1000 GAL.	$	¢/1000 GAL.
Salary	39060	15.1	34700	31.7	3800	4.3
Utilities	43000	16.6	31200	28.5	8806	10.1
Supplies	1280	0.5	5600	5.1	2637	3.0
Chemicals	9000	3.5	2800	2.6	0	0
Transportation	830	0.3	800	0.7	0	0
Training & Education	1520	0.6	800	0.7	0	0
Miscellaneous	24688	9.5	5500	5.0	1245	1.4
Operations Sub-total	119378	46.1	81400	74.3	16488	18.8
Capital Outlay	30000	11.6	38800	35.4	8840	10.1
Total	149378	57.7	120200	109.7	25328	28.9

*mgd x 3785 = cu m/day

TABLE G-3. (3 of 4) COST INFORMATION FOR 380-3800 CU M/DAY (0.1-1.0 MGD)
SUSPENDED GROWTH FACILITIES - PHASE II

PLANT IDENTITY	080		085		086	
FLOW (mgd)*	0.25		0.84		0.48	
CATEGORY	$	¢/1000 GAL.	$	¢/1000 GAL.	$	¢/1000 GAL.
Salary	4260	4.7	25831	8.4	18880	10.8
Utilities	1350	1.5	12236	4.0	15000	8.6
Supplies	400	0.4	2950	1.0	1250	0.7
Chemicals	0	0	2000	0.6	1250	0.7
Transportation	0	0	0	0	800	0.5
Training & Education	500	0.5	75	0.02	0	0
Miscellaneous	600	0.7	2790	0.9	3650	2.1
Operations Subtotal	7110	7.8	45882	15.0	40830	23.4
Capital Outlay	6670	7.3	28927	9.4	14500	8.3
Total	13780	15.1	74809	24.4	55330	31.7

*mgd x 3785 = cu m/day

TABLE G-3. (4 of 4) COST INFORMATION FOR 380-3800 CU M/DAY (0.1-1 MGD) SUSPENDED GROWTH FACILITIES -PHASE II

PLANT IDENTITY	097
FLOW (mgd)*	0.84

CATEGORY	$	¢/1000 GAL.
Salary	74900	24.4
Utilities	25700	8.4
Supplies	6000	2.0
Chemicals	5300	1.7
Transportation	950	0.3
Training & Education	675	0.2
Miscellaneous	300	0.1
Operations Sub-total	113825	37.1
Capital Outlay	33900	11.1
Total	147725	48.2

*mgd x 3785 = cu m/day

TABLE G-4. (1 of 2) COST INFORMATION FOR 3800-38,000 CU M/DAY (1.0-10.0 MGD) SUSPENDED GROWTH FACILITIES - PHASE II

PLANT IDENTITY	038		068		075	
FLOW (mgd)*	3.14		5.4		5.8	
CATEGORY	$	¢/1000 GAL.	$	¢/1000 GAL.	$	¢/1000 GAL.
Salary	96368	8.4	245200	12.4	137500	6.5
Utilities	41800	3.7	50400	2.6	173500	8.2
Supplies	2257	0.2	43300	2.2	10500	0.5
Chemicals	1500	0.1	5100	0.3	9000	0.4
Transportation	0	0	8500	0.4	1000	0.1
Training & Education	505	0.04	1200	0.1	500	0.02
Miscellaneous	5774	0.5	14500	0.7	4000	0.2
Operations Sub-total	148204	12.9	368200	18.7	336000	15.9
Capital Outlay	82587	7.2	77100	3.9	223000	10.5
Total	230791	20.1	445300	22.6	559000	26.4

*mgd x 3785 = cu m/day

TABLE G-4 (2 of 2) COST INFORMATION FOR 3800-38,000 CU M/DAY (1.0-10.0 MGD) SUSPENDED GROWTH FACILITIES - PHASE II

PLANT IDENTITY		092
FLOW (mgd)*		3.12
CATEGORY	$	¢/1000 GAL.
Salary	373700	32.8
Utilities	79000	6.9
Supplies	153500	13.5
Chemicals	65000	5.7
Transportation	12500	1.1
Training & Education	500	0.04
Miscellaneous	2000	0.2
Operations Subtotal	686200	60.3
Capital Outlay	83250	7.3
Total	769450	67.6

*mgd x 3785 = cu m/day

TABLE G-5. (1 of 1) COST INFORMATION FOR 3800-38,000 CU M/DAY (1.0-10.0 MGD) FIXED FILM FACILITIES - PHASE II

PLANT IDENTITY	070		093		095	
FLOW (mgd)*	1.1		2.2		1.2	
CATEGORY	$	¢/1000 GAL.	$	¢/1000 GAL.	$	¢/1000 GAL.
Salary	38633	9.7	41600	5.2	42800	9.8
Utilities	9707	2.4	21000	2.6	18300	4.2
Supplies	3900	1.0	1150	0.1	16800	3.8
Chemicals	2500	0.6	16500	2.1	2200	0.5
Transportation	1375	0.3	4600	0.6	900	0.2
Training & Education	740	0.2	350	0.04	0	0
Miscellaneous	3980	1.0	8550	1.1	900	0.2
Operations Subtotal	60835	15.2	93750	11.7	81900	18.7
Capital Outlay	3600	0.9	280500	34.9	78500	17.9
Total	64435	16.1	374250	46.6	160400	36.6

*mgd x 3785 = cu m/day

APPENDIX H

INDIVIDUAL PLANT PERFORMANCE EVALUATIONS

TABLE H-1. (1 of 5) PLANTS FOR WHICH AN IMPROVEMENT IN PERFORMANCE DID OCCUR - PHASE I

Plant No.	Flow Actual mgd*	Flow Design mgd	Before BOD mg/l	Before TSS mg/l	After BOD mg/l	After TSS mg/l	Reduction BOD lb/day**	Reduction BOD ton/yr***	Reduction TSS lb/day	Reduction TSS ton/yr	Plant Type - Comments
022	0.012	0.015	35	60	10	10	2.5	0.5	5.0	0.9	Activated sludge, extended aeration, with polishing pond. The return sludge flow rate was excessively high, causing solids loss over the clarifier weir. The R/Q ratio was reduced from about 1000% to about 100%, and excessive solids loss was eliminated. Presently, all treated sewage flows through a polishing pond. A pond bypass should be installed to discharge good final clarifier effluent to the receiving stream.
029	1.36	1.8	31	30	9.7	9.1	242	44	237	43	Activated sludge, conventional, without primary clarifier. Changes in return and waste sludge control procedure were implemented and a plant deficiency was corrected. The values shown represent a six-month average for "Before" data and an eight-month average for "After" data.
048	0.34	0.38	68	116	10	10	164	30	300	55	Activated sludge, conventional, without primary clarifier. Insufficient wasting was completed. Only about half of the sludge grown each day was wasted. The remainder bulked over the clarifier weir. The NPDES standards were violated but not reported as such. Increased wasting controlled sludge bulking. The plant has an I/I problem. If the I/I problem was corrected, the facility should continue to perform well.
050	0.17	0.18	45	80	10	10	50	9.1	100	18	Activated sludge, extended aeration, without primary clarifiers. Insufficient sludge wasting was completed. The approach was to "build solids". The NPDES permit standards were violated but were not reported as such. Increased wasting controlled sludge bulking. Operations testing and process controls were implemented and good effluent quality maintained.

* mgd x 3785 = cu m/day
** lb x .453 = kg
*** ton x 0.906 = metric ton (1000 kg)

TABLE H-1. (2 of 5) PLANTS FOR WHICH AN IMPROVEMENT IN PERFORMANCE DID OCCUR - PHASE I

Plant No.	Flow		Before		After		Reduction				Plant Type - Comments
	Actual mgd*	Design mgd	BOD mg/l	TSS mg/l	BOD mg/l	TSS mg/l	BOD lb/day**	BOD ton/yr***	TSS lb/day	TSS ton/yr	
053	0.11	0.16	32	50	10	10	20	3.7	37	6.7	Activated sludge, extended aeration, without primary clarifiers. Insufficient sludge wasting. The approach was to build solids to a specified level (3000 mg/l). The return rate was too high and too much "scum" recycle was directed back to the aeration basin to reach a MLSS of 3000 mg/l before solids bulking occurred. Decreased return, controlled scum withdrawal, and increased wasting, as well as implementation of operations testing and process controls were completed, and good effluent quality was maintained.
060	0.49	1.05	45	37	35	27	41	7.5	41	7.5	Two-stage trickling filter with primary clarifier (second-stage is an activated bio-filter system). A valve leaking mixed liquor to the chlorine contact basin influent was found. Plant effluent still does not meet NPDES standards because of design limitations in aeration capacity.
061	0.17	0.50	37	42	10	10	38	7.0	45	8.3	Activated sludge, contact-stabilization, without primary clarifier. Inadequate wasting and return control provided. Sludge wasted to an aerobic digester and recycled back into activated sludge system. Return flow rate not controlled. Operations testing and process control were implemented and good effluent quality maintained. A plant piping modification should be completed to operate conventionally rather than with the contact-stabilization mode to facilitate operation. In addition, nearly half the operations cost could be saved by operating only one of the two plants presently on line (one was recently completed).
Phase I Sub-Total	2.652	4.085	N/A	N/A	N/A	N/A	557.5	101.8	765	139.4	

* mgd x 3785 = cu m/day
** lb x .453 = kg
*** ton x 0.906 = metric ton (1000 kg)

TABLE H-1. (3 of 5) PLANTS FOR WHICH AN IMPROVEMENT IN PERFORMANCE DID OCCUR - PHASE I

Plant No.	Flow Actual mgd*	Flow Design mgd	Before BOD mg/l	Before TSS mg/l	After BOD mg/l	After TSS mg/l	Reduction BOD lb/day**	Reduction BOD ton/yr***	Reduction TSS lb/day	Reduction TSS ton/yr	Plant Type - Comments
065	0.13	0.15	72	143	21	7.9	55	10.1	146	27	Activated sludge, contact stabilization without primary clarifiers. Solids loss occurred for about 3 hours per day due to inadequate sludge mass and return sludge control. Minor modifications were made to the return sludge and wasting mechanism and to the chlorine contact tank. "After" data represents a 4-month period following implementation of improved process control and acquisition of more land for ultimate sludge disposal.
082	0.083	0.12	50	75	20	30	21	3.8	31	5.7	Activated sludge, contact stabilization and parallel trickling filter. Flow splitting to the two plants was not optimized. Solids loss from the contact stabilization plant occurred repeatedly due to inadequate process control. The digester was used as part of the reaeration basin. Sludge beds must be subsidized with wethaul of sludge for ultimate disposal. Plant 082 has the potential to achieve a 10 - 10 effluent with a full CCP without major construction.

* mgd x 3785 = cu m/day
** lb x .453 = kg
*** ton x 0.906 = metric ton (1000 kg)

TABLE H-1. (4 of 5) PLANTS FOR WHICH AN IMPROVEMENT IN PERFORMANCE DID OCCUR - PHASE I

Plant No.	Flow		Before		After		Reduction				Plant Type - Comments
							BOD		TSS		
	Actual mgd*	Design mgd	BOD mg/l	TSS mg/l	BOD mg/l	TSS mg/l	lb/day**	ton/yr***	lb/day	ton/yr	
085	0.84	0.98	50	108	10	10	280	51	687	125	Activated sludge, oxidation ditch without primary clarifiers and with sludge lagoons. Wasting sludge had been initiated shortly before the survey but excessive solids loss continued due to inadequate process control understanding. Mass control and process control testing were improved during and following the survey. Ultimate sludge disposal will again degrade effluent quality unless ultimate sludge disposal capability is expanded.
086	0.48	1.0	75	150	8.0	5.4	268	49	579	106	Activated sludge, extended aeration without primary clarifiers and with sludge lagoons. No wasting was practiced for seven months prior to the survey because the superintendent could not find help in setting up a rational mass control program. The "after" results represent the effluent quality for the 4-month period following the survey. Mass control and process control monitoring showed existing sludge lagoons to have inadequate capacity. The construction grant for the plant was reopened to purchase a sludge truck for land application of sludge.

* mgd x 3785 = cu m/day
** lb x .453 = kg
*** ton x 0.906 = metric ton (1000 kg)

TABLE H-1. (5 of 5) PLANTS FOR WHICH AN IMPROVEMENT IN PERFORMANCE DID OCCUR - PHASE I

Plant No.	Flow: Actual mgd*	Flow: Design mgd	Before: BOD mg/l	Before: TSS mg/l	After: BOD mg/l	After: TSS mg/l	Reduction BOD: lb/day**	Reduction BOD: ton/yr***	Reduction TSS: lb/day	Reduction TSS: ton/yr	Plant Type - Comments
092	3.12	5.5	8.4	2.0	5.0	2.0	88	16	0	0	Conventional activated sludge with carbon absorption. The plant has performed well and met secondary standards because of the tertiary portion of the plant. Process control capability was improved so that secondary effluent meets secondary standards and some overall improvement has been achieved.
097	0.84	1.0	23	34	10	15	91	17	133	24	Activated sludge contact stabilization without primary clarifiers, with aerobic digester and roller press sludge dewatering. Prior to the plant survey an improvement in plant performance did occur due to a change in plant management. However, the approach to process control was misdirected and was leading towards poor performance at the start of the survey. Process control understanding was increased and the impending problems were avoided. Actual effluent quality has been better in recent months than the "after" data shown, but values were adjusted up slightly to account for anticipated I/I problems in isolated cases.
Phase II	5.493	8.75	--	--	--	--	803	146.9	1576	287.7	
Phase I	2.652	4.085	--	--	--	--	557.5	101.8	765	139.4	
Total	8.145	12.835	--	--	--	--	1360.5	248.7	2341	427.1	

* mgd x 3785 = cu m/day
** lb x .453 = kg
*** ton x 0.906 = metric ton (1000 kg)

TABLE H-2. (1 of 9) PLANTS FOR WHICH AN IMPROVEMENT IN PERFORMANCE COULD OCCUR - PHASE I

Plant No.	Flow		Present		Potential		Reduction				Plant Type - Comments
							BOD		TSS		
	Actual mgd*	Design mgd	BOD mg/l	TSS mg/l	BOD mg/l	TSS mg/l	lb/day**	ton/yr***	lb/day	ton/yr	
002	0.43	0.8	65	117	10	10	197	36	384	70	Activated sludge, extended aeration, without primary clarifiers. Inadequate process understanding and control, and inadequate clarifier surface development causes uncontrollable excessive solids loss.
007	0.041	0.07	54	130	10	10	15	2.8	41	7.5	Activated sludge, oxidation ditch, without primary clarifier. Inadequate sludge wasting capability at the plant, as well as inadequate process understanding, testing, and control causes excessive solids loss.
012	8.1	12.0	40	35	30	30	676	123	338	62	One-half trickling filter and one-half trickling filter followed by contact-stabilization with anaerobic digestion. Inadequate flexibility in digester operation, which could be provided with a relatively small piping change, causes excessive TSS in digester supernatant recycle and degraded plant performance. Improved performance would probably not meet standards consistently.
013	0.5****	0.8	22	32	10	10	50	9.1	92	17	Activated sludge, conventional, without primary clarifiers and with polishing pond. Insufficient wasting, inadequate process understanding, testing and control, and inadequate clarifier surface development causes excessive solids loss. In addition, there was not a pond bypass to discharge good clarifier effluent when the pond effluent was poor.

* mgd x 3785 = cu m/day
** lb x .453 = kg
*** ton x 0.906 = metric ton (1000 kg)
**** Flow during survey was 0.8 mgd (peak tourist season). Average yearly flow estimated to be 0.5 mgd.

TABLE H-2. (2 of 9) PLANTS FOR WHICH AN IMPROVEMENT IN PERFORMANCE COULD OCCUR - PHASE I

Plant No.	Flow Actual mgd*	Flow Design mgd	Present BOD mg/l	Present TSS mg/l	Potential BOD mg/l	Potential TSS mg/l	Reduction BOD lb/day**	Reduction BOD ton/yr***	Reduction TSS lb/day	Reduction TSS ton/yr	Plant Type - Comments
014	1.0****	2.0	22	32	10	10	100	18	183	33	Activated sludge, conventional, without primary clarifiers and with polishing pond. Inadequate process understanding and control caused excessive solids loss. In addition, there was not a pond bypass to discharge good clarifier effluent when the pond effluent was poor.
019	0.035	0.065	57	53	10	10	14	2.5	13	2.3	Activated sludge, conventional, without primary clarifier and with polishing pond. Insufficient sludge wasting and inadequate process understanding, testing, and control caused incomplete organic removal. In addition, there was not a pond bypass to discharge good clarifier effluent when the pond effluent was poor.
020	.007	.025	47	62	10	10	2.2	0.4	3.0	0.5	Activated sludge, extended aeration, without primary clarifiers, and with polishing pond. Insufficient sludge wasting and inadequate process control caused excess solids loss. In addition, there was not a pond bypass to discharge good clarifier effluent when the pond effluent was poor.
027	5.5	10	27	20	10	10	780	142	459	84	Activated sludge, conventional, with anaerobic digesters. Plant effluent periodically violates minimum permit standards, including 85% removal requirement. Inadequate process understanding and control causes incomplete organic removal.

* mgd x 3785 = cu m/day
** lb x .453 = kg
*** ton x 0.906 = metric ton (1000 kg)
**** Flow during survey was 1.43 mgd (high tourist season). Average yearly flow estimated to be 1.0 mgd.

TABLE H-2. (3 of 9) PLANTS FOR WHICH AN IMPROVEMENT IN PERFORMANCE COULD OCCUR - PHASE I

Plant No.	Flow		Present		Potential		Reduction				Plant Type - Comments
							BOD		TSS		
	Actual mgd*	Design mgd	BOD mg/l	TSS mg/l	BOD mg/l	TSS mg/l	lb/day**	ton/yr***	lb/day	ton/yr	
028	0.15	0.25	29	10	10	10	24	4.3	0	0	Activated sludge, contact-stabilization, with polishing pond. Inadequate sludge wasting procedure (sludge wasted to pond) caused excessive sludge accumulation in pond and anaerobic decomposition to occur in the pond. The pond was covered with "duckweed" and had no sunlight penetration. As such, soluble BOD_5 in pond effluent was very high and TSS was low. There was not a pond bypass to discharge good clarifier effluent when the pond effluent was poor.
034	5.5	8	50	48	40	40	459	84	367	67	Trickling filter with anaerobic digestion. Inadequate control over flow splitting exercised, which causes imbalanced unit loadings. Also, improper anaerobic digester operation causes excessive solids in supernatant recycle stream, which, again, is not adequately split and causes imbalanced unit loadings.
039	0.21	0.41	44	78	10	10	60	11	119	22	Activated sludge, oxidation ditch, with aerated polishing pond. Insufficient sludge wasting and inadequate process control causes excessive solids loss. There was a pond bypass at this plant.
041	0.13	.40	25	25	20	20	5.4	1.0	5.4	1.0	Two-stage trickling filter, with anaerobic digesters. Slight plant design modification to change recirculation inlet piping location to a point away from the final clarifier weirs would improve final clarifier solids capture capability. It should be noted that no anaerobic digester supernatant is recycled back through the plant.

* mgd x 3785 = cu m/day
** lb x .453 = kg
*** ton x 0.906 = metric ton (1000 kg)

TABLE H-2. (4 of 9) PLANTS FOR WHICH AN IMPROVEMENT IN PERFORMANCE COULD OCCUR - PHASE I

Plant No.	Flow		Present		Potential		Reduction				Plant Type - Comments
	Actual mgd*	Design mgd	BOD mg/l	TSS mg/l	BOD mg/l	TSS mg/l	BOD lb/day**	BOD ton/yr***	TSS lb/day	TSS ton/yr	
047	0.050	0.063	36	76	10	10	11	2.0	28	5.0	Activated sludge, extended aeration, with polishing pond. Insufficient sludge wasting and inadequate process control causes excessive solids loss. In addition, there was not a pond bypass to discharge good clarifier effluent when the pond effluent was poor.
055	0.30	0.58	13	23	10	10	7.5	1.4	33	5.9	Activated sludge, extended aeration, with primary clarifiers and anaerobic digester. Inadequate process control caused periodic slight solids loss. As a general rule, standards have been met.
Phase I Sub-Total	21.953	35.463	N/A	N/A	N/A	N/A	2401.1	437.5	2065.4	377.2	

* mgd x 3785 = cu m/day
** lb x .453 = kg
*** ton x 0.906 = metric ton (1000 kg)

TABLE H-2. (5 of 9) PLANTS FOR WHICH AN IMPROVEMENT IN PERFORMANCE COULD OCCUR - PHASE I

Plant	Flow		Before		After		Reduction				
	Actual	Design	BOD	TSS	BOD	TSS	BOD		TSS		
No.	mgd*	mgd	mg/l	mg/l	mg/l	mg/l	lb/day**	ton/yr***	lb/day	ton/yr	Plant Type - Comments
038	3.14	4.5	40	60	10	10	786	143	1309	239	Conventional activated sludge. Inadequate process control including sludge mass control and return sludge control created less than optimum continuous treatment and periodic sludge "bulking". Actual effluent quality data was adjusted upward slightly to account for solids loss during bulking which is not measured.
051	0.21	0.28	55	110	20	30	61	11	140	26	Activated sludge, extended aeration. Inadequate process control and inadequate sludge wasting capability causes degraded effluent and repeated "bulking". The potential performance shown could be achieved without major facility additions. A 10-10 effluent would likely require the addition of sludge wasting capability which would not be affected by weather.
052	0.045	0.075	8.7	24	8.7	10	0	0	5.2	1.0	Extended aeration activated sludge. Conservative design and unsophisticated, but practical operating approach has allowed standards to be met. Performance could be improved considerably beyond requirements with good process control.

* mgd x 3785 = cu m/day
** lb x .453 = kg
*** ton x 0.906 = metric ton (1000 kg)

TABLE H-2. (6 of 9) PLANTS FOR WHICH AN IMPROVEMENT IN PERFORMANCE COULD OCCUR - PHASE I

Plant No.	Flow		Before		After		Reduction				Plant Type - Comments
							BOD		TSS		
	Actual mgd*	Design mgd	BOD mg/l	TSS mg/l	BOD mg/l	TSS mg/l	lb/day**	ton/yr***	lb/day	ton/yr	
062	0.20	0.34	20	80	10	10	17	3.0	117	21	Oxidation ditch extended aeration with aerobic digestion. Inadequate process control, poor digester design and lack of proper technical guidance cause standards to be violated freguently.
066	0.71	0.94	25	13	10	10	89	16	18	3.2	Two-stage activated sludge plant designed for nitrification and 10 mg/l BOD_5 effluent. Meets secondary standards but does not operate at optimum performance due to inadequate process control and poor operator motivation.
068	5.4	5.5	38	24	15	15	1036	189	405	74	Old 3-plants-in-one activated sludge plant. Standards have not been met due to heavy meat-packing loadings, I/I, and improper operator application of concepts to process control. Improved performance could be achieved with better process control and anticipation of I/I flows.

* mgd x 3785 = cu m/day
** lb x .453 = kg
*** ton x 0.906 = metric ton (1000 kg)

TABLE H-2. (7 of 9) PLANTS FOR WHICH AN IMPROVEMENT IN PERFORMANCE COULD OCCUR - PHASE I

Plant No.	Flow		Before		After		Reduction				Plant Type - Comments
							BOD		TSS		
	Actual mgd*	Design mgd	BOD mg/l	TSS mg/l	BOD mg/l	TSS mg/l	lb/day**	ton/yr***	lb/day	ton/yr	
069	0.08	0.07	65	37	20	20	48	8.9	18	3.3	Imhoff tank and single-stage trickling filter. Violates standards because of a lack of operator capabilities in understanding and applying concepts of wastewater treatment. Improved operation with possible small modifications could significantly improve performance.
074	0.30	0.35	10.6	26	10	10	1.5	0.3	133	24	Modification of activated sludge process called the Kehr process. Process design calls for sludge disposal in polishing lagoons. Increased operator application of concepts and a pond bypass would be necessary to achieve significantly improved effluent.

* mgd x 3785 = cu m/day
** lb x .453 = kg
*** ton x 0.906 = metric ton (1000 kg)

TABLE H-2. (8 of 9) PLANTS FOR WHICH AN IMPROVEMENT IN PERFORMANCE COULD OCCUR - PHASE I

Plant No.	Flow Actual mgd*	Flow Design mgd	Before BOD mg/l	Before TSS mg/l	After BOD mg/l	After TSS mg/l	Reduction BOD lb/day**	Reduction BOD ton/yr***	Reduction TSS lb/day	Reduction TSS ton/yr	Plant Type - Comments
075	5.8	9.0	14.6	15.3	10	10	223	41	256	47	Complete mix activated sludge with primary clarifiers, and aerobic and anaerobic sludge digestion. Underloaded condition, adequate design and continuous technical guidance provide good treatment. Improved treatment could be achieved with close process control.
077	0.24	0.308	65	176	15	25	100	18	302	55	Contact stabilization package plant without a wall between contact and reaeration zones. Administration's unfamiliarity with plant needs has resulted in inadequate manpower, budget, testing equipment and operator training. An operator and direction in the specific needs of the plant are required. Small facility modifications would be required in several areas to optimize performance. I/I would continue to hinder performance periodically. Overall performance could be improved dramatically without a major plant upgrade.

* mgd x 3785 = cu m/day
** lb x .453 = kg
*** ton x 0.906 = metric ton (1000 kg)

TABLE H-2. (9 of 9) PLANTS FOR WHICH AN IMPROVEMENT IN PERFORMANCE COULD OCCUR - PHASE I

Plant No.	Flow Actual mgd*	Flow Design mgd	Before BOD mg/l	Before TSS mg/l	After BOD mg/l	After TSS mg/l	Reduction BOD lb/day**	Reduction BOD ton/yr***	Reduction TSS lb/day	Reduction TSS ton/yr	Plant Type - Comments
080	0.25	0.42	28	53	10	10	37	6.8	90	16	Contact stabilization activated sludge without a wall between contact and reaeration zones. Improper operator application of concepts was largely responsible for historical poor performance. Increased process control applied to the plant between the site visit and the preliminary survey significantly improved performance. Further improvement could be achieved with minor plant modifications and improved process control.
Phase II	16.375	21.783	--	--	--	--	2398.5	437	2793.2	509.5	
Phase I	21.953	35.463	--	--	--	--	2401.1	437.5	2065.4	377.2	
Total	38.328	57.246	--	--	--	--	4799.6	874.5	4858.6	886.7	

* mgd x 3785 = cu m/day
** lb x .453 = kg
*** ton x 0.906 = metric ton (1000 kg)

TABLE II-3. (1 of 3) PLANTS FOR WHICH AN IMPROVEMENT IN PERFORMANCE IS DOUBTFUL - PHASE I

Plant No.	Flow		Present		Potential		Reduction				Plant Type - Comments
							BOD		TSS		
	Actual mgd*	Design mgd	BOD mg/l	TSS mg/l	BOD mg/l	TSS mg/l	lb/day**	ton/yr***	lb/day	ton/yr	
015	1.7	3.6	30	30	Same		-	-	-	-	Two-stage trickling filter with anaerobic digesters. Inherent design features in the plant cause good performance. Plant treats heavy industrial waste and achieves about 96% to 98% removal. Also, anaerobic digester supernatant is not recycled back to the plant, which helps performance significantly. Even so, standards are not met consistently.
021	0.59	0.9	4	7	Same		-	-	-	-	Activated sludge, oxidation ditch, without primary clarifiers. Some good design features in plant cause good performance to be possible. At the same time, good operation overcoming shortcomings in the design of sludge handling and, in addition, adequate process control, has caused good performance to be achieved.
024	4.9	6.0	45	31	Same		-	-	-	-	Activated bio-filter with chlorine oxidized sludge handling. Limited aeration capacity causes insufficient conversion of BOD_5 to TSS.
026	0.15	0.5	4	4	Same		-	-	-	-	Activated sludge, extended aeration, without primary clarifiers and with tertiary filters. Plant produces good effluent nearly all the time. However, periodically, once to twice per year, for short time periods, raw sewage is bypassed because bulking sludge clogs the filters or because of plant mechanical problems. Individual plant units cannot be bypassed. The flow must pass through the entire plant or be bypassed.

* mgd x 3785 = cu m/day
** lb x .453 = kg
*** ton x 0.906 = metric ton (1000 kg)

TABLE H-3. (2 of 3) PLANTS FOR WHICH AN IMPROVEMENT IN PERFORMANCE IS DOUBTFUL - PHASE I

Plant No.	Flow Actual mgd*	Flow Design mgd	Present BOD mg/l	Present TSS mg/l	Potential BOD mg/l	Potential TSS mg/l	BOD lb/day**	BOD ton/yr***	TSS lb/day	TSS ton/yr	Plant Type - Comments
032	0.22	0.5	30	30	Same		-	-	-	-	Trickling filter with anaerobic "cold" digester. Inherent design features cause plant to perform satisfactorily with minimum operation. Summer performance was good as measured during survey. Historical performance questionable because monitoring records were believed inaccurate. Winter performance believed to be poor because City was going to enter into a 201 Facilities plan for plant upgrade.
035	5.3	5.4	22	20	Same		-	-	-	-	Two-stage trickling filter with anaerobic digester. Conservative design features and good operation cause plant to perform as well as expected.
036	1.6	2.8	22	21	Same		-	-	-	-	Two-stage trickling filter with anaerobic digester. Conservative design features and good operation cause plant to perform as well as expected.
040	0.38	0.63	56	29	Same		-	-	-	-	Rotating biological surface with anaerobic digesters. Inadequate aeration capability limits conversion of BOD_5 to TSS.
063	0.7	1.5	7	10	Same		-	-	-	-	Activated sludge, extended aeration, without primary clarifiers. Plant can bypass flow it cannot handle to a larger facility. Plant saves money when it accepts more sewage because treated water is used for parks and golf course watering. At least 1.5 mgd can be adequately treated by the existing facility. Inadequate process control causes limited treatment capacity. However, because plant can accept less flow, standards are consistently met.
Phase I Subtotal	15.54	21.83	N/A	N/A	-		-	-	-	-	

* mgd x 3785 = cu m/day
** lb x .453 = kg
*** ton x 0.906 = metric ton (1000 kg)

TABLE H-3. (3 of 3) PLANTS FOR WHICH AN IMPROVEMENT IN PERFORMANCE IS DOUBTFUL - PHASE I

Plant No.	Flow Actual mgd*	Flow Design mgd	Before BOD mg/l	Before TSS mg/l	After BOD mg/l	After TSS mg/l	Reduction BOD lb/day**	Reduction BOD ton/yr***	Reduction TSS lb/day	Reduction TSS ton/yr	Plant Type - Comments
070	1.1	1.09	15	22	15	22	--	--	--	--	Single-stage trickling filter with anaerobic sludge digestion. Conservative trickling filter design and good maintenance already promotes performance near optimum for the facility.
093	2.2	5	31	18	31	18	--	--	--	--	Rotating biological contactors with anaerobic digestion. The aeration portion (RBC's) provide inadequate soluble BOD_5 removal and/or conversion to settleable solids. Supernatant is not returned thru the plant. Significantly improved performance would likely require expanded aerator capacity.
095	1.2	2.5	31	39	31	39	--	--	--	--	Single-stage plastic media trickling filter with polishing pond and anaerobic sludge digestion. I/I is a periodic problem. Toxics wastes are a problem because no control has been applied by city administration. A pond bypass, enforced sewer use ordinance and increased in-plant monitoring would be required before improved performance would be likely, even at considerably less than design flow.
Phase II	4.5	8.59	--	--	--	--	--	--	--	--	
Phase I	15.54	21.83	--	--	--	--	--	--	--	--	
Total	20.04	30.42	--	--	--	--	--	--	--	--	

* mgd x 3785 = cu m/day
** lb x .453 = kg
*** ton x 0.906 = metric ton (1000 kg)

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16. ABSTRACT

Many of the country's wastewater treatment plants do not meet design expectations and NPDES permit standards. A research project was initiated to identify, quantify and rank the causes of this poor performance by comprehensive evaluations of 50 plants in nine western states. The identified highest ranking causes of limited plant performance reflect an inability of in-plant personnel to optimize process control and the performance of existing facilities. Deficiencies in design features also ranked high. The performance of each plant is typically limited by a unique combination of problems which require individual identification and elimination. The Composite Correction Program (CCP) was introduced and demonstrated. This approach to improving the performance of existing facilities was conducted at selected facilities. Areas of special evaluation include aerator and clarifier design, sludge production in activated sludge plants, aerobic digester operation, reference materials used in treatment plants, operator time and tasks before and after a CCP, and the effects of toxic substances on well-operated treatment facilities.

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