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Handbook

Improving POTW Performance Using the Composite Correction Program Approach

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HANDBOOK

IMPROVING POTW PERFORMANCE USING THE COMPOSITE CORRECTION PROGRAM APPROACH

U.S. ENVIRONMENTAL PROTECTION AGENCY

Center for Environmental Research Information
Cincinnati, Ohio 45268

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NOTICE

FOREWORD

The formation of the Environmental Protection Agency marked a new era of environmental awareness in America. This Agency's goals are national in scope and encompass broad responsibility in the areas of air and water pollution, solid wastes, pesticides, hazardous wastes, and radiation. A vital part of EPA's national pollution control effort is the constant development and dissemination of new technology.

It is clear that only the most effective design and operation of pollution control facilities will be adequate to ensure continued protection of this Nation's natural resources. It is essential that we achieve the maximum performance possible of existing Publicly Owned Treatment Works (POTWs) to achieve maximum benefit from our expenditures.

The purpose of this Handbook is to provide POTW owners/administrators and the engineering community with a new source of information to be used in improving the performance of POTWs through application of the Composite Correction Program (CCP) approach. It is the intent of the manual to supplement the existing body of knowledge in this area.

This Handbook is one of several publications available from Technology Transfer to describe technological advances and present new information.

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CHAPTER 1

INTRODUCTION

1.1 Purpose and Scope

This Handbook provides information on methods to economically improve the performance of existing publicly owned treatment works (POTWs). It is "how-to" oriented and describes an approach that POTW owners can use to achieve improvements in treatment without major capital expenditures. The approach consists of an evaluation phase and a performance improvement phase.

The evaluation phase is a thorough review and analysis of a POTW's design capabilities and associated administration, operation, and maintenance practices. It is conducted to provide information for POTW administrators to make decisions regarding efforts necessary to improve performance. The primary objective is to determine if significant improvements in treatment can be achieved without making major capital expenditures. This objective is accomplished by assessing the capability of major unit processes and by identifying and prioritizing those factors that limit performance and can be corrected to improve performance.

The performance improvement phase is a systematic approach to eliminating those factors that limit performance in existing POTWs. Its major benefit is that it optimizes the capability of existing facilities to perform better and/or treat more wastewater.

This document has been prepared for the benefit of POTW owners and administrators. It is expected that consultants for POTWs, regulatory personnel, and administrators of privately owned treatment works will also find the information useful. This Handbook focuses on POTWs treating typical municipal wastewater compatible with common biological wastewater treatment processes. It has been written mainly for POTWs with flows up to about 40,000 m^3/d (10 mgd), which includes over 95 percent of existing POTWs in the United States (1). The scope of the Handbook is further focused on mechanical plants using activated sludge (suspended growth), trickling filters (fixed film), and variations of these processes for secondary treatment. Variations of suspended growth processes included are:

- Plug flow
- Complete mix
- Extended aeration
- Contact stabilization
- Tapered aeration
- Oxidation ditches
- Step feed

Fixed film processes included are:

- Conventional rock filters
- Plastic media filters
- Redwood media filters
- Activated biofilters (ABFs)
- Rotating biological contactors (RBCs)

1.2 Background

A 1980 General Accounting Office report indicated that 87 percent of 242 POTWs surveyed were in violation of the effluent requirements in their discharge permit (2). At 9 of the 15 POTWs studied further, operation and maintenance problems were determined to be a significant cause of poor performance. A comprehensive national study to identify and quantify the specific causes of inadequate POTW performance was conducted in the late 1970s (3-6). This study, involving site visits to 287 facilities and detailed evaluations of 103 of these facilities, identified the most predominant problems at POTWs. The top factors identified included problems in all four major areas that affect plant performance: design, administration, operation, and maintenance. A major conclusion from this study is that each POTW usually has a number of performance-limiting problems that are unique to that facility.

In response to these needs, a program that effectively eliminates all performance-limiting factors at an individual POTW has been developed and demonstrated. It is called the Composite Correction Program (CCP) because it brings together the positive features of many individual programs to correct all the specific performance-limiting problems identified at a subject plant.

CCPs have been successfully demonstrated at a number of facilities (6-8). The most successful of these demonstrations have occurred in POTWs where a combination of minor design changes, process adjustments, operator training, and appropriate administrative actions led to improving plant performance to the desired level.

Application of the CCP approach has been made more attractive by recent congressional actions. In December 1981, the EPA Construction Grants Program was changed to provide (starting October 1984) for 55 percent rather than 75 percent as the Federal funding share for POTW construction (9). In addition, the Federal share of planning and design phases will not be paid until the construction phase is approved and funded (10). These changes, and trends at both the national and State levels, make it more important than ever to achieve maximum utilization of existing facilities and to avoid or delay the need for capital improvement projects.

It is apparent that improved performance is not achievable in some facilities without making significant capital improvements. To identify facilities where performance could be improved using a nonconstruction-oriented approach, a Comprehensive Performance Evaluation (CPE) phase was developed. A CPE is performed to determine if a CCP could result in significant improvement in plant performance and/or capacity.

The 1981 changes to the EPA Construction Grants Program also added the requirement that, one year after being placed in operation, grantees either certify that their facilities are capable of meeting the treatment levels for which they were designed or propose a corrective course of action (10). A CPE, with its emphasis on identification of problems, and a CCP, with its emphasis on making existing plants perform to their optimum level, can be valuable tools for POTW owners to use in satisfying this grant requirement.

1.3 Overview

Many parties are involved in achieving optimum performance from wastewater treatment facilities (11). The following discussion provides perspective to the roles of these parties.

A recent project conducted to develop a strategy to improve POTW performance and achieve compliance with effluent permit requirements concluded that local owners and administrators of wastewater treatment facilities should be made more aware that they are clearly responsible for their plant's performance (8). Compliance with effluent permit requirements was found to be only a secondary objective of many local administrators. Often their primary concerns were obtaining facility grants, avoiding problems with State and Federal regulatory personnel, and providing safe working conditions for employees. Although each of these concerns is important, local facility administrators must recognize that their primary objective in treating wastewater is to achieve the required effluent quality. Once local priorities have been focused toward cost-effectively achieving adequate treatment, owners can direct their technical staffs or consultants toward the ultimate goal. Technical assistance is available from a variety of sources: engineers, operators, suppliers, contractors, trainers, contract operators, and financial consultants.

It is assumed that POTW owners and administrators have already recognized a need to improve the performance of their wastewater treatment facilities and will use this Handbook to economically accomplish the required wastewater effluent quality.

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National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650

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CHAPTER 2

APPROACH TO CONDUCTING COMPREHENSIVE PERFORMANCE EVALUATIONS

2.1 Objective

The objective of a Comprehensive Performance Evaluation (CPE) is to establish whether a major facility upgrade is necessary or if a Composite Correction Program (CCP) is capable of producing the desired effluent quality.

2.2 Methodology

A CPE achieves the above objective through several activities: evaluation of the major unit processes; identification of all performance-limiting factors; prioritization of performance-limiting factors; assessment of ability to improve performance with a CCP; and reporting CPE results. Although these are distinct activities, some of them are conducted concurrently with others. For example, evaluation of the major unit processes and identification of performance-limiting factors are generally conducted at the same time.

Although this Handbook presents all the information required to conduct a CPE, many references are available on techniques for evaluation of treatment plant performance, reliability, etc. (1-14). It is recommended that these references be consulted for further specifics on the subject.

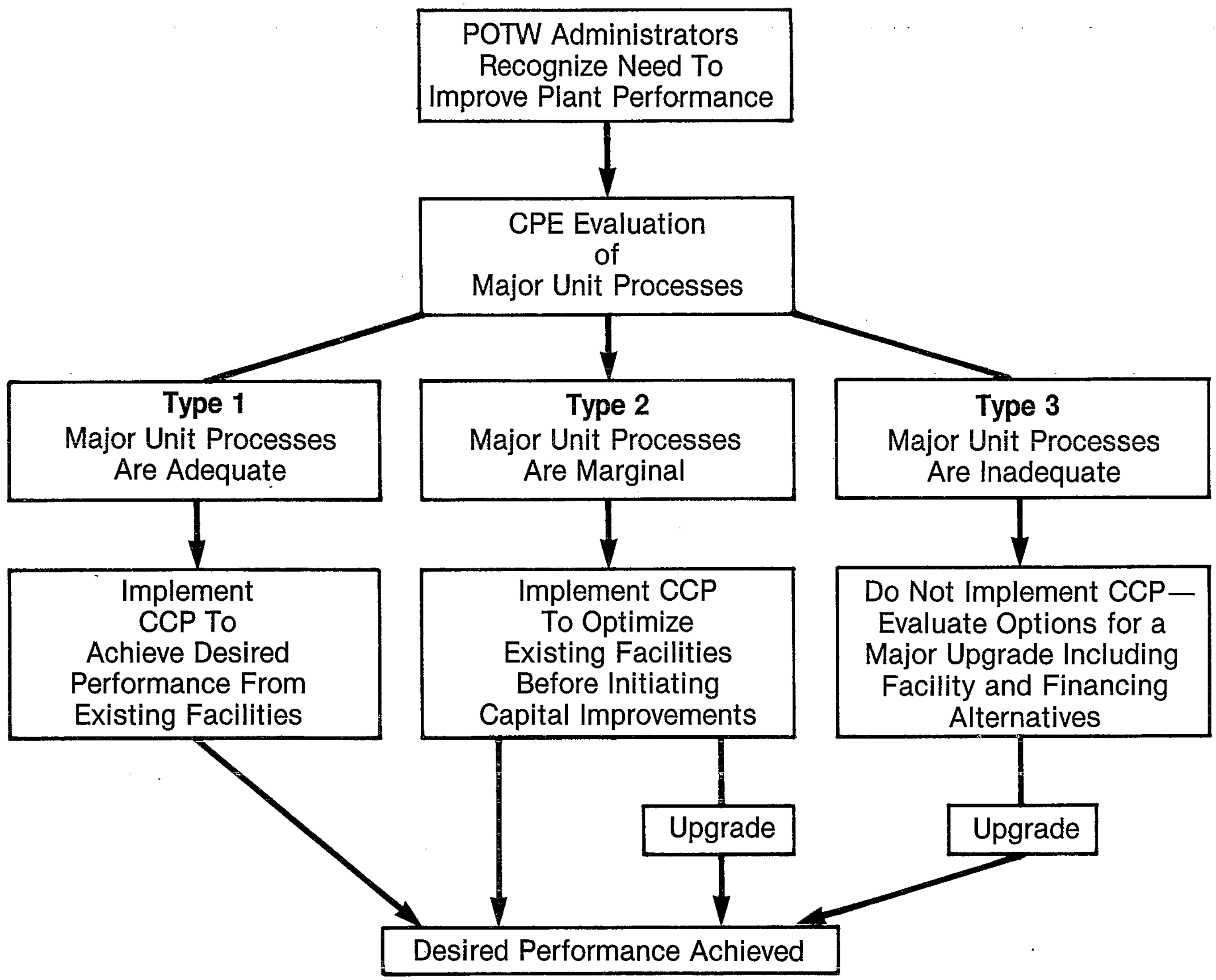
2.2.1 Evaluation of Major Unit Processes

Major unit processes are evaluated to assess the general ability of the CCP approach, as opposed to a major construction approach, to achieve desired performance levels. If the CPE indicates that the major unit processes are adequate, a major plant expansion or upgrade is not necessary and a properly conducted CCP should achieve the desired performance. If, on the other hand, the CPE shows that major unit processes are inadequate, owners should consider the expansion of these processes as the focus for achieving desired performance.

Results of evaluation of major unit processes can be summarized by categorization of plant type, as illustrated in Figure 2-1.

FIGURE 2-1

CPE/CCP SCHEMATIC OF ACTIVITIES



Type 1 plants are those POTWs where a CPE shows that current performance difficulties are not caused by limitations in the size or capabilities of the existing major unit processes. In these cases, the major problems are related to plant operation, maintenance, or administration, or to problems that can be corrected with only minor facility modifications. POTWs that fall into this category are most likely to achieve desired performance through the implementation of a nonconstruction-oriented CCP.

Identification of a POTW as Type 2 represents a situation where the marginal capacity of major unit processes will potentially prohibit the ability to achieve the desired performance level. For Type 2 facilities, implementation of a CCP will lead to improved performance but may not achieve required performance levels without significant physical plant improvements.

A Type 3 plant is one in which the existing major unit processes are inadequate. Although other limiting factors may exist, such as the operators' process control capability, minor design features, or the administration's unfamiliarity with plant needs, performance cannot be expected to improve significantly until physical limitations of major unit processes are eliminated. In this case, implementation of a nonconstruction-oriented CCP is of limited value and is not recommended. Owners with a Type 3 facility would best meet their needs by pursuing development of wastewater treatment facilities suitable for handling present and future waste loads as well as addressing factors identified in the CPE. A more detailed study of treatment alternatives and financing mechanisms would be warranted. CPEs that identify Type 3 facilities are still of benefit to POTW administrators in that the need for construction is clearly defined for facility owners. Additionally, the CPE provides an understanding of the capabilities and weaknesses of existing operation and maintenance practices and administrative policies. POTW owners can use this information to evaluate use of existing facilities as part of any major plant upgrade and as a guideline for optimizing operation, maintenance, and administration.

2.2.2 Identification of Performance-Limiting Factors

Whereas the evaluation of major unit processes in a plant is used to broadly categorize performance potential by assessing only physical facilities, the identification of performance-limiting factors focuses on one facility and the factors unique to that facility.

To assist in this identification, a list of 70 different factors that could potentially limit a POTW's performance is provided in Appendix A (1). These factors are divided into the categories of administration, maintenance, design, and operation. Suggested definitions of each factor are also provided. This list was developed as a result of many plant studies and is provided for convenience and reference. If alternate names or definitions provide a clearer understanding to those involved in conducting a CPE, they should be used instead. If different terms are used, each factor should be defined and these definitions should be readily available to those conducting the CPE and those interpreting the results.

Note that the list includes factors on capacity of major unit processes. If the evaluation of major unit processes results in a Type 2 or Type 3 classification, these same limitations should be documented in the list of factors limiting the POTW's performance. Completing the identification of factors is difficult in that true problems in a POTW are often masked. This concept is illustrated in the following discussion.

A contact stabilization plant was routinely losing sludge solids over the final clarifier weirs, through the chlorine contact tank, and to the receiving stream, resulting in noncompliance with the plant's permit. Initial observations could lead to the conclusion that the plant had an inadequately sized final clarifier. However, further investigation indicated that the solids loss was a result of the operator's routinely wasting less sludge than was produced. It was determined that, to properly control the sludge mass, increased operator time and additional equipment to adequately monitor and waste activated sludge to the digester would be required. It was further determined that the digester was undersized and would not provide adequate residence time for complete digestion.

The most obvious problem is the operator's lack of knowledge of how to apply the concept of sludge mass control. The needed laboratory equipment was within the approved budget for the facility and therefore was not assessed as a major problem. Plant administrators indicated that they could not afford additional operator time. This administrative policy was a significant factor limiting performance. The undersized digester was not a significant problem in this case because unlimited cropland for disposal of partially digested sludge was available. (Note: Disposal of partially digested sludge on cropland can no longer be considered a permanent solution since enactment of Federal regulations for land disposal of POTW sludges). It was concluded that four factors contributed to the solids loss that caused poor plant effluent quality:

1. Inadequate operator knowledge to apply the concept of sludge mass control.

2. Restrictive administrative policy that prohibited needed operator time.

3. Inadequate test equipment.

4. Inadequate digester capacity.

The above discussion illustrates that a comprehensive analysis of a performance problem is essential to identify the true performance-limiting factors. If the initial obvious problem of lack of clarifier capacity had been identified, improper corrective actions and unnecessary expenditures of funds would likely have occurred. In almost all CPEs, several factors are identified as limiting performance. Initially, each factor identified should be listed without regard to order of severity.

It is emphasized that the purpose of identifying performance-limiting factors is to identify, as accurately as possible, causes of poor performance unique to a particular plant. Observation that a factor does not meet the "industry standard" does not necessarily constitute cause for identifying that factor as limiting the POTW's performance. An actual link between poor plant performance and an identified factor must exist.

2.2.3 Prioritization of Performance-Limiting Factors

After the factors that limit performance have been identified, they are prioritized as to their adverse effect on achieving desired plant performance. The purposes of this prioritization are to establish the type of followup activities necessary to achieve compliance and the emphasis that would have to be put on each factor. If the highest ranking factors, i.e., those having the most negative impact on performance, are related to physical limitations in unit process capacity, initial corrective actions are directed toward defining plant modifications and obtaining administrative funding and action for their implementation. If the highest ranking factors are process control oriented, the initial emphasis of followup activities would be directed toward plant-specific operator training.

The prioritization of factors is accomplished by a two-step process. First, all factors that have been identified are individually assessed with regard to adverse impact on plant performance (Table 2-1); second, those factors receiving "A's" and "B's" are listed in order of priority.

TABLE 2-1

CLASSIFICATION SYSTEM FOR PRIORITIZING PERFORMANCE-LIMITING FACTORS

Rating	Adverse Effect of Factor on Plant Performance
A	Major effect on long-term repetitive basis
B	Minimum effect on routine basis or major effect on a periodic basis
C	Minor effect

Each factor previously identified as limiting performance is now assigned an "A," "B," or "C" rating. The checklist of factors in Appendix A includes a column to enter this rating.

The factors that receive an "A" are the major problems that cause a performance deficiency. They should be the central focus of any subsequent program to improve plant performance. An example of an "A" factor would be "ultimate sludge disposal" facilities, i.e., drying beds, that are too small to allow routine wasting of sludge from an activated sludge POTW.

All "B" factors (as well as "A's") typically must be eliminated before a plant will achieve consistent desired performance. Two categories of factors receive a "B" rating:

1. Those that routinely contribute to poor plant performance but are not the major problems. An example would be a shortage of person-hours to complete required process control testing in a small activated sludge plant where the underlying problem is that the operator does not understand how to run or interpret the tests or understand the need for a better testing program.

2. Those that cause a major degradation of plant performance, but only on a periodic basis. Typical examples are an inadequate spare parts inventory that causes excessive process downtime once or twice a year, or marginal oxygen transfer capacity that causes an oxygen shortage only during the hottest month of the year. As a comparison, the example "A" factor above ("ultimate sludge disposal") would receive a "B" rating if adequate drying bed capacity were available in the summer but winter weather inhibited drying bed use.

Factors that receive a "C" rating can be shown to contribute to a performance problem but their effect is minor. They would likely be corrected with little effort and/or time during followup activities. For example, if a critical process stream were accessible, but difficult to sample, it could indirectly contribute to poor performance by making process control less convenient and more time consuming. The problem would not be a major focus of a subsequent corrective program. As a further comparison, the example "A" factor above ("ultimate sludge disposal") would receive a "C"rating if adequate drying bed capacity were available but cleaning the beds with a front loader has crushed several underdrain tiles.

In the illustration presented in Section 2.2.2, "inadequate operator knowledge to apply the concept of sludge mass control" is assigned an "A" because of its continuous detrimental effect on plant performance; "administrative policy" a "B" because of its routinet effect; and "testing equipment" a "C" because its effect is only a minor contributing factor. "Inadequate digester size" is given a "B" because it made proper sludge mass control more difficult and labor intensive. It is not given an "A" because it did not limit performance in a major way since adequate sludge disposal capacity is available by utilizing nearby cropland.

Once each identified factor is assessed individually and assigned an "A," "B," or "C" classification, those receiving "A's" and "B's" are listed on a one-page summary sheet in order of priority. This requires that the evaluator assess all the "A's" and "B's" to determine the most serious cause of poor performance, second most serious, etc. A summary sheet for ranking the prioritized factors limiting plant performance in order of severity is presented in Appendix B. This process is effective in reducing the identified factors to a one-page summary and serves as a valuable reference for the next step of the CPE: assessing ability to improve plant performance.

2.2.4 Assessing Ability to Improve Performance

By definition of a CCP, all performance-limiting factors can theoretically be eliminated. Nevertheless, it is necessary to specifically assess the ability of a CCP to improve performance in each POTW. An effective approach is to evaluate each identified factor individually to determine whether there are any practical reasons a factor cannot be addressed. Examples of factors that may not be feasible to address are replacement of key personnel, drastic increases in funding, or extensive training of owners or administrators to support POTW needs.

Some factors have a variety of potential solutions or combinations of corrective actions that can effectively address the problem. For example, an activated sludge clarifier may be improved by installing baffles to decrease short-circuiting, by utilizing partial flow equalization to reduce hydraulic peaks, or by switching to other activated sludge mass modes to better control sludge settling characteristics and to reduce clarifier loading. Often a combination of these corrective actions would be appropriate. The systematic assessment of the prioritized factors helps assure that all factors can realistically be addressed, thus providing the basis for the comprehensive approach to improving performance.

It is the prioritization and assessment phase of a CPE that requires maximum application of the evaluators' judgment and experience. It should be noted that it is often necessary to later modify the original corrective steps and requirements as new or additional information becomes available during the conduct of a CCP phase. This concept is illustrated by the following:

A CPE conducted at an activated sludge plant identified the major performance-limiting factors as:

1. Inadequate operator understanding to make process adjustments to control sludge settling characteristics.

2. Inadequate staffing to make operational adjustments.

3. Inadequate program to keep equipment functioning continuously.

Based on these factors, a CCP was implemented to improve performance of the existing facilities. It was decided that this plant could perform best when the activated sludge settling rate was relatively slow. The plant operator's understanding was improved through training, and he became capable of making process control adjustments to achieve the desired slower sludge settling rate. Once the desired slower sludge settling rate was achieved, poor clarifier performance was observed and effluent quality deteriorated. Further investigation indicated that modifications made a year earlier to the clarifier inlet baffles were allowing short-circuiting to occur. This short-circuiting only became apparent after the slower settling had been achieved. These baffle modifications were reassessed and changed to reduce short-circuiting and effluent quality improved dramatically.

In this illustration, a minor design modification was determined to be a performance-limiting factor. This factor was not identified in the original CPE. An awareness that it may not be possible to identify all performance-limiting factors in the CPE, as well as an awareness that the CCP approach allows further definition and identification of factors during its implementation, is an important aspect of assessing a POTW's capability to achieve improved performance.

2.2.5 CPE Report

The results of a CPE should be summarized in a brief, written report to provide guidance for facility owners and administrators. An example is included in Appendix C. A typical CPE report is 8-12 pages in length and includes the following topics:

- Facility background
- Major process evaluation
- Performance-limiting factors
- Projected impact of a CCP
- CCP costs

A CPE report should not provide a list of specific recommendations for correcting individual performance-limiting factors. This often leads to a piecemeal approach to corrective actions where the goal of improved performance is not met. For Type 1 and Type 2 plants, the necessity of comprehensively addressing the combination of factors identified by the CPE through the implementation of a CCP should be stressed. For Type 3 plants, a recommendation for more detailed study to support the anticipated upgrade may be warranted.

2.3 Personnel Capabilities for Conducting CPEs

Persons responsible for conducting CPEs should have a knowledge of wastewater treatment, including the following areas:

- Regulatory requirements
- Process control
- Process design
- Sampling
- Laboratory testing
- Microbiology

- Hydraulic principles
- Operator training
- Wastewater facility budgeting
- Safety
- Maintenance
- Management

Consulting engineers who routinely work with POTW design and startup, and regulatory agency personnel with experience in evaluating wastewater treatment facilities, represent the types of personnel with adequate backgrounds to conduct CPEs. This Handbook is not intended as a guide to the design or operation of POTWs.

2.4 Estimating CPE Costs

The cost of conducting a CPE depends on the size and type of facility. Activated sludge plants tend to be more complex than trickling filter plants or other fixed film facilities. Guidelines for estimating CPE costs and person-days are presented in Table 2-2. These estimates are for contracting with a consultant who normally performs this type of service. The cost to a community for conducting a CPE with municipal employees would probably be less than the amounts shown in Table 2-2. However, municipal employees may not have the necessary qualifications or may be too close to the existing operation to be able to perform a truly objective evaluation.

TABLE 2-2

TYPICAL COSTS FOR CONDUCTING CPEs[a]

Type and Size of Facility	Typical Person-days Onsite	Typical Cost (1984 $)
Suspended Growth:[b,c]		
<800 m^3/d (0.2 mgd)	2	1,500- 3,000
800-8,000 m^3/d (0.2-2 mgd)	5	2,000-10,000
8,000-38,000 m^3/d (2.0-10 mgd)	7	4,000-16,000
Fixed Film:[d]		
<2,000 m^3/d (0.5 mgd)	2	1,500- 4,000
2,000-38,000 m^3/d (0.5-10 mgd)	5	3,000-12,000

[a]For contract consultant.
[b]Includes all variations of activated sludge.
[c]ABF systems, which combine suspended and fixed growth, require an effort similar to activated sludge.
[d]Includes trickling filters with both plastic and rock media and RBCs.

2.5 References

When an NTIS number is cited in a reference, that reference is available from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650

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CHAPTER 3

HOW TO CONDUCT COMPREHENSIVE PERFORMANCE EVALUATIONS

3.1 Introduction

This chapter provides guidance for persons conducting Comprehensive Performance Evaluations (CPEs). If a person associated directly with the POTW is the evaluator conducting the CPE, some of the steps may not be necessary.

3.2 Initial Activities

To determine the magnitude of the fieldwork required, and to make the onsite activities most productive, as much initial information as possible should be gathered by telephone. This information includes basic data on the POTW and sources for any needed additional information.

3.2.1 Personnel

The evaluator should obtain the names of those persons associated with the POTW who will be the primary sources of information for the CPE. The POTW superintendent, manager, or other person in charge of the wastewater treatment facility should be identified. If different persons are responsible for plant maintenance and process control, they should also be identified.

The person most knowledgeable about the details of the POTW budget should be identified by name, position, and physical location. A 1- to 2-hour meeting with this person during the fieldwork will have to be scheduled to obtain a copy of the budget and discuss it. In many small communities, this person is most often the city clerk; in larger communities, the utilities director, wastewater superintendent, or person of similar title can usually provide the best information on the budget.

The key administrative person or persons should also be identified. In many small communities or sanitation districts, an operator or plant superintendent may report directly to the elected governing administrative body, usually the city council or district board. In larger communities, the key administrative person is often the director of public works, city manager, or other nonelected administrator. In all cases, the administrator(s) who has the authority to effect a change in policy or budget for the POTW should be identified.

If a consulting engineer is currently involved with the POTW, that individual should be informed of the CPE and be provided a copy of the final report for comment. Normally, the consulting engineer will not be directly involved in conduct of the CPE. An exception may occur if there is an area of the evaluation that could be supplemented by the expertise available through the consultant.

3.2.2 Wastewater Treatment Plant

The initial information contained in Table 3-1 should be obtained by telephone to estimate field time required. The plant superintendent and/or chief operator should be the contact for this information. This information should be collected bearing in mind that some of the data may later be found to be inaccurate. Generally, the data that a chief operator can provide extemporaneously or from a readily available reference is sufficient at this time.

Irregularities that may warrant special consideration when planning or conducting the fieldwork should be identified, and more specific questions should be asked to define the potential effect on the evaluation. Frequently occurring irregularities include: major process or pieces of equipment out of service; key persons on vacation or scheduled for other priority work; and new or uncommon treatment processes.

The single trickling filter, aeration basin, or final clarifier being out of service will probably necessitate postponing fieldwork in small plants. In plants with two or more duplicate unit processes, a CPE can be conducted with one unit out of service if the results of the evaluation are needed before normal operation can be resumed.

3.2.3 Performance

An indication of past plant overall performance should be obtained from plant personnel. Most likely, a CPE will not be conducted unless a performance problem is at least suspected. However, an evaluator should not expect to learn on the telephone the exact details of a performance problem. That is, after all, the purpose of the CPE.

3.2.4 Scheduling

The major criterion for scheduling the time for a CPE should be the ability to get commitment of local personnel availability. Usually, one-half to two-thirds of the time scheduled for fieldwork will require the availability and help of these persons.

TABLE 3-1

PRELIMINARY PLANT INFORMATION TO COLLECT BY TELEPHONE

Plant Name ______________________________

Phone Contact ______________________________

Position ______________________________

Phone No. ______________ Date ______________

Design Flow ______________ Current Flow ______________

Service Population ______________________________

Year Plant Built ______________ Most Recent Upgrade ______________

Directions to Plant ______________________________

____

____

Major Processes (type and size):

Preliminary treatment ______________________________

Primary treatment ______________________________

Secondary treatment

Aeration basin ______________________________

Trickling filter ______________________________

Clarifier ______________________________

Disinfection ______________________________

Sludge treatment ______________________________

Unusual processes or equipment ______________________________

____

Any processes or major equipment currently not operational ______________

____

TABLE 3-1 (continued)

Who does performance monitoring tests? ______________________________

____

Who does process control tests? ______________________________

____

What process control test equipment is available? ______________________________

____

Plant coverage (8 am-5 pm, 24 hr, etc.) ______________________________

Work hours of key individuals ______________________________

____

____

Known conflicts with scheduling fieldwork ______________________________

Contact for scheduling fieldwork ______________________________

Administrator or owner (responsible official) ______________________________

Who has records on the budget? ______________________________

Who is consultant? ______________________________

Information resources (availability):

As-built construction plans ______________________________

O&M manual ______________________________

Monitoring records ______________________________

Equipment literature ______________________________

Scheduling should be coordinated with the availability of at least the major process control decisionmaker, the major administrative decisionmaker, and the person most knowledgeable of the plant budget. A commitment of time from these key persons is essential to the successful conduct of a CPE. It may also be beneficial to inform State and Federal regulatory personnel of the CPE schedule to avoid possible interference with enforcement activities. Responsibility for this task should be clearly identified between the evaluator and local personnel during the scheduling of activities.

During the fieldwork, the process control decisionmaker should be prepared to devote at least half of his/her time to the evaluation. The administrative decisionmaker should be available for 1 hour for a kickoff meeting, several hours for reviewing the budget, another several hours for talking about general administration, and 1-2 hours for a summary meeting.

The persons required for the conduct of a CPE are often very busy; however, the evaluator should make every effort to include all necessary individuals to ensure success of the CPE.

3.3 Data Collection

Initial onsite CPE activities are largely devoted to collection of data required for later evaluation of the POTW. As a courtesy, and to promote efficient data collection, the fieldwork is initiated with a kickoff meeting and a plant tour. These activities are followed by a period of time where a large amount of detailed data on the POTW is gathered.

3.3.1 Kickoff Meeting

A short meeting of key POTW personnel (including key administrators) and the evaluator should be held to initiate the fieldwork. The major purposes of this meeting are to explain and gain support for the CPE effort, to coordinate and establish the schedule, and to initiate the administrative evaluation activities. The objectives of the CPE should be presented along with the proposed activities. Specific meeting times with nonplant personnel should be scheduled. Information and resource requirements should be spelled out. Specific items that are required and may not be readily available are: budget information to provide a complete overview of costs associated with wastewater treatment; schedule of sewer use and tap charges; discharge permit (NPDES) for the POTW; historical monitoring data (2 years); utility bills (1 year); sewer use ordinance (if applicable); and any facility plans or other engineering studies completed on the existing facility. Administrative factors should be noted during this meeting, such as the priority put on permit compliance, familiarity with plant needs, and policies on increased funding. These initial perceptions often prove valuable when formally evaluating administrative factors later in the CPE effort.

3.3.2 Plant Tour

A plant tour should follow the kickoff meeting. The objectives of the tour are to familiarize the evaluator with the physical plant, make a preliminary assessment of design operational flexibility of the existing unit processes, and provide an initial basis for discussions on performance, process control, and maintenance. A walk-through tour following the flow of wastewater is suggested. It is then appropriate to tour the sludge treatment and disposal facilities, followed by the support facilities such as maintenance areas and laboratories. The evaluator should note the sampling points established throughout the plant for both process control and compliance monitoring. Suggestions to help the evaluator meet the objectives of the plant tour are provided in the following sections.

3.3.2.1 Preliminary Treatment

Major components of preliminary treatment typically include coarse screening or comminution, grit removal, and flow measurement.

Although inadequate screening rarely has a direct effect on plant performance, if, for example, surface mechanical aerators must be shut down twice a day to remove rags in an activated sludge plant with marginal oxygen transfer capacity, it could become a significant performance-limiting factor. Screening could be an identified area that could improve performance with minor design improvements (at least in a small plant that could utilize hand-cleaned bar screens). Indications of screening problems are:

- Plugging (with rags) of raw sewage or primary sludge pumps
- Plugging of trickling filter distributors
- Rag buildup on surface mechanical aerators
- Plugging of activated sludge return pumps where primary clarifiers are not used

Grit removal generally only has an indirect effect on plant performance. For example, inadequate grit removal can cause excessive wear on pumps or other downstream equipment resulting in excessive downtime, and replacement/repair costs, and could deprive critical processes of needed operator time.

Raw wastewater flow measurement facilities are important to accurately establish plant loadings. The plant tour should be used to observe the primary measuring device and to ask several questions regarding plant flows. If flow is turbulent or nonsymmetrical through flumes and over weirs commonly used as primary flow measurement devices, the flow records are immediately questionable. If flow is nonturbulent and symmetrical, there is a good chance the primary device is sufficiently accurate. The evaluator should always plan to check the accuracy of flow measurement later during the fieldwork.

3.3.2.2 Primary Clarification

The value of primary clarification in relation to overall plant performance is in decreasing the load on subsequent secondary treatment processes. As such, the evaluator should determine what performance monitoring of the primary processes is conducted. As a minimum, sufficient data to calculate average BOD_5 loadings on the secondary portion of the plant should be available. The areas of major concern that should be discussed during the tour are flexibility available for changing operational functions and clarifier performance.

The major operational variable that affects primary clarifier performance and can be controlled in most plants is sludge removal. The evaluator should discuss the process control method used to adjust sludge withdrawal. In general, primary clarifiers work best with a minimum of sludge in the clarifier (low sludge detention times and low blanket level). The practical limit for minimizing the sludge in the clarifier is when the sludge becomes too thin, i.e., too much water for the sludge handling facilities. A primary sludge concentration of greater than 5 percent total solids is an indication that primary clarifier performance may be improved by increased sludge pumping and warrants further investigation. A primary sludge concentration of less than 3 percent total solids indicates there is likely little opportunity to improve performance with increased sludge pumping. The operational approach used to improve primary clarifier performance must be weighed against the impact on the sludge handling processes.

The surface overflow rate (SOR), which is the daily average flow divided by clarifier surface area (CSA), can be a good indicator of the performance that can be expected from a primary clarifier handling typical domestic wastewater. A clarifier operating at an SOR of less than 25 $m^3/m^2/d$ (600 gpd/sq ft) will typically remove 35-45 percent of the BOD_5 in domestic wastewater. A clarifier operating at an SOR of 25-40 $m^3/m^2/d$ (600-1,000 gpd/sq ft) will typically remove 25-35 percent of the BOD_5.

3.3.2.3 Aerator

The term "aerator" is used in this Handbook to describe the unit process that provides the conversion of dissolved and suspended organic matter to settleable microorganisms. Examples of an aerator are: aeration basin, trickling filter, and rotating biological contactor (RBC). The aerator represents a critical process in the wastewater flow stream in determining overall plant performance capability. Evaluation of POTW capability will require careful analysis of the aerator unit in all plants. During the plant tour, the evaluator should determine if current operating conditions represent normal conditions and inquire about what operational flexibility is available. For example: Can trickling filters be run in parallel as well as series? Can recirculation be provided around the filter only? Can aeration basins be operated in a contact stabilization mode as well as plug flow and complete mix?

3.3.2.4 Secondary Clarification

In all biological wastewater treatment plants, the main function of secondary clarification is to separate the sludge solids from the treated wastewater. Another purpose is to thicken the sludge before removal from the clarifier. Characteristics that should be noted on the plant tour are configuration, depth, and operational flexibility.

The evaluator should note the general configuration of the clarifier, including shape, sludge removal mechanism, and weir and launder arrangement. A circular clarifier with a "donut" launder located several feet from the clarifier wall and a siphon-type, rapid withdrawal sludge collector typically provides optimum performance. A long, narrow, rectangular clarifier with effluent weirs only at the end and countercurrent sludge removal should signal an immediate concern about clarifier performance. Clarifiers with depth less than 3 m (10 ft) provide limited sludge storage and thickening capability and create concerns about capacity, especially in activated sludge plants.

The SOR can be used to roughly estimate final clarifier capacity. An SOR less than 25 $m^3/m^2/d$ (600 gpd/sq ft) for a circular clarifier indicates good clarifier capacity. A significantly higher SOR would mean that other processes would have to be fairly conservative to make the system perform adequately, and they should be evaluated with consideration of this higher clarifier loading.

When touring activated sludge facilities, the evaluator should become familiar with operation and flexibility of the return sludge scheme: how sludge is withdrawn from the clarifier; ability to operate at higher or lower loadings; availability of return sludge flow measurement; and flexibility to direct return sludge to different aeration basins or points in the flow stream.

3.3.2.5 Disinfection

Disinfection facilities should be toured to become familiar with the process and equipment available and because inspection of disinfection facilities often provides insight into performance of the secondary treatment process. Where disinfection is required, nearly all POTWs use chlorine as the disinfectant and incorporate a chlorine contact basin of sufficient size to provide 10 minutes to 2 hours of contact time.

In biological wastewater treatment facilities that periodically lose sludge solids over the final clarifier weirs, chlorine contact basins generally contain a buildup of sludge solids. If more than 5-10 cm (2-4 in) of sludge has built up on the bottom of the basin, there is a good chance that significant solids loss is occurring from the secondary clarifier.

3.3.2.6 Sludge Handling Capability

The evaluator's major concern with sludge handling facilities is in identifying any potential "bottlenecks" and possible alternatives if capacity problems are indicated. During the plant tour, the evaluator should become familiar with the general flow pattern of sludge from the point at which it is removed from the primary and secondary clarifiers to the point of final disposal.

All return flow streams should be identified during the tour and the plant personnel should be questioned regarding each stream's volume and strength and the availability of data. Return supernatant streams from anaerobic digesters are the most common return streams that cause performance problems. Supernatant from aerobic digesters and filtrate from dewatering operations are generally not a serious problem.

3.3.2.7 Laboratory

The laboratory should be included as part of the plant tour. Performance monitoring and process control testing should be discussed with laboratory personnel. Available analytical capability should also be determined. Sampling and analytical support are often essential parts of the evaluation effort and the evaluator should determine what level of support is available from the laboratory for the CPE.

3.3.3 Detailed Data Gathering

Following the plant tour, a major effort is initiated to collect all data necessary to assess the performance potential of the existing facilities. This data collection effort may require two or three persons for 3-7 days in a larger plant, and one or two persons for 1-2 days in a smaller plant.

Information is collected to document past performance, process design, maintenance, management, budget, process control, and administrative policies. Collecting information for many of these items requires the assistance of POTW and other personnel. As such, the data gathering should be scheduled around their availability. The time when key personnel are not available should be used by the evaluator to initially review documents such as O&M manuals and construction plans, to summarize notes and questions for POTW personnel, and to check completeness of data collection.

The forms in Appendix D have proven to be valuable working guidelines for the data collection effort (1-2). The items covered by these forms are listed below:

- General POTW Information, Form D-1
- Administrative Data, Form D-2

- Design Data, Form D-3
- Operations Data, Form D-4
- Maintenance Data, Form D-5
- Performance Data, Form D-6

When collecting data using these forms, the evaluator should be aware that the data are to be used to evaluate the performance capability of the existing POTW. The evaluator should continuously be asking "How does this affect plant performance?" If the area of inquiry is directly related to plant performance, such as a clarifier design or an administrative policy to cut electrical costs to an unreasonable level, the evaluator should spend sufficient time and effort to fully understand and define the effect on plant performance. If the area of inquiry is not directly related to plant performance, such as an operator's certification or the appearance of the plant grounds, the condition should be noted and efforts directed toward areas that specifically impact performance.

Completion of Form D-1 requires that values be selected to represent current plant hydraulic and organic loadings. Peak month loads should be used for these calculations to be compatible with the definition of secondary treatment requirements used as the basis for this Handbook. In POTWs where special allowance has been made for high infiltration/inflow, such as permitted bypassing above a selected flow, that flow at which secondary treatment is required should be used.

3.4 Evaluation of Major Unit Processes

Once data collection has been substantially completed, data evaluation is initiated. Initial focus is on evaluation of the POTW's major unit processes to determine the general applicability of a CCP to improve performance, i.e., define the facility as Type 1, 2, or 3 as described in Chapter 2.

Performance cannot be improved to a desired level unless existing major processes have adequate capacity to handle current loadings. The three basic unit processes whose capacities most frequently affect biological wastewater treatment plant performance are: aerator (the unit that provides for the conversion of nonsettleable organics), the clarifier (solids/liquid separator), and the sludge handling system (1-4).

A point system is used to quantify the evaluation of these three basic unit processes. Key loading and process parameters are calculated and results for each parameter assigned a score by comparison with standard tables. Subsequently, each of the three major unit processes receives a total score by adding together the points assigned the loading and process parameters. The totals are then compared with standards to assess whether a Type 1, Type 2, or Type 3 capability is indicated for that unit process. The overall plant type is determined by the "weakest link" among the three major process areas. It must be remembered in using this point system that this simplification can provide valuable assistance but cannot replace the overall judgment and experience of the evaluator.

3.4.1 Suspended Growth Major Unit Processes

Suspended growth facilities include those plants using variations of the activated sludge process. The three significant unit processes within these types of facilities that determine capacity and performance are the aeration basin, secondary clarifier, and sludge handling system.

3.4.1.1 Aeration Basin

Parameters that are used for scoring the capability of an aeration basin are: hydraulic detention time, organic loading, and oxygen availability. The point system for scoring these parameters is presented in Table 3-2. To obtain the necessary parameters, information is required on wastewater flow to the aeration basin, aeration basin BOD_5 loading, aeration basin liquid volume, and oxygen transfer capacity.

TABLE 3-2

PARAMETERS FOR SCORING CAPABILITY OF AERATION BASINS IN SUSPENDED GROWTH POTWs*

Current Operating Condition	Points
Hydraulic Detention Time, hr:	
24	10 (max.)
10	6
5	0
3	-6
Organic Loading, kg $BOD_5/m^3/d$ (lb/d/1,000 cu ft):	
0.24 (15)	10 (max.)
0.40 (25)	6
0.80 (50)	0
1.28 (80)	-6
Oxygen Availability, kg O_2/kg BOD_5 load:	
2.5	10 (max.)
1.5	5
1.2	0
1.0	-5
0.8	-10

*Interpolate to nearest whole number between loadings listed.

Oxygen transfer capacity is usually the most difficult information to obtain if the original engineering data are not available or if there is some reason to question the original design data based on current conditions. Generally, the evaluation proceeds by using available data on oxygen transfer capacity and assuming it is correct unless the transfer capacity appears to be marginal. If oxygen transfer capacity appears marginal, further investigation is warranted. Any of the following conditions would lead an evaluator to suspect marginal oxygen transfer:

- Difficulty in maintaining minimum DO
- Continuous operation of all blowers, or all aerators set at high speed
- Design data showing less than 1.4 kg oxygen transfer capacity per kg actual BOD_5 load

If design oxygen transfer capacity is unavailable or is believed suspect, oxygen transfer rates presented in Table 3-3 can be used to estimate oxygen transfer capacities.

TABLE 3-3

TYPICAL STANDARD OXYGEN TRANSFER RATES[a]

Aeration System	Standard Oxygen Transfer Rate lb O_2/hp-hr
Coarse bubble diffusers[b]	2.0
Fine bubble diffusers[c]	6.5
Surface mechanical aerators	3.0
Submerged turbine aerators[d]	2.0
Jet aerators[e]	2.8

[a]Guidance for adjusting to field conditions is presented in Appendix F.
[b]For 2.7-3.6 m (9-12 ft) submergence.
[c]For 18-26 w/m^3 (0.7-1.0 hp-hr/100 cu ft).
[d]Includes both blower and mixer horsepower.
[e]Includes both blower and pump horsepower.

Additional data required to make the estimate are field measurements to calculate wire horsepower and calculations to adjust oxygen transfer rates from standard conditions to the local conditions of the subject plant. The oxygen transfer capacity (kg/d) is equal to the wire horsepower (from Appendix E) times the actual oxygen transfer rate (lb/hp-hr, from Appendix F) times 24 hr/d times 0.454 kg/lb. When using Table 3-3 and Appendixes E and F, the evaluator should remember that data obtained through these estimating procedures are only approximate, but generally have the same degree of accuracy with which oxygen demands can be predicted.

Once data are available on wastewater flows, BOD_5 of influent to the aeration basin, aeration basin volume, and oxygen transfer capacity, the following calculations should be completed by the evaluator:

$$\text{Hydraulic Detention Time in Aerator} = \frac{\text{Aeration Basin Volume}}{\text{Average Daily Wastewater Flow}}$$

$$\text{Organic Loading} = \frac{BOD_5 \text{ Loading}}{\text{Aeration Basin Volume}}$$

$$\text{Oxygen Availability} = \frac{\text{Oxygen Transfer Capacity}}{BOD_5 \text{ Loading}}$$

When the above calculations have been completed for the subject POTW, the results are compared to the values given in Table 3-2 and appropriate points are assigned each parameter. If the parameters for the subject POTW fall between the values listed, interpolation is used to assign appropriate points.

3.4.1.2 Secondary Clarifiers

Parameters that are used for scoring the capability of suspended growth secondary clarifiers are: configuration, SOR, depth, return sludge removal mechanism, and return sludge control. The scoring system for these parameters is presented in Table 3-4. The configuration score addresses the influence of the weir location on the rise rate of the sludge blanket. A lower score is assigned when the effective clarifier surface area is judged to be decreased due to the location of effluent weirs and launders. For example, a clarifier 15 m long and 3 m wide (total surface area of 45 m^2) with a two-sided 1-m wide weir located 1 m from the end is judged to have 9 m^2 of launder coverage [(3 m wide) x (1 m + 1 m + 1 m)], or only 20% of the surface area. The parameter that needs to be determined to complete the clarifier's evaluation is SOR:

$$\text{SOR} = \frac{\text{Flow from the Clarifier}}{\text{Clarifier Surface Area}}$$

TABLE 3-4

PARAMETERS FOR SCORING CAPABILITY OF CLARIFIERS IN SUSPENDED GROWTH POTWs

Current Operating Condition	Points
Configuration:	
Circular with "donut" or interior launders	10
Circular with weirs on walls	7
Rectangular with 33% covered with launders	0
Rectangular with 20% covered with launders	-5
Rectangular with launder at or near end	-10
Surface Overflow Rate, $m^3/m^2/d$ (gpd/sq ft):	
12 (300)	15
20 (500)	10
27 (650)	5
33 (800)	0
41 (1,000)	-10
49 (1,200)	-15
Depth at Weirs, m (ft):	
4.6 (15)	10
3.7 (12)	4
3.0 (10)	0
2.4 (8)	-5
2.1 (7)	-10
Return Sludge Removal:	
Circular, rapid withdrawal	10
Circular, scraper to hopper	8
Rectangular, cocurrent scraper	2
Rectangular, countercurrent scraper	0
No mechanical removal	-5
Return Activated Sludge Control:	
Actual RAS flow range completely within recommended RAS flow range; capability to measure RAS flow	10
Actual RAS flow range completely within recommended RAS flow range; no capability to measure RAS flow	7
50% of recommended RAS flow range covered by actual RAS flow range; capability to measure RA	5
50% of recommended RAS flow range covered by actual RAS flow range; no capability to measure RAS flow	0
Actual RAS flow range completely outside recommended RAS flow range	-5

Evaluation of return activated sludge control is based on the ability to control the return activated sludge flow rate volume within the range normally recommended for the particular type of activated sludge plant. Typical ranges for return activated sludge pumping rates are presented in Table 3-5.

TABLE 3-5

TYPICAL RANGES FOR RETURN ACTIVATED SLUDGE PUMPING CAPACITIES

Process Type	Return Activated Sludge % of average daily wastewater flow
Conventional A.S. and ABF (plug flow or complete mix)	25-75
Extended Aeration (including oxidation ditches)	50-100
Contact Stabilization	50-125

3.4.1.3 Sludge Handling Capability

The capability of sludge handling facilities associated with an activated sludge plant is scored by the controllability of the wasting process and the capability of the available sludge treatment and disposal facilities. Scoring for sludge handling capability is not as straightforward as for the aerator or clarifier. This is because the capacity of existing facilities cannot be easily assessed due to the variability that exists in precalculated "standards" for process or loading parameters. To evaluate the sludge handling capacity, the evaluator must first calculate expected sludge production based on current loadings to the wastewater treatment processes. The evaluator then assesses the capability of the existing sludge facilities to handle the calculated sludge production.

The criteria and point system for evaluating sludge handling capability are presented in Table 3-6. As indicated by the lower points allocated, controllability is much less important than capacity.

TABLE 3-6

CRITERIA FOR SCORING SLUDGE HANDLING CAPABILITY
FOR SUSPENDED GROWTH POTWs

Current Operating Condition	Points
Controllability:	
Automated sampling and volume control	5
Metered volume and hand sampling	3
Hand measured volume and hand sampling	2
Sampling or volume measurement by hand not practical	0
Capacity:	
150% of calculated long-term average sludge production	25
125% of calculated long-term average sludge production	20
100% of calculated long-term average sludge production	15
75% of calculated long-term average sludge production	0
50% of calculated long-term average sludge production	-10

Controllability of the wasting process is indicated by the type of waste sludge volume measurement and the type of waste sludge sampling available. The optimum control for an activated sludge wasting system includes automatic volume control and automatic sampling. A positive displacement pump and automatic sampler, both controlled by an accurate and precise clock, is an example of this type of control.

Most small activated sludge plants can manually measure a wasted volume (rise in holding tank or digester, or the number of tank trucks filled) and manually sample (from a tap or the open end of the waste sludge line). Most larger plants have flow measuring and totaling devices on waste sludge lines.

Capacity of existing sludge handling facilities is evaluated using the following procedures:

- Calculate expected sludge production.
- Establish capacity of existing sludge handling unit processes.
- Determine percentage of the calculated sludge production each unit process can handle.
- Identify the "weakest link" process as the overall capacity of the existing sludge handling facilities and compare to scoring values in Table 3-6.

Expected sludge production is calculated using current BOD_5 loadings (unless believed inaccurate) and typical unit sludge production values for the existing wastewater treatment processes (5). Typical unit sludge production values for various processes are shown in Table 3-7. For example, an oxidation ditch removing about 1,000 kg BOD_5/d would be expected to have an average sludge production of about 650 kg TSS/d (1,000 kg BOD_5/d x 0.65 kg TSS/kg BOD_5 removed).

TABLE 3-7

TYPICAL UNIT SLUDGE PRODUCTION VALUES FOR SUSPENDED GROWTH POTWs

Process Type	kg TSS (sludge)/kg BOD_5 removed
Primary Clarification	1.7
Activated Sludge w/Primary Clarification	0.7
Activated Sludge w/o Primary Clarification	
Conventional[a]	0.85
Extended Aeration[b]	0.65
Contact Stabilization	1.0

[a]Includes tapered aeration, step feed, plug flow, and complete mix with wastewater detention times <10 hours.
[b]Includes oxidation ditch.

If plant records include sludge production data, the actual unit sludge production value should be compared to the typical value. If a discrepancy greater than 15 percent exists between these values, further evaluation is warranted. The most common causes of inaccurate recorded sludge production are:

- Excessive solids loss over the final clarifier weirs
- Inaccurate waste volume measurement
- Insufficient waste sampling and concentration analyses
- Inaccurate determination of BOD removed

Using the determined unit sludge production values and actual BOD_5 removals for the subject plant, the expected mass of sludge produced per day can be calculated. To complete the scoring of sludge handling capability, the expected volume of sludge produced per day should also be calculated.

Typical waste sludge concentrations for activated sludge plants are presented in Table 3-8 and can be used to convert the expected mass of sludge produced per day to the expected volume of sludge produced per day.

TABLE 3-8

TYPICAL SLUDGE CONCENTRATIONS
FOR SUSPENDED GROWTH POTWs

Sludge Type	Waste Concentration mg/l
Primary	50,000
Activated	
Return Sludge/Conventional	6,000
Return Sludge/Extended Aeration	7,500
Return Sludge/Contact Stabilization	8,000
Return Sludge/small plant with low SOR*	10,000
Separate waste hopper in secondary clarifier	12,000

*Returns can often be shut off for short periods to thicken waste sludge in clarifiers with SORs less than 20 $m^3/m^2/d$ (500 gpd/sq ft).

The capacity of each of the components of the sludge handling process must be evaluated with respect to its ability to handle the calculated long-term average sludge production for current loadings. Any process that may become a "bottleneck" should be considered critical. Typical components found in activated sludge facilities are: thickening, digestion, dewatering, hauling, and disposal.

Guidelines for the capacity evaluation of the components of the existing sludge handling processes are provided in Tables 3-9 and 3-10. The guidelines provided in Table 3-9 are used to compare existing facility capacity to expected sludge production. For example, an existing aerobic digester with a volume of 380 m^3 (100,000 gal) in a plant with a calculated waste sludge volume of 19 m^3/d (5,000 gal/d) would have a hydraulic detention time of 20 days. This is 133 percent of the guidelines provided for aerobic digesters in Table 3-9. Thus, this component of the sludge handling process in this particular POTW would have capacity for 133 percent of the long-term average sludge production. If the aerobic digester proved to have the lowest capacity to handle long-term average sludge production of all the components of the sludge handling processes in this POTW, sludge handling capability would score 22 points (interpolated from Table 3-6). The sludge handling capability evaluation is illustrated as part of the CPE example presented in Section 3.9.

TABLE 3-9

GUIDELINES FOR EVALUATING CAPACITY OF EXISTING SLUDGE HANDLING PROCESSES

Process	Parameters That Can Be Used to Represent 100% of Required Sludge Handling Capacity[a]
Gravity Thickeners	
Primary Sludge	125 kg/m^2/d (25 lb/d/sq ft)
Activated Sludge	20 kg/m^2/d (4 lb/d/sq ft)
Primary + Activated	50 kg/m^2/d (10 lb/d/sq ft)
Fixed Film	40 kg/m^2/d (8 lb/d/sq ft)
Primary + Fixed Film	75 kg/m^2/d (15 lb/d/sq ft)
Dissolved Air Flotation	
Primary Sludge	125 kg/m^2/d (25 lb/d/sq ft)
Activated Sludge	50 kg/m^2/d (10 lb/d/sq ft)
Primary + Activated	100 kg/m^2/d (20 lb/d/sq ft)
Fixed Film	75 kg/m^2/d (15 lb/d/sq ft)
Primary + Fixed Film	125 kg/m^2/d (25 lb/d/sq ft)
Digesters	
Aerobic	15 days' hydraulic detention time[b]
Anaerobic	
Single Stage	40 days' hydraulic detention time
Two Stage	30 days' combined hydraulic detention time
Drying Beds	Worst season turnover time
Mechanical Dewatering	
Single Unit	30 hours of operation/week
Multiple Units	60 hours of operation/week (with one unit out of service)
Liquid Sludge Haul	
Short Haul (<3 km)	6 trips/day maximum
Long Haul (>20 km)	4 trips/day maximum

[a]Capacity of existing unit processes should not be downgraded to these values if good operation and process performance are documented at higher loadings. For example, if records appear accurate and show that all sludge production has been successfully thickened in a gravity activated sludge thickener for the past year at an average loading of 25 kg/m^2/d (5 lb/d/sq ft), the existing thickener should be considered to have 100% of required capacity.

[b]Hydraulic detention time = Volume of digester/Volume of waste sludge expected to be produced.

TABLE 3-10

MISCELLANEOUS UNIT VALUES USED IN EVALUATING CAPACITY OF SLUDGE HANDLING CAPABILITY[a]

	Digester[b] HDT days	Total Solids Reduction %	Output Solids Concentration mg/l
Aerobic Digesters Following Extended Aeration (MCRT>20 days)	10	10	12,000
	15	20	15,000
	20	30	17,000
	>30	35	20,000
Aerobic Digesters Following Conventional A. S. (MCRT<12 days)	10	20	12,000
	15	35	15,000
	>20	40	17,000
Anaerobic Digesters for Activated + Primary, and Fixed Film (Supernating Capability Useable)	20	25	Equal to input
	30	35	10% greater than input
	40	45	20% greater than input
Volatile Solids Content of Waste Activated Sludge,			
Conventional (MCRT<12 days)		80%	
Extended Aeration (MCRT>20 days)		70%	

[a]Values in table are intended for use in allowing an evaluation of sludge handling capability to proceed in the absence of available plant data. Many other variables can affect the values of the parameters shown.
[b]Hydraulic detention time = Volume of digester/Volume of waste sludge expected to be produced.

3.4.1.4 Suspended Growth Major Unit Process Analysis

Once individual major unit processes are evaluated and given a score, these results should be recorded on a summary sheet, as shown in Table 3-11, and compared with standards for each major unit process and the total plant. This analysis results in the subject POTW being rated a Type 1, Type 2, or Type 3 facility, as described in Chapter 2. The sum of the points scored for aeration basin, secondary clarifier, and sludge handling capability must be 60 or above for the subject POTW to be designated a Type 1 facility. Furthermore, regardless of total points, the aerator must score at least 13 points, the secondary clarifier at least 25 points, and sludge handling capability at least 10 points for the plant to be considered Type 1.

TABLE 3-11

SUSPENDED GROWTH MAJOR UNIT PROCESS CAPACITY EVALUATION

	Points Scored	Points Required*		
		Type 1	Type 2	Type 3
Aeration Basin	________	13-30	0-12	<0
Secondary Clarifier	________	25-55	0-24	<0
Sludge Handling Capability	________	10-30	0- 9	<0
Total	________	60-115	20-59	<20

*Each unit process as well as the overall total points must fall in the designated range for the plant to achieve the Type 1 or Type 2 rating.

If the subject POTW meets the criteria for a Type 1 plant, the evaluation has indicated that all major processes have adequate capacity for a CCP to be able to bring the plant into compliance. If the total is less than 60 points, or if any one major unit process scores less than its minimum, the facilities must be designated as Type 2 or Type 3.

The minimum criteria for a Type 2 plant are 20 total points and zero for each individual process. If the total is less than 20, or if any major process scores a negative value, the POTW must be considered inadequate and the plant designated as Type 3. Type 3 plants generally require major construction before they can be expected to meet secondary treatment effluent limits.

A suspended growth POTW that scored the following during the evaluation of major unit processes would meet the criteria for a Type 3 plant:

Aeration Basin	14 points
Secondary Clarifier	-8 points
Sludge Handling Capability	10 points
Total	16 points

The point system in Table 3-11 has been developed to aid in assessing the capability of a POTW's major physical facilities. It cannot replace the overall judgment and experience of the evaluator, which is often the deciding factor in determining the applicability of a CCP.

3.4.2 Fixed Film Major Unit Processes

Fixed film facilities include those plants using rock or plastic media plus those using the RBC or ABF variations of the basic trickling filter process. The unit process in fixed film wastewater treatment plants that most significantly affects capacity and performance is the "aerator" portion of the plant, i.e., the amount and type of trickling filter media, RBC media, etc. Other significant unit processes are the secondary clarifier and sludge handling capability.

3.4.2.1 Aerator

a. Trickling Filters

An approach to develop "equivalency" is used to evaluate the capacity of trickling filters of varying media types. The unit surface area for common rock media is typically 43 m^2/m^3 (13 sq ft/cu ft) (6). This information can be used to convert data from trickling filters with artificial media to equivalent volumes of common rock media. For example, 1,000 m^3 (3,500 cu ft) of a plastic media with a specific surface area of 89 m^2/m^3 (27 sq ft/cu ft) is equivalent to (89/43) x (1,000 m^3) or 2,070 m^3 (7,300 cu ft) of common rock media. Unit surface area information for various media types is generally available in manufacturers' literature.

Using the equivalency calculation, organic loadings can be calculated for all types of media. Despite fixed film performance being a function of surface area, loadings for trickling filters are typically expressed as mass of BOD_5 per volume of media. The volumetric loading can be calculated using the equivalency calculation presented above. Results can be compared with criteria in Table 3-12 to compute a "score" for the trickling filter.

The capacity of a trickling filter can be significantly decreased if the media becomes plugged. Ponding on the filter is a common indicator of plugging and is generally due to overgrowth of microorganism mass or disintegration of the media. The evaluator should inspect the filter in several places by removing media to a depth of at least 15 cm (6 in) to ensure that ponding or plugging underneath the upper layer of rocks is not occuring.

b. RBCs

Parameters for scoring RBCs are presented in Table 3-13 (7). The key parameters to be evaluated are: organic loading on the first stage and on the entire system; number of stages provided; and whether or not sidestreams from anaerobic sludge treatment are received. Organic loading used for evaluating RBCs is soluble BOD_5 ($SBOD_5$) per unit of media. If data are not available, $SBOD_5$ is estimated for typical domestic wastewater as one-half

TABLE 3-12

PARAMETERS FOR SCORING AERATOR CAPABILITY FOR TRICKLING FILTER POTWs

Current Operating Condition	Points: Freezing Temperatures[b]	Points: Covered Filter or Nonfreezing Temperatures
Organic Loading, kg $BOD_5/m^3/d$ (lb/d/1,000 cu ft):[a]		
0.16 (10)	20	
0.32 (20)	15	20
0.48 (30)	0	10
0.80 (50)	-10	-5
1.12 (70)	-20	-10
Recirculation, ratio to raw flow:		
2:1	3	
1:1	2	
None	0	
Anaerobic Sidestreams:[c]		
Not returned ahead of the trickling filter	0	
Returned to the wastewater stream ahead of the trickling filter	-10	

[a]Based on primary effluent and common rock media having a specific surface area of about 43 m^2/m^3 (13 sq ft/cu ft).
[b]Temperatures below freezing for more than one month.
[c]Supernatant from anaerobic digesters or filtrate/concentrate from the dewatering processes following anaerobic digesters.

the primary effluent total BOD_5. If significant industrial contributions are present in the system, $SBOD_5$ should be determined by testing.

Surface area data for RBCs are generally available in manufacturers' literature or in plant O&M manuals. If these sources are unavailable or do not contain the needed information, the manufacturer's representative or the manufacturer should be contacted to obtain the data.

First-stage media loading is calculated by dividing the mass of $SBOD_5$ going to it by the total surface area of only the first-stage media. System media loading is calculated by dividing the total $SBOD_5$ load to the RBCs by the total surface area of all RBC media. In most cases, the mass of $SBOD_5$ will be the same for these calculations. They should only be different in plants where some of the $SBOD_5$ load is bypassed around the first stage.

TABLE 3-13

PARAMETERS FOR SCORING AERATOR CAPABILITY FOR RBC POTWs[a] (7)

Current Operating Condition	Points
First-Stage Loading, g $SBOD_5/m^2/d$ (lb/d/1,000 sq ft):	
12 (2.5)	10
20 (4.0)	0
29 (6.0)	-6
System Loading, g $SBOD_5/m^2/d$ (lb/d/1,000 sq ft):	
2.9 (0.6)	10
4.9 (1.0)	0
7.3 (1.5)	-6
Number of Stages:	
4	10
3	7
2	4
Anaerobic Sidestreams:[b]	
Not returned ahead of RBC	0
Returned to wastewater stream ahead of RBC	-10

[a]Includes mechanical and air drive RBCs.
[b]Supernatant from anaerobic digesters or filtrate/concentrate from the dewatering processes following anaerobic digesters.

c. ABFs

Parameters for evaluating ABF aerators are presented in Table 3-14 (8). The key parameters are: biocell organic loading and aeration basin detention time. A criterion of lesser importance is recirculation directly around the biocell.

Organic loadings on the biocell are calculated in a manner similar to trickling filter loadings: primary effluent BOD_5 is divided by the volume of the biocell media. Aeration basin detention time is calculated in a manner similar to activated sludge aeration basin hydraulic detention time: the aeration basin liquid volume is divided by the average daily wastewater flow. Sludge recirculation is not included in the calculation.

TABLE 3-14

PARAMETERS FOR SCORING AERATOR CAPABILITY
FOR ABF POTWs (8)

Current Operating Condition	Points
Biocell Organic Loading, kg $BOD_5/m^3/d$ (lb/d/1,000 cu ft):	
1.6 (100)	15
2.4 (150)	10
2.8 (175)	5
3.2 (200)	0
4.0 (250)	-5
4.8 (300)	-10
Aeration Basin Detention Time, hours:	
4	20
3	15
2	12
1	5
0.75	0
0.5	-10
Oxygen Availability in Aeration Basin, kg O_2/kg BOD_5 to Biocell:	
1.0	10
0.75	7
0.5	3
0.4	0
0.3	-15
Recirculation - Directly Around Biocell, ratio to raw flow:	
1:1	3
None	0

Oxygen availability in the aeration basin of an ABF plant is calculated by dividing mass of oxygen transfer capacity by the total mass of BOD_5 applied to the biocell. This is done because the removal attributed to the biocell versus that occurring in the aeration basin is not easily distinguished. Most ABF plants provide for recirculation directly around the biocell. Recirculation is calculated as a ratio to raw flow.

3.4.2.2 Secondary Clarifier

Criteria for scoring the capability of secondary clarifiers in trickling filter and RBC plants are presented in Table 3-15. The calculations require that wastewater flow rate and the clarifier configuration, surface area, and depth be known (see Section 3.4.1.2). For ABF plants, the criteria for suspended growth secondary clarifiers presented in Table 3-4 are more appropriate and should be used.

TABLE 3-15

PARAMETERS FOR SCORING CAPABILITY OF CLARIFIERS IN TRICKLING FILTERS AND RBCs*

Current Operating Condition	Points
Configuration:	
Circular with "donut" or interior launders	10
Circular with weirs on walls	7
Rectangular with 33% covered with launders	0
Rectangular with 20% covered with launders	-5
Rectangular with launder at or near end	-10
Surface Overflow Rate, $m^3/m^2/d$ (gpd/sq ft):	
12 (300)	15
20 (500)	10
27 (650)	5
33 (800)	0
41 (1,000)	-10
49 (1,200)	-15
Depth at Weirs, m (ft):	
3.7 (12)	5
3.0 (10)	3
2.1 (7)	0

*For ABF plants, criteria for suspended growth clarifiers (Table 3-4) should be used.

3.4.2.3 Sludge Handling Capability

Criteria for scoring sludge handling capability associated with fixed film plants are presented in Table 3-16. The criteria for controllability in Table 3-16 are self-explanatory. The capacity of sludge handling associated with fixed film is evaluated using the same four-step approach presented in Section 3.4.1.3 for suspended growth POTWs.

TABLE 3-16

CRITERIA FOR SCORING SLUDGE HANDLING CAPABILITY FOR FIXED FILM POTWs

Current Operating Condition	Points
Controllability:	
Automated sampling and volume control	5
Metered volume and hand sampling	3
Hand measured volume and hand sampling	2
Sampling or volume measurement by hand not practical	0
Capacity:	
125% of calculated long-term average sludge production	25
100% of calculated long-term average sludge production	15
75% of calculated long-term average sludge production	5
50% of calculated long-term average sludge production	-10

Different unit sludge production values are used in determining expected sludge production from fixed film facilities. A summary of typical unit sludge production values for the various types of fixed film plants is presented in Table 3-17.

Frequently, secondary sludge from fixed film facilities is returned to the primary clarifiers. Typical underflow concentrations of the combined sludge from the primary clarifier are shown in Table 3-17 as well as sludge concentrations from the individual fixed film processes.

The guidelines presented in Tables 3-9 and 3-10 can be used to help an evaluator determine the capacity limits of existing sludge treatment and disposal facilities.

TABLE 3-17

TYPICAL UNIT SLUDGE PRODUCTION VALUES AND SLUDGE CONCENTRATIONS FOR FIXED FILM POTWs

Process Type	kg TSS (sludge)/kg BOD_5 removed
Primary Clarification	1.7
Trickling Filter	1.0
RBC	1.0
ABF	1.0
Sludge Type	**Waste Concentration, mg/l**
Primary	50,000
Primary + Trickling Filter	45,000
Primary + RBC	45,000
Primary + ABF	35,000
Trickling Filter	30,000
RBC	30,000
ABF	12,000

3.4.2.4 Fixed Film Major Unit Process Analysis

Once major fixed film processes are evaluated, they should be summarized and compared to standards for each type of fixed film facility. Tables 3-18, 3-19, and 3-20 can be used for this purpose.

The standards are arranged similar to those for suspended growth facilities presented in Table 3-11 and discussed in Section 3.4.1.4. This analysis results in the subject POTW being rated Type 1, Type 2, or Type 3, as described in Chapter 2. Using these tables, the subject plant must score the minimum number of points listed for each individual process and the minimum number total points for all processes for the plant to qualify for a specific plant type. For example, a trickling filter plant scoring the following would meet the criteria for a Type 1 facility for overall points, aerator, and secondary clarifier, but would be classified Type 2 because of its score for sludge handling capability.

Trickling Filter	21 points
Secondary Clarifier	27 points
Sludge Handling Capability	6 points
Total	54 points

TABLE 3-18

TRICKLING FILTER MAJOR UNIT PROCESS CAPACITY EVALUATION

		Points Required*		
	Points Scored	Type 1	Type 2	Type 3
"Aerator"		17-23	0-11	<0
Secondary Clarifier		17-30	0-16	<0
Sludge Handling Capability		10-30	0- 9	<0
Total		45-83	15-44	<15

TABLE 3-19

RBC MAJOR UNIT PROCESS CAPACITY EVALUATION

		Points Required*		
	Points Scored	Type 1	Type 2	Type 3
"Aerator"		14-30	0-13	<0
Secondary Clarifier		17-30	0-16	<0
Sludge Handling Capability		10-30	0- 9	<0
Total		48-90	15-47	<15

TABLE 3-20

ABF MAJOR UNIT PROCESS CAPACITY EVALUATION

		Points Required*		
	Points Scored	Type 1	Type 2	Type 3
"Aerator"		15-48	0-14	<0
Secondary Clarifier		20-55	0-19	<0
Sludge Handling Capability		10-30	0- 9	<0
Total		50-133	15-49	<15

*Each unit process as well as the overall total points must fall in the designated range for the plant to achieve the Type 1 or Type 2 rating.

3.5 Evaluation of Performance-Limiting Factors

The identification of performance-limiting factors should be completed at a location other than the POTW so that all potential factors can be discussed objectively. The checklist of performance-limiting factors presented in Appendix A, as well as the guidelines for interpreting these factors, provide the structure for an organized review of problems in the subject POTW. The intent is to identify as clearly as possible the factors that most accurately describe the causes of limited performance. For example, poor activated sludge operation may be causing poor plant performance because the operator is improperly applying activated sludge concepts. If the operator is solely responsible for process control decisions as well as for testing for these decisions, the factor of improper application of concepts should be identified.

Often, operator inability can be traced to another source, such as an O&M manual containing inaccurate information or a technical consultant who provides routine assistance to the operator. In this case, improper application of concepts plus the source of the problem (O&M manual or improper technical guidance) should be identified as performance-limiting factors, since both must be corrected in a CCP to achieve desired plant performance.

Whereas the checklist and guidelines in Appendix A provide the structure for the identification of performance-limiting factors, notes taken during the plant tour and detailed data-gathering activities (including the completed forms from Appendix D) provide the technical resources for identifying these factors.

Each factor identified as limiting performance should be weighed with respect to impact on plant performance and assigned an "A," "B," or "C" rating as discussed in Section 2.2.3. Further prioritization is accomplished by completing the summary sheet presented in Appendix B. Generally, only those factors receiving either an "A" or "B" rating are prioritized on this sheet.

Additional guidance for identifying and prioritizing performance-limiting factors is provided in the following sections for the general areas of administration, design, operation, and maintenance.

3.5.1 Administration Factors

The budget is the mechanism whereby POTW owners/administrators generally implement their objectives. Therefore, evaluation and discussion of the budget is an effective mechanism for identifying administrative performance-limiting factors. For this reason, early during the onsite fieldwork the evaluator should schedule a meeting with the key POTW decisionmaker and the "budget person." This meeting should be scheduled to occur after the evaluator is technically familiar with the plant.

Nearly every POTW budget is set up differently so it helps to review the budget with the assistance of plant personnel to realistically rearrange the budget line items into categories emphasizing various costs. Forms for collecting budget data are presented in Appendix D. Analysis of these data can be supported by comparison with typical values for wastewater treatment plants (1)(4)(9)(10). POTWs larger than 8,000 m^3/d (2 mgd) in size usually have budgets that clearly describe wastewater treatment costs. Budgets for smaller POTWs are often combined with budgets for other utilities, such as wastewater collection, water treatment and distribution, or even street repairs and maintenance. For this reason, it is often more difficult and time consuming to establish realistic costs for small POTWs.

Key POTW administrators should be identified and interviews scheduled with them as described in Section 3.2.1. As a general rule, the POTW operating staff should not attend the interviews with POTW administrators because their presence may inhibit open discussion.

The evaluation of administrative performance-limiting factors is by nature subjective. Typically, all administrators verbally support goals of low costs, safe working conditions, good treatment performance, high employee morale, etc. An important question that the evaluator must ask is, "Where does good treatment fit in?" Often this question can be answered by observing the priority of items implemented or supported by administrators. The ideal situation is one in which the administrators function with full awareness that they want to achieve desired performance as an end product of their wastewater treatment efforts. Improving working conditions, lowering possible costs, and other similar goals would be pursued within the realm of first achieving adequate performance.

At the other end of the spectrum is an administrative attitude that "we just raised the monthly rates 100 percent last year; we aren't spending another dime on that plant." POTW administration can be judged by the following criteria:

Excellent:	Reliably provides adequate wastewater treatment at lowest <u>reasonable</u> cost.
Normal:	Provides best possible treatment with the money available.
Poor:	Spends as little as possible with no correlation made to achieving adequate plant performance.

Administrators who fall into the "poor" category typically are identified as contributing to inadequate performance during the factor identification activities.

Technical problems identified by the plant staff or the CPE evaluator, and the potential costs associated with correcting these problems, often serve as the basis for assessing administrative factors limiting plant performance. For example, the plant staff may have correctly identified needed minor modifications for the facility and presented those needs to the POTW administrators, but had their request turned down. The evaluator should solicit the other side of the story from the administrators to see if the administrative policy is indeed nonsupportive in correcting the problem. There have been many instances in which operators or plant superintendents have convinced administrators to spend money to "correct" problems that resulted in no improvement in plant performance.

Another area in which administrators can significantly, even though indirectly, affect plant performance is through personnel motivation. If administrators encourage professional growth through support of training, tangible awards for initial or upgrading certification, etc., a positive influence exists. If, however, administrators eliminate or skimp on essential operator training, downgrade operator positions through substandard salaries, or otherwise provide a negative influence on operator morale, administrators can have a significant detrimental effect on overall plant performance.

3.5.2 Design Factors

Data gathered during the plant tour, completed Form D-3, and the previously completed evaluation of major unit process capabilities provide the bulk of the information needed to complete the identification and prioritization of design-related performance-limiting factors. However, to complete the evaluation of design factors in many CPEs, the evaluator must make field investigation of the operational flexibility of the various unit processes.

Field investigations should be completed in cooperation with the POTW operator. The evaluator must not make any changes unilaterally. Any field testing desired should be discussed with the operator, whose cooperation should be obtained in making any needed changes. This approach is essential since the evaluator may wish to implement changes that, while improving plant performance, could be detrimental to specific equipment at the plant. The operator has worked with the equipment, repaired past failures, and read the manufacturers' literature and is in the best position to evaluate any adverse impact of proposed changes.

Field investigation of process flexibility defines the limitations of the equipment and processes and also promotes a better understanding of the time and difficulty required to implement better process control. This is illustrated by the following discussion:

> A 380 m^3/d (0.1 mgd) extended aeration facility has airlift sludge return pumps that have been operated to provide return rates of 200-300 percent of influent flow rates. The evaluator desired to know if returns could be held under 100 percent since this would substantially reduce solids loading on the final clarifier and potentially improve clarifier performance.
>
> Discussions with the plant operator revealed that he had previously tried to reduce the return rate by reducing the air to the airlift return pumps. The operator abandoned the ideas because the airlifts

repeatedly plugged overnight when left at the low rates. The evaluator convinced the operator to again try reducing returns so that the limits of return sludge flow control available could be defined.

An airlift pump consists of a vertical pipe with one end submerged, usually 2-3 m (6-10 ft), in the basin from which liquid is to be pumped and an air supply that introduces air into the pipe near its lower end. Air introduced into the pipe decreases the specific gravity of the pipe contents (air bubble and liquid mixture), and the heavier liquid in the surrounding basin forces the air/liquid mixture up the pipe. The pumping force created is proportional to the differential weight inside and outside the pipe. Increased flow is achieved by increasing the amount of air introduced thus reducing the specific gravity of the mixture further and increasing the driving force.

The air rate was initially reduced to produce a return flow rate of 100 percent of incoming wastewater flow as measured by a bucket and stopwatch. The airlift return pumps plugged completely in less than 2 hours because, as the sludge thickened due to reduced flow, the specific gravity increased. The air rate that produced the desired flow with thinner sludge was no longer adequate. The flow was reset to 100 percent by increasing the airflow substantially above the previous setting. An hour later the return flow rate was measured as 220 percent. Because the pumping rate affects specific gravity and specific gravity, in turn, affects the pumping rate, a "snowballing" effect was produced when the airlift pump was changed in either direction. These results supported the operator's contention that return flow rates could not be controlled at reasonable levels.

The air supply was again adjusted to provide a flow rate halfway between the current and the desired rate. This setting allowed better control to be exercised but plugging still occurred with existing sludge characteristics at return sludge flows of less than about 125 percent. It was concluded that this was the practical lower limit for return sludge flow rate control with the existing facilities and sludge character. To maintain a return sludge in the range of 125-150 percent required frequent checking, including an evening check not before asked of the operator. In this manner, part - but not all - of the design limitation could be overcome with increased operator attention.

The areas in a POTW that frequently require field investigations to determine process flexibility are:

1. <u>Suspended Growth Systems</u>

   - Control of return sludge flow rate within the ranges presented in Table 3-5

   - Control of aeration basin DO within the ranges presented in Figure 3-1

- Sludge mass control by wasting expected sludge production presented in Table 3-7, and actual waste concentrations or representative waste concentrations shown in Table 3-8

- Flow splitting to prevent unnecessary overloading of individual process units

- Available mode changes to provide maximum use of existing facilities:

  o Contact stabilization when the final clarifier appears to be the most limiting process

  o Plug flow when oxygen transfer is marginal

2. Trickling Filters

- Alternate disposal methods for anaerobic digester supernatant

- Ability to lower sludge levels in clarifiers without thinning out sludge to concentrations that would cause sludge treatment or handling problems

- Recirculation to the filter without excess hydraulic loads on the primary or secondary clarifiers

3. RBCs

- Alternate disposal methods for anaerobic digester supernatant

- Ability to lower sludge levels in clarifiers without thinning out sludge to concentrations that would cause sludge treatment or handling problems

- Ability to redistribute individual stage loadings to provide unit loadings within the ranges shown in Table 3-13

4. ABFs

- Control of return sludge flow rates within 50-100 percent of influent flow

- Ability to waste a precise mass of sludge on a daily basis

- Ability to spread a day's sludge wasting over a 24-hour period, or at least an extended period of time

- Ability to provide recirculation directly around the biocell

- Ability to maintain aeration basin DO at 2-3 mg/l

3.5.3 Operation Factors

Significant performance-limiting factors often exist in the process control activities of POTW unit processes (4)(11). The approach and methods used in maintaining process control can significantly affect the performance of plants that have adequate physical facilities. This section provides guidance to evaluators for identification and prioritization of operational factors that limit plant performance.

The evaluator starts collecting data for the process control evaluation by identifying the key POTW person for process control strategies implemented at the plant. The plant tour and data-gathering phases also provide opportunity to assess the process control applied. In addition, the process control capability of an operator can be subjectively assessed during the process capacity evaluation. If an operator recognizes the unit process functions and their relative influence on plant performance, a good grasp of process control is indicated. An approach to evaluating process control is discussed in the following sections.

3.5.3.1 Suspended Growth Facility Process Control

The process controls that should be available to an operator of an activated sludge facility are: sludge mass control, aeration basin DO control, and return sludge rate control. Techniques and approaches to improving these controls are presented in Chapter 5.

a. Sludge Mass Control

The activated sludge process removes colloidal and dissolved organic matter from wastewater resulting in a net increase in the sludge solids in the system. Control of the amount of sludge maintained in the system by wasting (removing) excess sludge is a key element in controlling plant performance. All variations of the activated sludge process require sludge mass control and periodic wasting. In line with this requirement, an operator who properly understands activated sludge mass control should be able to show the evaluator a recorded history of a controlled sludge mass, e.g., records of mean cell residence time (MCRT), mixed liquor volatile suspended solids (MLVSS), plots of aeration tank concentration in the aeration basin, total mass of sludge in the plant, etc.

The following are common indicators that sludge mass control is not applied adequately at an activated sludge plant:

- A sludge mass indicator parameter or calculation (MLVSS, MCRT, total sludge units) is not run on a routine basis (12). Routine would be daily for an 8,000 m^3/d (2 mgd) or larger plant and 3 times a week for a 400 m^3/d (0.1 mgd) plant.

- Only a settled sludge test is used to determine wasting requirements, e.g., waste if the 30-minute settled sludge volume in a graduated cylinder is greater than 600 mg/l.

- The operator does not relate mass control to control of sludge settling characteristics and sludge removal performance, i.e., sludge character.

- Significantly less mass is wasted than produced; i.e., the clarifiers lose solids over the weirs routinely.

- Poor performance persists and the mass of sludge maintained provides an MCRT significantly out of the ranges in Table 3-21.

TABLE 3-21

TYPICAL MEAN CELL RESIDENCE TIMES FOR SUSPENDED GROWTH POTWs

Process Type	Typical MCRT days
Conventional Aeration	6-12
Extended Aeration	20-40
Contact Stabilization	10-30

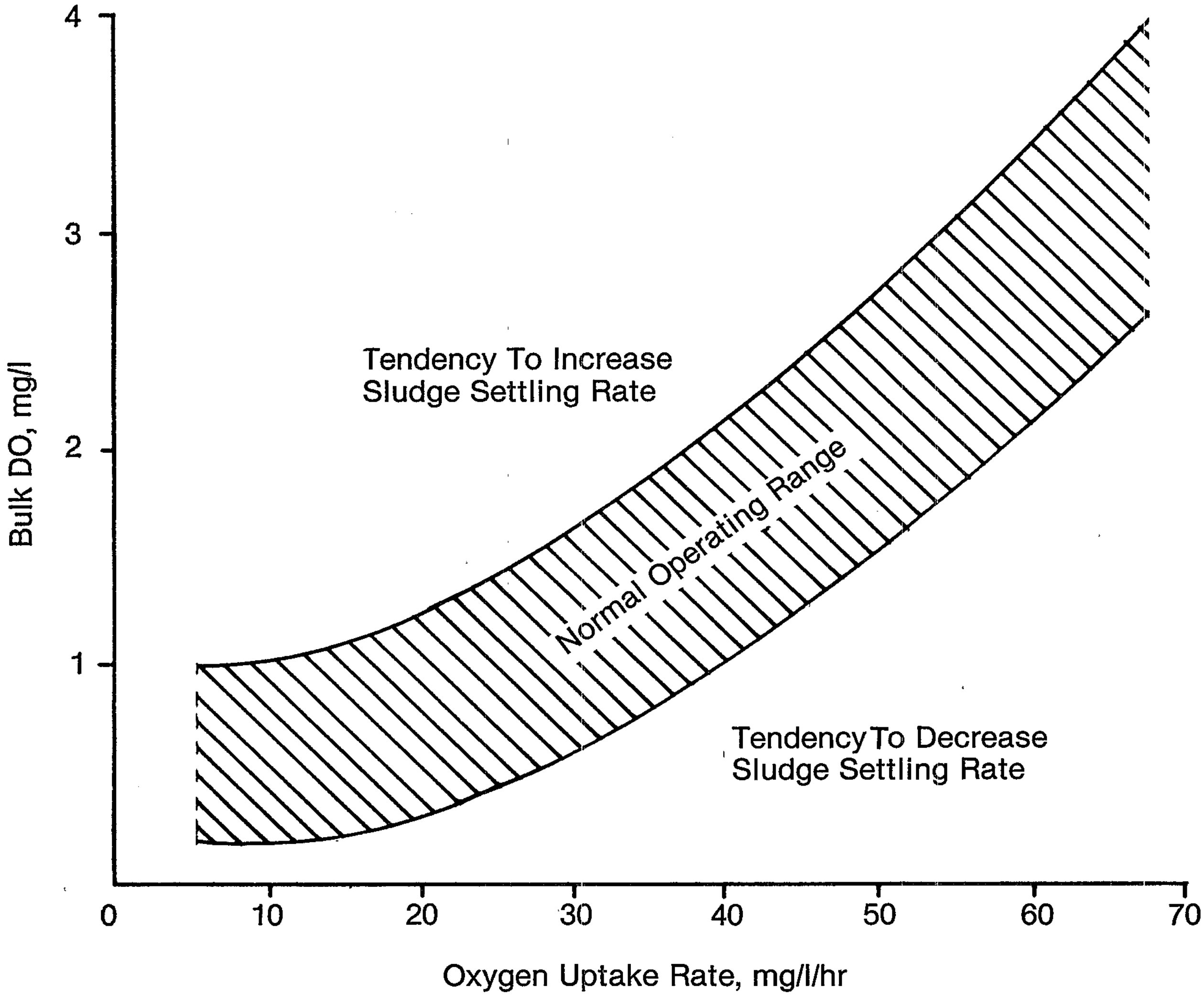
b. Aeration Basin DO Control

The aeration basin DO level is a significant factor in promoting the growth of either filamentous or zoogleal-type sludge organisms (13). Higher DO tends to speed up or slow down the relative populations of these major organism types toward primarily zoogleal. Conversely, lower DO encourages the growth of filamentous organisms and a bulky, slow settling sludge.

A general guideline for relating sludge characteristics to DO concentration in an aeration basin is presented in Figure 3-1. This information can be used to evaluate the DO control approach at the POTW under study.

FIGURE 3-1

EFFECT OF AERATION BASIN DO CONCENTRATIONS
ON SLUDGE SETTLING CHARACTERISTICS



The following are common indicators that aeration basin DO control <u>is not</u> applied adequately at an activated sludge plant:

- DO testing is not run on the aeration basin on a routine basis. Routine ranges from daily for an 8,000 m^3/d (2 mgd) or larger plant to weekly for a 400 m^3/d (0.1 mgd) plant.

- The operator does not understand or use the relationship between DO and sludge character; i.e., sludge settling is very slow and DO is very low, or sludge settling is very fast, effluent is turbid, and DO is very high.

c. Return Sludge Control

The objective of return sludge control is to optimize sludge distribution between the aerator and secondary clarifier to achieve and maintain good sludge character. The anoxic condition of the sludge in the secondary clarifiers is usually not conducive to producing desired sludge character. Thus, return sludge flow rate control should be used to maximize the sludge mass and sludge detention time in the aeration basins and minimize the sludge mass and sludge detention time in the clarifiers.

The following are common indicators that return sludge flow rate control <u>is not</u> adequately applied at an activated sludge plant:

- Returns are operated outside the ranges (especially higher) indicated in Table 3-5 and Figure 3-2.

- The operator believes that a high sludge blanket condition in a final clarifier can categorically be improved by increasing the sludge return rate.

- MLSS concentrations fluctuate widely on a diurnal basis, but return rates are not adjusted throughout the day to account for diurnal flow variations.

- The operator has not devised a method to estimate or measure the return sludge flow rate if measurement was not provided for in the original design.

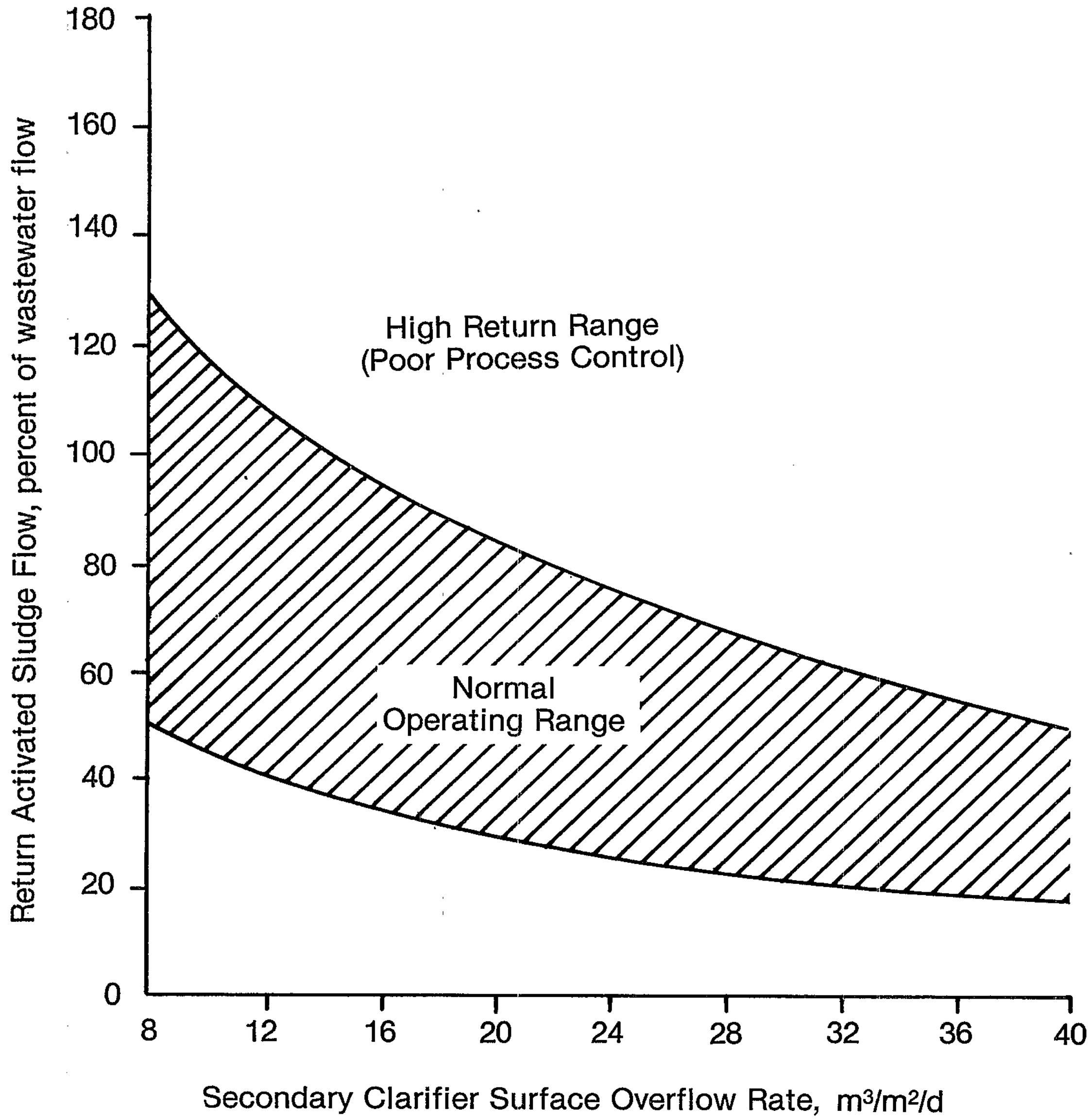
- The operator does not realize that increasing the return sludge flow rate increases the solids loading to the final clarifier and decreases the settling time in the final clarifier.

3.5.3.2 Fixed Film Facility Process Control

There is a lesser amount of process control that can be applied to fixed film facilities than to suspended growth facilities. However, because fixed film

FIGURE 3-2

TYPICAL RETURN SLUDGE FLOW RATES
WITH VARIOUS CLARIFIER SURFACE OVERFLOW RATES



facility performance is so dependent on media loading, process control, which may at first seem unimportant, can make a significant difference in plant performance. The following are common indicators that process control at a fixed film facility is not optimum.(1)(4):

- Sludge blankets in either the primary or secondary clarifiers are maintained at a high level, i.e., >0.3 m (1 ft).

- Organic loads from return process streams are not minimized despite poor plant performance.

- Lack of good maintenance, indicated by:

  o Distributors on trickling filters are plugged, or leaky distributor seals are not fixed.

  o Filter media is partially plugged and measures such as chlorination, flooding, and recirculation are not used to address the problem.

  o Trickling filter underdrain collector outlets are submerged or air vents are plugged.

- High recirculation, which increases primary or secondary clarifier overflow rates, is provided without regard to clarifier overloading. Some trickling filter plants provide recirculation that is directed to the raw wet-well and must pass through the primary clarifier a second time as well as the trickling filter. Likewise, some trickling filters provide recirculation through the secondary clarifier sludge return to the head of the plant. Recirculation provided by these methods should not be used.

3.5.4 Maintenance Factors

General information on POTW maintenance is gathered during the detailed data collection phase and is recorded on Form D-5. However, the evaluation of maintenance performance-limiting factors is done throughout the CPE by observation and questioning concerning the reliability and service requirements of pieces of equipment critical to process control and thus performance. If these units are out of service routinely or for extended periods of time, maintenance practices may be a direct cause of, or a significant contributing cause to, a performance problem. An adequate spare parts inventory, to prevent undue delays in restoring critical process functions while awaiting arrival of parts on order, is essential to the conduct of a good maintenance program. Equipment breakdowns are often used as excuses for process control problems. For example, one operator of an activated sludge plant blamed the repeated loss of sludge over the final clarifier weirs on the periodic breakdown of one sludge return pump. Even with one pump out of service, the return sludge capacity was over 200 percent of influent flow. The real cause of the sludge loss was inadequate process control, including inadequate sludge mass control and excessively high return sludge flow rates.

Observation and documentation are necessary portions of the approach utilized to evaluate emergency and preventive maintenance practices. Important aspects are examination and verification of spare parts inventories and recordkeeping systems. An example approach to a preventive maintenance scheduling system that has been applied successfully at several plants is presented in Appendix G. A good preventive maintenance program includes a schedule to distribute the workload evenly. Evaluation of these items provides a basis for discussion from which the specific results of maintenance, or lack of maintenance, of the unit processes can be assessed. This approach is illustrated by the following:

> A poorly performing trickling filter plant has acceptable organic loadings to the filter and very capable secondary clarifiers, but also has a large buildup of sludge in both the primary and secondary clarifiers. The excessive amount of sludge in the clarifiers indicates that inadequate process control by the operator might be contributing to poor plant performance. However, if sludge is not removed adequately because the heated anaerobic digesters are upset every time that more than a normal amount of sludge is added, a digester operation or loading problem could be suspected. Further investigation revealed that the boiler is being operated manually and just during the day because the operator had tried unsuccessfully to fix the automatic controls. Thus, inadequate maintenance is in fact a cause of poor plant performance.

The above discussion illustrates how a maintenance-related problem can initially be identified as something else and requires careful evaluation to identify the true cause of poor plant performance. Often, investigation of maintenance scheduling records, work order procedures, and spare parts inventories provides an adequate assessment of maintenance problems limiting performance. The evaluator must, therefore, evaluate maintenance during all phases of the CPE and should not expect to identify these factors solely in a formal evaluation of maintenance procedures.

3.6 Performance Evaluation

The plant performance evaluation is directed toward two goals: 1) establishing, or verifying, the magnitude of a POTW's performance problem; and 2) projecting the level of improved treatment that can be expected as the result of implementing a CCP.

3.6.1 Magnitude of the Performance Problem

During the CPE, the evaluator should develop a clear understanding of the performance problem associated with the subject POTW. As a first step of this assessment, recorded historical performance data can be used. These data are available from copies of NPDES permit reports in small POTWs and from monthly monitoring summary sheets in larger POTWs.

Once historical data are reviewed, the evaluator should attempt to verify the accuracy of the reported plant performance. It should be stressed that the purpose is not to blame the individual responsible, but rather to assist in identifying and substantiating the true cause(s) of poor plant performance.

The evaluator can indirectly collect data to establish authenticity of the monitoring results throughout the CPE. For example, major unit processes are assessed for their capability to achieve desired performance. If a POTW is rated a Type 3 plant (inadequate major process capability), recorded excellent effluent quality should be suspect. If recorded performance is consistent with the results of the overall evaluation, the validity and accuracy of the data are reinforced. Limitations of these comparisons are their subjective nature.

Fortunately, recorded monitoring data accurately represent the true performance in many plants. Small activated sludge plants have been shown to have the most variance between historical records and actual performance.

In small activated sludge plants - such as package extended aeration plants and contact stabilization plants and oxidation ditches - several days' or even an entire week's sludge production can be lost as the result of sludge bulking in a single afternoon. Effluent SS may be less than 10 mg/l before and after bulking occurs, but may reach 1,000-2,000 mg/l while bulking. Yet there is sufficient time between bulking periods to collect more than enough samples to meet permit monitoring requirements and show a good effluent quality. This situation is frequently revealed during the evaluation of major unit processes when expected sludge production is compared to actual sludge wasted or when bulking is actually observed during the CPE.

Another sampling procedure that can result in nonrepresentative monitoring is sometimes seen in fixed film facilities where performance degrades significantly during peak daytime loads. Samples collected from 6 a.m. to 10 a.m. may meet the required compositing criteria (e.g., three samples at 2-hour increments"), but would probably indicate better than overall average effluent quality. Likewise, samples collected from Noon to 4 p.m. may indicate worse than actual average effluent quality.

Occasionally, errors in laboratory procedures will cause a discrepancy between reported and actual effluent quality. A quick review by an evaluator experienced in laboratory procedures may identify a problem and assist the analyst as well as provide the evaluator insight into what the true analytical results should be. Major test parameters critical for completion of the CPE are influent BOD_5 and flow. The evaluator can roughly check both BOD_5 and flow data by calculating a per capita BOD_5 contribution. Per capita BOD_5 contributions are usually 0.07-0.09 kg (0.15-0.20 lb)/d for typical domestic wastewater. When estimating BOD_5 loads to a plant without actual data, or checking reasonableness of existing plant data, loads from significant industrial contributors must be added to the calculated per capita loads.

3.6.2 Projected Improved Performance with a CCP

The plant performance that is achievable through implementation of a CCP is initially estimated by evaluating the capability of major unit processes. If major unit processes are deficient in capacity, secondary treatment cannot be achieved with a CCP and the existing POTW is incapable of achieving the desired performance; i.e., it is a Type 3 plant.

If the evaluation of major unit processes shows that the major facilities have adequate capacity, the CCP approach is applicable and can likely be used to achieve improved POTW performance; i.e., it is a Type 1 or Type 2 plant. For plants of this type, all other performance-limiting factors are considered as possible to correct with adequate training of the appropriate POTW personnel. The training is addressed toward the operational staff for improvements in plant process control and maintenance; toward the POTW administration for improvements in administrative policies and budget limitations; and toward both operators and administrators to achieve minor design modifications. "Training" as used in this context describes activities whereby information is provided to facilitate understanding and encourage implementation of the CCP approach.

Once the plant's major unit process capability has been established and the performance-limiting factors have been identified and prioritized, the evaluator is in a position to assess the potential for improved performance with implementation of a CCP. During this effort, the evaluator must assess the practicability and potential time frame necessary to address each identified factor. Additionally, it is necessary to project levels of effort, activities, time frame, and costs associated with the CCP implementation. On occasion, for Type 1 and Type 2 plants, the approach to addressing a performance-limiting factor may be so unreasonable as to discourage a recommendation to implement a CCP; i.e., the number and/or magnitude of minor modifications exceeds the POTW's funding capability.

3.7 Presentation to POTW Administrators and Staff

Once the evaluator has completed the fieldwork for the CPE, a meeting should be held with the POTW administrators and staff. A presentation of preliminary CPE results should include brief descriptions of the following:

- Evaluation of major unit processes (Type 1, 2, or 3)
- Prioritized performance-limiting factors
- Performance potential with a CCP

If a CCP appears warranted, the evaluator should discuss the specific performance-limiting factors that the CCP will address and ask for local officials' support on how the identified factors can be eliminated. The attitude of the staff is critical to the success of the CCP, particularly in borderline cases where the evaluator feels a CCP can definitely help but where process control has to be precise and requires full cooperation from the POTW operating staff. If the staff is not behind the CCP approach, the CCP will take longer, require more qualified leadership, and may have to include some POTW personnel changes to be successful. The administrators should realize these requirements before deciding on a course of action.

In general, it is desirable to present all findings at the meeting with local officials. This approach eliminates surprises when the CPE report is received and begins the cooperative approach necessary for implementing a CCP. In situations where administrative or staff factors are difficult to present, the evaluator must use good judgment in presenting the results. Throughout the discussions, the evaluator must remember that the purpose of the CPE is to identify and describe facts to be used to improve the current situation, not to place blame for any past or current problems.

It should be made clear that, during conduct of the CCP, other factors are often identified and must be addressed to achieve the desired performance. The CCP approach targets plant performance as the end point, and any factors that interfere with achieving this goal must be addressed whether they were identified during the CPE or not. This understanding is often missed by local officials, and efforts may be developed to address only the items prioritized during the CPE. The evaluator should stress that a local commitment must be made to achieving the desired improved performance, not to addressing a "laundry list" of currently identified problems.

3.8 CPE Report

The objective of a CPE report is to summarize the CPE findings and conclusions. It is particularly important that the report be kept brief so that the maximum amount of resources are used for the evaluation rather than for preparing an all-inclusive report. The report should present the important CPE conclusions necessary to allow the decisionmaking officials to progress toward achieving desired performance from their facility. Eight to twelve typed pages are generally sufficient for the text of a CPE report. An example CPE report is presented in Appendix C. Typical contents are:

- Introduction
- Facility background
- Major unit process evaluation
- Performance-limiting factors
- Projected impact of a CCP
- CCP costs

The CPE report should be distributed to POTW administrators and key plant personnel, as a minimum. Further distribution of the report, e.g., to the design engineer or regulatory agencies, depends on the circumstances of the CPE but should be done at the direction, or with the awareness, of local administrators.

3.8.1 Introduction

The introduction of the CPE report should be brief and cover the following topics:

- Reason(s) for the CPE
- Objectives of the CPE
- Plant effluent performance requirements

3.8.2 Facility Background

This section should include general information about the POTW that will serve as the reference basis for the remainder of the report. The following information should be included as a minimum:

- POTW description (oxidation ditch, RBC, etc.)
- Design and current flows
- Age of plant and dates of upgrades
- Service population
- Significant industrial wastes
- Significant infiltration/inflow
- Unit process and/or flow diagram
- Staff number and plant coverage

3.8.3 Major Unit Process Evaluation

This section should include a description of the plant type (Type 1, 2, or 3) and a summary of data sources for calculating current loading. For example, "current loadings were calculated using plant laboratory results for concentrations and plant flow records lowered by 10 percent to adjust for high calibration of flow recording equipment."

Results should be presented for each major unit process (aerator, secondary clarifier, sludge handling capability). The evaluator may choose to present capacities of other unit processes if these data are pertinent to assessing the POTW's treatment capability.

3.8.4 Performance-Limiting Factors

Factors limiting performance that were identified during the CPE should be listed. Generally, the more serious factors (those receiving "A" or "B" ratings) are listed in order of priority and short, two- or three-sentence explanations of each are included.

3.8.5 Projected Impact of a CCP

The expected impact of a CCP on plant performance is discussed briefly with reference to treatment requirements. Any additional benefits, such as reduction in energy consumption, improved safety, etc., should also be indicated.

3.8.6 CCP Costs

Costs associated with a CCP should be projected as accurately as possible. Ranges of costs can be used if an evaluator does not feel comfortable projecting specific dollar amounts. Each cost projected should be indicated as a "one-time" or "annual" cost. Costs for a CCP facilitator (consultant) or for a piping modification are examples of "one-time" costs. Increased sludge handling and electrical or chemical costs are examples of "annual" costs.

3.9 Example CPE

A 4,500 m^3/d (1.2 mgd) oxidation ditch serves a primarily residential community with a population of 8,500. The wastewater is mainly domestic. The city council was notified by the State health department that a district engineer's field inspection report has confirmed data provided in the city's self-monitoring reports that improved POTW performance is required to meet the city's NPDES permit requirements of 30 mg/l (30-day maximum) for BOD_5 and TSS.

After researching several alternatives, the public works director recommended to the city council that a CPE be conducted to determine the causes of their performance problem and provide direction in selecting corrective actions. A consultant who specializes in conducting CPEs and CCPs was subsequently hired to conduct the CPE.

3.9.1 Plant Data

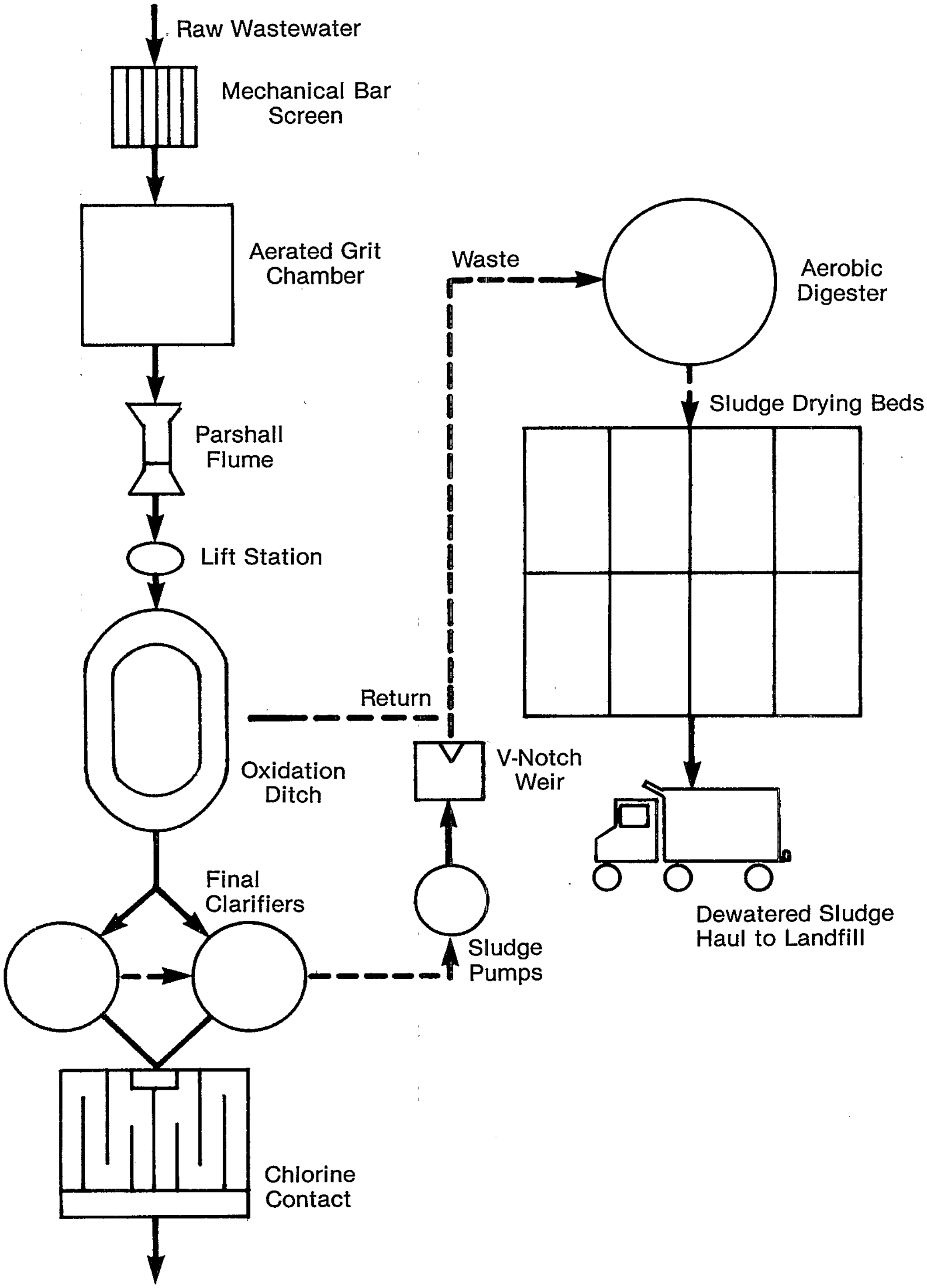
A flow diagram is presented in Figure 3-3. The following data were extracted from the completed data collection forms as presented in Appendix D.

<u>DESIGN DATA</u>

Design Flow:	4,500 m^3/d (1.2 mgd)
Hydraulic Capacity:	11,300 m^3/d (3.0 mgd)
Organic Loading:	900 kg (2,000 lb) BOD_5/d 900 kg (2,000 lb) TSS/d

FIGURE 3-3

FLOW DIAGRAM OF POTW IN EXAMPLE CPE



Preliminary Treatment:	Mechanical Bar Screen, Aerated Grit Chamber
Flow Measurement:	Parshall Flume, Sonic Level Sensor, Strip Chart Recorder
Oxidation Ditch:	Volume - 4,500 m^3 (160,000 cu ft) O_2 Transfer - 1,800 kg (4,000 lb)/d @ 38° C (100° F) with 2.0 mg/l residual DO brush rotors
Final Clarifiers:	Number of Clarifiers - 2 Diameter - 10.7 m (35.0 ft) Area - 90 m^2 (962 sq ft) each Sidewater Depth - 2.7 m (9.0 ft) Center Depth - 3.1 m (10.5 ft) Center Feed and Peripheral Weirs
Disinfection:	Number of Chlorinators - 2 Capacity - 113 kg (250 lb)/d each Contact Basin - 142 m^3 (37,500 gal)
Sludge Return:	Clarifier Scraper to Center Hopper Number of Vortex Pumps - 2 Flow Control - 1.9-5.7 m^3 (500-1,500 gal)/min Measurement - 90° V-notch Weir w/o Recording Sampling - Manual @ Weir
Aerobic Digester:	Volume - 680 m^3 (180,000 gal) Sludge Removal - Bottom Pipe to Drying Beds Supernatant Removal - Muliple-port Drawoff to Oxidation Ditch
Sludge Drying Beds:	Number of Beds - 8 Size - 15.2 m x 45.0 m (50 ft x 150 ft) Dried Sludge Buried to 0.5 m (1.5 ft) Summer Drying Time - 3 weeks Winter Drying Eliminated December-March Subnatant Returned to Head of Plant

CURRENT LOADING

Flow:	3,600 m^3/d (0.95 mgd)
Influent BOD_5:	190 mg/l or 680 kg (1,500 lb)/d
Influent TSS:	205 mg/l or 740 kg (1,600 lb)/d

3.9.2 Major Unit Process Evaluation

AERATOR

Hydraulic Detention Time: [(160,000 cu ft x 7.5)/(950,000 gpd)] x 24 = 30 hr

From Table 3-2, Score = 10 points

Organic Loading: [(1,500 lb/d)/(160,000 cu ft)] x 1,000 = 9.4 lb/d/1,000 cu ft

From Table 3-2, Score = 10 points

Oxygen Availability: (4,000 lb O_2/d)/(1,500 kg BOD_5/d)
= 2.6 lb O_2/lb BOD_5

From Table 3-2, Score = 10 points

Aerator Subtotal = 10 + 10 + 10 = 30 points

SECONDARY CLARIFIER

Configuration: Circular with Weirs on Wall

From Table 3-4, Score = 7 points

Surface Overflow Rate: (950,000 gpd)/(1924 sq ft) = 494 gpd/sq ft

From Table 3-4, Score = 10 points

Depth at Weirs: 9.0 ft

From Table 3-4, Score = -3 points

Return Sludge Removal: Scraped to Center Hopper

From Table 3-4, Score = 8 points

Return Sludge Control:

From Table 3-5, Typical Range is 50-100% of Raw Wastewater Flow.

Desired Range = (50% x 0.95 mgd) to (100% x 0.95 mgd)
= 0.47-0.95 mgd

Actual Range = (500 gpm x 1,440 x 10^{-6}) to (1,500 gpm x 1,440 x 10^{-6})
= 0.72-2.16 mgd

Actual Return Sludge Control is 50% (0.72 to 0.95 mgd) of Desired Range.

Return Sludge Measurement Provided.

From Table 3-4, Score = 5 points

Secondary Clarifier Subtotal = 7 + 10 - 3 + 8 + 5 = 27 points

SLUDGE HANDLING CAPABILITY

Controllability: Waste Volume Manually Calculated
Waste Stream Manually Sampled

From Table 3-6, Score = 2 points

Capacity:

a. Expected Sludge Production

Unit Sludge Production, From Table 3-7: 0.65 lb TSS/lb BOD_5 removed

BOD_5 Removed = (Influent BOD_5 - Effluent BOD_5 Achievable*) x Flow
= (190 mg/l - 15 mg/l) x (0.95 mgd) x (8.34)
= 1,385 lb/d

Expected Sludge Mass = (0.65 lb TSS/lb BOD_5) x (1,385 lb BOD_5/d)
= 900 lb TSS/d

Expected Sludge Concentration, From Table 3-8: 7,500 mg/l

Expected Sludge Volume = (900 lb/d)/(7,500 mg/l x 8.34 x 10^{-6})
= 14,400 gpd

b. Percentage of Expected Sludge Production Each Process Can Handle

1. Aerobic Digester

From Table 3-9, standard for evaluating aerobic digesters is a hydraulic detention time of 15 days.

Sludge Volume Existing Digester Can Handle = (180,000 gal)/(15 days)
= 12,000 gpd

Percentage of Expected Sludge Production = (12,000 gpd)/(14,4000 gpd)
= 83 percent

*Assumed value for a well operated oxidation ditch facility.

2. Drying Beds

From Table 3-9, the standard for evaluating drying beds is the worst season turnover time as demonstrated by past experience. Essentially, no drying is experienced from December through March so that beds operate only as storage during that period. Storage volume required must first be calculated.

Digester Hydraulic Detention Time = Digester Volume/Sludge Volume
HDT = (180,000 gal)/(14,400 gpd)
= 12 days

From Table 3-10, for HDT = 12 days, total solids reduction of 14% and output solids concentration of about 13,000 mg/l is expected.

Sludge to Drying Beds = (900 lb TSS/d) x (1.00 - 0.14) = 774 lb/d

Sludge Volume = (774 lb/d)/(13,000 mg/l x 8.34 x 10^{-6}) = 7,140 gpd

Storage Capacity of Existing Beds = (8) x (50 ft x 150 ft x 1.5 ft)
= 90,000 cu ft

Storage Capacity Available = (90,000 cu ft x 7.5)/(7,140 gpd)
= 94 days

Storage Capacity Required = 31 (December)
31 (January)
28 (February)
30 (March)
= 121 days

Drying bed capacity is available for 8 months of the year, but only 78% (94/121) of required storage capacity is available during the winter 4 months.

Existing Drying Bed Adequacy = [(4/12) x (78)] + [(8/12) x (100)]
= 26 + 67 = 93 percent

3. Hauling

From discussions with the POTW staff and administrators, "Hauling dried sludge is not a problem. If we have to, we can get the street crew down to the plant to help out."

Hauling Adequacy = 100 percent

4. Landfill

From discussions with the POTW staff and administrators, "If we can get it through the beds, we can get rid of it at the landfill."

Landfill Adequacy = 100 percent

From the capacity evaluation, the aerobic digester is the "weakest link" at 83 percent capacity.

From Table 3-6, Score = 3 points

Sludge Handling Capability Subtotal = 2 + 3 = 5 points.

Scores for each major unit process are presented in Table 3-22.

TABLE 3-22

SUSPENDED GROWTH MAJOR UNIT PROCESS CAPACITY EVALUATION FOR EXAMPLE CPE

	Points Scored	Points Required		
		Type 1	Type 2	Type 3
Aeration Basin	30	13-30	0-12	<0
Secondary Clarifier	27	25-55	0-24	<0
Sludge Handling Capability	5	10-30	0- 9	<0
Total	62	60-115	20-59	<20

The data in Table 3-22 indicate that the aerator, secondary clarifier, and total points scored for the example POTW are sufficient to rate a Type 1 plant. However, the points scored for sludge handling capability are only sufficient for a Type 2 rating. Therefore, the overall plant rating is Type 2. This rating indicates that a CCP is generally applicable and that improvement in plant performance is likely, but that improvement in performance to the desired level without any upgrade of major processes cannot be determined until a CCP is implemented.

3.9.3 Performance-Limiting Factors

The following performance-limiting factors were identified during the CPE and given rankings of "A" or "B." Further ranking of these identified factors was also completed as indicated by the number assigned to each factor.

1. Operator Application of Concepts and Testing to Process Control ("A")

   Less sludge was wasted than was produced on a routine basis. Excess sludge periodically bulked from the final clarifiers. Mixed liquor concentrations were monitored routinely, but the concept of controlling total sludge mass at a desired level was not implemented. Operation of return sludge flow rates at excessively high rates, typically 150-200 percent of wastewater flow, contributed to solids loss.

2. Sludge Wasting Capability ("B")

   An undersized digester and drying beds that do not provide adequate sludge disposal capability during winter months result in inadequate sludge wasting capacity.

3. Improper Technical Guidance ("B")

   The above process control and inadequate sludge disposal situation continued despite annual plant inspections by the State district engineer. "Periodic solids loss" was given the same emphasis in the annual inspection reports as plant housekeeping, timely submittal of monitoring reports, leveling and cleaning of clarifier weirs, and other items far removed from the true performance-limiting problems and potential solutions.

4. Clarifier ("B")

   The final clarifiers have sidewater depths of only 2.7 m (9.0 ft). This shallow depth promises loss of sludge solids and makes precise sludge mass and return control mandatory.

5. Performance Monitoring ("B")

   Performance monitoring samples were collected only during periods when clarifiers were not bulking sludge to conceal performance problems.

6. Familiarity with Plant Needs ("B")

   Administrators were not familiar enough with the plant requirements for performance and operations to recognize that a performance problem even existed.

7. Process Controllability ("B")

   Oversized return activated sludge pumps were provided in the plant design. This promoted poor operation with excessively high return flows and would require a modification to improve process control.

3.9.4 Potential Impact of a CCP

The most serious of the performance-limiting factors identified were process control oriented. The evaluation of major unit processes resulted in a Type 2 rating because of marginal, but not drastically deficient, sludge handling capability. The POTW appears to be a good candidate for a CCP. This recommendation should be presented to the city council. Performance of the POTW can be improved with a CCP. Continual compliance will depend on the ability to dispose of adequate quantities of waste sludge. Documentation of improved performance may be difficult because existing monitoring data do not reflect true past effluent quality.

3.10 CPE Results

The success of conducting CPE activities can be measured by POTW administrators selecting an approach and implementing activities to achieve the required performance from their wastewater treatment facility. If definite followup activities are not initiated within a reasonable time frame, the objectives of conducting a CPE cannot be achieved.

3.11 CPE Worksheets

Worksheets that can be used for evaluating POTW capability are presented in Appendices L through O. These worksheets are used to evaluate the capacity of existing major unit processes, i.e., aerator, secondary clarifier, and sludge handling system, and determine whether the POTW is a Type 1, Type 2, or Type 3 plant.

3.12 References

When an NTIS number is cited in a reference, that reference is available from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650

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CHAPTER 4

APPROACH TO CONDUCTING COMPOSITE CORRECTION PROGRAMS

4.1 Objective

The overall objective of a Composite Correction Program (CCP) is to improve the performance of an existing POTW (1). If the results of a Comprehensive Performance Evaluation (CPE) indicate a POTW is a Type 1 plant (see Figure 2-1), then the existing major unit processes have been determined to be adequate to meet current treatment requirements. For Type 1 facilities, the CCP focuses on systematically eliminating performance-limiting factors to achieve the desired effluent quality. This can be done without long-term planning or major plant modifications (2).

For Type 2 plants, the existing major unit processes have been determined to be marginal but improved performance is likely through the use of a CCP and the POTW may meet performance objectives without a major plant upgrade. For these plants, the CCP focuses on clearly defining the optimum capability of existing facilities.

A factor that influences the conduct of a CCP at Type 2 plants is the projected future growth in the service area. In an area with little projected growth, there is generally more incentive to make existing facilities perform adequately to meet long-term needs. Also, implementation time is not as important in low- or no-growth areas. A CCP of 12 months' duration that leads to long-term adequate performance with existing facilities is generally well worth the time. Even if the CCP does not achieve the desired effluent quality and some construction is indicated, plant administrators can be confident that any such construction is indeed necessary.

In a growth situation, implementation of a CCP for a Type 2 plant should closely parallel analysis of future treatment needs. The POTW should be planning expansion while the existing plant capability is being verified by a CCP. This parallel effort will allow administrators to make knowledgeable short-term decisions that will be compatible with long-term needs.

For Type 3 plants, major construction is indicated and a more comprehensive study is warranted rather than a CCP. A study of this type would look at long-term needs, treatment alternatives, potential location changes, financing mechanisms, and other factors beyond the scope of a CCP.

4.2 Methodology

The methodology for conducting a CCP is a combination of implementation of activities that support process requirements and systematic training of the staff and administrators responsible for wastewater treatment (2-4).

4.2.1 CPE Results

The basis for implementation and training efforts is the prioritized list of performance-limiting factors that was developed during the CPE (see Section 2.2.3). For example, if all of the prioritized factors were process control oriented (highly unlikely), the initial CCP effort would naturally be directed toward operator training in process control. More commonly, a combination of performance-limiting factors is identified during the CPE and a combination of implementation/training activities is therefore required. In addition, performance-limiting factors not identified in a CPE often become apparent during conduct of the CCP and must be addressed to achieve the desired level of treatment (3).

4.2.2 Process Control Basis

The areas in which performance-limiting factors have been broadly grouped (administration, design, operation, and maintenance) are all important in that a factor in any one of these areas can individually cause poor performance. Although no one area is more important than any other, it helps when implementing a CCP to understand the relationship of these areas to each other and the the goal of achieving a good, economical effluent.

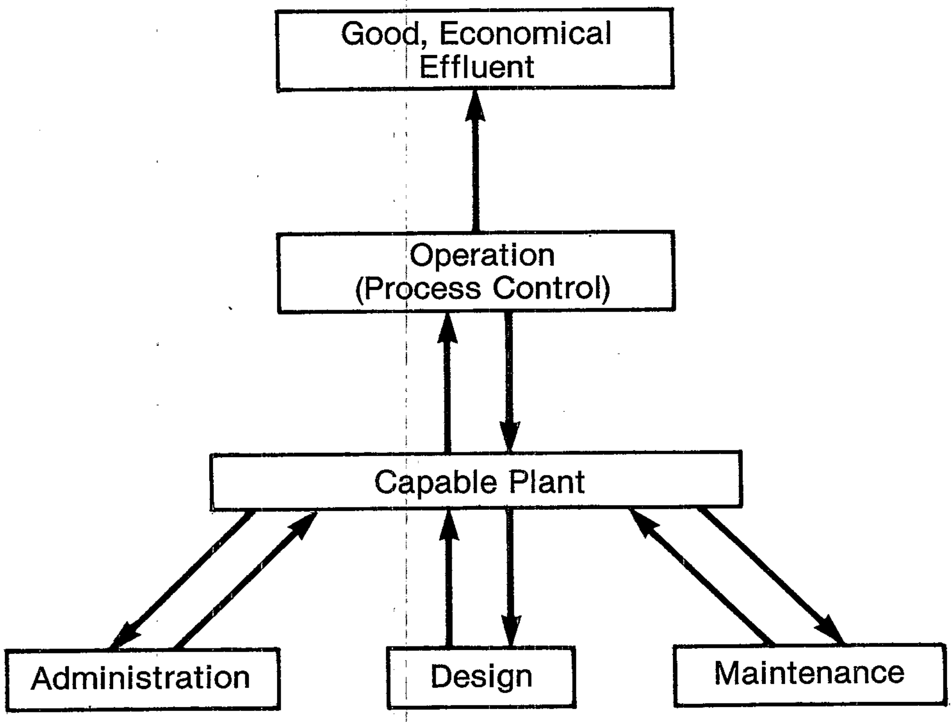
Administration, design, and maintenance activities all lead to a plant physically capable of achieving desired performance. It is the operation, or more specifically the process control, that takes a physically capable plant and produces adequately treated wastewater, as indicated by Figure 4-1.

A CCP continually focuses toward the goal of achieving desired plant effluent quality. It often becomes difficult to prioritize the changes needed to achieve this performance level, due to the typical multiple performance-limiting factors that exist. However, by focusing on the needs of the biological treatment process, as established through process control efforts, priorities for changes to achieve improved performance can be developed.

For example, if good performance in an extended aeration activated sludge plant cannot be maintained because bulky sludge has developed as a result of inadequate oxygen transfer capability, better performance requires meeting the oxygen deficiency. Limitations in meeting process needs (inadequate DO) establish the need for design changes. The plant must be improved to the point where it is capable of providing an adequate level of DO to allow desired performance to be achieved.

FIGURE 4-1

RELATIONSHIP OF PERFORMANCE-LIMITING FACTORS
TO ACHIEVING A PERFORMANCE GOAL



On the other hand, a plant may exhibit extensive limitations in grounds maintenance and housekeeping. If these limitations do not interfere with meeting the needs of the biological treatment process, low priority for addressing these limitations is indicated.

Figure 4-1 and the above example illustrate how the process control basis can be used to prioritize improvements in physical facilities. Proposed improvements must alleviate a deficiency in the existing "incapable plant," as identified by process requirements, so that progress toward the performance goal can be pursued. In this way the most direct approach to improved performance is implemented. Nonperformance-related improvements can properly be delayed until the plant has achieved the treatment objective for which it is intended.

4.2.3 Long-Term Involvement

Implementation of a CCP is a long-term effort, typically involving one year, for several reasons:

- Inherently long response times associated with making changes and achieving stability in biological systems. Biological systems typically respond slowly to process control adjustments that affect the environment in which the microorganism population lives. New environmental conditions eventually result in changes in the relative numbers of different microorganisms. Although some changes can be accomplished for activated sludge systems in the period of three to five MCRTs, it is not uncommon for some changes to take weeks and even months before desired shifts in microorganism populations are accomplished (6).

- Time required to make physical and procedural changes. This is especially true for those changes requiring financial expenditures where governing board or council approval is necessary.

- Greater effectiveness of repetitive training techniques. Operator and administrator training can be conducted under a variety of actual operating and administrative experiences.

- Time required for identification and elimination of any additional performance-limiting factors that may be found during the CCP.

4.3 Personnel Capabilities for Conducting CCPs

Persons responsible for conducting a CCP must have a comprehensive understanding of wastewater treatment (see Section 2.3) as well as extensive hands-on experience in biological wastewater treatment operations and strong capabilities in personnel motivation. Authoritative understanding of, and experience in, biological wastewater processes are necessary because the current state-of-the-art in biological treatment leaves room for much individual judgment in both design and process control. For example, references can be found to support the use of a variety of activated sludge process control strategies. Those responsible for implementing a CCP must have sufficient process experience to determine which of these is most applicable to the POTW in question. Leadership and motivational skills are required to implement changes required. These individuals must implement changes, direct activities, provide training, set priorities, exercise judgment, and, in general, facilitate those functions that lead to improved performance. The term "facilitator" will therefore be used to describe those individuals responsible for implementing a CCP.

Individuals who routinely work in the area of improving wastewater treatment plant performance will likely be best qualified to be CCP facilitators. These persons are, typically, engineers or operators who have focused their careers on wastewater treatment plant troubleshooting and have gained experience in correcting deficiencies at several plants of various types. It is important that CCP facilitators have experience in a variety of plants because the ability to recognize true causes of limited performance is a skill developed only through experience. Similarly, the successful implementation of a cost-effective CCP is greatly enhanced by experience.

By the very nature of the CCP approach, the CCP facilitator must often address improved operation, maintenance, and minor design modifications with personnel already responsible for these wastewater treatment functions. A "worst case situation" is one in which the POTW staff is trying to prove that "the facilitator can't make it work either." The CCP facilitator must be able to get all parties involved to focus on the common goal of achieving desired plant performance.

A CCP facilitator must be able to conduct training in both formal classroom and on-the-job situations. Training capabilities must also be broadly based, i.e., effective with both the operating as well as the administrative personnel. When addressing process control limitations, training must be geared to the specific process control decisionmakers. Some may be inexperienced and uncertified; others may have considerable experience and credentials. Administrative "training" is often a matter of clearly providing information to justify or support CCP activities. Although many administrators are competent, successful, and experienced, some may not know what their facilities require in terms of manpower, minor modifications, or specific funding needs.

CCP facilitators can be either consultants or utility employees. When local administrators decide to use a consultant to implement the CCP, they should conduct interviews and check references thoroughly. Nearly every CCP involves correction of some administrative factors, actual expenses to the POTW, and could involve a substantial construction cost if the CCP is not capable of bringing the POTW to the desired level of treatment. As such, the administrators should have complete confidence in the abilities of the CCP facilitator. An important attribute of a consultant providing CCP services is the ability to explain problems and potential solutions clearly to a variety of audiences, both technical and nontechnical.

When local administrators decide to conduct a CCP without the services of outside personnel, they should recognize that some inherent problems may exist. The individuals implementing the CCP, for example, often find it difficult to provide an unbiased assessment of the area in which they normally work: operating personnel tend to look at design and administration as problem areas; administrators typically feel the operating personnel should be able to do better with what they have; the engineer who designed a facility is often reluctant to admit design limitations, etc. These biases should be recognized and discussed before personnel closely associated with the POTW initiate a CCP.

4.4 Estimating CCP Costs

CCP costs vary widely depending on the size and complexity of the facility, who implements the CCP, the number and nature of performance-limiting factors, and the capability and cooperation available from the POTW technical and administrative staff. The cost of a CCP falls into two main areas: 1) cost of a consultant to implement the CCP; and 2) cost of implementing activities to support the CCP effort, such as minor plant modifications, additional staffing, more testing equipment, and certain process changes. Estimated costs for using a CCP consultant are presented in Table 4-1.

TABLE 4-1

TYPICAL COSTS FOR CONDUCTING A CCP[a]

Facility	CCP Consultant Cost (1984 $)
Suspended Growth:[b]	
<800 m^3/d (0.2 mgd)	3,000- 20,000
800-8,000 m^3/d (0.2-2 mgd)	5,000- 50,000
8,000-38,000 m^3/d (2-10 mgd)	15,000-100,000
Fixed Film:[c]	
<2,000 m^3/d (0.5 mgd)	3,000- 25,000
2,000-38,000 m^3/d (0.5-10 mgd)	5,000- 80,000

[a]For contract facilitator.
[b]Includes all variations of activated sludge, and ABF systems.
[c]Includes trickling filters with both plastic and rock media and RBCs.

Wide ranges are presented in Table 4-1 because the performance-limiting factors generally vary widely from plant to plant and require different types and amounts of training before they can be eliminated.

The costs of implementing activities to support the CCP effort and for operating the POTW at a higher level of performance are difficult to generalize. They must be developed on an individual POTW basis since they are more dependent on the particular performance-limiting factors than the size or type of facility. In most CCPs these costs equal or exceed the typical costs of a CCP consultant, as presented in Table 4-1.

4.5 References

When an NTIS number is cited in a reference, that reference is available from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650

1. Hegg, B. A., K. L. Rakness, and J. R. Schultz. Evaluation of Operation and Maintenance Factors Limiting Municipal Wastewater Treatment Plant Performance. EPA-600/2-79-034, NTIS No. PB-300331, U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory, Cincinnati, OH, 1979.

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4. Gray, A. C., Jr., P. E. Paul, and H. D. Roberts. Evaluation of Operation and Maintenance Factors Limiting Biological Wastewater Treatment Plant Performance. EPA-600/2-79-087, NTIS No. PB-297491, U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory, Cincinnati, OH, 1979.

5. Palm, J. C., D. Jenkins, and D. S. Parker. The Relationship Between Organic Loading, Dissolved Oxygen Concentration, and Sludge Settleability in the Completely-Mixed Activated Sludge Process. Presented at the 51st Annual Conference, Water Pollution Control Federation, Anaheim, CA, 1978.

6. Jenkins, D. and W. E. Garrison. Control of Activated Sludge by Mean Cell Residence Time. JWPCF 40(11):1905-1919, 1968.

CHAPTER 5

HOW TO CONDUCT COMPOSITE CORRECTION PROGRAMS

5.1 Introduction

This chapter presents techniques, schedules, and guidelines that have been successfully used in implementing Composite Correction Programs (CCPs). The methods presented should not be taken as the only workable methods, since experience has shown that no single approach will work at every POTW (1). When implementing a CCP, it must be remembered that the concept of correcting performance-limiting factors until the desired POTW performance is achieved must remain the controlling guidance, with the specifics left to the CCP facilitator.

5.2 CCP Activities

A CCP facilitator should schedule periods of onsite involvement interspersed with offsite limited involvement. During the onsite periods, the facilitator assumes a leadership role in making process control decisions, assigning responsibilities, training POTW staff, and checking progress. When not onsite, POTW personnel are responsible for this leadership and the CCP facilitator monitors their progress as well as the process control and performance of the plant.

The CCP should be scheduled and implemented using the following tools, keeping their advantages and limitations in mind:

- <u>Telephone calls</u>, because of convenience and low cost, for routine monitoring of CCP progress. Use of the telephone promotes acceptance by POTW personnel of responsibility for making critical plant observations, interpreting data, and summarizing important indicators and conclusions. The effectiveness of telephone calls is limited in that the CCP facilitator must rely on observations of the POTW personnel rather than his/her own. To ensure common understanding of the telephone conversations, the CCP facilitator should always summarize important points, decisions that have been reached, and actions to be taken subsequent to the call. Both the CCP facilitator and POTW personnel should keep written phone logs.

- Site visits to verify or clarify plant status, indicate major process control changes, test completed facility modifications, provide onsite operator training, and report progress to POTW administrators. Specific dates for site visits should be scheduled as indicated by the plant status and training requirements.

- Written reports to promote clarity and continuity. Because the cost of written reports depletes funds available for action-oriented work by both the POTW staff and the CCP facilitator, only concise, quarterly status reports are recommended. Short (1-page) written summaries should also be prepared for each facility modification. Initially, these may be prepared by the CCP facilitator, but this responsibility should ultimately be transferred to the POTW staff.

- Final CCP report to summarize activities, since all major recommendations should have been implemented during the CCP. Current status of the POTW performance and capacity should be presented.

The approach of interspersing onsite with offsite involvement is illustrated in Figure 5-1. As the CCP progresses, fewer site visits and telephone calls should be used. This is in line with the transfer of responsibility back to the permanent POTW staff. Typical levels of effort required by CCP facilitators are presented in Table 5-1. For any particular POTW, the level of effort is dependent on the specific performance-limiting factors.

5.3 Initial Site Visit

The initial site visit is used to establish the working relationship between the CCP facilitator and the POTW staff and administration. A good working relationship - based on mutual respect, communication, and understanding of the CCP - greatly enhances the potential for a successful CCP.

5.3.1 CPE Results

If the CCP facilitator was not involved in the CPE, 25-50 percent of the initial site visit time may be required to re-create or confirm the conclusions of the CPE.

A CCP is often implemented by individuals more experienced in identifying and correcting factors limiting POTW performance than those who conducted the CPE. During the initial site visit, the CCP facilitator should schedule time with key plant personnel and key administrators to discuss confirmation and/or modification of the original performance-limiting factors identified in the CPE. This discussion should also address the Type 1 or Type 2 status of the POTW and the improvement in plant performance and/or capacity expected from implementation of a CCP.

FIGURE 5-1

TYPICAL SCHEDULING OF ONSITE AND OFFSITE INVOLVEMENT

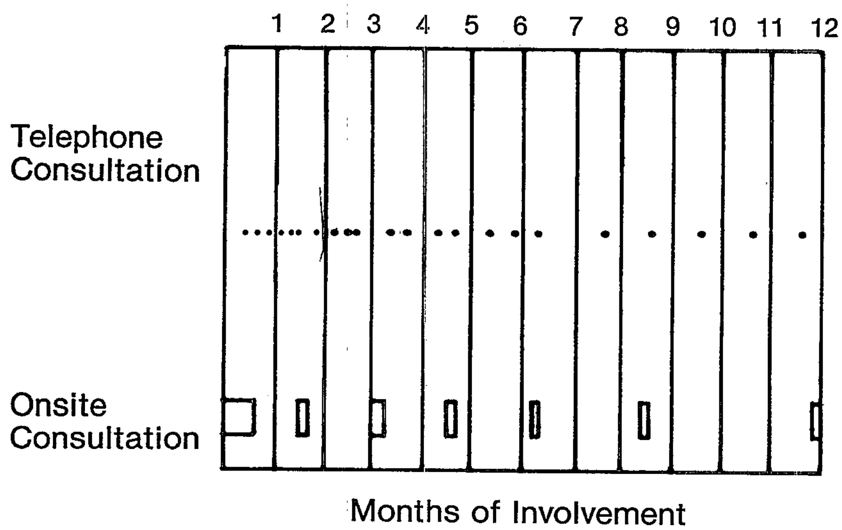


TABLE 5-1

TYPICAL CCP FACILITATOR INVOLVEMENT

Facility Size and Type*	Initial Site Visit days	Telephone Consultation no./wk initial	Telephone Consultation no./wk end	Additional Site Visits no./yr
Suspended Growth:				
3,800 m^3/d (1 mgd)	3- 5	2-6	2-4	4-12
38,000 m^3/d (10 mgd)	4-10	3-8	2-4	6-20
Fixed Film:				
3,800 m^3/d (1 mgd)	2- 5	1-3	1-4	3- 8
38,000 m^3/d (10 mgd)	4-10	2-3	1-4	5-12

*Suspended growth facilities have greater process control flexibility and typically require a greater level of effort by the CCP facilitator.

The initial site visit should also be used to begin the elimination of all major performance-limiting factors (rated "A" or "B" in the CPE) and as many other factors as possible. It is usually most advantageous to first work on improving process control. Existing process control testing should be reviewed and modified so that all necessary process control elements are adequately monitored. Sampling frequency and location, collection procedures, and laboratory analyses should be standardized so that subsequent data collected by POTW personnel and reviewed by the CCP facilitator can be used to evaluate the results of CCP activities and represent the complete process control monitoring needs of the POTW. New or modified sampling or analyses procedures should be demonstrated by the CCP facilitator and then performed by plant personnel under the supervision of the CCP facilitator.

5.3.2 Monitoring Equipment

Any needed sampling or testing equipment should be obtained. The CCP facilitator should assist the POTW personnel in obtaining any required administrative approvals.

5.3.3 Process Control Summaries

The CCP facilitator should, with the help of plant personnel, draft a precise weekly summary form for process control parameters and performance monitoring results. Monthly records are often available, but monthly data are too infrequent to allow timely process control adjustments. POTW personnel should provide the weekly summaries to the CCP facilitator throughout the CCP.

In some small plants, process control and monitoring results can often be recorded on a single page. An example process control form used both for in-plant records and as a summary sent to the CCP facilitator is shown in Figure 5-2.

5.3.4 Process Control Adjustments

The CCP facilitator should, as much as possible, initiate process control adjustments during the initial site visit. Where process controls are grossly out of line, e.g., 300 percent estimated return sludge flows, the CCP facilitator should initiate adjustments toward more reasonable values at the earliest possible time. Fine tuning of process control and training of the POTW staff cannot legitimately progress until this first level of effort is initiated.

During major process control adjustments, every effort should be made to minimize adverse impact on the POTW operators' morale. Recommendations for process control changes should be explained in terms of attempting to optimize plant capabilities through process adjustments with both the CCP facilitator

FIGURE 5-2

SAMPLE PROCESS CONTROL AND PERFORMANCE MONITORING FORM FOR A SMALL POTW

Plant Name ______________________ Week of __________ 19 ____

Day	Sun	Mon	Tue	Wed	Thur	Fri	Sat	Weekly Average
Date								
Flow, m^3/d								
Return Flow, m^3/d								
Aeration Basin Temp., °C								
Aeration Basin DO, mg/l								
Digester DO, mg/l								
Digester Temp., °C								
Aeration Basin Solids, mg/l								
Aeration Basin Mass, kg								
Return Sludge Conc., mg/l								
Clarifier Solids Conc., mg/l								
Clarifier Mass, kg								
Total Mass, kg								
30-Min Setting Sludge, ml/l								
Effluent Turbidity, NTU								
Waste Volume, m^3								
Waste Solids Conc., mg/l								
Waste Mass, kg								
Sludge Age, days								
Oxygen Uptake Rate, mg/l/hr								
Disposal Volume, m^3								
Disposal Solids Conc., mg/l								
Disposal Mass, kg								
Raw BOD_5, mg/l								
Raw TSS, mg/l								
Final BOD_5, mg/l								
Final TSS, mg/l								
Fecal Coli, no./100 ml								
Final Cl_2, mg/l								

and POTW operators involved in all aspects. Even with this approach, a CCP facilitator should not expect to obtain immediate complete support from POTW personnel on all changes. A response such as "well, let's try it then and see" is often the best that can be expected. Some changes may be made with only the degree of consensus expressed by the statement: "I don't think it'll work, but we can try it."

5.3.5 Minor Design Changes

Any minor design changes identified as necessary by the CPE and confirmed by the CCP facilitator should be initiated during the initial site visit. Minor design changes often require significant amounts of time for approvals, delivery of parts or equipment, or construction. It is necessary, therefore, to start the process as soon as needs are identified so that the effect of any changes can be evaluated during the majority of the CCP.

5.4 Improving Design Performance-Limiting Factors

The performance of Type 1 and Type 2 POTWs can often be improved by making minor modifications or additions to the original design. Examples of design limitations identified in a CPE are included in Appendix H. Examples of common minor modifications implemented during CCPs are:

- Return sludge flow measurement in small activated sludge POTWs
- Sample taps on sludge drawoff lines
- Piping to operate in alternative activated sludge modes (plug flow, contact stabilization, etc.)
- Piping to provide recirculation without overloading clarifiers
- Time clocks on waste and return sludge pumps
- Bypasses on "polishing" ponds
- Supplemental air in aeration basins
- Supplemental sludge disposal - usually land application capability

5.4.1 Identification and Justification

The CCP facilitator and POTW personnel must be able to justify each proposed modification based on the resulting increased capacity or operability the modification will provide. The degree of justification required for each modification usually varies with the associated costs and specific plant circumstances. For example, little justification may be required to convince a superintendent to add a sampling tap in a sludge line if the necessary staff and tools to do the job are already available. The same tap would require more justification if a part-time operator would have to buy or rent tools and complete the installation on his/her own time or obtain authorization for additional paid time.

5.4.2 Implementation

The CCP facilitator should ensure that each minor design modification or addition is formally documented in writing. This documentation is more valuable in terms of training and commitment if it is completed by POTW personnel. It should include:

- Purpose of the proposed change
- Detailed description of the change
- Quantitative criteria for evaluating success or failure of the change
- Individual(s) responsible for completing the change
- Cost estimate
- Anticipated improvement in plant performance
- Schedule

Another role of the CCP facilitator is to assist POTW personnel in understanding and implementing their responsiblity in regard to the modification. Ideally, the CCP facilitator should be a technical and managerial reference throughout the implementation of the modification, and the POTW staff should have, or develop, the technical expertise, available time, and motivation to complete the modification. If there is a breakdown in completing assigned responsibilities, the CCP facilitator must become more aggressive in assuring completion of the modification.

5.4.3 Assessment

Following completion of a minor modification, the CCP facilitator should perform an evaluation of the improved POTW capability. This assessment should compare the quantitative criteria established for the project with the capability of the actual modification. A one-page summary is often helpful in informing, and maintaining support from, POTW personnel and administrators.

5.5 Improving Maintenance Performance-Limiting Factors

Plant maintenance can generally be improved in nearly all POTWs, but it is a serious performance-limiting factor in only a small percentage of them (2-4). Nevertheless, adequate maintenance is essential to achieve consistent effluent quality. As such, a CCP facilitator may end up improving the maintenance program during a CCP to ensure that improved performance achieved during a CCP is maintained afterwards.

The first step in addressing maintenance factors that limit plant performance is to review any undesirable results of the current maintenance effort. If plant performance is degraded as a result of equipment breakdowns that could have been avoided with better preventive maintenance, the problem is easily documented. Likewise, if high cost of major corrective maintenance is experienced, a need for improved preventive maintenance is easily recognized. These situations should have been identified during the CPE when filling out the appropriate form in Appendix D and identifying and prioritizing performance-limiting factors. However, many POTWs lacking good maintenance programs do not have such obvious evidence directly correlating poor maintenance practices with poor performance. For these POTWs, maintenance would not have been identified as a significant factor limiting performance.

Once the need for improved preventive maintenance is established, the next step is to gain the commitment of the plant operating staff. Simply formalizing recordkeeping will generally improve maintenance practices to an acceptable level in many POTWs, particularly smaller ones.

A suggested four-step procedure for developing a maintenance recordkeeping system is to: 1) list all equipment; 2) gather manufacturers' literature on all equipment; 3) complete equipment information summary sheets for all equipment; and 4) develop time-based preventive maintenance schedules.

A list of equipment can most easily be developed by touring the POTW. As new equipment is purchased it can be added to the list. Existing manufacturers' literature should be inventoried to identify missing but needed materials. Maintenance literature can be obtained from the factory (usually a source is identified on the equipment nameplate) or from local equipment representatives.

An equipment information sheet is presented in Appendix G. Once sheets are completed for each piece of equipment, a time-based schedule can be developed. This schedule typically includes daily, weekly, monthly, quarterly, semiannual, and annual checkoff lists of required maintenance tasks. An example of this scheduling system is also presented in Appendix G.

In many small POTWs, the number of pieces of equipment is so small that scheduling is not critical. In larger plants, preventive maintenance activities should be spaced to provide an even workload throughout the year. Similarly, all monthly maintenance activities should be scheduled for accomplishment over the entire 4-week period.

The above system for developing a maintenance recordkeeping system has worked successfully at several small POTWs. However, there are many other good maintenance references available for use by CCP facilitators and POTW staffs (5-7).

5.6 Improving Administrative Performance-Limiting Factors

Frequently encountered administrative factors that limit plant performance are administrators who are unfamiliar with plant needs and policies that conflict with plant needs. For example, such items as minor modifications, testing equipment, expanded operator coverage, or increased utility costs may be recognized by plant operating personnel as performance-limiting factors but changes cannot be pursued due to lack of appreciation of their importance by nontechnical administrators. Nearly all POTW administrators want to provide adequate treatment capacity and performance. Their support and understanding is essential to the successful implementation of a CCP. The following techniques have proven useful in overcoming administrative limitations:

- Involve plant administrators from the start of the CCP. The initial site visit should include time with key administrators at the plant to increase their understanding of plant processes and problems.

- Educate administrators in the fundamentals of biological wastewater treatment and in the specific needs of the plant's processes. Administrators may be reluctant to pursue corrective actions because of lack of understanding of treatment processes and the role the desired change plays in improving such processes.

- Listen carefully to the concerns of administrators so that they can be addressed during the CCP. Some of their concerns or ideas may be technically unimportant, but must be addressed to ensure continued progress of the CCP.

- Use technical data based on process needs to persuade administrators to take appropriate actions; do not rely on "authority." Alternatives should be presented, when possible, and the administrators left with the decision.

5.7 Improving Operational Performance-Limiting Factors

Improvement of POTW operations during a CCP is achieved by providing training while improved process control procedures, tailored for the particular plant, are developed and implemented. The initial training efforts should be directed at the key process control decisionmakers. In most plants with flows less than 1,900 m^3/d (0.5 mgd), one person typically makes and implements all major process control decisions. In these cases, on-the-job training is usually more effective than classroom training and is recommended. As the number of operators to be trained increases with plant size, the need for and effectiveness of combining classroom training with on-the-job training also increases.

As discussed in Chapter 4, process control is the primary goal in implementing a CCP because it represents the essential step that enables a capable plant to achieve the ultimate goal of cost-effectively producing a good quality effluent. A detailed discussion of process control for suspended growth and fixed film facilities is therefore presented.

5.7.1 Suspended Growth Process Control

Process control of suspended growth facilities can be achieved through control of the following important parameters associated with the process:

- Activated sludge mass
- Return sludge flow
- Aeration basin DO

These items can be utilized to apply "pressure" to the biological environment. If a particular pressure is held for an adequate length of time to get biological system response, a desired change in activated sludge characteristics - such as settling velocity - will result. The interrelationships between sludge characteristics, pressure, and time for biological system response to occur relative to sludge mass control, return sludge control, and DO control are discussed in the following sections.

5.7.1.1 Activated Sludge Characteristics

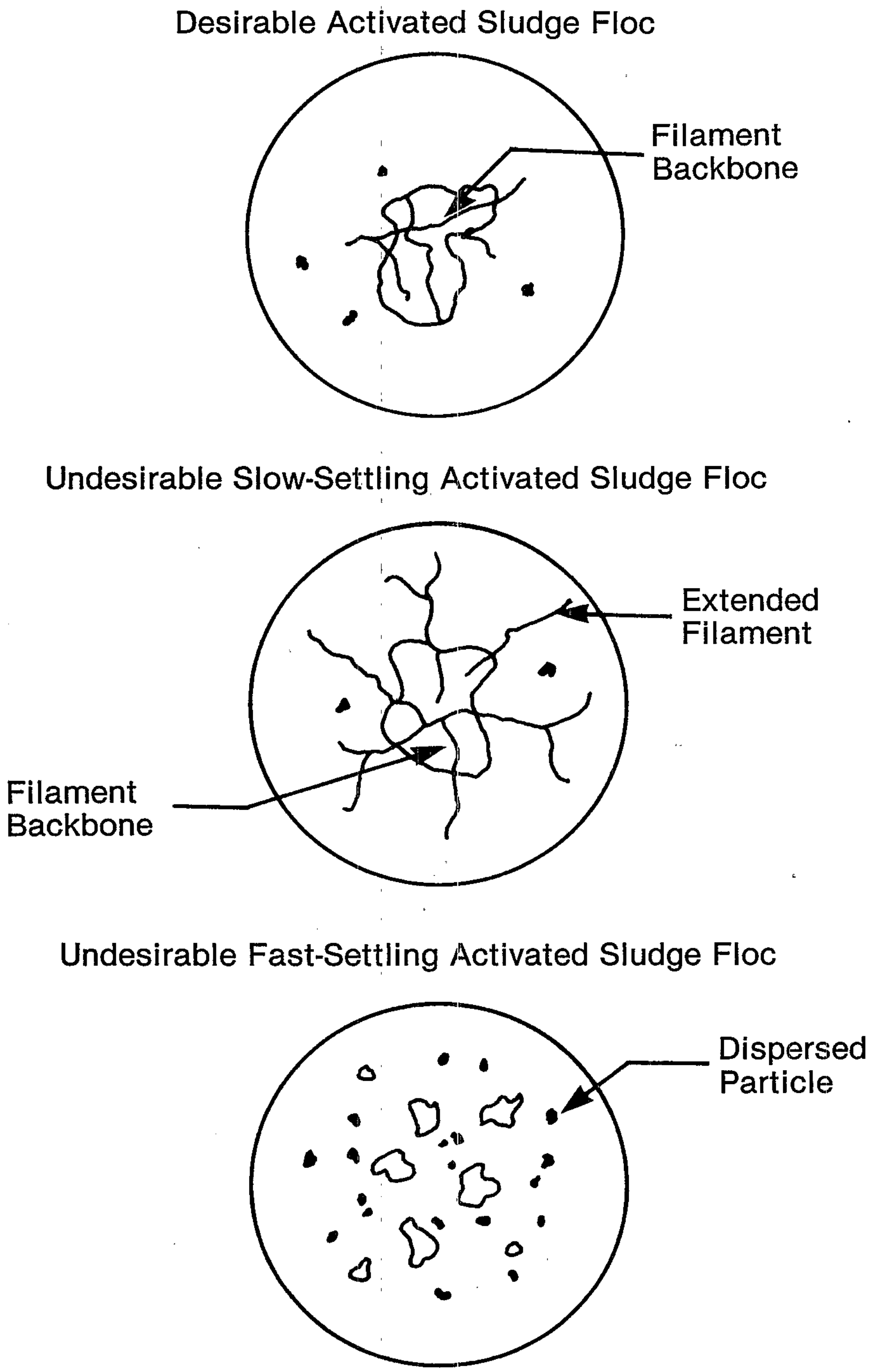
The primary objective of activated sludge process control is achieving good performance by maintaining proper sludge character. Sludge character is defined as those physical and biological characteristics of a sludge that determine its ability to remove organic material from wastewater. Good sludge character requires filamentous and zoogleal bacteria to be in proper balance. Enough filaments should be present to form a skeleton for the floc particles, but the filaments should not extend significantly beyond the floc.

More filaments tend to produce a slower settling, larger sludge floc that produces a clearer supernatant. Too many filaments, however, produce a sludge that will not adequately settle and thicken in the final clarifier, often causing sludge to be carried over the clarifier weirs. Having fewer filaments produces a more rapid settling sludge but also leaves more turbidity. The faster settling, small sludge floc exhibits discrete settling and produces "pin floc" or "straggler floc" as well as higher turbidities.

A representation of a microscopic view of this desirable type of sludge is shown in Figure 5-3.

FIGURE 5-3

REPRESENTATIONS OF ACTIVATED SLUDGE FLOC



It is desirable to obtain good solids/liquid and the good sludge thickening characteristics of a faster settling sludge along with the high quality effluent produced by a slower settling sludge. This is achieved by control of the sludge character to obtain the best balance of fast- and slow-settling characteristics.

Settling tests can be used to monitor the sludge conditions shown in Figure 5-3.

5.7.1.2 Activated Sludge Mass Control

Activated sludge mass is controlled to achieve and maintain desired sludge character and, as such, represents a critical aspect of good process control. There are several ways to control sludge mass in a POTW. These variations put emphasis on different calculations or different control parameters, but the basic objective of each is to obtain the desired mass of microorganisms in the system.

Some mass control techniques are based on the assumption that sludge can best handle diurnal and day-to-day variations in influent wastewater strength and the cyclic nature of sludge growth rates by maintaining relatively constant MLVSS concentration. Another technique attempts to adjust sludge mass to produce a desired food to microorganism ratio (F/M). Yet another attempts to maintain a consistent average age of the activated sludge in the system, i.e., mean cell residence time (MCRT).

Mass control by monitoring only the MLSS or MLVSS concentration in the aeration basin and wasting sludge to maintain a desired level assumes that variations in the amount of sludge in the secondary clarifiers is insignificant. A preferred approach includes secondary sludge in the mass control monitoring program.

The F/M method of sludge mass control is difficult to implement because a method to quickly and accurately monitor the food portion of this parameter is not commonly available. Typically, BOD_5 or chemical oxygen demand (COD) are used to indicate the amount of food available. The BOD_5 test requires five days to complete and is therefore unsatisfactory for process control purposes. Although the COD test can be completed in only several hours, it requires equipment and laboratory capabilities that are not usually available in smaller plants.

Mass control using the MCRT approach can be set up to include the mass of sludge in the aeration basin and the secondary clarifier (10). A variation of this technique is to select a desired level of total mass for the system (i.e., both the aeration basin and secondary clarifier) and adjust the amount of sludge wasted to approach the selected total mass. It is recommended that one of these two strategies be selected for controlling sludge mass. The following discussion identifies the differences between the two strategies.

Activated sludge mass control using the MCRT approach requires that the total sludge mass be measured each day and that total be divided by the target MCRT. This calculated mass is then attempted to be wasted. Actual MCRTs are calculated by dividing the total sludge mass in the system by the actual sludge mass wasted. Actual data for a 3-week period of sludge mass control using the MCRT approach are shown in Figure 5-4. During this period the target MCRT was kept constant at 10 days. The data in Figure 5-4 show that fairly constant MCRT can be maintained. An advantage of mass control by this method is that it requires daily wasting.

Sludge mass control using the total mass in the system approach requires that wasting be varied depending on increases or decreases in the total sludge mass. For example, if the total sludge mass was increasing above the selected target level, wasting would be increased until the desired sludge mass was again achieved. Actual data for a 3-week period of sludge mass control using the target total mass approach are shown in Figure 5-5. An important observation from Figure 5-5 is that total mass was held relatively constant despite individual MCRTs ranging from 10 to infinity (no wasting that day). Control of total sludge mass can be a useful process control parameter, especially in activated sludge plants where wasting is not done every day.

5.7.1.3 Return Sludge Flow Rate Control

The return sludge flow rate determines the distribution of sludge between the aeration basin and secondary clarifier. In general, return sludge flow rate control should be used to maximize the sludge mass and sludge detention time in the aeration basin and minimize the sludge mass and sludge detention time in the final clarifier. This represents the optimum condition for an aerobic biological treatment system and can be summarized as maximizing the sludge distribution ratio (aerator sludge mass divided by clarifier sludge mass).

A general misconception concerning the use of return sludge flow rates for process control is that increasing the flow of return sludge decreases the sludge blanket level in the secondary clarifier. This is not as straightforward as it first appears. Within the normal range of operation for sludge settling characteristics, increasing the return rate will remove the sludge mass from the clarifier faster. However, the return sludge ultimately contributes to the total hydraulic load to the clarifier and therefore to the total solids load on the clarifier from the aeration basin (see Figure 5-6).

Depending on the sludge settling characteristics, increased solids loading on the clarifier may or may not increase the solids mass in the clarifier in conjunction with the faster solids removal rate. Although the sludge detention time in the clarifier may go down, the sludge mass in the clarifier may go up. When the mass of sludge in the clarifier is increased along with the rate of sludge removal, the objective of maximizing the sludge distribution ratio is obviously not achieved. The positive aspect of a decreased detention time in the clarifier must be weighed against the negative aspect of a decreased sludge distribution ratio and a decreased sludge detention time in the aerator.

FIGURE 5-4

ACTIVATED SLUDGE MASS CONTROL USING MCRT

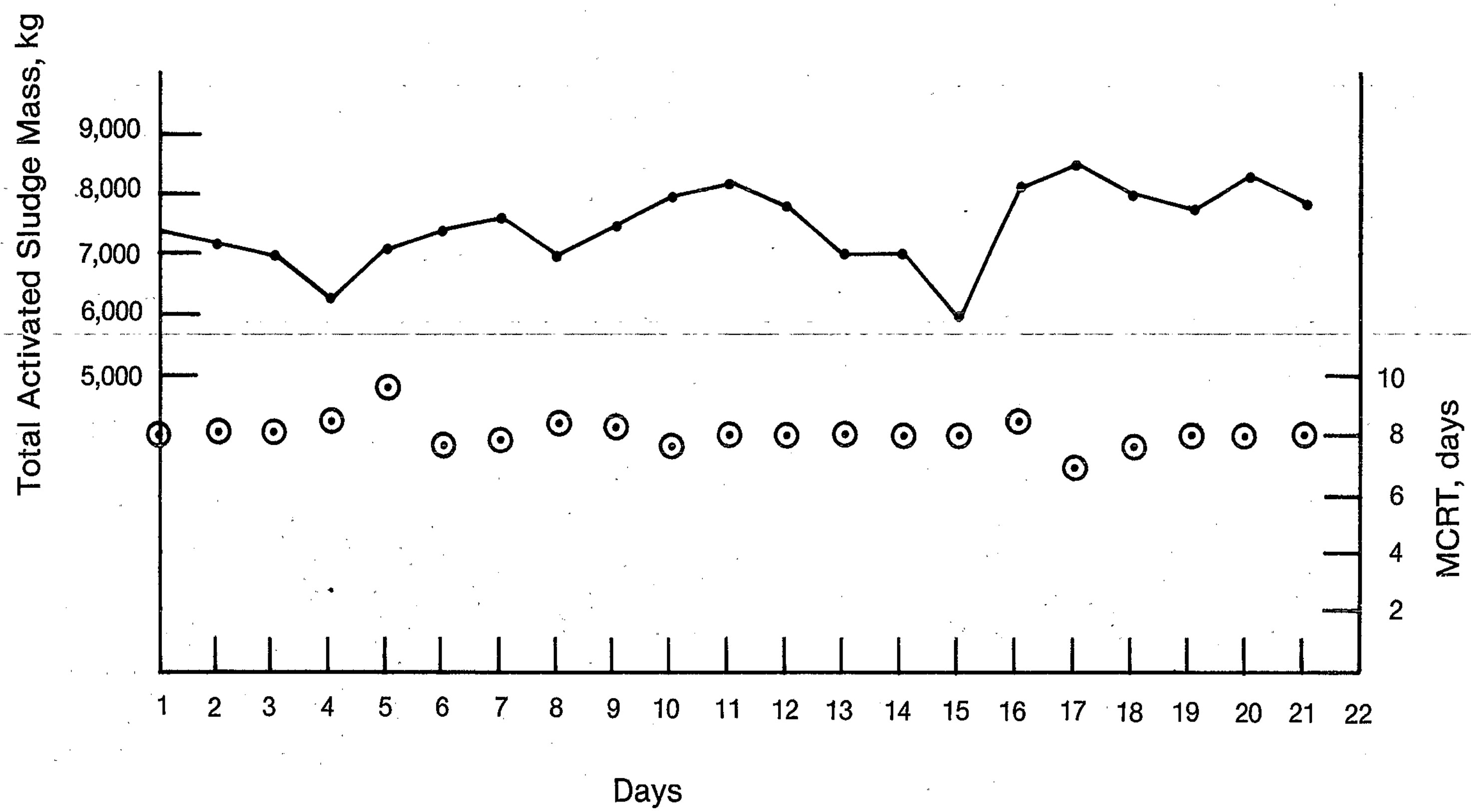


FIGURE 5-5

ACTIVATED SLUDGE MASS CONTROL USING TOTAL SLUDGE MASS

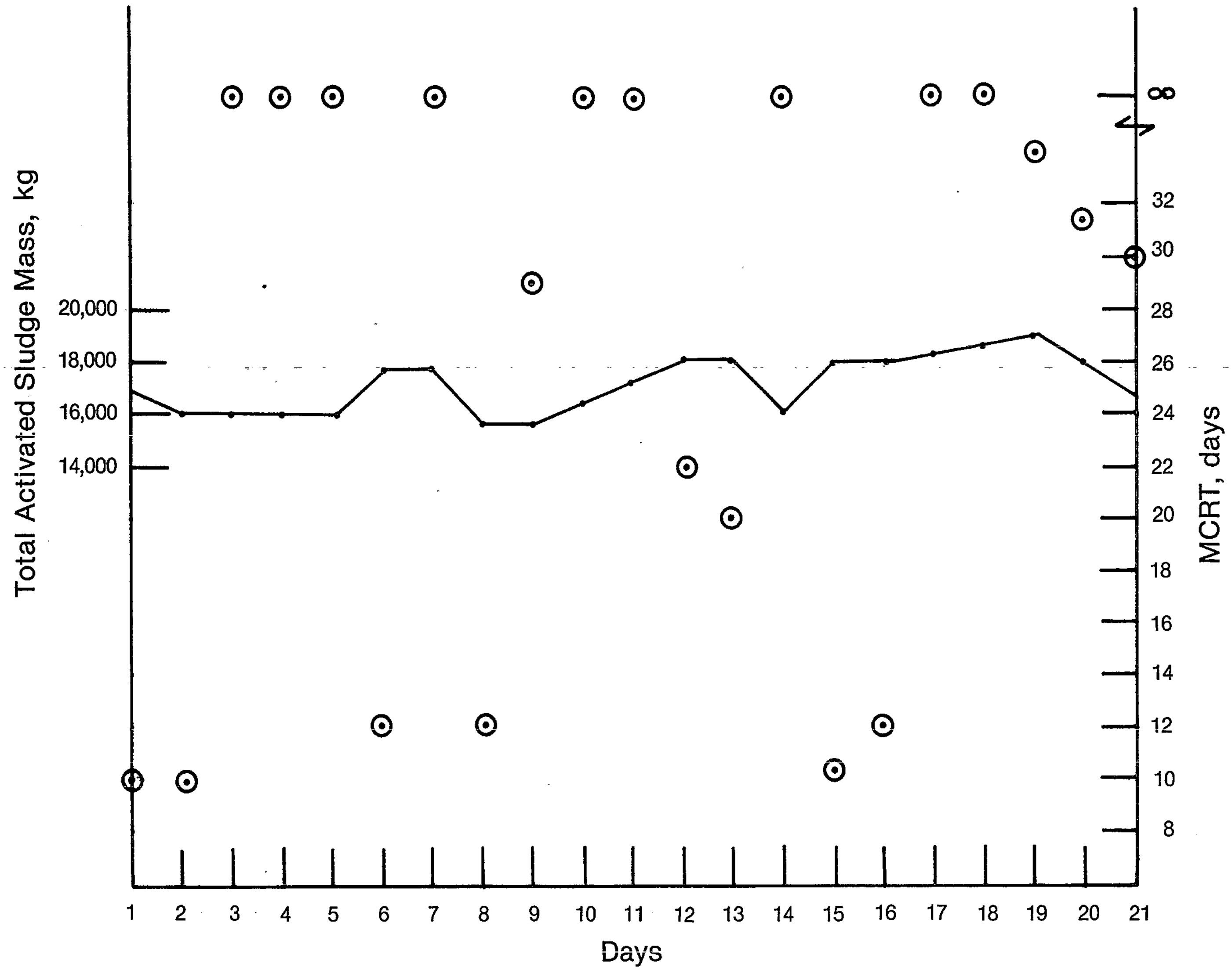
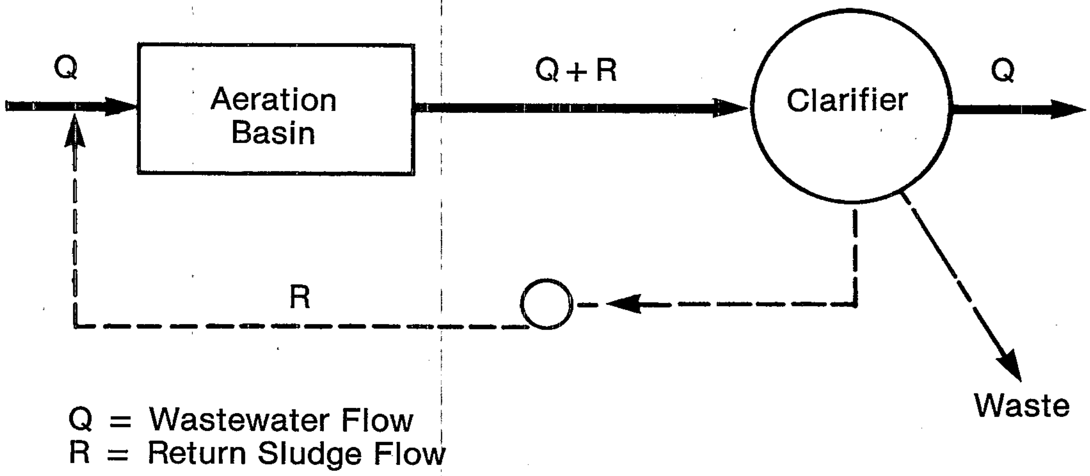


FIGURE 5-6

SIMPLIFIED ACTIVATED SLUDGE PROCESS DIAGRAM



Two levels of improved sludge return control are typically encountered when implementing a CCP: gross adjustments to bring the operation into normal operating ranges followed by fine tuning to optimize performance. Thus, a grossly out of line return rate should first be adjusted to fall in the middle of the appropriate range presented in Table 3-5.

Most activated sludge plants with flows less than 7,500 m^3/d (2.0 mgd) are designed conservatively enough that, at wastewater flows less than design, gross adjustments to bring the sludge return rate within normal ranges often provide sufficiently improved control. Furthermore, most plants that have been determined to be Type 1 (major unit processes are adequate) are conservatively enough loaded that such gross adjustments may be all that is necessary for current loadings. The applicability and results of gross sludge return adjustments are illustrated by the following discussion:

> An activated sludge plant was experiencing almost continuous problems with sludge bulking in the final clarifier. This continued despite repeated efforts by the plant superintendent to control the filamentous nature of the sludge. The superintendent had chlorinated and dumped the entire activated sludge mass to polishing ponds twice and was now considering adding clay as a settling aid.

Review of plant operation indicated that the return sludge flow rates were about 150 percent of the raw wastewater flow rate. After a discussion of the advantages of a lower return rate, the superintendent reduced the return sludge rate to about 50 percent of the raw wastewater flow. Solids loss from the clarifiers stopped in about 3 hours.

This gross return rate adjustment did not solve all of the plant problems, but it did significantly improve process control and performance. At the higher return rate, hydraulic loading to the final clarifier had been 2.5 times the raw wastewater flow. After the adjustment, the hydraulic loading was reduced to 1.5 times the raw wastewater flow. Although overflow rates were not affected, detention time in the clarifier for settling was increased by 67 percent and solids loading to the clarifier was reduced by 40 percent. This greatly enhanced the solids/liquid separation function of the clarifier.

Most Type 2 plants (major unit processes are marginal) or plants where gross return sludge flow adjustments do not produce the desired results will require a higher level of return sludge flow control, such as diurnal adjustments based on variations in wastewater flow and sludge character that occurs due to variations in POTW loadings over a 24-hour period.

Fine tuning return sludge flow rates is an area in which several differing philosophies exist within the technical community. A complete explanation of each is beyond the scope of this Handbook. The selection of a specific technique, and evaluation of the results, is best left to the skill and judgment of an experienced CCP facilitator.

5.7.1.4 Aeration Basin DO Control

Oxygen levels in an aeration basin can be used to promote or hinder the growth rates of filamentous organisms in the activated sludge process (8-11). DO control can therefore be used to promote the desired balance between filamentous and zoogleal microorganisms, control sludge character, and improve plant performance.

In most activated sludge plants, regardless of size, the greatest single use of energy is for aeration and mixing in the aeration basin. The desire to cut energy and associated costs while maintaining good performance makes the decision as to how much oxygen to use a critical one. Some guidelines and tests that have been used to aid in making this decision in other plants are presented below.

Oxygen supply in an aeration basin can be thought of as satisfying two needs: oxygen demand and residual DO. Typically, these are satisfied without differentiation, but an understanding of both may be helpful when evaluating oxygen needs. Oxygen demand is the mass of oxygen required to meet BOD and nitrification demand and maintain a viable microorganism population. The required residual DO is that mass of oxygen needed to provide the environment that produces good sludge character. The residual DO, which exists in an aeration basin when the oxygen demand is satisfied, varies with the type of process. Generally, the higher the organic loading rate on the activated sludge system, the higher the residual DO will be when the demand is met. A general guideline for residual bulk DO is shown in Figure 3-1. Higher oxygen rates are, in general, associated with activated sludge systems that have higher organic loadings.

Operating experience has shown that DO becomes a growth-limiting factor for zoogleal-type microorganisms before becoming a limiting factor for filamentous microorganisms. Do control at low levels in an aeration basin can therefore be used to apply pressure to shift sludge characteristics toward slower settling. Conversely, higher DO levels can be used to apply pressure for faster settling.

If a decision is made to lower DO by reducing aeration, proper tesing is essential as it is a necessity to recognize when too little oxygen is being transferred. Tests that will be most beneficial are residual DO measurements and oxygen uptake rate tests (12). Residual DO measurements should be taken initially at several locations throughout the aeration basin and verified periodically to determine a sample point that can be considered "average."

When determining residual DO, it is important to take measurements several times during the day to be coincident with diurnal flow variations, since residual DO demand typically varies with loadings. Where 24-hour operator coverage or in-basin DO meters with recorders are available, diurnal fluctuations should be obtainable as often as needed. In other plants, a few "special DO tests" in the middle of the night may be sufficient. The importance of getting DO readings for all major plant load conditions is that anoxic, or DO-deficient, conditions promote the growth of filamentous organisms leading to bulky sludge character.

In general, plants operating at low DO levels during peak loading may still provide good treatment if considerably higher DO residuals exist before the day's peak loading is received. For example, a plant may operate very successfully with a DO of 0.4-0.6 mg/l during the day if the morning DO is 1.0-1.5 mg/l. This daily fluctuation in DO levels can produce the desired mix of zoogleal and filamentous organisms.

The oxygen uptake test can also be used as a measure of adequacy of oxygen transfer (13). For example, if the oxygen uptake test indicates an oxygen demand significantly greater than 0.65 kg O_2/kg BOD_5 removed plus 0.1 kg O_2/kg total sludge in an activated sludge system, the test may be indicative of an inadequate oxygen supply. This analysis is illustrated by the following.

> An activated sludge facility was removing approximately 240 kg (530 lb) BOD_5/d with a total sludge mass in the aeration basin and secondary clarifier of about 2,000 kg (4,500 lb). The calculated oxygen demand is [(240 kg BOD_5/d) x (0.65 kg O_2/kg BOD_5)] + [(2,000 kg sludge) x (0.1 kg O_2/kg sludge/d)], or 356 kg (783 lb) O_2/d. However, the measured oxygen uptake in the 760 m^3 (200,000 gal) aeration basin was 30 mg/l/hr, or 550 kg (1,200 lb) O_2/d, or 150 percent of calculated

oxygen demand. This indicated that the realistic oxygen requirements are not being met with the current residual DO of 0.5-0.8 mg/l. Oxygen supply was increased, turbidity of the effluent dropped, and the oxygen demand measured by the oxygen uptake rate decreased to 110 percent of the calculated demand.

The above illustrates the use of a successful troubleshooting technique for identifying and correcting a DO deficiency. Like return sludge control, the capability to use DO control to fine tune activated sludge processes is a function of the experience and technical judgment of the CCP facilitator.

5.7.1.5 Process Control Pressure

As discussed in Section 5.7.1.1, overall activated sludge plant treatment performance is primarily a function of the sludge character. Process control tests and adjustments should be made with the purpose of achieving changes in the direction of desirable sludge character. The specific process controls discussed earlier (sludge mass, sludge returns, and aeration basin DO) are used to apply a "pressure" to change sludge character by changing the environment for the sludge mass.

When a change in sludge character is desired, a combination of operational adjustments may be necessary to provide enough pressure to achieve that desired range. For example, if sludge settling has slowed to an undesirable level and a wet weather season (which will cause higher average and peak clarifier hydraulic loadings) is approaching, it would be advantageous to expedite efforts to increase the settling rate. Simultaneous adjustments of several process control parameters could provide more pressure in the desired direction than making a change in only one control. In general, a raise in the sludge inventory, a raise in aeration basin DO, and more frequent return rate adjustments to minimize sludge mass and sludge detention time in the clarifier would all be appropriate to achieve faster settling and better clarifier performance in a minimal time under the higher hydraulic loading conditions.

5.7.1.6 Time for Biological System Response

When adjusting process control at activated sludge plants, it is important to realize that changes in sludge character develop slowly and time must be allowed for the biological system to respond to the pressures applied. Adjustments may change the environment of the activated sludge very quickly, but a considerably longer period of time may be required before sludge character changes to reflect the new environment. For example, if low DO in a diffused air aeration basin is believed to be a cause of slow-settling sludge, it would be appropriate to increase the oxygen transfer by increasing blower output. Two changes should be monitored, one immediate and one long-term. Mixed liquor DO measurements a few hours after the change as well as the next day should indicate whether the increased blower output selected was sufficient to change the environment (DO level) in the aeration basin, but it may take several weeks of sludge settling tests to determine if that new environment applied enough pressure to cause the sludge to settle more rapidly.

There is a tendency to return to status quo if a desired result is not achieved quickly. In the above example, a person using a trial and error approach may decide after 3 days of higher DO that additional aeration was the wrong adjustment and a waste of energy. However, a person directing a CCP must have enough experience and confidence to hold the changed environmental conditions long enough to produce the desired result. If the desired change in sludge character has not started to take place in a length of time equal to two or three MCRTs, additional pressure should be applied. As a general reference, a time equal to three to five MCRTs may be necessary to produce changes in sludge character due to process control adjustments.

An appreciation for the time required for a biological system to respond to new pressures should be a major training objective of the CCP effort to improve process control. Graphing monitoring results to produce trend charts can enhance this appreciation.

5.7.1.7 Activated Sludge Testing

Activated sludge plant monitoring for effective process control must include sludge character, sludge mass, return sludge, and DO. Several references are available for selecting tests and their frequency for activated sludge plants (9)(14)(15).

The tests and schedule shown in Table 5-2, developed for a 190 m^3/d (50,000 gpd) plant operating under highly variable conditions due to drastic climate changes and wide seasonal population fluctuations, are applicable to many small activated sludge plants. The concept of providing two different frequency schedules is a compromise between the desirable higher frequencies and the minimum operator time typically allocated to this function in small facilities. Under normal operating conditions, with little stress on the processes, the "routine" frequency is adequate. When the system is under stress, the "critical" frequency is appropriate. This occurs during transitions to higher loadings, during peak seasonal populations, and can occur unpredictably if bulky sludge character develops or equipment fails.

Even in small activated sludge plants a concentrated process control effort based on reliable testing and understanding of process fundamentals is necessary, as illustrated by the process control testing schedule and recording sheet developed for a 950 m^3/d (0.25 mgd) contact stabilization plant and shown in Figure 5-7. (Note: When the CCP was initiated, monitoring of aeration basin DO was not included because the testing capability was not available at the time.)

TABLE 5-2

PROCESS CONTROL MONITORING AT A SMALL ACTIVATED SLUDGE PLANT

Test, Parameter, or Evaluation	Frequency Routine	Frequency Critical*
Flow Equalization:		
Water Level	Daily	2/day
Pump Setting vs. Daily Flow, DO	3/week	Daily
Activated Sludge:		
Control Tests Centrifuge Spins (Aeration Tank Conc./ Return Sludge Conc./Clarifier Core Sample Conc.), Settleometer Test, Depth to Blanket, Aeration Basin DO	3/week	Daily
Control Calculations Total Sludge Mass, Aerator Sludge Mass, Clarifier Sludge Mass, Return Sludge Percentage, Sludge Distribution Ratio, Clarifier Solids Loading, MCRT	3/week	Daily
Control Plots Graph 1: Settling Results, Return Sludge Conc., MCRT, DO, Aerator Conc. Graph 2: Total Sludge Mass (Aerator and Clarifier), Wasted Sludge Mass	3/week	Daily
Wasting Volume, Concentration, Mass	3/week	Daily
Digester:		
DO, Concentration, Temperature, pH	Weekly	2/week
Waste Activated Sludge, Digested Sludge Volatile Solids Percentage, Volatile Solids Reduction	Monthly	2/month
Chlorine Residual:	5/week	Daily

*"Critical" refers to periods of transition to higher loadings and during peak loadings and periods of stressed operation, i.e., bulky sludge, process out of service, or major change in process control.

FIGURE 5-7

PROCESS CONTROL TESTING AT A 950 m^3/d
CONTACT STABILIZATION POTW*

Week of ____________ through ____________

MO/DAY/YR						
DAY OF WEEK						
CENTRIFUGE TEST		1% = ________ mg/l				Weekly Average
CTC						
RTC						
RSC						
DC						
DSU						
SLUDGE BLANKET TEST						
DTB						
RSFP						
SLUDGE INVENTORY						
CTSU						
RTSU						
CSU						
TSU						

SLUDGE SETTLING TEST	$\frac{SSV}{1000}$	SSC	$\frac{SSV}{1000}$	SSC	$\frac{SSV}{1000}$	SSC	$\frac{SSV}{1000}$	SSC	$\frac{SSV}{1000}$	SSC	$\frac{SSV}{1000}$	SSC
0 min												
5 min												
30 min												
60 min												

SLUDGE WASTING						Weekly Total
centimeters						
cubic meters						
WSC						
WSU						
SLUDGE HAULING						
loads						
cubic meters						
SC						
SU						

WEEKLY CALCULATIONS

Avg. Waste = Total WSU ÷ 7 = ________

Sludge Age = Avg. TSU ÷ Avg. Waste =
________ ÷ ________ = ________

Avg. Flow ________ m^3/d

	INFLUENT	EFFLUENT
BOD_5		
TSS		

*Acronyms for test parameters are defined on the following page.

FIGURE 5-7 (continued)

ACRONYMS FOR TEST PARAMETERS

CTC	Contact Tank Concentration
RTC	Reaeration Tank Concentration
RSC	Return Sludge Concentration
DC	Digester Sludge Concentration
DSU	Digester Sludge Units (mass of sludge)
DTB	Depth to (Sludge) Blanket (in final clarifier)
RSFP	Return Sludge Flow Percentage (of wastewater flow)
CTSU	Contact Tank Sludge Units (mass of sludge)
RTSU	Reaeration Tank Sludge Units (mass of sludge)
CSU	Clarifier Sludge Units (mass of sludge)
TSU	Total Sludge Units (mass of sludge in contact tank, reaeration tank, and clarifier)
SSV	Settled Sludge Volume (volume of settled sludge in a settleometer jar after the indicated number of minutes)
SSC	Settled Sludge Concentration (calculated concentration of sludge in the settled sludge volume in the settleometer jar after the indicated number of minutes)
WSC	Waste Sludge Concentration
WSU	Waste Sludge Units (mass of sludge wasted)
SC	Sludge Concentration
SU	Sludge Units (mass of digested sludge hauled out)

Larger activated sludge POTWs require that the same parameters be monitored, but these plants are often designed less conservatively and therefore require more frequent monitoring and process adjustments. For example, at a 21,000 m^3/d (5.5 mgd) activated sludge plant, settling and mass control tests were conducted once per 8-hour shift, 7 days per week. At the contact stabilization plant mentioned above, sludge settling and mass control tests were conducted only once per day, 5 days per week.

To improve process control, all activated sludge plants should include monitoring for at least the following:

- Sludge settling
- Total sludge mass control
- Sludge wasting
- Return sludge concentration and flow control
- Aeration basin DO control

Appendix I contains an example process control daily data sheet that has proven to be useful in monitoring activated sludge POTWs. However, the specific tests and sampling frequency must be selected for each individual POTW.

5.7.2 Fixed Film Process Control

The performance of fixed film (trickling filter and RBC) POTWs is not as critically affected by process control adjustments as suspended growth facilities (1)(3). There are only a limited number of process controls in fixed film systems that can be optimized by a CCP, and the resulting improvement in effluent quality is accordingly less. Two areas of fixed film process control that can be optimized are return process stream loadings and clarifier performance.

5.7.2.1 Reducing Return Process Stream Loadings

The CCP facilitator should strive to reduce the organic loading returned through the plant from anaerobic digestion and from sludge dewatering operations. Disposal of all digester supernatant with the digested sludge can significantly reduce plant organic loadings. This has been implemented most frequently in smaller POTWs where sludge disposal is by liquid haul to nearby farmland. Another way to achieve organic load reduction is by filtering the digester supernatant through a drying bed.

When dewatering digester sludge with a belt press, vacuum filter, or centrifuge, chemical dosages are often optimized to lower costs. If a low, or relatively low, solids capture is being accomplished, increased chemical usage to increase capture and reduce return flow through the plant should be considered.

Since land disposal of anaerobic digester supernatant or increased chemical usage to improve dewatering capture can result in significantly higher operating costs, a short-term (e.g., one month) trial period should be conducted before advocating a permanent change in these controls.

5.7.2.2 Optimizing Clarifier Operation

Optimizing primary clarifier process control will decrease organic loading on subsequent fixed film processes. Optimizing secondary clarifier process control will improve overall organic removal for any fixed film system. Organic removals in both primary and secondary clarifiers can be optimized by minimizing overflow rates and controlling sludge quantities in the clarifiers.

Overflow rates can be minimized by eliminating any unnecessary flow through the clarifiers. The most common situation that can be addressed by process control occurs when trickling filter recycle also goes through either the primary or secondary clarifier. At normal organic loadings associated with domestic secondary treatment facilities, recirculation does not provide significantly improved organic removals in fixed film processes (16). This is especially true if the recirculation results in increased clarifier overflow rates. If recirculation does in fact increase soluble BOD removal in the fixed film process and the existing recirculation flow pattern is through the primary or secondary clarifier, a facility modification to provide recirculation only through the fixed film process may be justified (see Section 5.4).

Keeping sludge blankets and sludge detention times low in both primary and secondary clarifiers also tends to optimize organic removals. This can often be accomplished by increasing sludge pumping, but must not be carried to the extreme that removed sludge is so thin that it adversely affects sludge treatment processes. Experience and judgment of the CCP facilitator must be used to achieve the best compromise.

5.7.2.3 Fixed Film Testing

Process control monitoring for fixed film facilities is generally simpler than for suspended growth systems. It is normally comprised of process loading and performance monitoring. The performance of the primary clarifier, fixed film reactor, and final clarifier should be monitored on a routine basis. Fixed film reactor performance can best be monitored by measuring soluble BOD_5 removals. The soluble BOD test more directly addresses the primary function of the biological reactor, to convert dissolved and colloidal organics to microorganism solids. Measuring soluble BOD_5 across the fixed film reactor monitors this conversion process.

An example process control summary sheet developed for a 7,500 m^3/d (2.0 mgd) RBC POTW during a CCP is presented in Appendix J.

5.7.3 ABF Process Control

The ABF design contains elements of both suspended growth and fixed film facilities as does ABF process control. Sludge character (settling rates, compaction capability, appearance, etc.) is more like that of fixed film sludge in that wide fluctuations are not common and are not as dependent on process control adjustments. Consequently, overall sludge return rates and diurnal adjustments are not as critical in the ABF system as in activated sludge. The same is true for aeration basin DO. DO must be provided to meet the demand in an ABF system without special consideration for the residual DO and its effect on sludge character (17). A DO residual of 2-3 mg/l is usually sufficient.

The process control in an ABF system that is similar to an activated sludge system and slightly more susceptible to problems is suspended growth sludge mass control. Mass control is very critical in an ABF system because a large fraction of the mass, usually one-quarter to one-half, is wasted daily. Any error in wasting has a significant effect because the MCRT is usually only 2-4 days.

Process control parameters monitored in two ABF POTWs are presented in Appendix K.

5.8 Example CCP

An example CCP is difficult to present because many of the performance-limiting factors are addressed through training, interpersonnel relationships, weekly data review, phone consultations, and other activities conducted over a long period of time. These activities do not lend themselves readily to an abbreviated discussion (18). As such, an overview of a CCP is presented based on the example CPE presented in Section 3.9.

5.8.1 Addressing Performance-Limiting Factors

The most serious performance-limiting factors identified in the CPE were process control oriented. The major emphasis, therefore, of the initial portion of the CCP was directed at improving plant operations (process control).

1. Operation (Process Control)

- Process control testing to monitor sludge settling, sludge mass, sludge wasting, sludge return concentration and flow, and aeration basin DO was initiated using the guidelines in Table 5-2.

- A process control summary was developed and process control calculations were implemented as shown in Appendix I.

- Trend graphs were initiated to monitor activated sludge mass inventory and wasting, and activated sludge character and return concentrations.

- On-the-job training was provided in the areas of biological treatment fundamentals and specific process control tasks and monitoring requirements (see Section 5.7)

- Effluent TSS was monitored closely to detect excess sludge losses and provide justification for adequate sludge disposal capability.

Results of the improved process control activities led to the following sequence of events:

- Operational tests showed that actual sludge production averaged 0.81 kg TSS produced/kg BOD_5 removed. It was estimated that the amount of sludge produced that was discharged as effluent SS would decrease from 40 percent to 10 percent if adequate sludge disposal facilities were available and used properly. New sludge wasting requirements were 0.73 kg TSS/kg BOD_5 removed. This actual value was higher than the projected sludge production of 0.65 kg TSS/kg BOD_5 removed used in the CPE example, further aggravating the capacity limitation of the anaerobic digester.

- POTW administrators were presented with the sludge production values and existing plant capabilities by using the following explanation: "Your POTW treats about 350 million gallons of wastewater a year which results in about 5.5 million gallons of sludge. This sludge must be disposed of properly. The existing aerobic digester is too small to handle the total sludge produced. This one deficiency negates a significant portion of the pollution control already accomplished in the rest of the plant. If you want to bring your plant into compliance and obtain full benefit from the rest of the plant, additional acceptable sludge handling capacity will have to be provided."

- After considering various options, including construction, it was decided to utilize a contract hauler to dispose of liquid sludge in a nearby large POTW at a charge of $15.85/m^3 ($0.06/gal).

- The first month of contract hauling resulted in a supplemental sludge disposal cost of $4,500 and all involved believed a significant effort to reduce this cost was justified. An effort was made to increase the concentration of the sludge fed to the digester by thickening the sludge in an old clarifier available on the plant site. Polymer was used to aid in the sludge thickening. After several trial tests, a polymer was found that significantly improved waste sludge concentrations from the "thickening tank." The concentration fed to the digester was increased about 250 percent by adding 20-25 lb polymer/ton sludge solids. The net effect was to decrease supplemental sludge disposal cost by 56 percent from the $4,500/month initially incurred.

2. Design

- Minor piping changes and a polymer feed system had to be provided to use the available tankage at the plant as a "thickener." Major design changes, such as enlarging the aerobic digester, were avoided as a result of the CCP efforts.

3. Maintenance

- Suggested preventive maintenance forms (similar to those in Appendix G) were provided the plant superintendent during the CCP. However, the lack of a documented preventive maintenance program had not been a significant performance-limiting problem before the CCP was implemented and did not become significant during the CCP. Consequently, emphasis was placed on factors more directly related to performance.

4. Administration

- Administrators' familiarity with plant needs and their ability to make appropriate decisions regarding the plant was increased during the CCP by explaining process fundamentals at the plant, providing oral status reports, and involving them in correction of the sludge capacity deficiency.

5.8.2 Plant Performance

Plant performance was improved dramatically by implementation of the CCP. The results are summarized below:

	Effluent BOD_5 mg/l	Effluent TSS mg/l
Before CCP		
Reported	14	15
Estimated Actual	44	75
After CCP		
Actual	14	17

The reported values prior to the CCP were collected only during periods when the clarifiers were not bulking sludge. The estimated actual effluent quality was projected by comparing sludge wasted prior to the CCP with sludge wasted after the CCP was initiated. The difference in these values was projected to have been consistently lost from the system in the plant effluent during periods of bulking sludge. Actual results are based on proper testing and represent a true picture of plant performance after the CCP was initiated.

5.8.3 CCP Costs

The costs for the example CPE and CCP described in Sections 3.9 and 5.8 are summarized below:

CPE Consultant	$ 3,500 (one-time)
CCP Consultant	12,000 (one-time)
Test Equipment	700 (one-time)
Polymer Addition Equipment	550 (one-time)
Sludge Disposal	26,500 (annual)
Polymer	2,500 (annual)
Total	$45,750 (first year)
	$29,000 (ongoing annual costs)

5.8.4 Summary

This example illustrates several important points of the CCP approach and includes several problems and associated solutions that occur frequently during CCP implementation. These are:

- The primary objective of a CCP is attaining adequate performance. The second is minimizing costs within the framework of adequate treatment.

- Some potential performance-limiting factors identified during a CPE are later found to be incorrect or less significant when actually eliminating problems with a CCP. This was true of the digester design limitations in this plant.

- The degree of administrative support is sometimes difficult to assess during a CPE but often becomes a major concern during a CCP. This was true when the administrators were faced with supporting dramatically increased sludge handling costs in the example CCP.

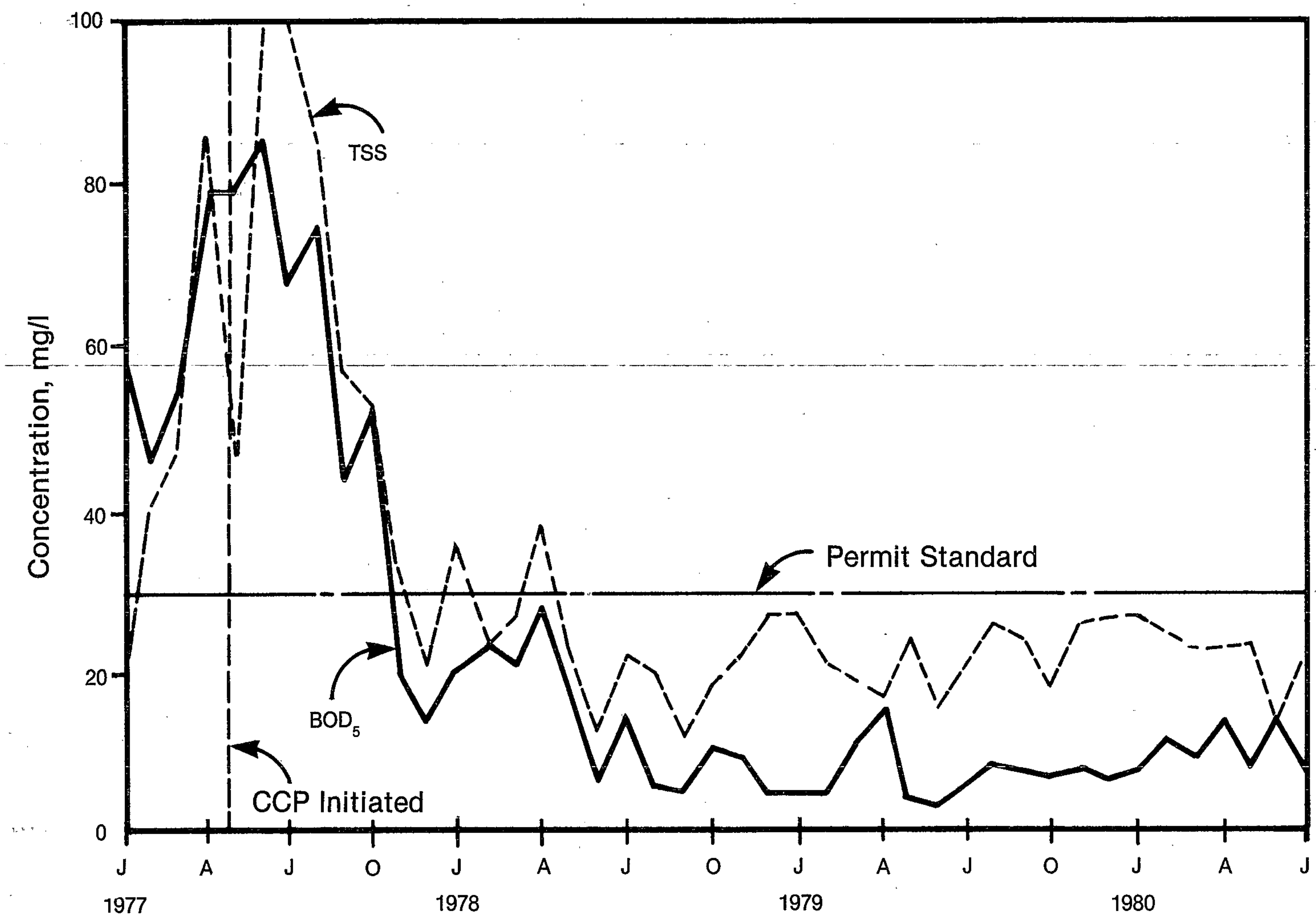
- A Type 2 POTW was brought into compliance <u>without</u> a major plant upgrade.

5.9 CCP Results

The success of conducting CCP activities can often be measured by a variety of parameters, such as improved operator capability, cost savings, improved maintenance, etc. However, the true success of a CCP should be documented improved performance to the degree that the plant has achieved compliance. Given this measure, the results of a successful CCP effort should be easily depicted in graphical form. Results from an actual CCP are presented in Figure 5-8. It is desirable to present CCP results in this format.

FIGURE 5-8

GRAPHICAL PRESENTATION OF IMPROVED PERFORMANCE FROM A SUCCESSFUL CCP



5.10 References

When an NTIS number is cited in a reference, that reference is available from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650

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APPENDIX A

CPE CLASSIFICATION SYSTEM, CHECKLIST, AND GUIDELINES FOR PERFORMANCE-LIMITING FACTORS

CLASSIFICATION SYSTEM FOR PRIORITIZING PERFORMANCE-LIMITING FACTORS

Rating	Adverse Effect of Factor on Plant Performance
A	Major effect on a long-term repetitive basis
B	Minimum effect on a routine basis or major effect on a periodic basis
C	Minor effect

CHECKLIST OF PERFORMANCE-LIMITING FACTORS

Factor	Rating	Comments
A. ADMINISTRATION		
1. Plant Administrators		
a. Policies		
b. Familiarity with Plant Needs		
2. Plant Staff		
a. Manpower		
1) Number		
2) Plant Coverage		
b. Morale		
1) Motivation		
2) Pay		
3) Supervision		
4) Working Conditions		
c. Productivity		
d. Personnel Turnover		
3. Financial		
a. Insufficient Funding		
b. Unnecessary Expenditures		
c. Bond Indebtedness		
B. MAINTENANCE		
1. General		
a. Housekeeping		
b. Equipment Age		

CHECKLIST OF PERFORMANCE-LIMITING FACTORS (continued)

Factor	Rating	Comments
c. Scheduling & Recording		
d. Manpower		
2. Preventive		
a. Lack of Program		
b. References Available		
c. Spare Parts Inventory		
d. Workload Distribution		
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		

CHECKLIST OF PERFORMANCE-LIMITING FACTORS (continued)

Factor	Rating	Comments
1) Process Flexibility		
2) Process Controllability		
3) "Aerator"		
4) Clarifier		
d. Advanced Waste Treatment		
1)		
2)		
3)		
4)		
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		

CHECKLIST OF PERFORMANCE-LIMITING FACTORS (continued)

Factor	Rating	Comments
1) Monitoring		
2) Control		
h. Lack of Standby Units for Key Equipment		
i. Laboratory Space and Equipment		
j. Process Accessibility for Sampling		
k. Equipment Accessibility for Maintenance		
l. Plant Inoperability Due To Weather		
m.		
n.		
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		

CHECKLIST OF PERFORMANCE-LIMITING FACTORS (continued)

Factor	Rating	Comments
a. Operator Application of Concepts and Testing to Process Control		
b. Technical Guidance		
4. O&M Manual		
a. Adequacy		
b. Use by Operators		
5. Miscellaneous		
a. Equipment Malfunction		
b. Shift Staffing Adequacy (Operations)		
c.		
d.		
e.		
f.		
g.		
h.		
i.		

GUIDELINES FOR INTERPRETING PERFORMANCE-LIMITING FACTORS

Category	Explanation
A. ADMINISTRATION	
1. Plant Administrators	
a. Policies	Do the appropriate staff members have the authority to make required decisions regarding operation (e.g., adjust valve), 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" (which has caused critical decisions to be delayed and in turn has affected plant performance and reliability)? Does any 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.? If not, has this been a cause of poor plant performance and reliability through poor budget decisions, poor staff morale, poor operation and maintenance procedures, poor design decisions, etc.?
2. Plant Staff	
a. Manpower	
1) Number	Does a limited number of people employed have a detrimental effect on plant operations (e.g., not getting the necessary work done)?
2) Plant Coverage	Does the time period of plant operation cause unnecessary operational adjustments to be made or inefficient use of the number of people on the staff (e.g., operators getting in each other's way)?

b. Morale	
1) Motivation	Does the plant staff want to do a good job because they are motivated by self-satisfaction?
2) Pay	Does a low payscale discourage more highly qualified persons from applying for operator positions or cause operators to leave after they are trained?
3) Supervision	Does the working relationship of the plant superintendent and operator or supervisor and operator cause adverse operator incentive?
4) Working Conditions	Does a poor working environment create a condition for more "sloppy work habits" and lower operator morale?
c. Productivity	Does the plant staff conduct the daily operation and maintenance tasks in an efficient manner? Is time used efficiently?
d. Personnel Turnover	Does a high personnel turnover rate cause operation and/or maintenance problems that affect process performance or reliability?
3. Financial	
a. Insufficient Funding	Does the lack of available funds cause poor salary schedules, insufficient stock of spare parts that results in delays in 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.? Are funds spent on lower priority items while needed, higher priority items are unfunded?
c. Bond Indebtedness	Does the annual bond debt payment limit the amount of funds available for other needed items such as equipment, staff, etc.?

B. MAINTENANCE

1. General

a. Housekeeping	Does a lack of good housekeeping procedures (e.g., grit channel cleaning; bar screen cleaning; unkempt, untidy, or cluttered working environment) cause an excessive equipment failure rate?
b. Equipment Age	Does the age or outdatedness of critical pieces of equipment cause excessive equipment downtime and/or inefficient process performance and reliability (due to unavailability of replacement parts)?
c. Scheduling and Recording	Does the absence or lack of an effective maintenance scheduling and recording procedure create a condition for an erratic preventive maintenance program that results in unnecessary equipment failure?
d. Manpower	Does the lack of adequate maintenance manpower result in preventive maintenance functions (to prevent equipment breakdown) not being completed or in emergency equipment repairs being delayed?

2. Preventive

a. Lack of Program	Does the absence or lack of an effective maintenance program cause unnecessary equipment failures or excessive downtime that results in plant performance or reliability?
b. References Available	Does the absence or lack of good equipment reference sources cause unnecessary equipment failure and/or downtime for repairs (includes maintenance portion of O&M manual)?
c. Spare Parts Inventory	Does a critically low or nonexistent spare parts inventory cause unnecessary long delays in equipment repairs that result in degraded process performance?
d. Workload Distribution	Does uneven distribution of preventive maintenance tasks cause neglect of other important duties at certain times of the month or year?

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 — Do delays in getting replacement parts cause extended periods of equipment downtime?

c. Technical Guidance — If technical guidance for repairing or installing equipment is necessary to decrease equipment downtime, is it available and retained?

C. DESIGN

1. Plant Loading — Does 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, cause degraded process performance by one or more of the loadings (a-e) listed below?

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 Streams — Does excessive volume and/or a highly organic or toxic return process flow stream cause adverse effects on process performance, equipment problems, etc.?

2. Unit Design Adequacy

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

b. Primary	Does the shape or location of the unit contribute 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	
1) Process Flexibility	Does the unavailability of adequate valves, piping, etc., limit plant performance and reliability when other modes of operation of the <u>existing plant</u> can 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)?
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" (aeration basin, trickling filter, RBC, etc.) hinder its ability to adequately treat the sewage and provide for stable operation? Is oxygen transfer capacity inadequate?
4) Clarifier	Does a deficient design cause poor sedimentation due to the size, type, or depth of the clarifier; placement or length of the weirs; or other miscellaneous problems?
d. Advanced Waste Treatment	Advanced waste treatment is any process of wastewater treatment that upgrades water quality to meet specific effluent limits that cannot be met by conventional primary and secondary treatment processes (i.e., nitrification towers, chemical treatment, multimedia filters). (Space is available in the Checklist to accommodate advanced processes encountered during the CPE.)

e. Disinfection	Does the shape or location of the unit contribute to its accomplishing disinfection of the wastewater (i.e., proper mixing, detention time, feed rates, feeding rates proportional to flow, etc.)?
f. Sludge Wasting Capability	Does the plant have sludge wasting facilities? If so, can desired volume of sludge be wasted? Can sludge wasting be adequately controlled? Can sludge wasted be sampled without extreme difficulty?
g. Sludge Treatment	Does the type or size of the sludge treatment process hinder sludge stabilization (once sludge has been removed from the wastewater treatment system), thereby causing process operation problems (e.g., odors, limited sludge wasting, etc.)?
h. Ultimate Sludge Disposal	Is the ultimate sludge disposal program, including facilities and disposal area, of sufficient size and type to adequately handle the sludge production from the plant? Are there any specific areas that limit ultimate sludge disposal such as seasonal weather variations or crop harvesting?
3. Miscellaneous	The design "miscellaneous" category covers areas of design inadequacy not specified in the previous design categories. (Space is available in the Checklist 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 a unit bypass 1) cause plant upset and long-term poor treatment when a short-term bypass could have minimized pollutional load to the receiving waters; 2) cause necessary preventive or emergency maintenance items to be cancelled or delayed; or 3) cause 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

Does inadequate flow proportioning or flow splitting to duplicate units cause problems or partial unit overloads that degrade effluent quality or hinder achievement of optimum process performance?

e. Alarm Systems

Does the absence or inadequacy of a good alarm system for critical pieces of equipment cause unnecessary equipment failure or in any way cause degraded process performance?

f. Alternate Power Source

Does the absence of an alternate power source cause problems in plant operation leading to degraded plant performance?

g. Process Automation

1) Monitoring

Does the lack of needed automatic monitoring devices (DO meter, pH meter, etc.) cause excessive operator time to watch for slug loads or process upset to occur because of slug loads? Does the breakdown or improper workings of automated process monitoring features cause disruption of automated control features and subsequent degradation of process performance?

2) Control — Does the lack of a needed automatic control device (time clock, flow activated controls, etc.) cause excessive operator time to make process control changes or necessary changes to be cancelled or delayed? Does the breakdown or the improper workings of automatic control features cause degradation of process performance?

h. Lack of Standby Units for Key Equipment — Does the lack of standby units for key equipment cause 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 limit plant performance by the lack of operational testing and performance monitoring?

j. Process Accessibility for Sampling — Does the inaccessibility of various process flow streams (e.g., recycle streams) for sampling prevent needed information from being obtained?

k. Equipment Accessibility for Maintenance — Does the inaccessibility of various pieces of equipment cause extensive downtime 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 temperatures) and, as such, do not operate at all or do not operate as efficiently as necessary to achieve the required performance?

D. OPERATION

1. Staff Qualifications

a. Ability

1) Aptitude — Does the lack of capacity for learning or understanding new ideas by critical staff members cause poor O&M decisions leading to poor plant performance or reliability?

2) Level of Education

Does a low level of education cause poor O&M decisions? Does a high level of education or 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 operator's inattendance at available training programs cause poor process control decisions?

c. Sewage Treatment Understanding

Is the operator's lack of understanding of sewage treatment, in general, a factor in poor operational decisions and poor plant performance or reliability?

d. Insufficient Time on Job (Green Crew)

Does the short time on the job cause improper process control adjustments to be made (e.g., 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 and are they truly representative of plant performance?

b. Process Control Testing

Does the absence or wrong type of process control testing cause improper operational control decisions to be made?

3. Process Control Adjustments

a. Operator Application of Concepts and Testing to Process Control

Is the operator deficient in the application of his/her knowledge of sewage treatment and interpretation of process control testing to process control adjustments?

b. Technical Guidance	Does false operational information received from a technical consultant cause improper operational decisions to be continued? Does a technical person (e.g., design engineer, equipment representative, State trainer or inspector) fail to address obvious operational deficiencies while being in a position to correct the problem?
4. O&M Manual	
a. Adequacy	Does a poor O&M manual used by the operator result in poor or improper operational decisions?
b. Use by the Operator	Does a good O&M manual not used by the operator cause poor process control and poor treatment that could have been avoided?
5. Miscellaneous	The operation "miscellaneous" category deals with any pertinent operational information not covered in the previous operational sections. (Space is available in the Checklist to accommodate additional items not listed.)
a. Equipment Malfunction	Does malfunctioning equipment cause deteriorated process performance?
b. Shift Staffing Adequacy (Operations)	Does the improper distribution of adequate manpower prevent process controls from being made or made at inappropriate times, resulting in poor plant performance?

APPENDIX B

CPE SUMMARY SHEET FOR RANKING PERFORMANCE-LIMITING FACTORS

CPE SUMMARY SHEET FOR RANKING PERFORMANCE-LIMITING FACTORS

Plant Name/Location ______________________________

CPE Performed by ______________________ Date ______________

Plant Type:
Design Flow:
Actual Flow:
Year Plant Built:
Year of Most Recent Upgrade:
Plant Performance Summary:

RANKING TABLE

Ranking	Performance-Limiting Factors
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

CPE SUMMARY SHEET TERMS

PLANT TYPE	Brief but specific description of type of plant (e.g., two-stage trickling filter with anaerobic digester 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	Wastewater flow rate for current operating condition (e.g., for past year). Also, significant seasonal variation in flows should be noted.
YEAR PLANT BUILT	Year initial units were put into operation.
YEAR OF MOST RECENT UPGRADE	Year last additional major units were put into operation (e.g., digester, chlorine contact chamber, etc.).
PLANT PERFORMANCE SUMMARY	Brief description of plant performance as related to present and anticipated treatment requirements.
RANKING TABLE	In descending order, a list of the major causes of decreased plant performance and reliability.
RANKING	Causes of decreased plant performance and reliability, with the most critical ones listed first.
PERFORMANCE-LIMITING FACTORS	Categories listed in the Checklist (Appendix A).

APPENDIX C

EXAMPLE CPE REPORT

RESULTS OF A CPE AT THE SPRINGFIELD, KS, POTW

FACILITY BACKGROUND

The Springfield POTW is a rotating biological contactor (RBC) type of treatment plant designed for an average daily wastewater flow of 7,600 m^3/d (2.0 mgd). The plant was originally completed as a primary treatment plant in 1965 and upgraded for secondary treatment in 1980. The plant serves the City of Springfield with an estimated population of 9,000. A railcar washing operation is thought to be the source of the only significant industrial waste, but sampling has not confirmed this.

Plant records indicated that wastewater flows had been averaging close to design flow; however, flow calibration during the CPE indicated that flow was actually about 4,500 m^3/d (1.2 mgd), or only 60 percent of design flow. Current organic loading was estimated to also be about 60 percent of design.

The Springfield plant consists of the following unit processes:

- Vortex grit chamber
- Mechanical bar screen
- 23-cm (9-in) Parshall flume
- Lift station
- One 18-m (60-ft) diameter primary clarifier
- Four-stage RBCs (12 shafts)
- Two 6 x 33 m (20 x 110 ft) secondary clarifiers
- Two-cell chlorine contact chamber
- Two 11-m (35-ft) diameter anaerobic digesters (Note: During the CPE, the second-stage digester was not in service.)
- 2,800 m^2 (30,000 sq ft) drying beds

The Springfield plant is required to meet standard secondary treatment effluent requirements with 20,000/40,000 fecal coliform limits. NPDES monitoring data indicate performance of the plant has generally been within standards, but individual analyses indicate erratic performance. During the CPE, sludge was bulking from both the primary and secondary clarifiers.

MAJOR UNIT PROCESS EVALUATION

Major plant processes were evaluated for their capacity to adequately treat current loadings and the general applicability of a CCP to improve performance. Current hydraulic loadings were estimated with flow data measured during the CPE. Organic loading on the RBC as measured by soluble BOD_5 was estimated using 30 percent total BOD removal in the primary clarifier and 50 percent of the primary effluent total BOD as soluble BOD.

The ability to handle current loads was assessed using a numerical point system, which resulted in the plant's being categorized Type 1, 2, or 3 as described below:

- Type 1. Loadings are conservatively low, but performance problems could be alleviated with training and/or minor facility modifications.

- Type 2. Loadings are not conservatively low but also not so high as to preclude improved performance from existing facilities.

- Type 3. Loadings are so high in relation to capacity that it is not considered reasonably possible to consistently meet effluent requirements without a major facility upgrade.

The results of the major process evaluation are shown in Table C-1.

TABLE C-1

SPRINGFIELD, KS, POTW MAJOR UNIT PROCESS EVALUATION

	Points	Assessed Type
Aerator	26	1
Secondary Clarifier	18	1
Sludge Handling Capability	5	2
Total of Major Processes	49	1

As shown in Table C-1, the aerator, secondary clarifier, and the total of major processes all received sufficient points to receive a Type 1 classification. Sludge handling capability received a Type 2 classification. The major limitation regarding sludge handling was ultimate sludge disposal capability in winter.

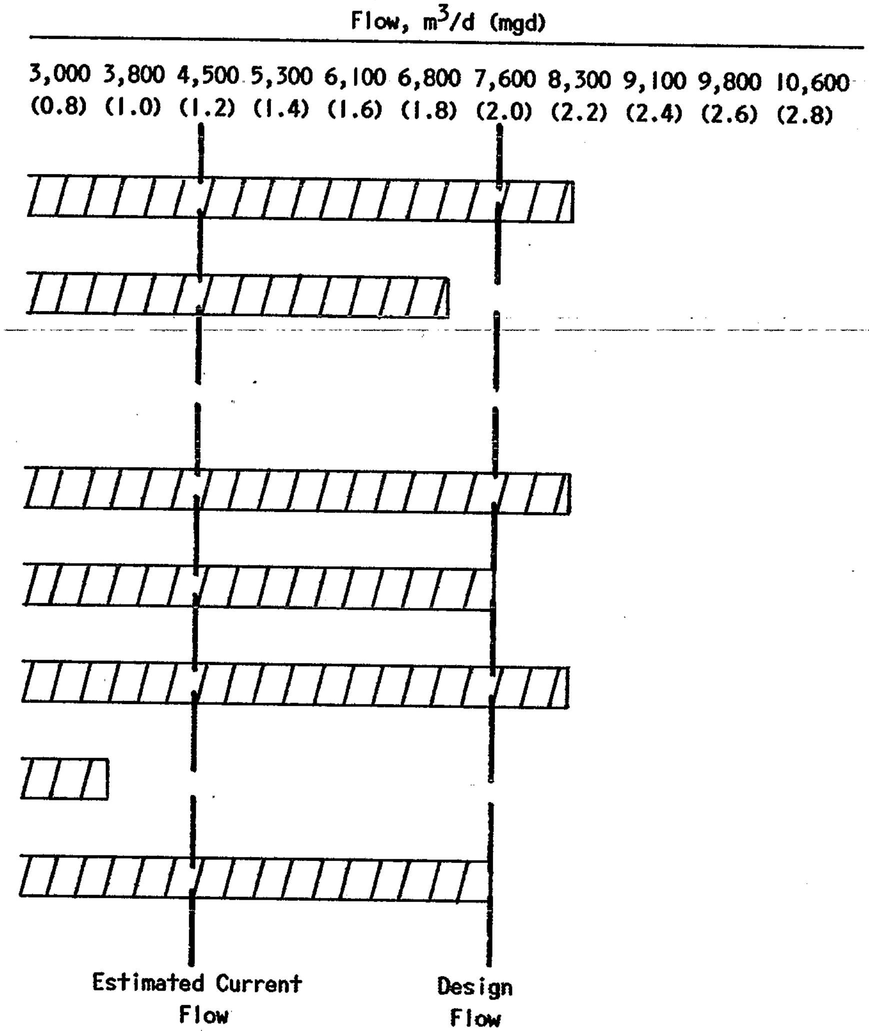
The evaluation of major unit processes indicates that sludge handling will likely require supplemental capacity, but the other major processes have adequate capacity. In general, the CCP approach appears applicable if additional ultimate sludge disposal capacity can be provided.

The potential capacity of major unit processes in the Springfield plant is illustrated in Table C-2. The horizontal bar graph associated with each major process depicts the potential capacity of that process.

Primary clarifiers, secondary clarifiers, and anaerobic digesters are all believed to have capacities a little greater than design capacities. The chlorine contact basin has capacity sufficient for design flows; however,

TABLE C-2

SPRINGFIELD, KS, POTW CAPACITY POTENTIAL



Major Unit Process	Comments
Primary Clarifier	33 $m^3/m^2/d$ (800 gpd/sq ft) Est. 30% BOD_5 removed
RBCs	3.9 kg SBOD/m^2/d (0.8 lb SBOD/d/1,000 sq ft) lower than 4.9 kg SBOD/m^2/d (1.0 lb SBOD/d/1,000 sq ft) because of sidestream return
Secondary Clarifier	20 $m^3/m^2/d$ (500 gpd/sq ft) because of configuration
Chlorine Contact	30 min average
Digesters	30 days' detention time 4.5% combined sludge
Ultimate Disposal	42 days' turnover marginally adequate in summer
Ultimate Disposal Liquid Haul to Land	

it appears that the RBCs may not have quite enough capacity to adequately treat design loadings. RBC capacity should be evaluated as flows approach design.

The ultimate sludge disposal capability as represented by the sludge drying beds appears to be the only major process that will be limiting at current flows. The limitation in ultimate sludge disposal is during the winter when the drying beds freeze and do not dry.

PERFORMANCE-LIMITING FACTORS

During the CPE, the plant's performance-limiting factors in the areas of design, administration, operation, and maintenance were identified. These factors are listed below and the most significant ones briefly discussed.

1. Sewage Treatment Understanding (Operation). A lack of understanding of biological treatment process fundamentals and operational requirements and goals significantly limit plant performance. This limitation could be addressed with onsite training over a period of months or by periodic attendance at seminars, schools, etc., over a period of many years.

2. Process Control Testing (Operation). An almost complete lack of process control testing existed prior to the CPE. Base-level testing was initiated during the CPE. Onsite training is required to optimize process control testing and to teach the operational staff to properly apply the test results to process controls.

3. Return Process Streams (Design). Secondary sludge being returned to the primary clarifier was causing primary clarifier "bulking." Anaerobic digester supernatant return will also adversely impact plant performance. The capability to minimize the adverse impact of return process streams can be acquired through long-term, onsite training.

4. Equipment Malfunction (Maintenance). The waste gas burner, the digester gas mixing system, the heat exchanger temperature control system, and the primary sludge pump were all out of service during the CPE. A significant safety problem, as well as operational problems, had developed. Administrative and operator training are needed.

5. Improper Training Guidance (Operation). Current operation and equipment problems have been existing for years despite formal grant-supported startup of the expanded facilities and periodic State inspections.

6. Administrative Familiarity With Plant Needs (Administration). Through past poor communication and improper operation, the plant administrators have been misled regarding plant needs. Increased

familiarity in the areas of treatment fundamentals, operation and maintenance requirements, funding needs, and safety concerns is needed.

7. Process Controllability (Design). Existing flow-splitting capability to the RBCs is inadequate. Correction of this deficiency will likely require minor design modifications.

8. Ultimate Sludge Disposal (Design). Existing drying beds are inadequate for needed year-round sludge disposal. Additional beds may be a long-term solution. Liquid sludge haul to farmland may be a workable interim solution. Documentation for the need and administrative training are necessary.

9. Performance Monitoring (Operation). Improved sampling to represent actual performance and flow discharge is needed. Onsite training coupled with administrative support to eliminate problems are required.

10. Insufficient Funding (Administration). Administrative unfamiliarity with plant needs, inadequate technical guidance, and improper past operation and maintenance have all led to insufficient funding. Administrative training is needed.

Other factors that contributed to limited performance, but in a less significant way, include: an inadequate spare parts inventory, limited staff expertise in handling emergency maintenance, a lack of an alternate power source, a marginally equipped laboratory, poor accessibility for maintenance in part of the plant, a lack of needed sample taps, and a relatively "green" staff.

PROJECTED IMPACT OF A CCP

Improved effluent quality, to within NPDES permit limits, and overall operational stability, safety, and administrative ability to protect the existing capital investment and provide for future wastewater treatment needs, are expected if a CCP is implemented.

CCP COSTS

Costs associated with a 12-month CCP at Springfield would be for the CCP facilitator and for equipment repairs, minor modifications, and supplemental winter sludge disposal. Estimated costs for conducting a CCP at Springfield are listed below:

CCP Facilitator	$ 9,500	(one-time)
City Costs		
Minor Modifications	1,000	(one-time)
Lab Equipment	400	(one-time)
Supplemental Sludge Disposal	18,000	(annual)
	$19,400	
Total CCP Costs	$28,900	

APPENDIX D

DATA COLLECTION FORMS USED IN CONDUCTING CPEs

Form	Title
D-1	General POTW Information
D-2	Administration Data
D-3	Design Data
D-4	Operations Data
D-5	Maintenance Data
D-6	Performance Data

FORM D-1

GENERAL POTW INFORMATION

A. NAME AND LOCATION:

Name of Facility ______________________________

Type of Facility ______________________________

Owner ______________________________

Administrative Office:

Mailing Address ______________________________

____

____

Primary Contact ______________________________

Title ______________________________

Telephone No. ______________________________

Treatment Plant:

Mailing Address ______________________________

____

____

Primary Contact ______________________________

Title ______________________________

Telephone No. ______________________________

Directions to Plant ______________________________

____

____

B. RECEIVING STREAM AND CLASSIFICATION:

Receiving Water ______________________________

Tributary to ______________________________

Major River Basin ______________________________

Comments:

FORM D-1 (continued)

GENERAL POTW INFORMATION

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, no./100 ml	______	______	______	______
Chlorine Residual, mg/l	______	______	______	______
pH, units	______	______	______	______
Ammonia, mg/l	______	______	______	______
Oil & Grease, mg/l	______	______	______	______
Others	______	______	______	______

Compliance Schedule:

FORM D-1 (continued)

GENERAL POTW INFORMATION

D. MAJOR PROCESS TYPE ____________________

E. DESIGN FLOW:

Present Design Flow ____________ mgd x 3,785 = ____________ m^3/d

F. UPGRADING AND/OR EXPANSION HISTORY (original construction, date completed, plant upgrade, date completed):

G. PROPOSED UPGRADES:

H. SERVICE AREA:

Number of Taps ____________________

General Description (residential, approximate commercial and/or industrial contribution, etc.):

FORM D-1 (continued)

GENERAL POTW INFORMATION

I. PLANT FLOW DIAGRAM:

FORM D-2

ADMINISTRATION DATA

A. ORGANIZATION:

Governing Body ______________________________

Scheduled Meeting Dates and Times ______________________

Authority and Responsibility:

Members' Names (notes on leadership, funding preferences, knowledge of plant needs, etc.):

Chain of Command (from governing body through major in-plant decisionmakers):

FORM D-2 (continued)

ADMINISTRATION DATA

B. PLANT PERSONNEL:

Personnel Classification

No.	Title	Certification	Pay Scale	Fraction of Time Spent with Wastewater Treatment

C. PLANT COVERAGE:

Weekdays ______________________________

Weekends & Holidays ______________________________

FORM D-2 (continued)

ADMINISTRATION DATA

D. PLANT BUDGET (Attach copy of actual budget if available):

(Budget Year ___________)

FORM D-2 (continued)

ADMINISTRATION DATA

E. BOND RETIREMENT:

Bond Type	Year Issued	Duration	Interest Rate	Project Financed

Comments:

FORM D-2 (continued)

ADMINISTRATION DATA

F. REVENUE:

Type of Tap	Tap Fee	User Fee

Other Sources of Revenue:

Comments:

FORM D-2 (continued)

ADMINISTRATION DATA

G. DISCUSSION OF EXPENDITURES:

Budget for:	Dollar Amount	Percent of Total
Salaries (incl. fringes)	$________	________
Utilities	________	________
Training	________	________
Other	________	________
Operations Subtotal	$________	________
Capital Outlay (incl. bond debt retirement and capital replacement)	________	________
Total	________	100

Operational Cost Per Thousand Gallons (Operations Subtotal $ ÷ Yearly Flow)

$______ ÷ ______ Mgal/yr ÷ 10 = ______ ¢/1,000 gal x 0.264 = ______ ¢/m^3

Approximate Annual Cost Per Tap (Total $ ÷ No. of Taps)

$________ ÷ ________ taps = $________/tap

Comments:

FORM D-2 (continued)

ADMINISTRATION DATA

H. POLICY, SUPPORT, AND ATTITUDE:

Owner Responsibility:

- Attitude toward staff?
- Attitude toward regulatory agency?
- Self-sustaining facility attitude?
- Attitude toward consultants?
- Future plans?
- Policies?

Performance Goal:

- Is plant in compliance?
    - o If yes, what's making it that way?
    - o If no, why not?
- Is regulatory pressure felt for performance?
- What are performance requirements?

Administrative Support:

- Budget
    - o Within range of other plants?
    - o Covers capital improvements?
    - o "Drained" to general fund?
    - o Unnecessary expenditures?
    - o Sufficient?

FORM D-2 (continued)

ADMINISTRATION DATA

- Personnel
  - o Within range of other plants?
  - o Allows adequate time?
  - o Motivation, pay, supervision, working conditions?
  - o Productivity?
  - o Turnover?

- Involvement
  - o Visits to treatment plant?
  - o Awareness of facility performance?
  - o Request status reports (performance and cost-related)?
  - o Familiarity with plant needs?

Attitude Assessment:

Excellent:	Reliability provides adequate treatment at lowest reasonable cost.
Normal:	Provide as good a treatment as possible with the money available.
Poor:	Spend as little as possible with no correlation made to achieving plant performance.

FORM D-2 (continued)

ADMINISTRATION DATA

I. ENERGY CONSUMPTION:

<u>Electricity</u>

Source of Information ______________________________

Base Cost __________ ¢/kWh (Attach rate schedule if available)

Month/ Year	Days in Billing Period	Energy Usage (kWh)	Energy Demand Cost	ECA* Cost	Base Cost	Total Cost	Flow (Mgal)
Total							

Total Flow (Mgal) ______

________ kWh/d
________ kWh/1,000 gal x 0.264 = ________ kWh/m^3
________ $/d
________ ¢/1,000 gal x 0.264 = ________ $¢/m^3$

*ECA = Energy Cost Adjustment, which is the pass-through cost allowed to public service companies for increased fuel cost to generate electricity.

FORM D-2 (continued)

ADMINISTRATION DATA

J. ENERGY CONSUMPTION:

Natural Gas

Source of Information ____________________

Unit Cost ____________ (Attach rate schedule if available)

Month/Year	Days in Billing Period	Usage (cu ft)	Cost
Total			
Average			

Miscellaneous (Fuel Oil, Digester Gas, etc.)

FORM D-3

DESIGN DATA

A. INFLUENT CHARACTERISTICS:

Average Daily Flow:	Design	________mgd x 3,785 =	________	m^3/d
	Current	_______mgd x 3,785 =	________	m^3/d
Maximum Monthly Flow:	Design	________mgd x 3,785 =	________	m^3/d
	Current	_______mgd x 3,785 =	________	m^3/d
Maximum Hourly Flow:	Design	________mgd x 3,785 =	________	m^3/d
	Current	_______mgd x 3,785 =	________	m^3/d
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 Variations:

Major Industrial Wastes:

Collection System:

Comments:

FORM D-3 (continued)

DESIGN DATA

B. UNIT PROCESSES:

<u>Flow Measurement</u>

(Form for each flow measuring device)

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.):

Accuracy Check During CPE:

Method of Check:

Results:

FORM D-3 (continued)

DESIGN DATA

B. UNIT PROCESSES:

Pumping

(Complete as many forms as necessary)

Flow Stream Pumped	Type	No. of Pumps	Name	Model	HP	Capacity	Head

Comments (flow control, suitability of installed equipment, results of capacity check during CPE, etc.):

Comments:

Comments:

FORM D-3 (continued)

DESIGN DATA

B. UNIT PROCESSES:

<u>Preliminary Treatment</u>

Mechanical Bar Screen:

Name ______________________________

Model ______________ Horsepower ______________

Bar Screen Width __________ inch x 2.54 = __________ cm

Bar Spacing __________ inch, O.C. x 2.54 = __________ cm, O.C.

Within Building? __________ Heated? __________

Description of Operation:

Hand-Cleaned Bar Screen:

Bar Screen Width __________ inch x 2.54 = __________ cm

Bar Spacing __________ inch, O.C. x 2.54 = __________ cm, O.C.

Cleaning Frequency ______________________________

Within Building? ______________ Heated? ______________

Screenings Volume:

Normal __________ cu yd/d x 0.75 = __________ m^3/d

Peak __________ cu yd/d x 0.75 = __________ m^3/d

Screening Disposal:

Comments:

FORM D-3 (continued)

DESIGN DATA

B. UNIT PROCESSES:

Preliminary Treatment

Comminutor:

Name ______________________________

Model ______________ Horsepower ______________

Within Building? __________ Heated? ______________

Maintenance:

Comments:

Grit Removal:

Description of Unit:

Grit Volume:

Normal __________ cu yd/d x 0.75 = __________ m^3/d

Peak __________ cu yd/d x 0.75 = __________ m^3/d

Disposal of Grit:

Comments:

FORM D-3 (continued)

DESIGN DATA

B. UNIT PROCESSES:

Primary Treatment

Primary Clarifier(s):

Number ____________ Surface Dimensions ____________
____

Water Depth (Shallowest) ________ ft x 0.3 = ____________ m
Water Depth (Deepest) ________ ft x 0.3 = ____________ m
Weir Location ________________________
Weir Length ____________ ft x 0.3 = ____________ m
Total Surface Area ________ sq ft x 0.093 = ________ m^2
Total Volume ____________ cu ft x 0.028 = ____________ m^3
Flow (Design) ____________ mgd x 3,785 = ____________ m^3/d
(Operating) ____________ mgd x 3,785 = ____________ m^3/d
Weir Overflow Rate
(Design) ____________ gpd/ft x 0.012 = ________ $m^3/m/d$
(Operating) ____________ gpd/ft x 0.012 = ________ $m^3/m/d$
Surface Settling Rate
(Design) ____________ gpd/sq ft x 0.04 = ________ $m^3/m^2/d$
(Operating) ________ gpd/sq ft x 0.04 = ________ $m^3/m^2/d$
Hydraulic Detention Time (Design) ______ hr (Operating) ______ hr
Collector Mechanism Name ________________________
Model ________________ Horsepower ________________
Scum Collection and Treatment:
Scum Volume:
Normal: ________ cu ft/d x 0.028 = ________ m^3/d
Peak: ________ cu ft/d x 0.028 = ________ m^3/d

FORM D-3 (continued)

DESIGN DATA

B. UNIT PROCESSES

Secondary Treatment

Aeration Basin(s):

No. of Basins ____________ Surface Dimensions ____________

____

Water Depth ____________ ft x 0.3 = ____________ m

Total Volume ____________ cu ft x 0.028 = ____________ m^3

Flow (Design) ____________ mgd x 3,785 = ____________ m^3/d

(Operating) ____________ mgd x 3,785 = ____________ m^3/d

Sewage Detention Time (Design ____________ hr

(Operating) ____________ hr

BOD_5 Loading

(Design) ____________ lb/d/1,000 cu ft x 0.16 = ____________ $kg/m^3/d$

(Operating) ____________ lb/d/1,000 cu ft x 0.16 = ____________ $kg/m^3/d$

Covered? ____________

Type of Aeration ____________ No. of Aerators ____________

Name ____________ Model ____________ Horsepower ____________

Modes of Operation (Current and Other Options):

Types of Diffusers ____________ Manufacturer ____________

Model ____________ Depth ____________ ft x 0.3 = ____________ m

No. of Blowers ____________ Name ____________

Model ____________ Horsepower ____________

Air Capacity (cfm) ____________ Location ____________

Oxygen Transfer Capacity ____________ lb/d x 0.454 = ____________ kg/d

Comments:

FORM D-3 (continued)

DESIGN DATA

B. UNIT PROCESSES:

Secondary Treatment

Contact Basin:

Surface Dimension ______________________________

Water Depth ______________ ft x 0.3 = ______________ m

Volume ______________ cu ft x 0.028 = ______________ m^3

Flow (Design) ______________ mgd x 3,785 = ______________ m^3/d

(Operating) ______________ mgd x 3,785 = ______________ m^3/d

Sewage Detention Time (Design) ________ min (Operating) ________ min

Covered? ______________________________

Comments:

Reaeration Basin:

Surface Dimensions ______________________________

Water Depth ______________ ft x 0.3 = ______________ m

Volume ______________ cu ft x 0.028 = ______________ m^3

Hydraulic Detention Time at 100% Return

(Design) ______________ hr (Operating) ______________ hr

Flexibility to Operate as Conventional or Step Feed:

Covered? ______________________________

Comments:

FORM D-3 (continued)

DESIGN DATA

B. UNIT PROCESSES:

Secondary Treatment

Oxygen Transfer:

Type of Aeration ____________ No. of Aerators ____ Name____________

Model ____________________________ Horsepower ____________________

Capacity ______________________ cfm x 0.028 = ______________ m^3/min

______________________ lb/d x 0.454 = ________________ kg/d

No. of Blowers __________ Name ___________ Model ______________

Horsepower ________ Capacity ________ cfm x 0.028 = ________ m^3/min

Location ____

Type of Diffusers ____________________ Manufacturer ______________

Model ___________________ Depth _____________ ft x 0.3 = ________ m

Comments:

FORM D-3

DESIGN DATA

B. UNIT PROCESSES:

<u>Secondary Treatment</u>

Trickling Filter:

No. of Filters ______________ Covered? ______________

Surface Dimensions ______________________________

Media Type ______________________________

Specific Surface _______ sq ft/cu ft x 32.8 = _______ m^2/m^3

Media Depth ______________ ft x 0.3 = ______________ m

Surface Area ______________ ft x 0.093 = ______________ m^2

Media Volume ______________ cu ft x 0.028 = ______________ m^3

Flow (Design) ______________ mgd x 3,785 = ______________ m^3/d

(Operating) ______________ mgd x 3,785 = ______________ m^3/d

Organic Loading

(Design) _______ lb/d/1,000 cu ft x 0.016 = _______ $kg/m^3/d$

(Operating) _______ lb/d/1,000 cu ft x 0.016 = _______ $kg/m^3/d$

Hydraulic Loading

(Design) ______________ gpd/sq ft x 0.04 = ______________ $m^3/m^2/d$

(Operating) ______________ gpd/sq ft x 0.04 = ______________ $m^3/m^2/d$

Recirculation (description, ranges, current operation):

Mode of Operation:

Comments:

FORM D-3 (continued)

DESIGN DATA

B. UNIT PROCESSES:

Secondary Treatment

Rotating Biological Contactor (RBC):

No. of Shafts ____ Length of Shafts ________ ft x 0.3 = _________m

No. of Cells ______ Cell Volume _______cu ft x 0.028 =___________m^3

Name____

Disc Diameter _______________ ft x 0.3 = ________________________ m

RPM ____

Peripheral Velocity __________ ft/sec x 0.3 =________________ m/sec

Total Surface Area ___________ sq ft x 0.093 = _________________ m^2

Percent Submergence ______________________________________

Flow (Design) __________________ mgd x 3,785 =_______________ m^3/d

(Operating) ________________ mgd x 3,785 = ______________ m^3/d

Hydraulic Loading:

(Design)_____________ gpd/sq ft x 0.04 = _____________ $m^3/m^2/d$

(Operating)__________ gpd/sq ft x 0.04 = _____________ $m^3/m^2/d$

Temperature (Design) ______________ ^oC (Operating) ______________ ^oC

Organic Loading (Design) _____________ lb SBOD/d/1,000 sq ft x 4.88

= _____________ g SBOD/m^2/d

(Operating)___________ lb SBOD/d/1,000 sq ft x 4.88

= _____________ g SBOD/m^2/d

Total Detention Time (Design) _________ hr (Operating) __________hr

Covered? ______________________ Heated?____________________________

Flexibility to Distribute Load to Stages:

Comments:

FORM D-3 (continued)

DESIGN DATA

B. UNIT PROCESSES

Secondary Treatment

Activated Biofilter (ABF)

Biocell: Model _______________ No. of Cells _____________________

Surface Dimensions ____

Total Surface Area __________ sq ft x 0.093 =________________ m^2

Media Depth ____________________ ft x 0.3 = ________________ m^2

Total Media Volume __________ cu ft x 0.028 = _______________ m^3

Media Type __________ Specific Surface ________sq ft/cu ft x 32.8

= ____________________ m^2/m^3

BOD_5 Loading

(Design) ________ lb/1,000 cu ft/d x 0.016 = _______ $kg/m^3/d$

(Operating)______ lb/1,000 cu ft/d x 0.016 = _______ $kg/m^3/d$

Recirculation Tank: Dimensions (LxWxD) _______ft = ____________m

Volume ___________cu ft x 0.028 =_________ m^3

Aeration Basin: Surface Dimensions ______________________________

Total Surface Area ______________ sq ft x 0.093 = _____________ m^2

Depth ____________________ ft x 0.3 = _________________________m

Volume _______________ cu ft x 0.028 = ______________________ m^3

Hydraulic Detention Time (Design)______min (Operating) _____ min

Comments:

FORM D-3 (continued)

DESIGN DATA

B. UNIT PROCESSES

Secondary Treatment

Secondary Clarifier(s):

No. of Clarifiers ____________ Dimension(s) ____________________

Water Depth (Shallowest) ____________ ft x 0.3 = ______________m

(Deepest) ______________ ft x 0.3 = ______________m

Weir Location ____

Percent of Clarification Developed by Launders ________________

Weir Length _____________________ ft x 0.3 = __________________m

Surface Area __________________sq ft x 0.093 =_ _______________m^2

Volume _________________________ cu ft x 0.028 =_______________m^3

Flow (Design) _____________ mgd x 3,785 ____________________m^3/d

(Operating)___________ mgd x 3,785 ____________________m^3/d

Weir Overflow Rate

(Design)_____________ gpd/ft x 0.012 = ______________$m^3/m/d$

(Operating)__________ gpd/ft x 0.012 = ______________$m^3/m/d$

Surface Settling Rate

(Design) ____________ gpd/sq ft x 0.04 = __________ $m^3/m^2/d$

(Operating)__________ gpd/sq ft x 0.04 = __________ $m^3/m^2/d$

Hydraulic Detention Time

(Design) ___________ hr (Operating) ______________ hr

Collector Mechanism Name _______ Model _______ Horsepower _______

Return Sludge Collector Mechanism Type __________________________

Scum Collection and Removal:

Scum Volume: (Normal)__________ gpd x 0.028 = _____________m^3/d

(Peak) ___________ gpd x 0.028 = _____________m^3/d

Comments:

FORM D-3 (continued)

DESIGN DATA

B. UNIT PROCESSES:

Return Sludge

Description of Sludge Movement (i.e., scrap to clarifier hopper, pump to aeration basin inlet channel):

Controllable Capacity Range:

(Low) ______________________ mgd x 3,785 = ____________________ m^3/d

(High) _____________________ mgd x 3,785 = ____________________ m^3/d

Method of Control:

Sampling Location:

Comments:

Waste Sludge

Description of Waste Procedure (i.e., variable-speed pump wastes from separate clarifier hopper, continuous or by timeclock):

Method of Waste Volume Measurement:

Sampling Location:

Comments:

FORM D-3 (continued)

DESIGN DATA

B. UNIT PROCESSES:

Disinfection

Contact Basin(s):

No. of Separate Basins ____________________

Surface Dimension(s) ____________________

Channel Length-to-Width Ratio ____________ No. of Bends ________

Water Depth ____________ ft x 0.3 = ____________ m

Total Volume ____________ cu ft x 0.028 = ____________ m^3

Detention Time (Design) ____________ min (Operating) ____________ min

Drain Capability:

Scum Removal Capability:

Comments:

Chlorinator(s):

Name ____________ No. of Chlorinators ____________

Capacity ____________ lb/d x 0.454 ____________ kg/d

Type of Injection ____________ Flow Proportioned? ____________

Feed Rate (Operating) ________ lb/d x 0.454 = ____________ kg/d

Dosage (Operating) ____________________ mg/l

Chlorine Diffusion ____________________

Comments:

Form D-3 (continued)

DESIGN DATA

B. UNIT PROCESSES:

Sludge Handling

Aerobic Digestion:

No. of Basins ____________ Surface Dimension(s) ________________

Water Depth ______________ ft x 0.3 = _________________________m

Volume _________________ cu ft x 0.028 = ____________________m^3

Covered? ______________________ Heated? _______________________

Type of Aeration ____

Supernatant Capability ____

No. of Aerators __________________ Name _______________________

Model ______________________ Horsepower _________________________

Type of Diffusers _________________ Manufacturer _______________

Model ________________ Depth ___________ ft x 0.3 = ____________m

No. of Blowers __________________ Name ________________________

Model ______________________ Horsepower _________________________

Air Capacity _______________ cfm x 0.47 = ____________________l/s

Oxygen Transfer Capacity ___________lb/d x 0.454 = ___________kg/d

Location ____

Mode of Operation:

Comments:

FORM D-3 (continued)

DESIGN DATA

B. UNIT PROCESSES:

Sludge Handling

Anaerobic Digestion:

No. of Digesters _______ Diameter ________ ft x 0.3 = ____________m

Sidewall Depth __________________ ft x 0.3 = _____________________m

Center Depth ____________________ ft x 0.3 = _____________________m

Total Volume __________________ cu ft x 0.028 = _________________m^3

Floating Cover? ____

Flow (Design) __________________ mgd x 3,785 = _______________m^3/d

(Operating) _______________ mgd x 3,785 = _______________m^3/d

Detention Time (Design) __________ days (Operating) ___________days

Heating:

Mixing:

Sampling Ports:

Mode of Operation:

Comments:

FORM D-3 (continued)

DESIGN INFORMATION

B. UNIT PROCESSES:

<u>Sludge Handling</u>

Sludge Drying Beds:

No. of Beds ____________ Size of Beds ____________

Covered? ____________ Subnatant Drain To ____________

Dewatered Sludge Removal:

Mode of Operation:

Comments:

Other Dewatering Unit(s):

No. of Units ______ Type of Unit(s) ______ Manufacturer ____________

Model ____________ Horsepower ____________ Hr/Wk ____________

Loading Rate ____________ lb/hr x 0.454 = ____________ kg/h

Polymer Used ____________

lb/dry ton ____________ x 0.5 = ____________ g/kg

Cake Solids ____________ % Solids

Comments:

FORM D-3 (continued)

DESIGN DATA

B. UNIT PROCESSES:

Summary of Plant Horsepower

Item	HP	Usage (%)	Weighted HP

FORM D-3 (continued)

DESIGN DATA

C. OTHER DESIGN INFORMATION:

Standby Power (description of unit; automatic activation? capacity for which processes? frequency of use, etc.):

Alarm Systems (description of system, units covered, etc.):

Miscellaneous:

FORM D-3 (continued)

DESIGN DATA

D. PLANT AUTOMATION (description of any plant automation not covered under more specific topics):

E. LABORATORY CAPABILITY:

Location ____________________ Floor Dimensions ____________________

Counter Space ___________ ft x 0.3 = __________m Hot Water? ______

File Cabinet? ___________________ Desk? _____________________

Tests Performed by Whom? ______________________________

Monitoring Tests Conducted (TSS, BOD, pH, Fecal Coliform, Others):

According to Permit ______________________________

Tests Conducted More Frequently ______________________________

Tests Conducted Less Frequently ______________________________

Tests with Suspected or Known Analytical Problems ___________

____

Operational Test Capability (Equipment/Chemicals):
(Check if available)

______ DO meter

______ BOD_5

______ Mallory-type settleometer

______ Graduated cylinder

______ Imhoff cone

______ Turbidity

______ Ammonia

______ Nitrate

FORM D-3 (continued)

DESIGN DATA

E. LABORATORY CAPABILITY:

Operational Test Capability: (Check if available)

______ Total Kjeldahl nitrogen
______ Suspended solids
______ Volatile suspended solids
______ Sludge blanket depth measurement
______ Core sample taker
______ Alkalinity
______ Volatile acids
______ pH meter
______ Centrifuge solids concentrations
______ Oxygen uptake rates

FORM D-4

OPERATIONS DATA

A. PROCESS CONTROLS:

Who sets major process control strategies and decisions?

Where is help sought when desired performance is not achieved?

Are staff members asked their opinions?

B. SPECIFIC PROCESS CONTROLS:

<u>Primary Clarification</u>

1. Sludge Removal:

2. Performance Monitoring:

3. Other:

<u>Suspended Growth POTW Secondary Systems</u>

1. Sludge Mass Control:

2. Return Sludge Control:

3. DO Control:

4. Clarifier Solids Loading:

5. Other:

FORM D-4 (continued)

OPERATIONS DATA

Fixed Film POTW Secondary Systems

1. Secondary Clarifier Sludge Removal:

2. Anaerobic Sidestream Returns:

3. Other:

Sludge Handling

1. Purpose Relative to Other Processes:

2. Sludge Stabilization:

3. Sludge Disposal:

4. Other:

C. PROCESS CONTROL REFERENCES USED (Specifically note references that are the source of poor process control decisions or strategies, suspected or definitely identified):

FORM D-5

MAINTENANCE DATA

A. EQUIPMENT OR PROCESSES OUT OF SERVICE DUE TO BREAKDOWNS (Identify equipment or process, description of problem, length of time out of service, what has been done, what remains to be done, estimated time before repair, how it affects performance):

DURING THE CPE (List and explain):

DURING THE LAST 24 MONTHS (List and explain):

FORM D-5 (continued)

MAINTENANCE DATA

B. PREVENTIVE MAINTENANCE PROGRAM:

Method of Scheduling:

Method of Documenting Work Completed:

Adequacy of Resources Available:

Lubricants:

Tools:

Others:

C. EMERGENCY MAINTENANCE PROGRAM:

Small Spare Parts (fuses, belts, bearing, packing diffusers, etc):

Major Spare Parts (large motors, gear boxes, blowers, flowmeter, etc.

Manpower:

Expertise:

References:

O&M Manual:

Accurate As-Builts:

Manufacturer's Literature:

FORM D-5

MAINTENANCE DATA

D. GENERAL HOUSEKEEPING:

FORM D-6

PERFORMANCE DATA

A. SOURCE OF DATA:

B. REPORTED MONITORING DATA FOR PREVIOUS 12 MONTHS (flows in mgd; others in mg/l, except as noted):

	Raw						Primary Effluent				
Mo/Yr	Flow	BOD_5	TSS				BOD_5	TSS			
AVG											

FORM D-6 (continued)

PERFORMANCE DATA

B. REPORTED MONITORING DATA FOR PREVIOUS 12 MONTHS (cont.)

	Final Effluent						Other				
Mo/Yr	Flow	BOD_5	TSS				BOD_5	TSS			
AVG											

FORM D-6 (continued)

PERFORMANCE DATA

C. PERMIT PERFORMANCE VIOLATIONS WITHIN LAST 12 MONTHS (30-day averages, 7-day averages, instantaneous violations, effluent mass violations, percent removal violations):

No. of Months Without a Violation ______________________

No. of Months With a Violation ______________________

D. REASONS (if any) REPORTED MONITORING DATA ARE NOT BELIEVED TO REPRESENT ACTUAL EFFLUENT QUALITY (unrepresentative sampling, improper lab analyses, unaccounted-for sludge loss, selective reporting, etc.):

APPENDIX E

GUIDELINES FOR FIELD ESTIMATING EQUIPMENT POWER USAGE

FIELD ESTIMATING EQUIPMENT POWER USAGE

The power a particular piece of equipment is drawing can be estimated in the field by measuring the current being drawn by the motor. The measured power being drawn by a motor (inductive user) is "apparent power" and must be multiplied by the power factor (PF) to calculate actual power. Four methods are available to arrive at a suitable power factor:

1. Assume a power factor:

   Use 0.9 for recently constructed plants that likely included use of capacitors to adjust the power factor toward 1.0. Use 0.75 for old and small plants where it is unlikely that capacitors have been added.

2. Measure the "plant power factor" using an ammeter and the plant kilowatthour meter and assume the power factor applies for larger pieces of equipment. See Table E-1 for calculation worksheet. (WARNING: DO NOT USE THIS METHOD UNLESS QUALIFIED.)

3. Ask the electric company to measure the power factor or actual power usage of specific equipment.

4. Rent an appropriate instrument and measure power factor or actual power usage. (WARNING: DO NOT USE THIS METHOD UNLESS QUALIFIED.)

Once the PF has been determined, the following calculations can be used to estimate power drawn by a particular piece of equipment:

Measure:

Average Voltage (line-to-line) = ____________ Volts

Average Amperage = ____________ Amps

Calculate:

$$kVA = \frac{V \times A \times \sqrt{3}}{1000} \quad \text{(3-phase power)}$$

$$kW = kVA \times PF$$

$$whp = \frac{kW}{0.746}$$

TABLE E-1

WORKSHEET FOR CALCULATION OF POWER FACTOR

<u>Apparent Power</u>

Line-to-Line Voltage on Incoming Power:

V_{1-2} = ______________ Volts

V_{2-3} = ______________ Volts

V_{1-3} = ______________ Volts

V_{avg} = ______________ Volts

Amperage for Each Phase on Incoming Power:

I_1 = ______________ Amps

I_2 = ______________ Amps

I_3 = ______________ Amps

I_{avg} = ______________ Amps

$$\text{kVA} = \frac{\text{Volts} \times \text{Amps} \times \sqrt{3}}{1000} = \underline{\hspace{3cm}}$$

<u>Actual Power</u>

K_h = ______________ watthours/revolution (from meter)

CTR[a] = ________:________ PTR[b] ________:________

TR[c] = CTR x PTR = __________ x __________ = __________

Disc Speed = __________ Seconds/__________ Revolution(s)

$$\text{kW} = K_h \times \text{TR} \times \frac{\text{Disc Rev}}{\text{Sec}} \times \frac{3600\ \text{Sec}}{\text{Hour}} \times \frac{1\ \text{kW}}{1000\ \text{Watts}} = \underline{\hspace{3cm}}$$

<u>Power Factor</u>

$$\text{PF} = \frac{\text{kW}}{\text{KVA}} = \underline{\hspace{3cm}}$$

[a]CTR (Current Transformer Ratio) - ratio of primary to secondary current. For current transformer rated 200:5, ratio is 200/5 or 40/1.

[b]PTR (Potential Transformer Ratio) - ratio of primary to secondary voltage. For potential transformer rated 480:120, ratio is 480/120 or 4/1.

[c]TR (Transformer Ratio) - total ratio of current and potential transformers. For CTR = 200:5 and PTR = 480:120, TR = 40 x 4 = 160.

APPENDIX F

PROCEDURE FOR CONVERTING STANDARD OXYGENATION RATES TO ACTUAL OXYGENATION RATES

PROCEDURE FOR CONVERTING STANDARD OXYGENATION RATES (SORs) TO ACTUAL OXYGENATION RATES (AORs)

$$AOR = SOR\ (\alpha) \left[\frac{\beta C_{sw} - C_L}{C_s}\right] \theta^{(T-20)}$$

Where:

AOR = actual oxygen transfer rate, lb O_2/hp-hr

SOR = standard oxygen transfer rate, lb O_2/hp-hr (from Table 3-3)

α = relative rate of oxygen transfer in wastewater compared to water. Estimate from Table F-1.

β = relative to oxygen saturation value in wastewater compared to water. Estimate $\beta \doteq 0.95$ for mixed liquor.

θ = temperature correction constant, $\theta = 1.024$

C_s = oxygen saturation value of clean water at standard conditions, $C_s = 9.17$ mg/l

C_{sw} = oxygen saturation value of clean water at site conditions of temperature and pressure, mg/l

$$C_{sw} = C_{14.7}\left(\frac{P}{14.7}\right)$$

C_L = mixed liquor DO concentrations, mg/l

T = temperature of the liquid, ^oC

$C_{14.7}$ = oxygen saturation value of clean water at standard pressure of 14.7 psi and actual water temperature (see Table F-2).

P = actual pressure at oxygen transfer point

a) For surface aerators, use atmospheric pressure (see Figure F-1).

b) For others, use atmospheric pressure from Figure F-1, plus the pressure at mid-depth of the tank from the surface to the diffusers (i.e., diffuser depth in feet x 0.5 x 0.434 psi/ft).

TABLE F-1

TYPICAL VALUES OF ALPHA (α) USED FOR ESTIMATING AOR/SOR

Aeration Device	Typical
Course Bubble Diffusers	0.85
Fine Bubble Diffusers	0.50
Jet Aeration	0.75
Surface Mechanical Aerators	0.90
Submerged Turbines	0.85

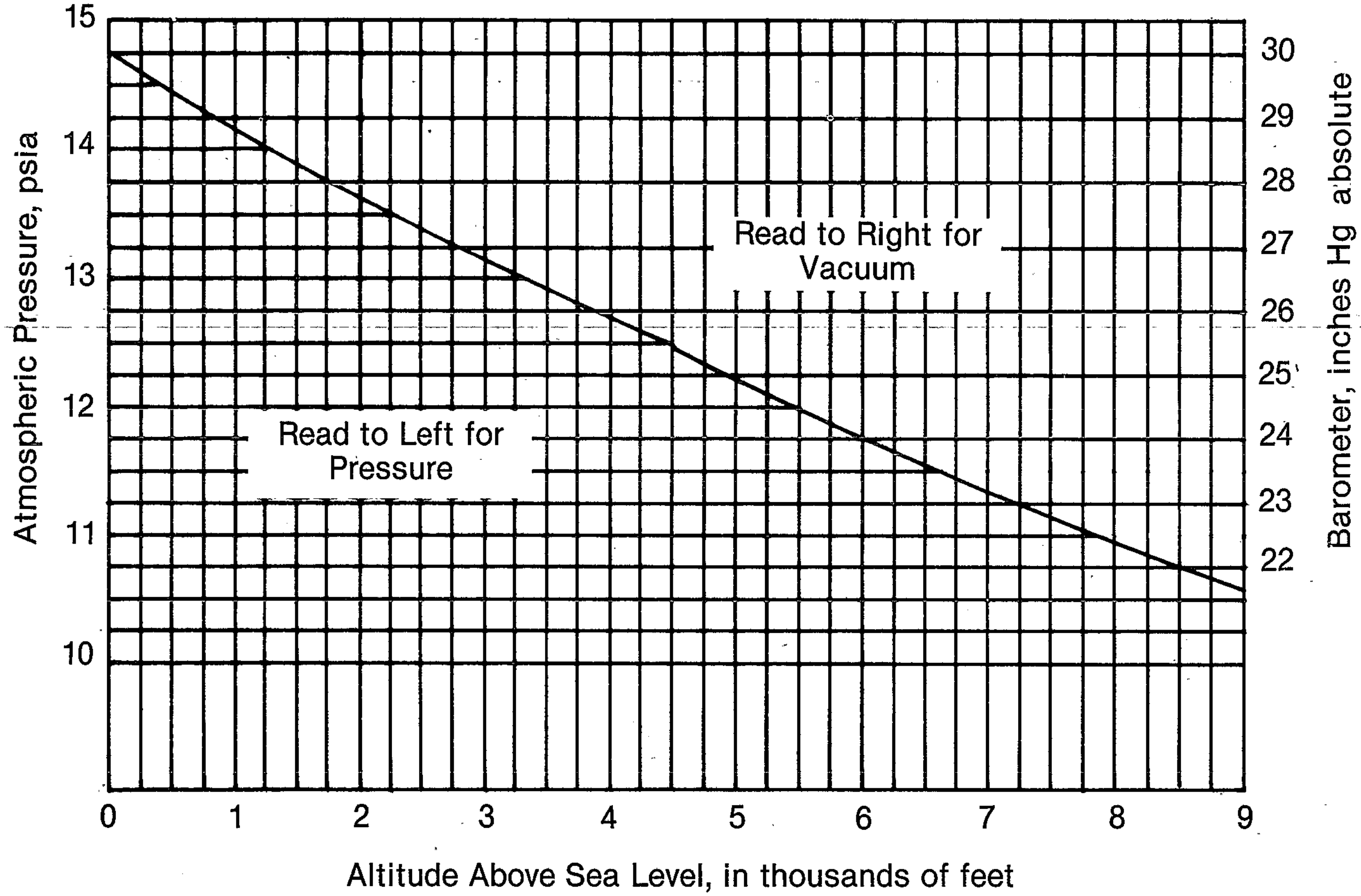
TABLE F-2

OXYGEN SATURATION AT STANDARD PRESSURE AND ACTUAL WATER TEMPERATURE

Temperature (°C)	Dissolved Oxygen Saturation Level (mg/l)
0	14.62
1	14.23
2	13.84
3	13.48
4	13.13
5	12.80
6	12.48
7	12.17
8	11.87
9	11.59
10	11.33
11	11.09
12	10.83
13	10.60
14	10.37
15	10.15
16	9.95
17	9.74
18	9.54
19	9.35
20	9.17
21	8.99
22	8.83
23	8.68
24	8.53
25	8.38
26	8.22
27	8.07
28	7.92
29	7.77
30	7.63

FIGURE F-1

ATMOSPHERIC PRESSURE AT VARIOUS ALTITUDES



APPENDIX G

EXAMPLE FORMS FOR ESTABLISHING A PREVENTIVE MAINTENANCE PROGRAM FOR SMALL POTWs

Form	Title
G-1	Equipment Information Sheet
G-2	Daily Preventive Maintenance
G-3	Weekly Preventive Maintenance
G-4	Monthly Preventive Maintenance

FORM G-1

EQUIPMENT INFORMATION SHEET

Plant Equipment Number ______________

EQUIPMENT ____

Location ______________________ Original Installation Date ____________

Manufacturer ____________ Model ____________ Serial No: ______________

Type __________ Rated Capacity ________ Rated Pressure or Head ____________

Additional Data ____

DRIVE Type ________________ Manufacturer ______________________

Description ____

____

MOTOR Manufacturer __________________________ HP ________ RPM ________

Frame ______________ Enclosure Type ____________ S.F. ____________

Type ______________ Rated Amperage ______________________

Rated Voltage ____________________

SUPPLIER(S):

Company Name & Address	Contact Person	Telephone No.

Additional Information and Comments:

____

____

____

____

____

____

FORM G-1 (continued)

EQUIPMENT INFORMATION SHEET

RECOMMENDED PREVENTIVE MAINTENANCE:

	Frequency

RECOMMENDED LUBRICANTS:

Part	Lubricant Name & Description	Source

RECOMMENDED SPARE PARTS:

Part Description	Number	Quantity

FORM G-2

DAILY PREVENTIVE MAINTENANCE

	TIME	INITIALS
Inlet Building		
- Check operation of grit pump, cyclone, grit bin, pump seal water pressure _______(psi), leakage_______(drops/min).	a.m.________ p.m.________	__________ __________
- Check grit collector for unusual noise or torque.	a.m.________ p.m.________	__________ __________
- Check flow meter operation, chain, float, stilling well.	a.m.________ p.m.________	__________ __________
- Check auto sampler operation and bottle installation.	a.m.________ p.m.________	__________ __________
Grit Separator #2 Building		
- Check for unusual noise or vibration in collector or conveyor.	a.m.________ p.m.________	__________ __________
Primary Clarifier		
- Check for unusual noise or vibration in drive unit.	a.m.________ p.m.________	__________ __________
Aeration Building		
- Check blowers for unusual noise or vibration.	a.m.________ p.m.________	__________ __________

Temperature:

	Inlet		Outlet
#1	__________ °C	Outlet	__________ °C
#2	__________ °C	Outlet	__________ °C
#3	__________ °C	Outlet	__________ °C

	TIME	INITIALS
- Check auto sampler operation and bottle installation.	a.m.________ p.m.________	__________ __________

(Form continued to include all process units and buildings requiring daily maintenance.)

FORM G-3

WEEKLY PREVENTIVE MAINTENANCE

	DATE	INITIALS
Inlet Building		
- Grit #1 Collector Drive: Apply grease to upper and lower bearings in worm gear housing.	________	________
- Grit #1 Collector Drive: Check oil level in gear housing; remove condensate in gear drive.	________	________
- Grit #1 Collector Drive: Lubricate chain between drive unit and motor gear.	________	________
- Grit #1 Collector Drive: Check torque overload alarm for proper operation.	________	________
- Communitor: Check oil level in main gear box (lower).	________	________
- Communitor: Check oil level in motor gear unit.	________	________
- Automatic Sampler: Remove and clean sampling tube and strainer.	________	________
Grit Separator #2 Building		
- Grit #2 Drive Unit: Check oil level in Philadelphia gear reducer.	________	________
- Grit #2 Conveyor Unit: Apply grease to all bearings of chain drive and support sprockets.	________	________
- Grit #2 Conveyor Unit: Check oil level in conveyor drive reducer.	________	________
Aeration Building		
- Automatic Sampler: Remove and clean sampling tube and strainer.	________	________
- Aeration Blowers: Check oil level - 3 points (gears, two bearings)	________	________
- Aeration Blowers: Operate blower(s) (10 min each) not in service. Check oil level and temperature.	________	________

(Form continued to include all process units and buildings requiring weekly maintenance.)

FORM G-4

MONTHLY PREVENTIVE MAINTENANCE

	DATE	INITIALS
Inlet Building		
- Automatic Sampler: Check pump tubing for signs of failure. Remove from pump housing to inspect.	______	______
Grit Separator #2 Building		
- Gear Reducer: Apply grease to upper and lower bearings.	______	______
Primary Clarifier		
- Drive Mechanism: Check gear lubrication (dipstick). Check base plate lubrication (oil cap)	______	______
- Gear Reducer: Apply grease to upper, lower, and two side bearings.	______	______

(Form continued to include all process units and buildings requiring monthly maintenance.)

Porvide Similar Forms For:

QUARTERLY PREVENTIVE MAINTENANCE
SEMIANNUAL PREVENTIVE MAINTENANCE
ANNUAL PREVENTIVE MAINTENANCE

APPENDIX H

DESIGN-RELATED PERFORMANCE-LIMITING FACTORS IDENTIFIED IN ACTUAL CPEs

DESIGN-RELATED PERFORMANCE-LIMITING FACTORS

The design problems listed in this appendix were identified during actual comprehensive performance evaluations. Most of these problems have resulted in unnecessary or excessive maintenance, difficult process control, inaccurate or excessive sampling, and poor POTW performance.

These design-related problems are discussed in the context of the following categories:

- Plant Layout
- Flow Measurement
- Bar Screens
- Comminutors
- Grit Removal
- Primary Clarifiers
- Aeration Basins
- Aerators
- Trickling Filters
- ABF Towers
- RBCs
- Secondary 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

- Individual process trains, without interconnection, require operation of units as if three separate activated sludge plants exist at one POTW rather than just one

- Covered basins without adequate observation access prevent observation of processes

- Return sludge air compressors are located outside and repeatedly break down

- No flow splitting flexibility to parallel units

- Bar screen located downstream from comminutor

- Freezing of influent sampler located outside

- Plant location inaccessible during inclement weather

- Excessive compressor noise

- Disinfection before polishing pond

- Parallel secondary treatment units not capable of being operated as one facility

- Inadequate piping flexibility requires shutdown of one trickling filter if one clarifier is down

- One scraper drive for primary and final clarifiers requires shutdown of both for maintenance on either

- Lack of bypasses on individual treatment units such as aeration basins, trickling filters, chlorine contact basins, etc.

- Use of a septic tank for inplant domestic and laboratory wastes and overflow from the septic tank to the 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 appropriate

- 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 instrumentation
- Parshall flume on POTW effluent submerged during high river flows
- Recycle flows (cooling water) included in plant flow measurement
- Rollup flow chart requires removal to observe flow for more than the preceding 4 hours
- Wires crossed in totalizer, resulting in wrong reading
- Humid influent structure causes problem with moisture-sensitive level sensor
- Flow velocity too high in Kennison nozzle
- Liquid level sensing float freezes
- Downstream bar screen backs flow into flume throat as screen plugs

<u>Bar Screens</u>

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

<u>Comminutors</u>

- 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 oversized grit channel
- Pump discharge to grit chamber directed at grit buckets, and washes grit from buckets
- Grit auger not functional
- Grit auger discharges too low for disposal in truck

Primary Clarifiers

- Overloaded by excessively large trickling filter humus return pump
- Overload due to trickling filter recirculation designed to route 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 and from oversized return pump on timeclock
- Loss of solids caused by flooding due to aeration basin design elevation and lack of drainage control
- Action of aeration rotors and revolving bridge and configuration of basin creates swells and voids that result in wavelike stresses on bridge
- Leakage between contact and reaeration basins of contact stabilization plant due to movable wall design
- No wall between contact and reaeration areas of contact stabilization plant

Aerators

- Inadequate capacity for oxygen transfer
- Surface mechanical aerators overheat and shut off under increased flows due to infiltration/inflow
- Inadequate DO control because blowers provided are too large
- With floating aerators, repeated breaking of cables when operated on intermittent basis
- With submerged turbine aerators, repeated downtime due to bearing and shaft failure
- Surface aerators that do not provide adequate bottom mixing in a deep oxidation ditch
- Inadequate freeboard for splashing with surface mechanical aerators
- Brush aerators provided in cold climate without ice protection
- Icing problems with surface mechanical aerators
- Rag accumulation on surface mechanical aerators
- Inadequate DO control

Trickling Filters

- Recirculation only through primary clarifier
- Inadequate capacity of trickling filter arms
- Poor flow splitting to trickling filters

ABF Tower

- Inadequately sized for organic load
- 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
- No flow measurement on direct recycle flow around tower

RBCs

- No positive flow splitting to various trains
- No access provided through covers to take dissolved oxygen measurements
- Inadequate shaft design causes excessive downtime

Secondary Clarifiers

- Poor flow splitting to clarifiers
- Poor development of surface area with weirs
- Sludge scraper mechanism directing contercurrent to wastewater flow
- Hydraulically connected clarifiers not of the same elevation causes unequal flow splitting
- Freezing during cold weather
- Inlet and outlet on circumference, a large diameter, a large design overflow rate, and failure to consider process recycle flows cause problems with hydraulic washout of solids
- Scum 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 drawoff overloads final clarifier
- Weirs on single launder not balanced to pull evenly from each side
- No skimming device
- Shallow depth promotes thin underflow concentrations and solids washout

Return Sludge Flows

- Constant-speed centrifugal pumps make it difficult to adjust flow
- Oversized constant-speed pumps provided
- Return sludge flow not visible at any point
- No measurement
- Single pump returning from multiple clarifiers; balancing return flow difficult
- Variable-speed return pumps too large even at lowest setting
- Plugging of telescoping valves at lower flows
- Sludge returned to a point near the outlet of the aeration basin
- Not accessible for sampling
- Piping prohibits return sludge flow for several hours while sludge is being removed from the aerobic digester
- Measurement with 90^{o} V-notch weir not sensitive enough for needed flow adjustments
- Oversized pump on timeclock draws down final clarifier, then hydraulically overloads aeration basin
- Waste piping and appurtenances require 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, resulting in unsafe working conditions
- Sludge return from clarifiers controlled by plug valve into wet well. 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
- Partial plugging with rags of butterfly valve used for return sludge flow control
- Rapid withdrawal sludge removal designed without sampling or adjustment capability from various ports

Polishing Ponds

- No pond bypass
- Sludge wasted to polishing pond
- Pond located after disinfection

Chlorination

- Chlorine diffuser located at center of contact tank rather than at inlet
- Chlorine diffuser located at outlet of contact tank
- Single contact tank prohibits disinfection during cleaning and discourages cleaning of contact basin
- 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 chlorine contact time in outfall pipe
- No depth control device on contact tank results in inadequate contact time and short-circuiting
- Short-circuiting over baffles during high flows
- Short-circuiting due to inlet design

Wasting Capability

- No digester or sludge holding facility; inadequate drying beds
- Downtime of exotic sludge treatment facility causes inadequate wasting
- Wasting capability only from mixed liquor requires excessive waste volume
- Insufficient wasting capacity
- Sludge lagoons undersized

- No waste flow measurement
- 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
- Undersized storage capacity given ultimate sludge disposal limitations
- Potential gas buildup problem with covered, unaerated sludge storage

Aerobic Digesters

- High groundwater and pressure relief valve prevents batch operation
- Inadequate air supply
- Inadequate supernating capability
- 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
- Provided with "automatic" supernating device that cannot work

Anaerobic Digesters

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

- Plugging problem between bottom of primary digester and second-stage digester
- Water seal on sludge recirculation pump loads digester with cold water
- Sludge pumping line from clarifier plugs prevents digester loading at concentrations above about 6 percent
- No gas meters
- No mixing
- Cold digester produces poor supernatant quality and poor digestion
- Single gas meter for two digesters
- Uninsulated heating pipes outside

Sludge Dewatering & Ultimate Disposal

- Truck ramp too steep for use during winter
- Excessive maintenance on sludge incineration facilities
- Insufficient sludge drying lagoons
- Disposal of sludge in polishing lagoon
- Truck capacity too small for sludge produced
- Insufficient drying beds for wet or cold weather operation
- Land application not possible during certain times of the year; no alternate disposal or storage

Laboratory Facilities

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

Miscellaneous

- Stabilization of sludge with chlorine releases heavy metals to recycled supernatant
- Wooden gates in flow diversion structure swell and cannot be removed
- No automatic restart after power outage
- Butterfly valve used between mixed liquor and final effluent leaks mixed liquor into effluent
- Undersized raw lift pumps

APPENDIX I

EXAMPLE PROCESS MONITORING SUMMARY FOR AN ACTIVATED SLUDGE POTW

DAILY CONTROL CALCULATION SHEET FOR AN ACTIVATED SLUDGE POTW[a]

Aerator Volume (AV) = ____________ m^3 Clarifier Depth (CD) = ____________ m

Clarifier Volume (CV) = ____________ m^3 Clarifier Surface Area (CSA) = ____________ m^2 Location ____________ Month/Year ____________

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
DATE	ATC (%)	RSC (%)	CSC (%)	DTB (m)	TURB (NTU)	FLOW (m^3/d)	RSF (m^3/d)	RFP (%)	RSP (%)	ASU (m^3 x %)	CSU (m^3 x %)	SDR (ASU/CSU)	TSU (m^3 x %)	ESU (m^3 x %)	XSU (m^3 x %)	WSU (m^3 x %)	MCRT (d)	RSU (m^3 x %)	SDT_A (hr)	SDT_C (hr)	SDT_A x ATC (hr x %)	CSL (units/m^2)	OFR (m^3/m^2/d)	SSC_5 (%)	SSC_{60} (%)
1																									
2																									
3																									
4																									
5																									
6																									
7																									
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28																									
29																									
30																									
31																									
TOTAL																									
AVG																									

[a]See following page for an explanation of symbols used on this sheet.

COLUMN INFORMATION FOR DAILY CONTROL CALCULATION SHEET

Column	Symbol	Symbol Meaning	Explanation
1	DATE	Self-Explanatory	
2	ATC	Aeration Tank Concentration	Average of values recorded during the day on the Daily Data Sheet.
3	RSC	Return Sludge Concentration	Average of values recorded during the day on the Daily Data Sheet.
4	CSC	Clarifier Sludge Concentration	Average concentration of sludge within the clarifier as determined from a core sample (Method 1) or by calculation (Method 2). Method 1. Core Sample – average of values recorded during the day on the Daily Data Sheet. Method 2. Calculation – average of ATC and RSC. $CSC = \frac{ATC + RSC}{2}$
5	DTB	Depth to (Sludge) Blanket	Average of values recorded during the day on the Daily Data Sheet.
6	TURB	Turbidity	Average of values recorded during the day on the Daily Data Sheet.
7	FLOW	Daily Wastewater Flow	Total wastewater flow for a given 24-hour time period (e.g., 8:00 a.m. to 8:00 a.m.).
8	RSF	Return Sludge Flow	Total daily return sludge flow. (Note: Time period for determining this rate should be the same as the time period used for determining daily wastewater flow rate [e.g., 8:00 a.m. to 8 :00 a.m.])
9	RFP	Return Sludge Flow Percentage	Return sludge flow divided by average daily wastewater flow. $RFP = \frac{RSF}{FLOW} \times 100\%$

COLUMN INFORMATION FOR DAILY CONTROL CALCULATION SHEET (continued)

Column	Symbol	Symbol Meaning	Explanation
10	RSP	Return Sludge Percentage	Return sludge flow percentage based on mass balance. $$RSP = \frac{1}{\frac{RSC}{ATC} - 1} \times 100\%$$
11	ASU	Aerator Sludge Units	Total aeration tank volume (AV) times ATC. $$ASU = (AV)(ATC)$$
12	CSU	Clarifier Sludge Units	Method 1. Core Sample - clarifier sludge concentration times the clarifier volume (CV). $$CSU = (CSC)(CV)$$ Method 2. Calculation - clarifier sludge concentration times the fraction of the clarifier filled with sludge, times the clarifier volume (CV). $$CSU = (CSC)\frac{CD - DTB}{CD}(CV)$$
13	SDR	Sludge Distribution Ratio	Ratio of the quantity of solids under aeration vs the quantity of solids in the clarifier. $$SDR = \frac{ASU}{CSU}$$
14	TSU	Total Sludge Units	$TSU = ASU + CSU$
15	ESU	Effluent Sludge Units	Quantity of sludge lost in the effluent each day. ESU = Effluent suspended solids (TSS) times FLOW divided by ratio of MLSS to percent solids by centrifuge (e.g., ratio = MLSS divided by ATC). $$ESU = \frac{(TSS)(FLOW)}{Ratio}$$

COLUMN INFORMATION FOR DAILY CONTROL CALCULATION SHEET (continued)

Column	Symbol	Symbol Meaning	Explanation
16	XSU	Intentionally Wasted Sludge Units	Quantity of Sludge intentionally wasted from the system each day = average concentration of wasted sludge times the volume of sludge wasted (from the Daily Data Sheet).
17	WSU	Total Waste Sludge Units	WSU = ESU + XSU
18	MCRT	Mean Cell Residence Time	Average of number of days a given quantity of sludge remains in the system. $MCRT = \frac{TSU}{WSU}$
19	RSU	Return Sludge Units	Return sludge flow rate times the return sludge concentration. RSU = (RSF)(RSC)
20	SDT_A	Sludge Detention Time in the Aerator	Average number of hours a given quantity of sludge ramain in the aerator. $SDT_A = \frac{(AV)(24\ hr/d)}{FLOW + RSF}$
21	SDT_C	Sludge Detention Time in the Clarifier	Average length of time a given quantity of sludge remains in the clarifier. $SDT_C = \frac{(CSU)(24\ hr/d)}{RSU}$
22	$SDT_A \times ATC$	See meanings above	Indication of the treatment pressure in the system.
23	CSL	Clarifier Solids Loading	Average daily mass of sludge to the clarifier divided by the clarifier surface area (CSA). $CSL = \frac{(FLOW + RSF)(ATC)}{CSA}$

COLUMN INFORMATION FOR DAILY CONTROL CALCULATION SHEET (continued)

Column	Symbol	Symbol Meaning	Explanation
24	OFR	Clarifier Surface Overflow Rate	Upward velocity of the treated wastewater in the secondary clarifier. $OFR = \frac{FLOW}{CSA}$
25	SSC_5	Settled Sludge Concentration in 5 minutes	Average of values recorded during the day on the Daily Data Sheet.
26	SSC_{60}	Settled Sludge Concentration in 60 minutes	Average of values recorded during the day on the Daily Data Sheet.

APPENDIX J

EXAMPLE PROCESS MONITORING SUMMARY FOR AN RBC POTW

EXAMPLE RBC PROCESS MONITORING SUMMARY*

Week of ____________ 19_____

Date								
Day	Sun	Mon	Tues	Wed	Thurs	Fri	Sat	
Flow, mgd								Avg
INFLUENT								
BOD, mg/l								Avg
SBOD, mg/l								
TSS, mg/l								Avg
pH, units								
Temp., ^{o}C								Avg
WET WELL								
$SBOD_5$ mg/l								
PRIMARY CLARIFIER								
DTB,* m								Avg
BOD_5, mg/l								
$SBOD_5$, mg/l								
TSS, mg/l								
pH, units								
Temp., ^{o}C								
SECONDARY CLARIFIERS								
DTB_1, m								Avg
DTB_2, m								Avg
BOD_5, mg/l								Avg
$SBOD_5$, mg/l								

*Explanation provided at the end of Appendix J.

EXAMPLE RBC PROCESS MONITORING SUMMARY (continued)

Week of ____________ 19____

	Sun	Mon	Tues	Wed	Thurs	Fri	Sat		
Date									
Day	Sun	Mon	Tues	Wed	Thurs	Fri	Sat		
CHLORINE CONTACT EFFLUENT									
Cl_2 Res, mg/l								Avg	
Fecal Coliform, MPN/l								GM*	
pH, units								Avg	
TSS, mg/l								Avg	
O&G,* mg/l									
SECONDARY SLUDGE									
min/d pumped									
l/s									
m^3/d								Avg	
spin.* %									
ratio*									
mg/l									
kg/d								Avg	
PRIMARY SLUDGE									
Start Time									
End Time									
Minutes									
m^3/d									
m^3								Avg	
spin, %									
ratio									
mg/l									
kg/d								Avg	

EXAMPLE RBC PROCESS MONITORING SUMMARY (continued)

RBC DISSOLVED OXYGEN

(Date ________ Time ________)

	Train 1	Train 2	Train 3
Stage 1	________	________	________
Stage 2	________	________	________
Stage 3	________	________	________
Stage 4	________	________	________

RBC TRAIN PERFORMANCE

(Date ________ Time ________)

$SBOD_5$

Train 1 __________mg/l

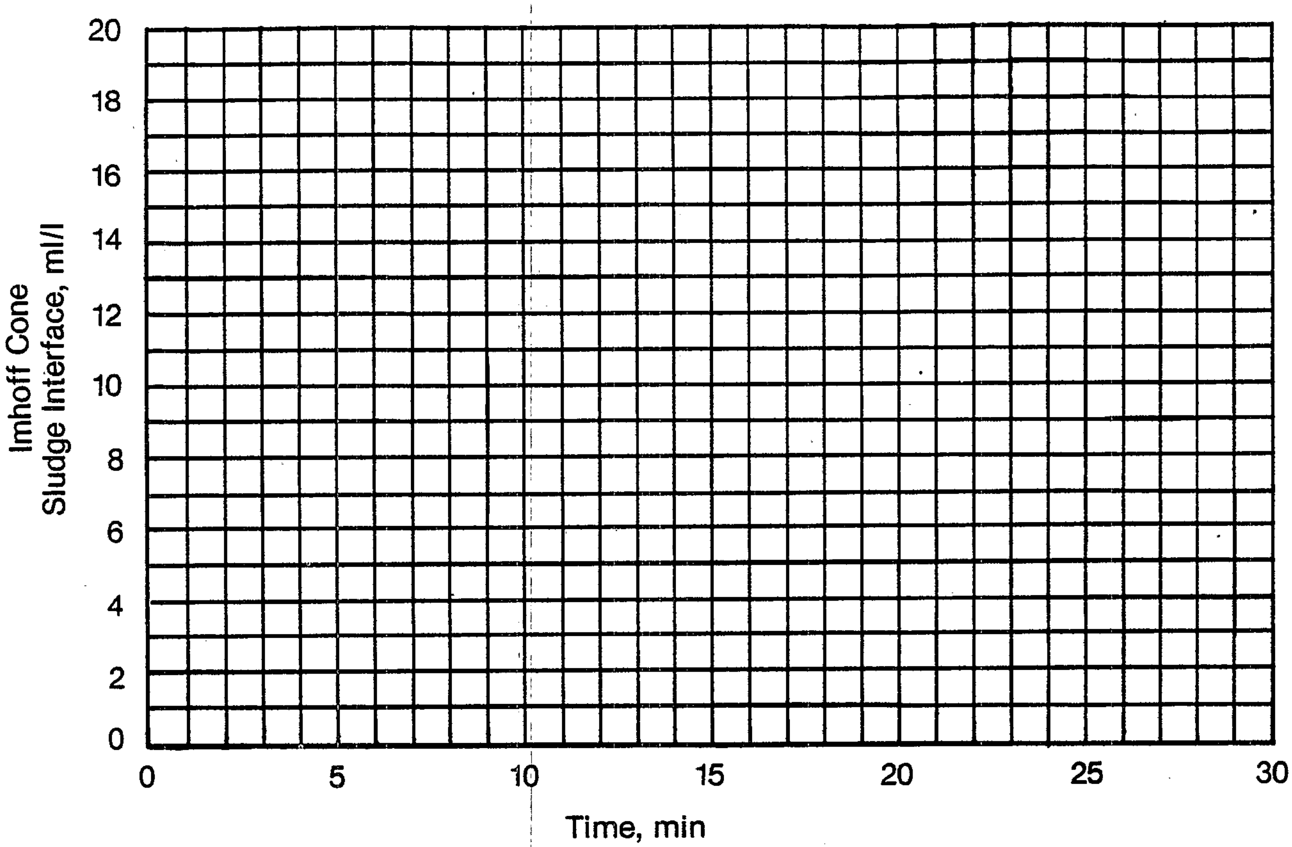
Train 2 __________mg/l

Train 3 __________mg/l

RBC EFFLUENT

(Date ________ Time ________)

DO __________mg/l TSS __________mg/l pH __________ Temp __________°C



EXAMPLE RBC PROCESS MONITORING SUMMARY (continued)

Term	Explanation
DTB	Depth to (Sludge) Blanket
GM	Geometric Mean
O&G	Oil and Grease
SPIN	Concentration; percent of sample volume the compacted sludge occupies after a 15-minute laboratory centrifuge spin
RATIO	MLSS divided by ATC (see Appendix I, Column Information for Daily Control Calculation Sheet)

APPENDIX K

PARAMETERS USED TO MONITOR THE ABF TREATMENT PROCESS

PARAMETERS USED TO MONITOR THE ABF TREATMENT PROCESS

Column	Symbol	Symbol Meaning	Explanation
1	DATE	Self-Explanatory	
2	ATC	Aeration Tank Concentration	Average of values recorded during the day on the Daily Data Sheet.
3	RSC	Return Sludge Concentration	Average of values recorded during the day on the Daily Data Sheet.
4	CSC	Clarifier Sludge Concentration	Average concentration of sludge within the clarifier. Average of values recorded during the day on the Daily Data Sheet.
5	DTB	Depth to (Sludge) Blanket	Average of values recorded during the day on the Daily Data Sheet.
6	TURB	Turbidity	Average of values recorded during the day on the Daily Data Sheet.
7	FLOW	Daily Wastewater Flow	Wastewater flow for a given 24-hour time period (e.g., 8:00 a.m. to 8:00 a.m.).
8	RSF	Return Sludge Flow	Total daily return sludge flow. (Note: Time period for determining this rate should be the same as the time period used for determining daily wastewater flow rate [e.g., 8:00 a.m. to 8:00 a.m.])
9	RFP	Return Sludge Flow Percentage	Return sludge flow divided by average daily wastewater flow. $RFP = \frac{RSF}{FLOW} \times 100\%$
10	BCRF	Biocell Direct Recirculation Flow	Daily total flow from the biocell under drain directly to the recirculation wet well. (Note: Time period for determining this flow should be the same as for determining the average daily wastewater flow.)

*A Daily Control Calculation Sheet similar to the one presented for activated sludge in Appendix I can be used to present these parameters in tabular form.

PARAMETERS USED TO MONITOR THE ABF TREATMENT PROCESS (continued)

Column	Symbol	Symbol Meaning	Explanation
11	BCRFP	Biocell Direct Recirculation Flow Percentage	Percentage expression of the ratio of the volume of direct biocell recirculation to the volume of raw wastewater. $BCRFP = \frac{BCRF}{FLOW} \times 100\%$
12	TFBC	Total Flow to the Biocell	Total volume of liquid pumped to the biocell. $TFBC = FLOW + RSF + BCRF$
13	BCHL	Biocell Hydraulic Load	Volume of liquid pumped to the biocell per unit area of biocell in operation. $\frac{TFBC \times 695}{\text{Biocell Surface Area}}$
14	ASU	Aerator Sludge Units	Total aerator volume (AV) times ATC. $ASU = AV \times ATC$
15	CSU	Clarifier Sludge Units	Clarifier volume (CV) times clarifier sludge concentration. $CSU = CV \times CSC$
16	TVBC	Total Volume in the Biocell	Volume of mixed liquor in the biocell and associated appurtenances. TVBC = volume in tower, volume in underdrain, volume in recirculation, and volume in tower piping.
17	BCSU	Biocell Sludge Units	$BCSU = TVBC \times ATC$
18	TSU	Total Sludge Units	$TSU = ASU + BCSU + CSU$
19	SDR	Sludge Distribution Ratio	Ratio of the mass of solids in the aeration tank + mass of sludge in the biocell to the mass of sludge in the final clarifier. $SDR = \frac{ASU + BCSU}{CSU}$

PARAMETERS USED TO MONITOR THE ABF TREATMENT PROCESS (continued)

Column	Symbol	Symbol Meaning	Explanation
20	ESU	Effluent Sludge Units	Quantity of sludge lost in the effluent each day. $ESU = \frac{(TSS)(FLOW)}{Ratio}$ $Ratio = \frac{MLSS}{ATC}$
21	XSU	Intentionally Wasted Sludge Units	Quantity of Sludge intentionally wasted from the system each day = average concentration of wasted sludge times the volume of sludge wasted (from the Daily Data Sheet).
22	WSU	Total Waste Sludge Units	WSU = ESU + XSU
23	MCRT	Mean Cell Residence Time	Indication of sludge age or the "mean time an average sludge cell is in residence in the system." $MCRT = \frac{TSU}{XSU}$
24	RSU	Return Sludge Units	Return sludge flow rate times the return sludge concentration. RSU = (RSF)(RSC)
25	SDT_A	Sludge Detention Time in the Aerator	Average length of time in hours a given quantity of sludge remains in the aerator. $SDT_A = \frac{AV \times 24\ hr/d}{TFBC - BCRF}$
26	SDT_{BC}	Sludge Detention Time in the Biocell	Indication of the length of the time in hours the suspended growth sludge spends in the biocell and associated appurtenances, equal to the hydraulic detention time. $SDT_{BC} = \frac{TVBC}{TFBC}$

PARAMETERS USED TO MONITOR THE ABF TREATMENT PROCESS (continued)

Column	Symbol	Symbol Meaning	Explanation
27	SDT_C	Sludge Detention Time in the Clarifiers	Average length of time the sludge remains in the clarifiers during each pass around the system. $SDT_C = \frac{CSU}{RSU}$
28	TDT	Total Detention Time	$TDT = SDT_A + SDT_{BC} + SDT_C$
29	CYCLES	Sludge Cycles per Day	Number of times the sludge cycles through the entire system during the day. $CYCLES = \frac{24\ hr/d}{TDT}$
30	$SDT_A \times ATC$	See meanings above	Indication of the treatment pressure in the system.
31	CSL	Clarifier Solids Loading	Indicates the mass loading of solids on the final clarifiers. $CSL = \frac{ATC\ (TFBC - BCRF)}{CSA}$
32	OFR	Clarifier Overflow Rate	Indication of the hydraulic upflow rate in the final clarifiers. $OFR = \frac{FLOW}{CSA}$
33	SSC_5	Settled Sludge Concentration in 5 minutes	Average of values from the Daily Data Sheet.
34	SSC_{30}	Settled Sludge Concentration in 30 minutes	Average of values from the Daily Data Sheet.
35	SSC_{60}	Settled Sludge Concentration in 60 minutes	Average of values from the Daily Data Sheet.
36	SVI	Sludge Volume Index	$\frac{1,000,000}{(SSC_{30})(MLSS/ATC)}$

PARAMETERS USED TO MONITOR THE ABF TREATMENT PROCESS (continued)

Column	Symbol	Symbol Meaning	Explanation
37	RSP	Return Sludge Percentage	Indication of return flow percentage that is based on a solids balance. $RSP = \frac{ATC \times 100}{RSC - ATC}$
38	OUR	Oxygen Uptake Rate	Average of values from the Daily Data Sheet.
39	WASTE	Waste Volume	Average of values from the Daily Data Sheet.
40	RECIRC	Recirculation Power	Average of values from the Daily Data Sheet.
41	AERATION	Aeration Blower Power	Average of values from the Daily Data Sheet.
42	WASTE	Waste Power	Average of values from the Daily Data Sheet.

Appendix L

Suspended Growth Major Unit Process Evaluation Worksheet

This worksheet is used to evaluate the capacity of existing major unit processes, i.e., aerator, secondary clarifier, and sludge handling system. Key loading and process parameters are compared with standard values and point scores are assigned. These points are subsequently compared with expected point scores for Type 1, Type 2, and Type 3 facilities and a determination of the plant Type is made.

Instructions for Use:

- Proceed through the steps contained in this worksheet *in order.*
- Use actual values in lieu of calculations if such data are collected and available, e.g., waste sludge volume.
- When assigning points, interpolate and use the nearest whole number.
- Minimum and maximum point values are indicated—do not exceed the range illustrated.

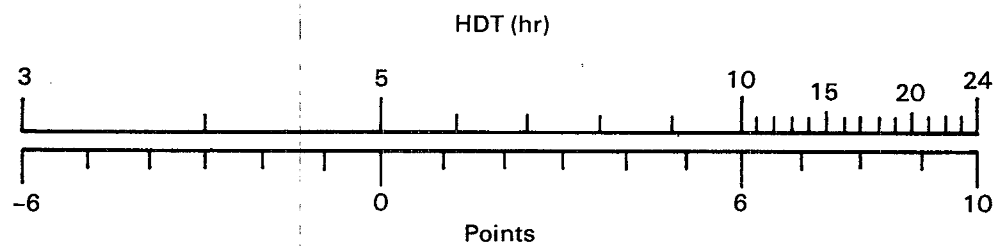
Aeration Basin

Calculate Hydraulic Detention Time (HDT):

$$HDT = \frac{\text{Aeration Basin Volume}}{\text{Average Daily Wastewater Flow}}$$

$$= \frac{(\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\ \text{cu ft})}{(\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\ \text{gpd})} \times (180) = \_\_\_\_\_\_\_\_\ \text{hr}$$

Determine HDT Point Score:



HDT Point Score = ________ (1)

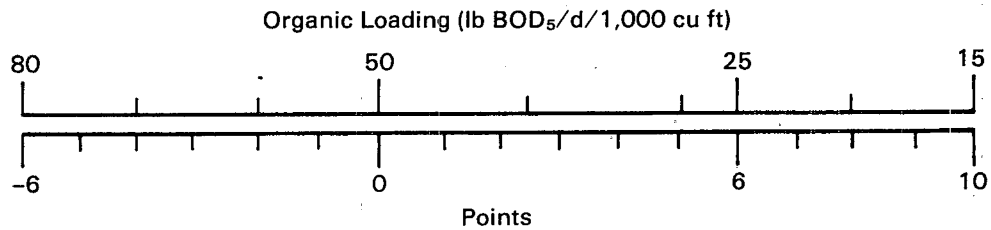
Calculate Organic Loading:

$$\text{Organic Loading} = \frac{BOD_5 \text{ Loading}}{\text{Aeration Basin Volume}}$$

Organic Loading = $\frac{(\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \text{ lb/d})}{(\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \text{ cu ft})} \times (1{,}000)$

= ________ lb BOD_5/d/1,000 cu ft

Determine Organic Loading Point Score:



Organic Loading Point Score = ________ (2)

Calculate Oxygen Availability

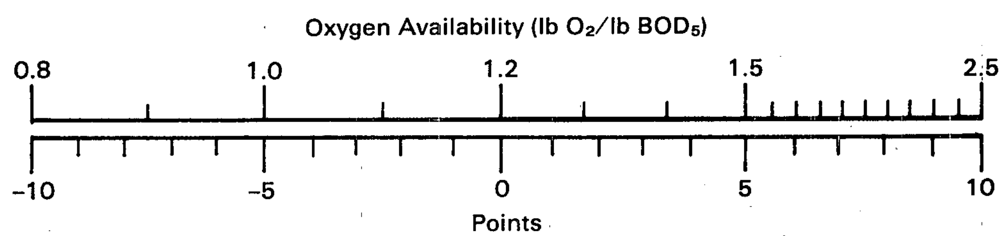
If data are not available on oxygen transfer capacity, calculate it as Wire Horsepower (Appendix E) times actual Oxygen Transfer Rate (Appendix F).

(__________ hp) x (__________ lb/hp-hr) x (24) = ________ lb/d

Oxygen Availability = $\frac{\text{Oxygen Transfer Capacity}}{BOD_5}$

= $\frac{(\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \text{ lb/d})}{(\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \text{ lb/d})}$ = ________ lb O_2/lb BOD_5

Determine Oxygen Availability Point Score:



Oxygen Availability Point Score = ________ (3)

Add Scores 1, 2, and 3 to Obtain Subtotal for Aeration Basin:

Aeration Basin Subtotal = ________ (4)

Secondary Clarifier

Determine Clarifier Configuration Point Score:

Configuration	Points
Circular with "donut" or interior launders	10
Circular with weirs on walls	7
Rectangular with 33% covered with launders	–5
Rectangular with 20% covered with launders	–5
Rectangular with launder at or near end	–10

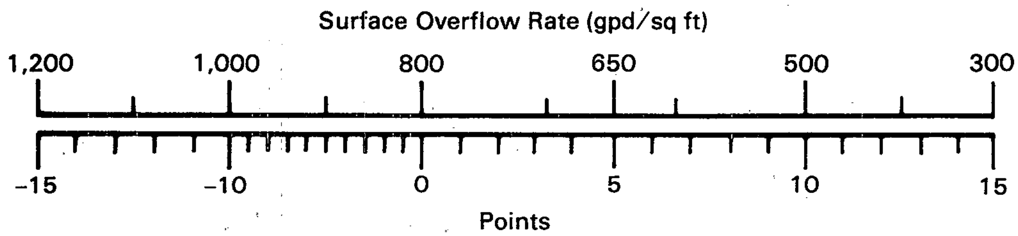
Clarifier Configuration Point Score = ________ (5)

Calculate Clarifier Surface Overflow Rate (SOR):

$$SOR = \frac{\text{Clarifier Effluent Flow}}{\text{Clarifier Surface Area}}$$

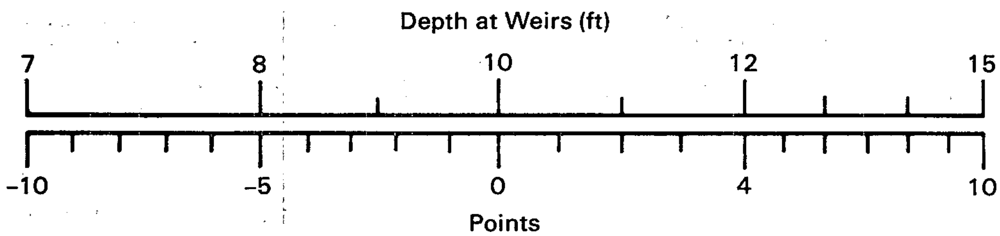
$$= \frac{(\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \text{gpd})}{(\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \text{sq ft})} = \_\_\_\_\_\_\_\_ \text{gpd/sq ft}$$

Determine SOR Point Score:



SOR Point Score = ________ (6)

Determine Depth at Weirs Point Score:



Depth at Weirs Point Score = ________ (7)

Determine Return Activated Sludge (RAS) Removal Point Score:

RAS Removal	Points
Circular, rapid withdrawal	10
Circular, scraper to hoper	8
Rectangular, co-current scraper	2
Rectangular, counter-current scraper	0
No mechanical removal	-5

RAS Removal Score = ________ (8)

Determine Typical RAS Rate from Following:

Process Type	Return Activated Sludge Rate	
	Minimum	Maximum
	% of average daily wastewater flow	
Conventional (plug flow or complete mix)	25	75
Extended Aeration (including oxidation ditches)	50	100
Contact Stabilization	50	125

Minimum Typical RAS Rate = ________percent

Maximum Typical RAS Rate = ________percent

Calculate Recommended RAS Flow Range:

Min. Typical Typical RAS Rate x POTW Flow = Min. Recommended RAS Flow

(________%) x (________________gpd) x (0.01) = ________gpd

Max. Typical Typical RAS Rate x POTW Flow = Min. Recommended RAS Flow

(________%) x (________________gpd) x (0.01) = ________gpd

Determine Actual RAS Flow Range:

Minimum Actual RAS Flow = ________gpd

Maximum Actual RAS Flow = ________gpd

Determine RAS Control Point Score:

RAS Control	Points
The actual RAS flow range is completely within the recommended RAS flow range and the capability to measure RAS flow exists	10
The actual RAS flow range is completely within the recommended RAS flow range but the capability to measure RAS flow does not exist	7
50% of the recommended RAS flow range is covered by the actual RAS flow range and the capability to measure RAS flow exists	5
50% of the recommended RAS flow range is covered by the actual RAS flow range but the capability to measure RAS flow does not exist	0
The actual RAS flow range is completely outside the recommended RAS flow range	-5

RAS Control Point Score = ________ (9)

Add Scores 5, 6, 7, 8, and 9 to Obtain Subtotal for Secondary Clarifier:

Secondary Clarifier Subtotal = ________ (10)

Sludge Handling Capability

Determine Sludge Controllability Point Score:

Controllability	Points
Automated sampling and volume control	5
Metered volume and hand sampling	3
Hand measured volume and hand sampling	2
Sampling or volume measurement by hand not practical	0

Sludge Controllability Point Score = ________ (11)

Calculate BOD_5 Mass Removed:

POTW w/Primary Clarification:

Prim. BOD_{5in} – Prim. BOD_{5out} = Prim. BOD_5 Conc. Removed

(________ mg/l) – (________ mg/l) = ________mg/l

Prim. BOD_{5out} – POTW Eff. BOD_5 = Sec. BOD_5 Conc. Removed

(________ mg/l) – (________ mg/l) = ________ mg/l

Prim. BOD_5 Conc. Removed x POTW Flow = Prim. BOD_5 Mass Removed

(__________ mg/l) x (__________ gpd) x (8.34×10^{-6}) = ________lb/d

Sec. BOD_5 Conc. Removed x POTW Flow = Sec. BOD_5 Mass Removed

(__________ mg/l) x (__________ gpd) x (8.34×10^{-6}) = ________lb/d

POTW w/o Primary Clarification:

BOD_{5in} – POTW Eff. BOD_5 = Total BOD_5 Conc. Removed

(__________ mg/l) – (__________ mg/l) = ________mg/l

Total BOD_5 Conc. Removed x POTW Flow = Total BOD_5 Mass Removed

(__________ mg/l) x (__________ gpd) x (8.34×10^{-6}) = ________lb/d

Determine Typical Unit Sludge Production from Following:

Process Type	lb TSS (sludge)/lb BOD_5 Removed
Primary Clarification	1.7
Activated Sludge w/Primary Clarification	0.7
Activated Sludge w/o Primary Clarification	
Conventional[a]	0.85
Extended Aeration[b]	0.65
Contact Stabilization	1.0

[a]Includes tapered aeration, step feed, plug flow, and complete mix with wastewater detention times <10 hours.
[b]Includes oxidation ditch.

If plant records include actual sludge production data, the actual unit sludge production value should be compared to the typical value. If a discrepancy of more than 15 percent exists between the two values, further evaluation is needed. If not, use the actual unit sludge production value.

Calculate Expected Sludge Mass:

POTW w/Primary Clarification:

Unit Sludge Prod. x Prim. BOD_5 Mass Removed = Prim Sludge Mass

(__________ lb/lb) x (__________ lb/d) = ________lb/d

Unit Sludge Prod. x Sec. BOD_5 Mass Removed = Sec. Sludge Mass

(________ lb/lb) x (________ lb/d) = ________ lb/d

Total Sludge Mass = ________ lb/d

POTW w/o Primary Clarification:

Unit Sludge Mass x Total BOD_5 Mass Removed = Total Sludge Mass

(________ lb/lb) x (________ lb/d) = ________ lb/d

Determine Sludge Concentration from Following:

Sludge Type	Waste Concentration mg/l
Primary	50,000
Activated	
Return Sludge/Conventional	6,000
Return Sludge/Extended Aeration	7,500
Return Sludge/Contact Stabilization	8,000
Return Sludge/small plant with low SOR[a]	10,000
Separate waste hopper in secondary clarifier	12,000

[a]Returns can often be shut off for short periods to thicken waste sludge in clarifiers with surface overflow rates less than 500 gpd/sq ft.

Calculate Expected Sludge Volume:

POTW w/Primary Clarification:

$$\text{Sludge Volume} = \frac{\text{Prim. Sludge Mass}}{\text{Prim. Sludge Conc.}}$$

$$= \frac{(\_\_\_\_\_\_\_\_\ \text{lb/d})}{(\ 50{,}000\ \text{mg/l})} \times (120{,}000) = \_\_\_\_\_\_\_\_ \text{gpd}$$

$$\text{Sludge Volume} = \frac{\text{Sec. Sludge Mass}}{\text{Sec. Sludge Conc.}}$$

$$= \frac{(\_\_\_\_\_\_\_\_\ \text{lb/d})}{(\_\_\_\_\_\_\_\_\ \text{mg/l})} \times (120{,}000) = \_\_\_\_\_\_\_\_ \text{gpd}$$

Total Sludge Volume = ________ gpd

POTW w/o Primary Clarification:

$$\text{Total Sludge Volume} = \frac{\text{Total Sludge Mass}}{\text{Total Sludge Conc.}}$$

$$= \frac{(\_\_\_\_\_\_\_\_\_\_\_\_\ \text{lb/d})}{(\_\_\_\_\_\_\_\_\_\_\_\_\ \text{mg/l})} \times (120{,}000) = \_\_\_\_\_\_\_\_\ \text{gpd}$$

Calculate Capacity of Sludge Handling Unit Processes:

1. Establish capacity of *each* existing sludge handling process (treatment and disposal). The most common unit processes for which this calculation will have to be performed are:

   - Aerobic digestion
   - Anaerobic digestion
   - Gravity thickening
   - Mechanical dewatering
   - Drying beds
   - Liquid haul

   For example, the capacity of a gravity thickener is the maximum sludge loading it can handle:

$$\text{Thickener Loading} = \frac{\text{Total Sludge Mass}}{\text{Thickener Surface Area}}$$

$$= \frac{(\_\_\_\_\_\_\_\_\_\_\_\_\ \text{lb/d})}{(\_\_\_\_\_\_\_\_\_\_\_\_\ \text{sq ft})} = \_\_\_\_\_\_\_\_\ \text{lb/d/sq ft}$$

2. Determine percentage of the expected sludge production that each process can handle.

$$\text{Process Capacity} = \frac{\text{Typical Process Loading}}{\text{Actual Process Loading}}$$

   Assume the sludge being thickened by the gravity thickener above is mixed primary and activated. From Table 3-9, 10 lb/d/sq ft is considered typical loading for the thickener. Its capacity would therefore be calculated as:

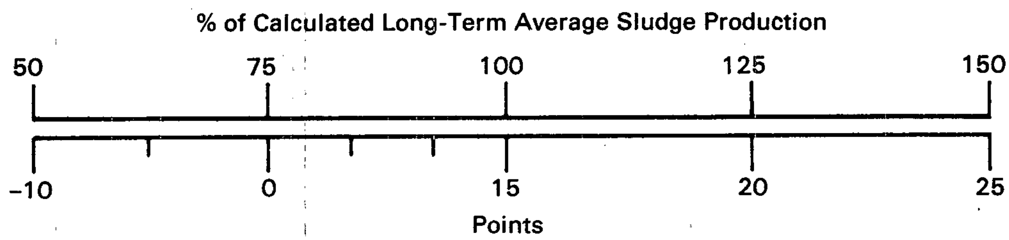
$$\frac{(\ 10\ \text{lb/d/sq ft})}{(\_\_\_\_\_\_\_\_\ \text{lb/d/sq ft})} \times (100) = \_\_\_\_\_\_\_\_\ \text{percent}$$

List Each Process and Its Associated Sludge Handling Capacity and Identify the Lowest Percentage Capacity:

Process	Percentage

Lowest Capacity = ________ percent

Determine Sludge Handling Capacity Point Score:



Sludge Handling Capacity Point Score = ________ (12)

Add Scores 11 and 12 to Obtain Subtotal for Sludge Handling Capability:

Sludge Handling Capability Subtotal = ________ (13)

Compare Subtotals and Total Score with Following to Determine Whether POTW is Type 1, Type 2, or Type 3:

		Points Required		
	Score	Type 1	Type 2	Type 3
Aeration Basin	______ (4)	13-30	0-12	<0
Secondary Clarifier	______ (10)	25-55	0-24	<0
Sludge Handling Capability	______ (13)	10-30	0- 9	<0
Total	______	60-115	20-59	<20

	Type
Aeration Basin	______
Secondary Clarifier	______
Sludge Handling Capability	______
Total	______

Select the Worst Case: POTW is Type______

Appendix M

Trickling Filter Major Unit Process Evaluation Worksheet

This worksheet is used to evaluate the capacity of existing major unit processes, i.e., aerator, secondary clarifier, and sludge handling system. Key loading and process parameters are compared with standard values and point scores are assigned. These points are subsequently compared with expected point scores for Type 1, Type 2, and Type 3 facilities and a determination of the plant Type is made.

Instructions for Use:

- Proceed through the steps contained in this worksheet *in order.*
- Use actual values in lieu of calculations if such data are collected and available, e.g., waste sludge volume.
- When assigning points, interpolate and use the nearest whole number.
- Minimum and maximum point values are indicated—do not exceed the range illustrated.

"Aerator" ***Calculate Equivalent Filter Media Volume:***

$$\text{Equivalent Filter Media Volume} = \frac{\text{Actual Filter Media Specific Surface Area}}{\text{Rock Filter Media Specific Surface Area}} \times \text{Actual Media Volume}$$

$$= \frac{(\_\_\_\_\_\_\ \text{sq ft/cu ft})}{(\ 43\ \text{sq ft/cu ft})} \times (\_\_\_\_\_\_\ \text{cu ft}) = \_\_\_\_\_\_\ \text{cu ft}$$

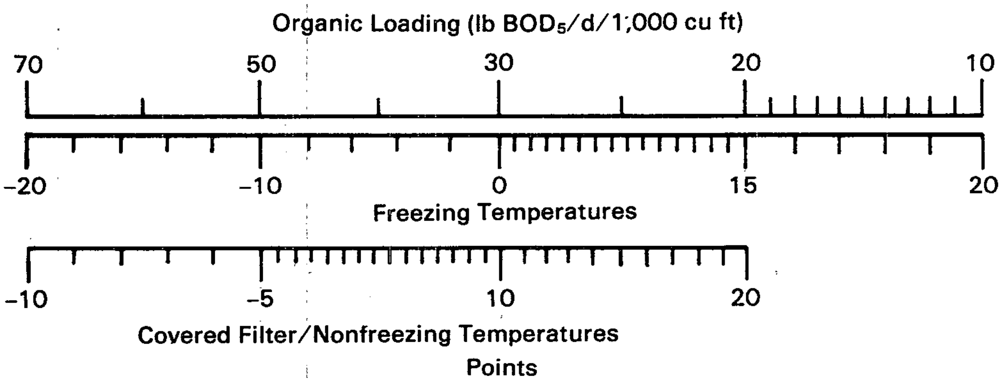
Calculate Organic Loading:

$$\text{Organic Loading} = \frac{\text{Primary Effluent } BOD_5}{\text{Equivalent Filter Media Volume}}$$

$$= \frac{(\_\_\_\_\_\_\ \text{lb/d})}{(\_\_\_\_\_\_\ \text{cu ft})} \times (1{,}000)$$

$$= \_\_\_\_\_\_\ \text{lb } BOD_5\text{/d/1,000 cu ft}$$

Determine Organic Loading Point Score:



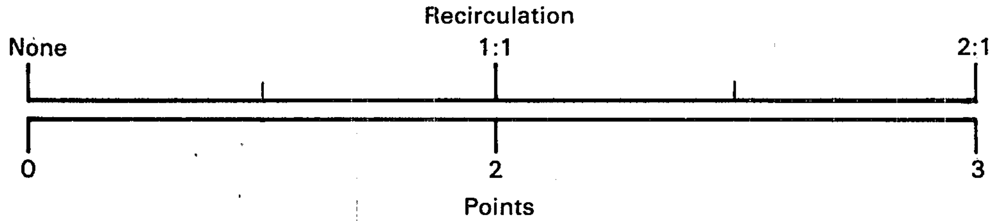
Organic Loading Point Score = ______ (1)

Calculate Recirculation Ratio:

$$\text{Recirculation Ratio} = \frac{\text{Return Flow}}{\text{Average Daily Wastewater Flow}}$$

$$= \frac{(\qquad\qquad\qquad \text{gpd})}{(\qquad\qquad\qquad \text{gpd})} = \_\_\_\_\_ :1$$

Determine Recirculation Ratio Point Score:



Recirculation Ratio Point Score = _______ (2)

Determine Anaerobic Side Streams Point Score:

Anaerobic Side Streams*	Points
Not returned ahead of trickling filter	0
Returned to the wastewater stream ahead of the trickling filter	-10

*Supernatant from anaerobic digesters or filtrate/concentrate from the dewatering processes following anaerobic digesters.

Anaerobic Side Streams Point Score = _______ (3)

Add Scores 1, 2, and 3 to Obtain Subtotal for "Aerator":

"Aerator" Subtotal = _______ (4)

Secondary Clarifier

Determine Clarifier Configuration Point Score:

Configuration	Points
Circular with "donut" or interior launders	10
Circular with weirs on walls	7
Rectangular with 33% covered with launders	0
Rectangular with 20% covered with launders	-5
Rectangular with launder at or near end	-10

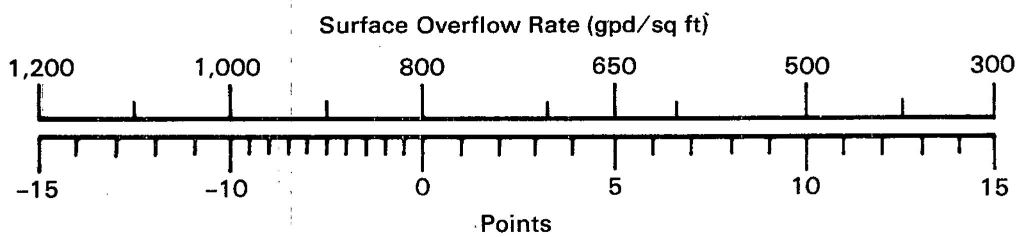
Clarifier Configuration Point Score = _______ (5)

Calculate Clarifier Surface Overflow Rate (SOR):

$$SOR = \frac{\text{Clarifier Effluent Flow}}{\text{Clarifier Surface Area}}$$

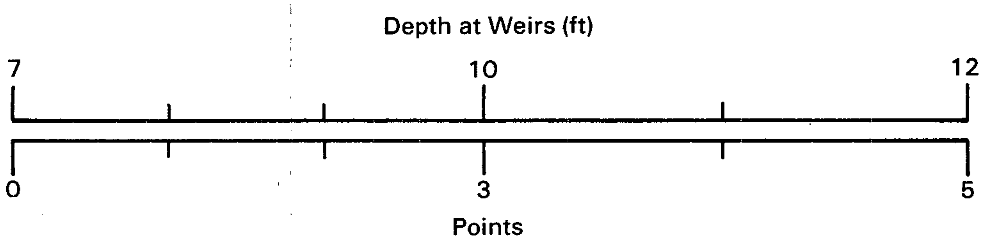
$$= \frac{(\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \text{ gpd})}{(\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \text{ sq ft})} = \_\_\_\_\_\_\_\_ \text{gpd/sq ft}$$

Determine SOR Point Score:



SOR Point Score = ________ (6)

Determine Depth at Weirs Point Score:



Depth at Weirs Score = ________ (7)

Add Scores 5, 6, and 7 to Obtain Subtotal for Secondary Clarifier:

Secondary Clarifier Subtotal = ________ (8)

Sludge Handling Capability

Determine Sludge Controllability Point Score:

Controllability	Points
Automated sampling and volume control	5
Metered volume and hand sampling	3
Hand measured volume and hand sampling	2
Sampling or volume measurement by hand not practical	0

Sludge Controllability Point Score = ________ (9)

Calculate BOD_5 Mass Removed:

Prim. BOD_{5in} – Prim. BOD_{5out} = Prim. BOD_5 Conc. Removed

(________ mg/l) – (________ mg/l) = ________ mg/l

Prim. BOD_{5out} – POTW Eff. BOD_5 = Sec. BOD_5 Conc. Removed

(________ mg/l) – (________ mg/l) = ________ mg/l

Prim. BOD_5 Conc. Removed x POTW Flow = Prim. BOD_5 Mass Removed

(________ mg/l) x (________ gpd) x (8.34×10^{-6}) = ________ lb/d

Sec. BOD_5 Conc. Removed x POTW Flow = Sec. BOD_5 Mass Removed

(________ mg/l) x (________ gpd) x (8.34×10^{-6}) = ________ lb/d

Determine Typical Unit Sludge Production from Following:

Process Type	lb TSS (sludge)/lb BOD_5 Removed
Primary Clarification	1.7
Trickling Filter	1.0

If plant records include actual sludge production data, the actual unit sludge production value should be compared to the typical value. If a discrepancy of more than 15 percent exists between the two values, further evaluation is needed. If not, use the actual unit sludge production value.

Calculate Expected Sludge Mass:

Unit Sludge Prod. x Prim. BOD_5 Mass Removed = Prim Sludge Mass

(________ lb/lb) x (________ lb/d) = ________ lb/d

Unit Sludge Prod. x Sec. BOD_5 Mass Removed = Sec. Sludge Mass

(________ lb/lb) x (________ lb/d) = ________ lb/d

Total Sludge Mass = ________ lb/d

Calculate Expected Sludge Volume:

Method 1

$$\text{Sludge Volume} = \frac{\text{Prim. Sludge Mass}}{\text{Prim. Sludge Conc.}}$$

$$= \frac{(\_\_\_\_\_\_\_\_ \text{ lb/d})}{(50{,}000 \text{ mg/l})} \times (120{,}000) = \_\_\_\_\_\_\_\_ \text{gpd}$$

$$\text{Sludge Volume} = \frac{\text{Sec. Sludge Mass}}{\text{Sec. Sludge Conc.}}$$

$$= \frac{(\_\_\_\_\_\_\_\_ \text{ lb/d})}{(30{,}000 \text{ mg/l})} \times (120{,}000) = \_\_\_\_\_\_\_\_ \text{gpd}$$

Total Sludge Volume = ________ gpd

Method 2

$$\text{Total Sludge Volume} = \frac{\text{Total Sludge Mass}}{\text{Total Sludge Conc.}}$$

$$= \frac{(\_\_\_\_\_\_\_\_ \text{ lb/d})}{(45{,}000 \text{ mg/l})} \times (120{,}000) = \_\_\_\_\_\_\_\_ \text{gpd}$$

Calculate Capacity of Sludge Handling Unit Processes:

1. Establish capacity of *each* existing sludge handling process (treatment and disposal). The most common unit processes for which this calculation will have to be performed are:

   - Aerobic digestion
   - Anaerobic digestion
   - Gravity thickening
   - Mechanical dewatering
   - Drying beds
   - Liquid haul

   For example, the capacity of a gravity thickener is the maximum sludge loading it can handle:

   $$\text{Thickener Loading} = \frac{\text{Total Sludge Mass}}{\text{Thickener Surface Area}}$$

   $$= \frac{(\qquad\qquad\qquad\qquad \text{lb/d})}{(\qquad\qquad\qquad\qquad \text{sq ft})} = \underline{\qquad\qquad}\text{lb/d/sq ft}$$

2. Determine percentage of the expected sludge production that each process can handle.

   $$\text{Process Capacity} = \frac{\text{Typical Process Loading}}{\text{Actual Process Loading}}$$

   Assume the sludge being thickened by the gravity thickener above is trickling filter. From Table 3-9, 8 lb/d/sq ft is considered typical loading for the thickener. Its capacity would therefore be calculated as:

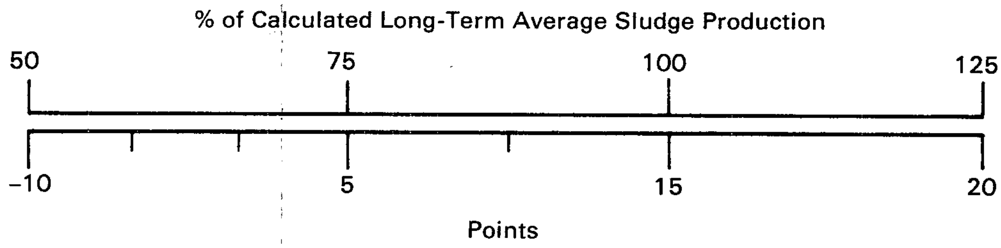
   $$\frac{(\qquad 8 \qquad \text{lb/d/sq ft})}{(\qquad\qquad\qquad \text{lb/d/sq ft})} \times (100) = \underline{\qquad\qquad}\text{percent}$$

List Each Process and Its Associated Sludge Handling Capacity and Identify the Lowest Percentage Capacity:

Process	Percentage
________________________	____________
________________________	____________
________________________	____________
________________________	____________

Lowest Capacity = ________ percent

Determine Sludge Handling Capacity Point Score:



Sludge Handling Capacity Point Score = ________ (10)

Add Scores 9 and 10 to Obtain Subtotal for Sludge Handling Capability:

Sludge Handling Capability Subtotal = ________ (11)

Compare Subtotals and Total Score with Following to Determine Whether POTW is Type 1, Type 2, or Type 3:

		Points Required		
	Score	Type 1	Type 2	Type 3
"Aerator"	________ (4)	17-23	0-11	<0
Secondary Clarifier	________ (8)	17-30	0-16	<0
Sludge Handling Capability	________ (11)	10-30	0- 9	<0
Total	________	45-83	15-44	<15

	Type
"Aerator"	________
Secondary Clarifier	________
Sludge Handling Capability	________
Total	________

Select the Worst Case: POTW is Type________

Appendix N

RBC Major Unit Evaluation Worksheet

This worksheet is used to evaluate the capacity of existing major unit processes, i.e., aerator, secondary clarifier, and sludge handling system. Key loading and process parameters are compared with standard values and point scores are assigned. These points are subsequently compared with expected point scores for Type 1, Type 2, and Type 3 facilities and a determination of the plant Type is made.

Instructions for Use:

- Proceed through the steps contained in this worksheet *in order.*
- Use actual values in lieu of calculations if such data are collected and available, e.g., waste sludge volume.
- When assigning points, interpolate and use the nearest whole number.
- Minimum and maximum point values are indicated—do not exceed the range illustrated.

"Aerator" ***Calculate First-Stage Loading:***

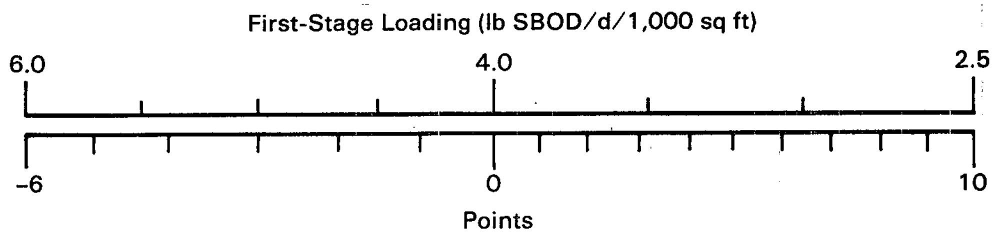
$$\text{Organic Loading} = \frac{\text{First-Stage Soluble BOD}_5\text{ Loading}}{\text{First-Stage Media Surface Area}}$$

or

$$\text{Organic Loading} = \frac{(0.5) \times (\text{First-Stage BOD}_5\text{ Loading})}{\text{First-Stage Media Surface Area}}$$

$$= \frac{(\qquad\qquad\qquad \text{lb/d})}{(\qquad\qquad\qquad \text{sq ft})} \times (1{,}000) = \underline{\qquad\qquad}\text{lb SBOD/d/1,000 sq ft}$$

Determine First-Stage Loading Point Score:



First-Stage Loading Point Score =________ (1)

Calculate System Loading:

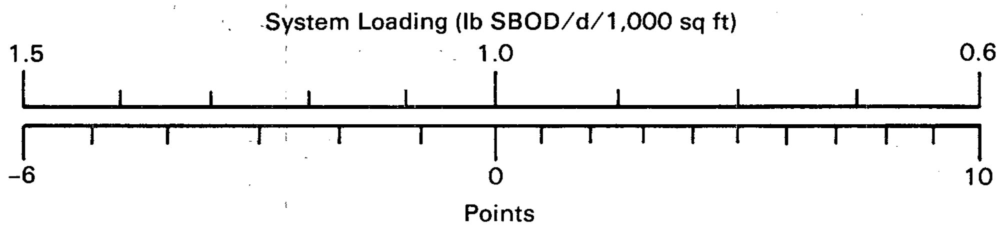
$$\text{Organic Loading} = \frac{\text{Total Soluble BOD}_5\text{ Loading}}{\text{Total Media Surface Area}}$$

or

$$\text{Organic Loading} = \frac{(0.5) \times (\text{Total BOD}_5\text{ Loading})}{\text{First-Stage Media Surface Area}}$$

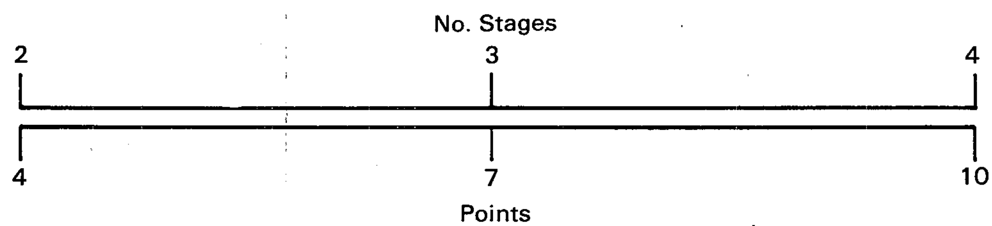
$$= \frac{(\underline{\qquad\qquad\qquad} \text{ lb/d})}{(\qquad\qquad\qquad \text{ sq ft})} \times (1{,}000) = \underline{\qquad\quad} \text{ lb SBOD/d/1,000 sq ft}$$

Determine System Loading Point Score:



System Loading Point Score = ________ (2)

Determine Number of Stages Point Score:



Number of Stages Point Score = ________ (3)

Determine Anaerobic Side Streams Point Score:

Anaerobic Side Streams*	Points
Not returned ahead of RBC	0
Returned to the wastewater stream ahead of the RBC	–10

*Supernatant from anaerobic digesters or filtrate/concentrate from the dewatering processes following anaerobic digesters.

Anaerobic Side Streams Point Score = ________ (4)

Add Scores 1, 2, 3, and 4 to Obtain Subtotal for "Aerator":

"Aerator" Subtotal = ________ (5)

Secondary Clarifier

Determine Clarifier Configuration Point Score:

Configuration	Points
Circular with "donut" or interior launders	10
Circular with weirs on walls	7
Rectangular with 33% covered with launders	0
Rectangular with 20% covered with launders	–5
Rectangular with launder at or near end	–10

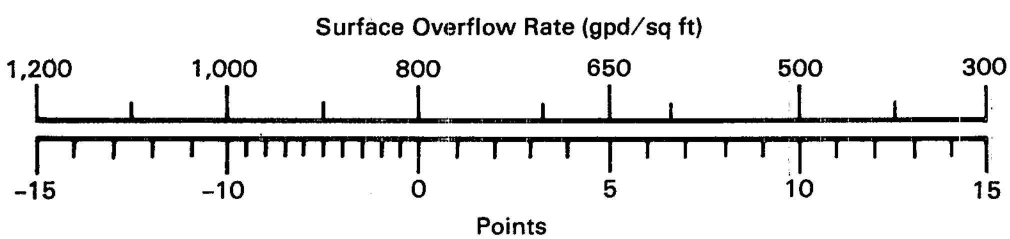
Clarifier Configuration Point Score = ________ (6)

Calculate Clarifier Surface Overflow Rate (SOR):

$$SOR = \frac{\text{Clarifier Effluent Flow}}{\text{Clarifier Surface Area}}$$

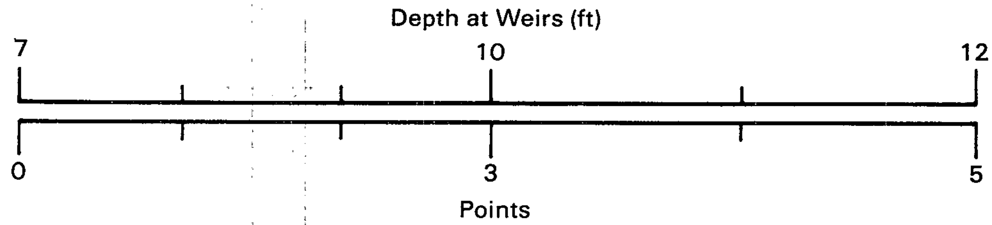
$$= \frac{(\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\ \text{gpd})}{(\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\ \text{sq ft})} = \_\_\_\_\_\_\_\_\ \text{gpd/sq ft}$$

Determine SOR Point Score:



SOR Point Score = ________ (7)

Determine Depth at Weirs Point Score:



Depth at Weirs Score = ________ (8)

Add Scores 5, 6, and 7 to Obtain Subtotal for Secondary Clarifier:

Secondary Clarifier Subtotal = ________ (9)

Sludge Handling Capability

Determine Sludge Controllability Point Score:

Controllability	Points
Automated sampling and volume control	5
Metered volume and hand sampling	3
Hand measured volume and hand sampling	2
Sampling or volume measurement by hand not practical	0

Sludge Controllability Point Score = ________ (10)

Calculate BOD_5 Mass Removed:

Prim. BOD_{5in} – Prim. BOD_{5out} = Prim. BOD_5 Conc. Removed

(________ mg/l) – (________ mg/l) = ________mg/l

Prim. BOD_{5out} – POTW Eff. BOD_5 = Sec. BOD_5 Conc. Removed

(________ mg/l) – (________ mg/l) = ________ mg/l

Prim. BOD_5 Conc. Removed x POTW Flow = Prim. BOD_5 Mass Removed

(________ mg/l) x (________ gpd) x (8.34×10^{-6}) = ________ lb/d

Sec. BOD_5 Conc. Removed x POTW Flow = Sec. BOD_5 Mass Removed

(________ mg/l) x (________ gpd) x (8.34×10^{-6}) = ________ lb/d

Determine Typical Unit Sludge Production from Following:

Process Type	lb TSS (sludge)/lb BOD_5 Removed
Primary Clarification	1.7
Trickling Filter	1.0

If plant records include actual sludge production data, the actual unit sludge production value should be compared to the typical value. If a discrepancy of more than 15 percent exists between the two values, further evaluation is needed. If not, use the actual unit sludge production value.

Calculate Expected Sludge Mass:

Unit Sludge Prod. x Prim. BOD_5 Mass Removed = Prim Sludge Mass

(________ lb/lb) x (________ lb/d) = ________ lb/d

Unit Sludge Prod. x Sec. BOD_5 Mass Removed = Sec. Sludge Mass

(________ lb/lb) x (________ lb/d) = ________ lb/d

Total Sludge Mass = ________ lb/d

Calculate Expected Sludge Volume:

Method 1

$$\text{Sludge Volume} = \frac{\text{Prim. Sludge Mass}}{\text{Prim. Sludge Conc.}}$$

$$= \frac{(\_\_\_\_\_\_\_\_ \text{ lb/d})}{(50{,}000 \text{ mg/l})} \times (120{,}000) = \_\_\_\_\_\_\_\_ \text{gpd}$$

$$\text{Sludge Volume} = \frac{\text{Sec. Sludge Mass}}{\text{Sec. Sludge Conc.}}$$

$$= \frac{(\qquad\qquad \text{lb/d})}{(\quad 30{,}000 \quad \text{mg/l})} \times (120{,}000) = \underline{\qquad\qquad}\text{gpd}$$

Total Sludge Volume = ________gpd

Method 2

$$\text{Total Sludge Volume} = \frac{\text{Total Sludge Mass}}{\text{Total Sludge Conc.}}$$

$$= \frac{(\qquad\qquad \text{lb/d})}{(\quad 45{,}000 \quad \text{mg/l})} \times (120{,}000) = \underline{\qquad\qquad}\text{gpd}$$

Calculate Capacity of Sludge Handling Unit Processes:

1. Establish capacity of *each* existing sludge handling process (treatment and disposal). The most common unit processes for which this calculation will have to be performed are:

   - Aerobic digestion
   - Anaerobic digestion
   - Gravity thickening
   - Mechanical dewatering
   - Drying beds
   - Liquid haul

   For example, the capacity of a gravity thickener is the maximum sludge loading it can handle:

   $$\text{Thickener Loading} = \frac{\text{Total Sludge Mass}}{\text{Thickener Surface Area}}$$

   $$= \frac{(\qquad\qquad \text{lb/d})}{(\qquad\qquad \text{sq ft})} = \underline{\qquad\qquad}\text{lb/d/sq ft}$$

2. Determine percentage of the expected sludge production that each process can handle.

   $$\text{Process Capacity} = \frac{\text{Typical Process Loading}}{\text{Actual Process Loading}}$$

   Assume the sludge being thickened by the gravity thickener above is mixed primary and RBC. From Table 3-9, 15 lb/d/sq ft is considered typical loading for the thickener. Its capacity would therefore be calculated as:

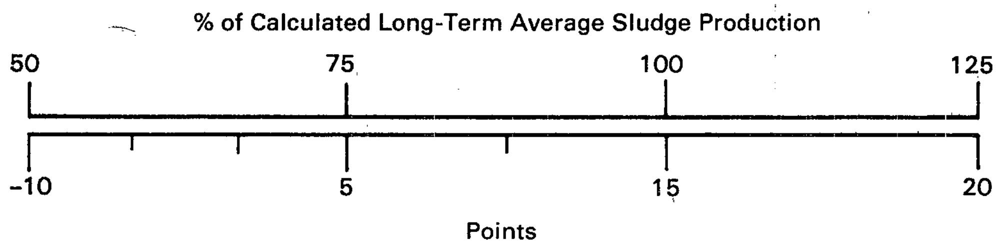
   $$\frac{(\quad 15 \quad \text{lb/d/sq ft})}{(\qquad\qquad \text{lb/d/sq ft})} \times (100) = \underline{\qquad\qquad}\text{percent}$$

List Each Process and Its Associated Sludge Handling Capacity and Identify the Lowest Percentage Capacity:

Process	Percentage
____________________	__________
____________________	__________
____________________	__________
____________________	__________

Lowest Capacity = ________ percent

Determine Sludge Handling Capacity Point Score:



Sludge Handling Capacity Point Score = ________ (11)

Add Scores 10 and 11 to Obtain Subtotal for Sludge Handling Capability:

Sludge Handling Capability Subtotal = ________ (12)

Compare Subtotals and Total Score with Following to Determine Whether POTW is Type 1, Type 2, or Type 3:

	Score	Points Required		
		Type 1	Type 2	Type 3
"Aerator"	________ (5)	14-30	0-13	<0
Secondary Clarifier	________ (9)	17-30	0-16	<0
Sludge Handling Capability	________ (12)	10-30	0- 9	<0
Total	________	48-90	15-47	<15

	Type
"Aerator"	________
Secondary Clarifier	________
Sludge Handling Capability	________
Total	________

Select the Worst Case: POTW is Type ________

Appendix O

ABF Major Unit Evaluation Worksheet

This worksheet is used to evaluate the capacity of existing major unit processes, i.e., aerator, secondary clarifier, and sludge handling system. Key loading and process parameters are compared with standard values and point scores are assigned. These points are subsequently compared with expected point scores for Type 1, Type 2, and Type 3 facilities and a determination of the plant Type is made.

Instructions for Use:

- Proceed through the steps contained in this worksheet *in order.*
- Use actual values in lieu of calculations if such data are collected and available, e.g., waste sludge volume.
- When assigning points, interpolate and use the nearest whole number.
- Minimum and maximum point values are indicated—do not exceed the range illustrated.

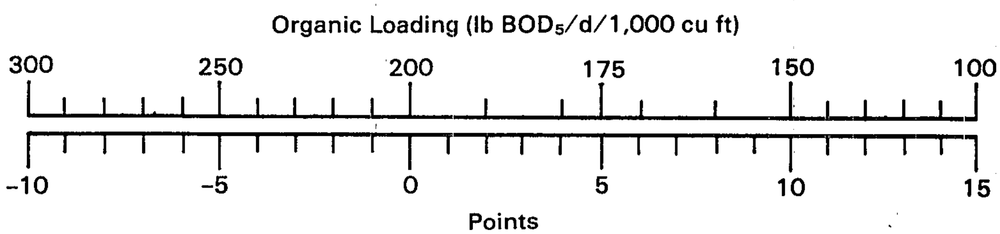
"Aerator" ***Calculate Biocell Organic Loading:***

$$\text{Organic Loading} = \frac{\text{BOD}_5\text{ Loading}}{\text{Biocell Media Volume}}$$

$$= \frac{(\_\_\_\_\_\_\_\_\_\_\ \text{lb/d})}{(\_\_\_\_\_\_\_\_\_\_\ \text{cu ft})} \times (1{,}000)$$

$$= \_\_\_\_\_\_\_\_\ \text{lb BOD}_5\text{/d/1,000 cu ft}$$

Determine Biocell Organic Loading Point Score:



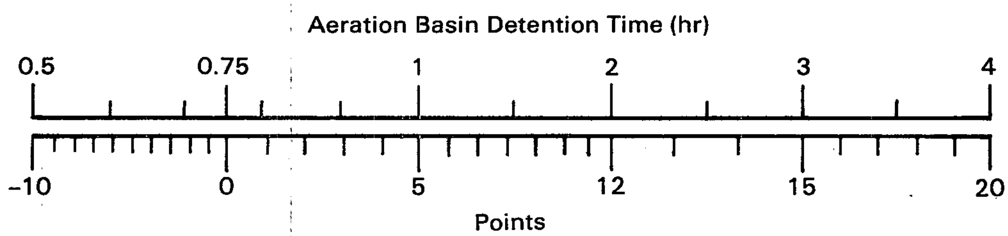
Organic Loading Point Score = ________ (1)

Calculate Aeration Basin Detention Time:

$$\text{Aeration Basin Detention Time} = \frac{\text{Aeration Basin Volume}}{\text{Average Daily Wastewater Flow}}$$

$$= \frac{(\qquad\qquad\qquad\qquad \text{cu ft})}{(\qquad\qquad\qquad\qquad \text{gpd})} \times (180) = \underline{\qquad\qquad}\text{hr}$$

Determine Aeration Basin Detention Point Score:



Aeration Basin Detention Point Score = ________ (2)

Calculate Oxygen Availability:

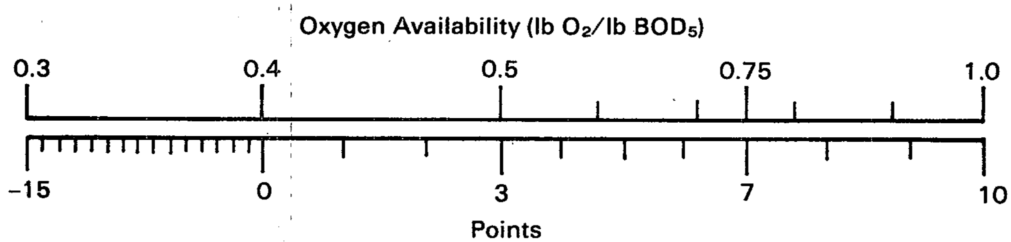
If data are not available on oxygen transfer capacity, calculate it as Wire Horsepower (Appendix E) times actual Oxygen Transfer Rate (Appendix F).

(__________hp) x (__________lb/hp-hr) x (24) = ________lb/d

$$\text{Oxygen Availability} = \frac{\text{Oxygen Transfer Capacity}}{\text{Biocell } BOD_5 \text{ Loading}}$$

$$= \frac{(\qquad\qquad\qquad\qquad \text{lb/d})}{(\qquad\qquad\qquad\qquad \text{lb/d})} = \underline{\qquad\qquad}\text{lb } O_2/\text{lb } BOD_5$$

Determine Oxygen Availability Point Score:



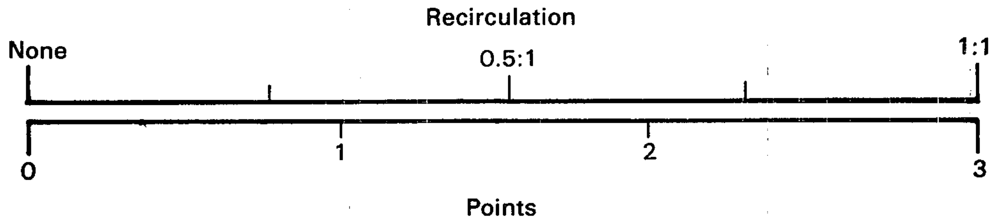
Oxygen Availability Point Score = ________ (3)

Calculate Recirculation Ratio:

$$\text{Recirculation Ratio} = \frac{\text{Return Flow}}{\text{Average Daily Wastewater Flow}}$$

$$= \frac{(\qquad\qquad\qquad \text{gpd})}{(\qquad\qquad\qquad \text{gpd})} = \underline{\qquad\quad}:1$$

Determine Recirculation Ratio Point Score:



Recirculation Ratio Point Score = ________ (4)

Add Scores 1, 2, 3, and 4 to Obtain Subtotal for "Aerator":

"Aerator" Subtotal = ________ (5)

Secondary Clarifier

Determine Clarifier Configuration Point Score:

Configuration	Points
Circular with "donut" or interior launders	10
Circular with weirs on walls	7
Rectangular with 33% covered with launders	0
Rectangular with 20% covered with launders	–5
Rectangular with launder at or near end	–10

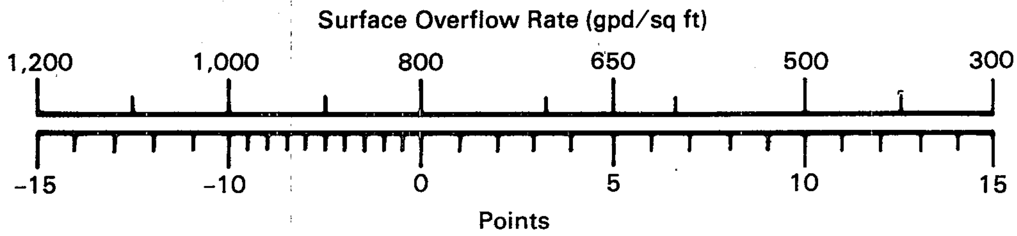
Clarifier Configuration Point Score = ________ (6)

Calculate Clarifier Surface Overflow Rate (SOR):

$$\text{SOR} = \frac{\text{Clarifier Effluent Flow}}{\text{Clarifier Surface Area}}$$

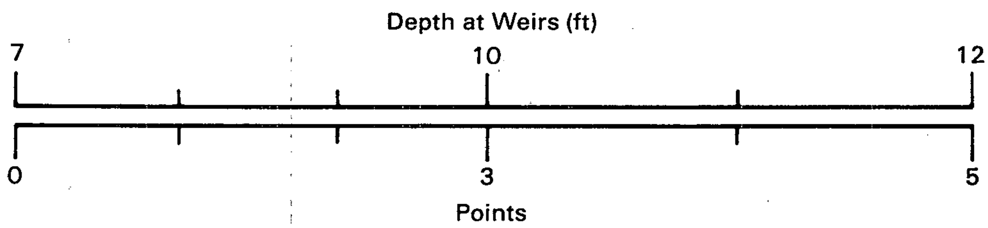
$$= \frac{(\qquad\qquad\qquad \text{gpd})}{(\qquad\qquad\qquad \text{sq ft})} = \underline{\qquad\quad}\text{gpd/sq ft}$$

Determine SOR Point Score:



SOR Point Score = ________ (7)

Determine Depth at Weirs Point Score:



Depth at Weirs Score = ________ (8)

Calculate Recommended RAS Flow Range:

Min. Typical Typical RAS Rate x POTW Flow = Min. Recommended RAS Flow

(25 %) x (____________________ gpd) x (0.01) = ________ gpd

Max. Typical Typical RAS Rate x POTW Flow = Min. Recommended RAS Flow

(75 %) x (____________________ gpd) x (0.01) = ________ gpd

Determine Actual RAS Flow Range:

Minimum Actual RAS Flow = ________ gpd

Maximum Actual RAS Flow = ________ gpd

Determine RAS Control Point Score:

RAS Control	Points
The actual RAS flow range is completely within the recommended RAS flow range and the capability to measure RAS flow exists	10
The actual RAS flow range is completely within the recommended RAS flow range but the capability to measure RAS flow does not exist	7
50% of the recommended RAS flow range is covered by the actual RAS flow range and the capability to measure RAS flow exists	5
50% of the recommended RAS flow range is covered by the actual RAS flow range but the capability to measure RAS flow does not exist	0
The actual RAS flow range is completely outside the recommended RAS flow range	–5

RAS Control Point Score = ________ (9)

Add Scores 5, 6, 7, 8, and 9 to Obtain Subtotal for Secondary Clarifier:

Secondary Clarifier Subtotal = ________ (10)

Sludge Handling Capability

Determine Sludge Controllability Point Score:

Controllability	Points
Automated sampling and volume control	5
Metered volume and hand sampling	3
Hand measured volume and hand sampling	2
Sampling or volume measurement by hand not practical	0

Sludge Controllability Point Score = ________ (11)

Calculate BOD_5 Mass Removed:

Prim. BOD_{5in} – Prim. BOD_{5out} = Prim. BOD_5 Conc. Removed

(________ mg/l) – (________ mg/l) = ________ mg/l

Prim. BOD_{5out} – POTW Eff. BOD_5 = Sec. BOD_5 Conc. Removed

(________ mg/l) – (________ mg/l) = ________ mg/l

Prim. BOD_5 Conc. Removed x POTW Flow = Prim. BOD_5 Mass Removed

(________ mg/l) x (________ gpd) x (8.34×10^{-6}) = ________ lb/d

Sec. BOD_5 Conc. Removed x POTW Flow = Sec. BOD_5 Mass Removed

(________ mg/l) x (________ gpd) x (8.34×10^{-6}) = ________ lb/d

Determine Typical Unit Sludge Production from Following:

Process Type	lb TSS (sludge)/lb BOD_5 Removed
Primary Clarification	1.7
Trickling Filter	1.0

If plant records include actual sludge production data, the actual unit sludge production value should be compared to the typical value. If a discrepancy of more than 15 percent exists between the two values, further evaluation is needed. If not, use the actual unit sludge production value.

Calculate Expected Sludge Mass:

Unit Sludge Prod. x Prim. BOD_5 Mass Removed = Prim Sludge Mass

(________ lb/lb) x (________ lb/d) = ________ lb/d

Unit Sludge Prod. x Sec. BOD_5 Mass Removed = Sec. Sludge Mass

(________ lb/lb) x (________ lb/d) = ________ lb/d

Total Sludge Mass = ________ lb/d

Calculate Expected Sludge Volume:

Method 1

$$\text{Sludge Volume} = \frac{\text{Prim. Sludge Mass}}{\text{Prim. Sludge Conc.}}$$

$$= \frac{(\_\_\_\_\_\_\_\_\ \text{lb/d})}{(\ 50{,}000\ \text{mg/l})} \times (120{,}000) = \_\_\_\_\_\_\_\_ \text{gpd}$$

$$\text{Sludge Volume} = \frac{\text{Sec. Sludge Mass}}{\text{Sec. Sludge Conc.}}$$

$$= \frac{(\_\_\_\_\_\_\_\_\ \text{lb/d})}{(\ 12{,}000\ \ \text{mg/l})} \times (120{,}000) = \_\_\_\_\_\_\_\_\ \text{gpd}$$

Total Sludge Volume = ________gpd

Method 2

$$\text{Total Sludge Volume} = \frac{\text{Total Sludge Mass}}{\text{Total Sludge Conc.}}$$

$$= \frac{(\_\_\_\_\_\_\_\_\ \text{lb/d})}{(\ 35{,}000\ \ \text{mg/l})} \times (120{,}000) = \_\_\_\_\_\_\_\_\ \text{gpd}$$

Calculate Capacity of Sludge Handling Unit Processes:

1. Establish capacity of *each* existing sludge handling process (treatment and disposal). The most common unit processes for which this calculation will have to be performed are:

   - Aerobic digestion
   - Anaerobic digestion
   - Gravity thickening
   - Mechanical dewatering
   - Drying beds
   - Liquid haul

   For example, the capacity of a gravity thickener is the maximum sludge loading it can handle:

   $$\text{Thickener Loading} = \frac{\text{Total Sludge Mass}}{\text{Thickener Surface Area}}$$

   $$= \frac{(\_\_\_\_\_\_\_\_\ \text{lb/d})}{(\_\_\_\_\_\_\_\_\ \text{sq ft})} = \_\_\_\_\_\_\_\_\ \text{lb/d/sq ft}$$

2. Determine percentage of the expected sludge production that each process can handle.

   $$\text{Process Capacity} = \frac{\text{Typical Process Loading}}{\text{Actual Process Loading}}$$

   Assume the sludge being thickened by the gravity thickener above is ABF. From Table 3-9, 4 lb/d/sq ft is considered typical loading for the thickener. Its capacity would therefore be calculated as:

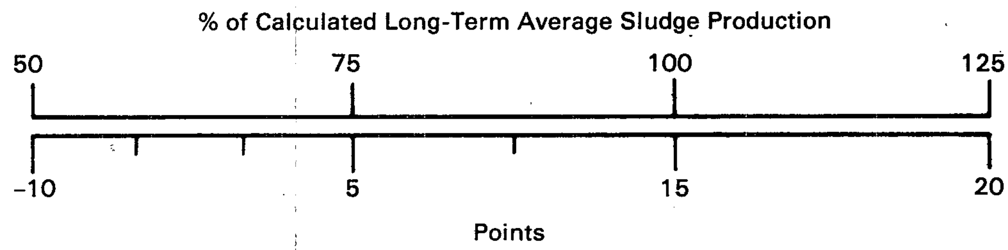
   $$\frac{(\ 4\ \ \text{lb/d/sq ft})}{(\_\_\_\_\_\_\_\_\ \text{lb/d/sq ft})} \times (100) = \_\_\_\_\_\_\_\_\ \text{percent}$$

List Each Process and Its Associated Sludge Handling Capacity and Identify the Lowest Percentage Capacity:

Process	Percentage

Lowest Capacity = ________ percent

Determine Sludge Handling Capacity Point Score:



Sludge Handling Capacity Point Score = ________ (12)

Add Scores 11 and 12 to Obtain Subtotal for Sludge Handling Capability:

Sludge Handling Capability Subtotal = ________ (13)

Compare Subtotals and Total Score with Following to Determine Whether POTW is Type 1, Type 2, or Type 3:

		Points Required		
	Score	Type 1	Type 2	Type 3
"Aerator"	________ (5)	15-48	0-14	<0
Secondary Clarifier	________ (10)	20-55	0-19	<0
Sludge Handling Capability	________ (13)	10-30	0- 9	<0
Total	________	50-133	15-49	<15

	Type
"Aerator"	________
Secondary Clarifier	________
Sludge Handling Capability	________
Total	________

Select the Worst Case: POTW is Type________

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