THE ONTARIO COMPOSITE CORRECTION PROGRAM MANUAL FOR OPTIMIZATION OF SEWAGE TREATMENT PLANTS

Prepared for

Ontario Ministry of Environment and Energy
Environment Canada
The Municipal Engineers Association

Prepared by

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and

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The Ontario Composite Correction Program Manual for Optimization of Sewage Treatment Plants describes how to apply the Composite Correction Program to economically improve the performance of existing municipal sewage treatment plants in Ontario. The Composite Correction Program was developed by the U.S. Environmental Protection Agency and the contents of this handbook were adapted for Ontario from the Handbook: Retrofitting POTWs, published by the U.S. Environmental Protection Agency in 1989. The project team involved in the revisions wishes to thank the U.S. Environmental Protection Agency and acknowledge the Agency's role in developing and promoting the CCP approach.

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Chapter 1
Introduction

1.1 Purpose

This manual is intended as a source document for optimizing the performance of an existing wastewater treatment facility. Described are: a.) methods to evaluate an existing facility's capability to achieve improved performance, and b.) a process for systematically improving its performance. The manual emphasizes meeting effluent requirements as established by the plant's Certificate of Approval (C of A) or Procedure F-5-1, "Guidelines for the Determination of Treatment Requirements for Municipal and Private Sewage Treatment Works, Discharging to Surface Waters" of the Ontario Ministry of Environment and Energy. Although not intended to describe cost saving options or to present alternatives for designing new facilities for expansion purposes (i.e., to provide increased hydraulic and/or BOD loading capacity), the manual describes approaches which may result in cost savings and/or increased capability in some cases.

1.2 Background

The need for better treatment performance from existing facilities is widespread. Usually the most cost effective approach for operating agencies to achieve improved performance is to optimize existing facilities either in terms of capital or operational improvements. A major tool for economically improving the performance of existing facilities is the Composite Correction Program. The following sections describe the origin of this program in the United States and its demonstration and subsequent adoption in Ontario.

1.2.1 Origin in the U.S.

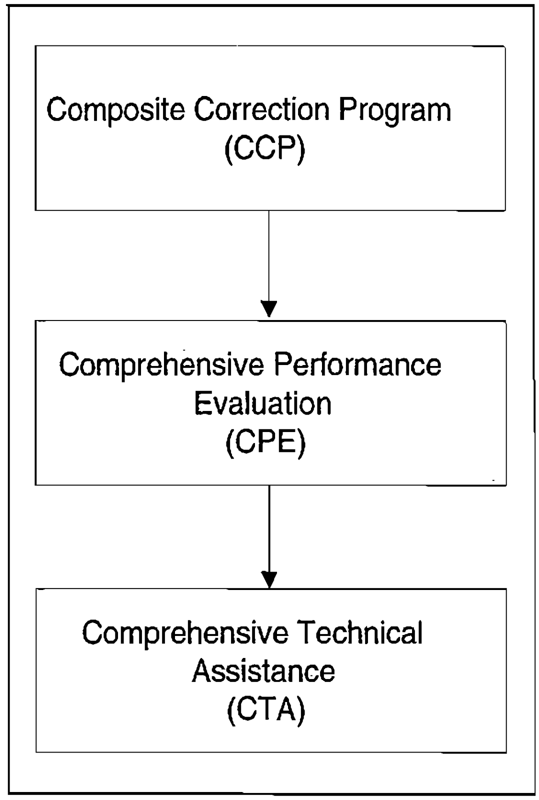
The U.S. Environmental Protection Agency conducted a comprehensive national survey in the late 1970s to identify and quantify the specific causes of inadequate STP performance (1-4). Site visits were conducted at 287 facilities and detailed evaluations conducted at 103 facilities to identify the most predominant problems. Top factors identified were in four major areas that affect plant performance: design, administration, operation and maintenance. A major conclusion from the study was that each STP has a combination of performance-limiting factors which are unique to that facility.

In response to the survey, the U.S. Environmental Protection Agency developed a program to effectively address performance-limiting factors at an individual STP. The program, termed the Composite Correction Program, brings together positive features of many individual approaches to correct the specific performance-limiting factors at an individual STP. The U.S. Environmental Protection Agency's National Municipal

Policy requires non-complying facilities to develop a Composite Correction Plan to identify the causes of non-compliance and to outline corrective actions and a schedule for completing the corrective actions in order to achieve compliance.

In the late 1980's, pressure to optimize the performance of water treatment facilities was precipitated by the Safe Drinking Water Act. In response to this need, the Composite Correction Program was adapted to surface water treatment plants (5). After, development of the technical documentation work was initiated and has continued through 1994 to encourage the implementation of the CCP approach by the State water program personnel.

Figure 1-1. CCP Components.



The Composite Correction Program (CCP) as developed by the US EPA, is a two step process. This process is shown in Figure 1-1. The first step is the Comprehensive Performance Evaluation (CPE). The CPE examines four areas - operations, design, administration, and maintenance - and from these areas performance-limiting factors are identified. The relationship between these factors and the goal of a good, economical effluent is shown in Figure 1-2.

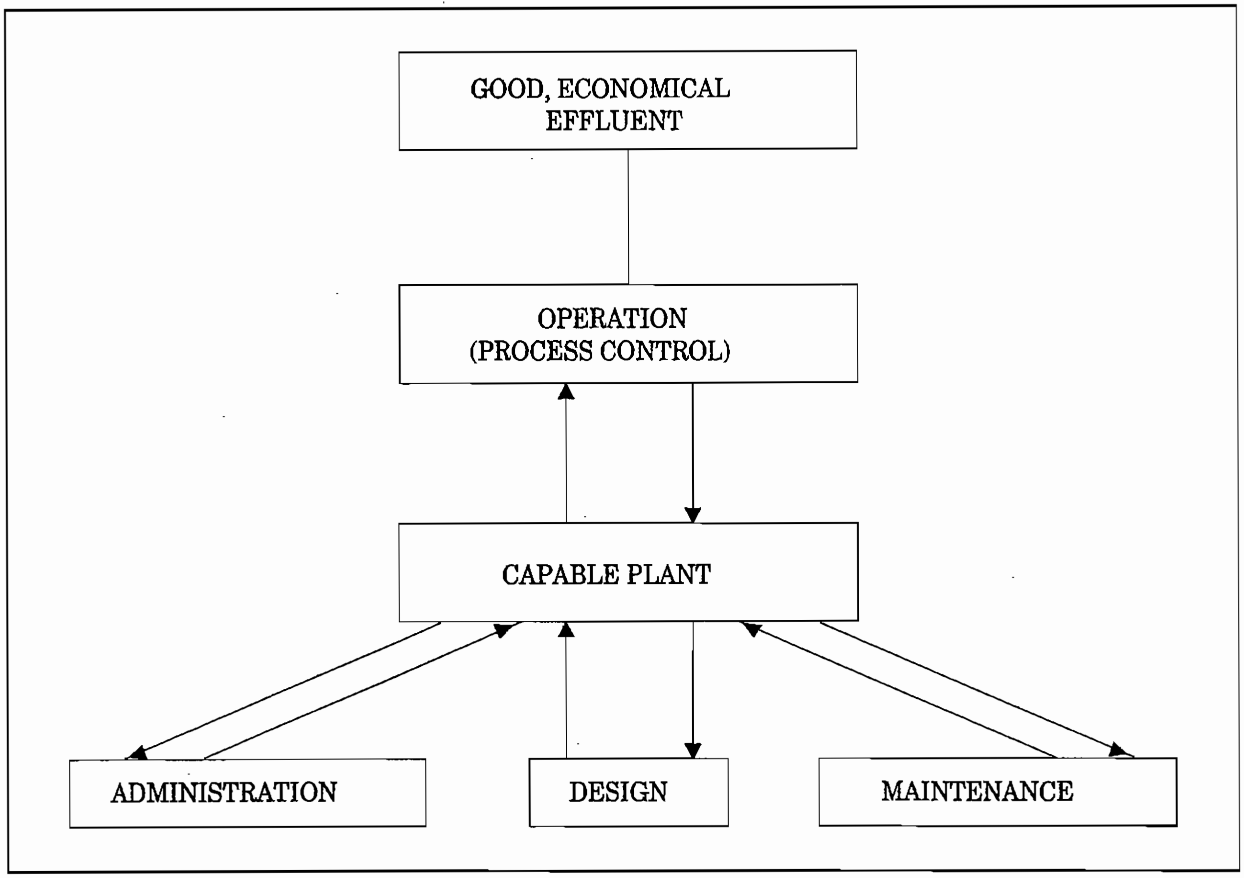
If the STP is deemed capable, then the CPE determines the combination of performance-limiting factors (from the four areas) that are preventing the STP from achieving a good, economical effluent. After determining that the STP is capable, the next step is to address the prioritized list of performance limiting factors through a Comprehensive Technical Assistance (CTA) program.

If the STP is deemed not capable, then the next step is to go to a process audit or design upgrade. The CTA cannot be instigated at this point because there are major design limitations that are preventing the STP from achieving a good, economical effluent.

1.2.2 History in Ontario

In May 1991, the Ontario Ministry of Environment and Energy and Environment Canada, in cooperation with the Municipal Engineers Association initiated a three-year study to: a.) identify factors contributing to poor effluent quality at Ontario STPs, and b.) identify, evaluate, and demonstrate procedures for improving the ability

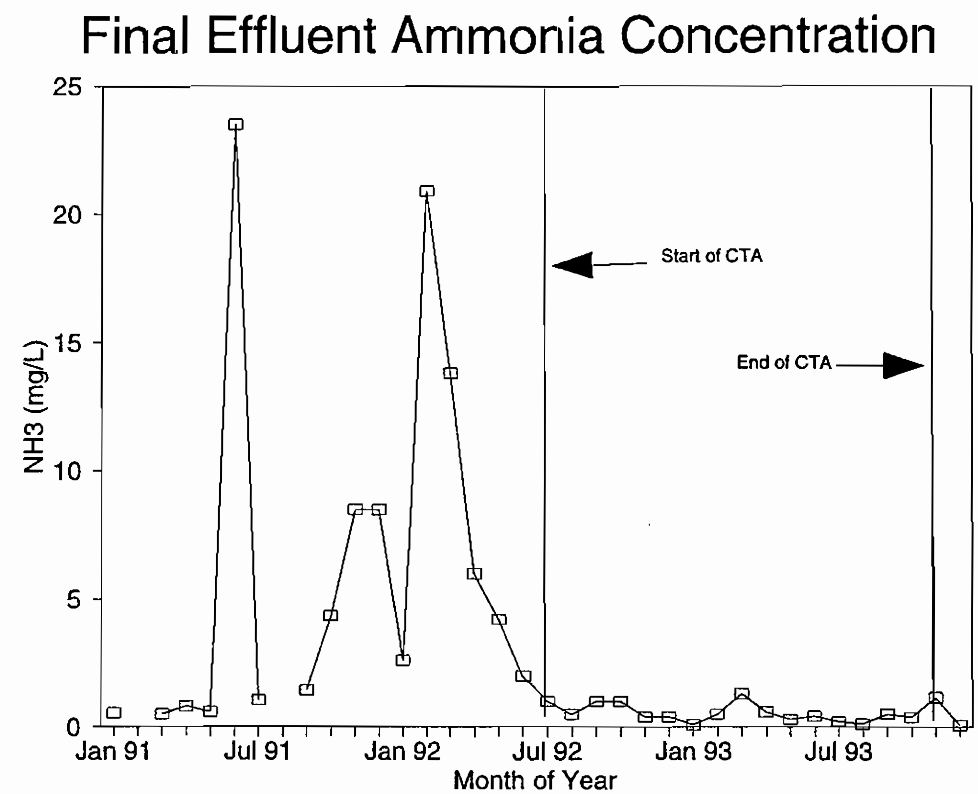
Figure 1-2. Relationship of Factors to a Good, Economical Effluent.



of existing facilities to meet compliance limits without major expansion. The first phase of the study identified the principal factors limiting the performance of Ontario STPs (6). Subsequent phases demonstrated and evaluated the Composite Correction Program as a tool for diagnosing and subsequently improving the performance of Ontario STPs (7-8).

The study determined that the Composite Correction Program was an effective and valuable tool for identifying and resolving performance-limiting factors at existing STPs in Ontario. No major modifications to the existing program were required prior to broadscale applications in Ontario. It was recommended that on-site training be provided to develop the necessary skills to effectively deliver the Composite Correction Program. In addition, it was recommended that the U.S. EPA's Handbook: Retrofitting POTWs, the most recent source document describing the Composite Correction Program, be modified for use in Ontario. The recommended modifications include conversion to metric, inclusion of procedures to estimate sludge production from the addition of metal salts for phosphorus removal, simplified oxygen transfer calculations, and Ontario examples.

Figure 1-3. Example of Improved Effluent Quality Achieved by a CTA.



1.3 Documented Benefits

The results from the three-year study conducted by MOEE and Environment Canada indicated the potential for low-cost optimization of many Ontario treatment plants through application of the Composite Correction Program. Benefits demonstrated through application of the CCP included enhanced effluent quality (Figure 1-3), improved operator motivation/confidence (Table 1-1) and, in some cases, reduced operating costs (Table 1-2).

A strategy was recommended to effectively implement the Composite Correction Program as part of a broad-scale approach to cost-effectively optimize all municipal STPs in Ontario. This strategy is outlined in Section 1.4.

Table 1-1 Verbatim Quotes from Operators

Before CCP	After CCP
"I have worked at MOEE for 10 years. I used to hate getting up in the morning and going to work." "There was no challenge to plant operation, or opportunity to be part of a good operations program."	"...having learned and witnessed the impact of good process control, I can't wait to get to work in the morning." "I can see an environmental benefit and I know how it is being achieved. The program works!" "This is satisfaction! We control the plant now, instead of in the past when the plant controlled the operators."

Table 1-2 Reduction in Sludge Haulage Costs at a 681 m^3/d Package Plant

Period	Costs
1992 - Prior to Technical Assistance	$28,600.
1993 - With Technical Assistance	$12,800.
Savings - $	$15,800.
Savings - %	55.%

1.4 Proposed Approach in Ontario

Figure 1-4 outlines the strategy proposed by the Ontario Ministry of Environment and Energy to employ the Composite Correction Program to improve the performance of existing plants. The first step of the overall strategy is a Self-Assessment Report which will be completed by the operating agency on an annual basis. The objectives of the Self-Assessment Report are:

- to assist operating agencies and the MOEE to evaluate the performance of an STP, providing an early warning system for deteriorating performance or the need for possible upgrading or expansion to accommodate growth,

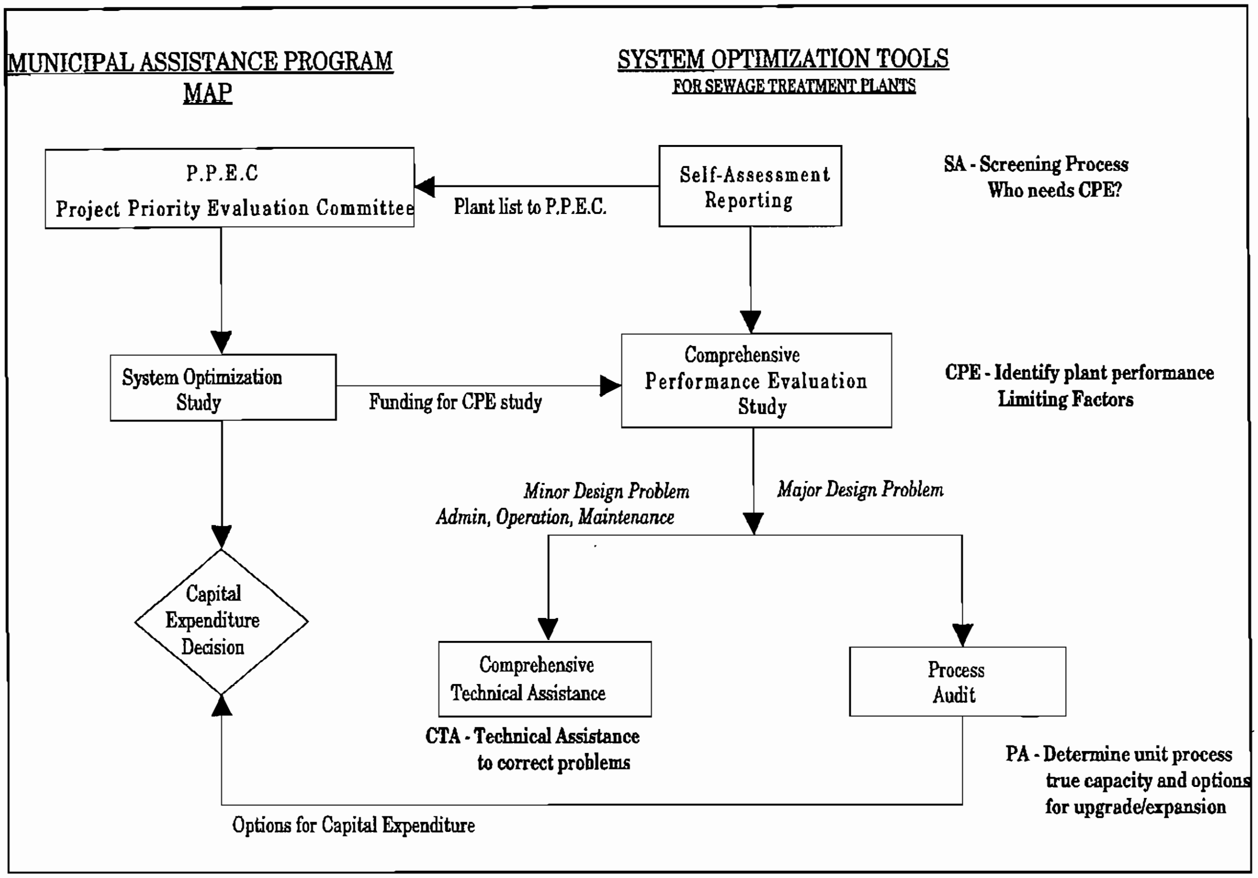
- to identify plants in need of optimization to improve performance,

- to prioritize plants for optimization study funding under Ontario's Municipal Assistance Program,

- to minimize unnecessary capital expansion, and

- to satisfy all MOEE reporting requirements with one comprehensive format.

Figure 1-4. Methodology for achieving STP compliance.



The Self Assessment report is divided into sections to establish such indicators as the condition, performance, and capacity of the treatment system based on the previous year's data. Point scores are assigned to each response, with the total point score indicating the need for action to correct deficiencies or plan for future growth. Plants with a point score above the Action Range can apply to the Municipal Assistance Program for funding to conduct a Comprehensive Performance Evaluation, the first phase of the Composite Correction Program.

During a Comprehensive Performance Evaluation, the major unit processes are evaluated to determine if they are capable of achieving the facility's discharge C of A at existing flows and loads. Operation, design, maintenance, and administration of the plant are evaluated to determine how performance is affected. When the evaluation establishes that the major unit processes are capable of treating the existing flow and loadings, and the performance of the STP does not meet effluent requirements, the second step of the program, the Comprehensive Technical Assistance, is initiated.

During Comprehensive Technical Assistance, prioritized performance-limiting factors are systematically addressed and resolved to enable the treatment plant to achieve the desired effluent quality. Assistance is provided to operations staff so that process control skills are in place to produce a good, economical effluent quality from the capable plant. Activities may include a process control workshop, routine site visits, facilitating staff to improve data trending and interpretation, special studies to address non-routine problems, assisting operators to prepare their own process control operations manuals, and working with administration to facilitate better communication and understanding of plant needs. Where administration limitations are identified, (i.e., inadequate staff, improper manpower allocation, morale, budget support, etc.) assistance is offered to resolve the limitation.

When the Comprehensive Performance Evaluation establishes that the unit processes are incapable of treating the existing flow to achieve the required performance, a process audit is recommended. The process audit employs on-line monitoring and composite sampling to accurately evaluate the actual capacity of a treatment facility and to identify any process bottlenecks which limit plant performance. During an audit, measurements are made to determine the oxygen transfer capacities of existing equipment, more accurately characterize flows and concentrations, and evaluate secondary sedimentation tanks under stress conditions. Based on the results from the audit, information is obtained to design the selective expansion of the facility and to determine the opportunity for further optimizing the process through low-cost modifications and elimination of process bottlenecks.

Should major plant upgrades, modifications, or expansions be made as a result of the process audit, Comprehensive Technical Assistance is recommended following the upgrading or expansion. The objective is to address any outstanding operations, administration, or maintenance limitations.

1.5 Intended Audience

The intended users of this manual are process consultants, operators, regulators, trainers, designers, and others associated with the responsibility of achieving compliance or more reliable performance from their existing facilities. The manual provides procedures for: a.) conducting Comprehensive Performance Evaluations, and b.) implementing Comprehensive Technical Assistance activities to correct performance-limiting factors. The manual focusses on mechanical secondary treatment facilities ie. conventional activated sludge, extended aeration, contact stabilization, oxidation ditches, etc.

Table 1-3 Revisions and Additions to Handbook: Retrofitting POTWs

Revisions	Additions
- conversion to metric; - Major unit process evaluation based on performance potential graph in place of point scoring system (sec 2.3.3) - Text and figures revised to reflect conditions in Ontario, ie. STP for POTW, etc. - Oxygen transfer nomographs provided simplify the calculations; calculations placed in Appendix E; - A sludge accountability example provided reflecting Ontario conditions; - CCP costs updated to 1993 dollars; - Information removed on wastewater stabilization ponds; - The typical RAS values table was moved from Chapter 2 to Chapter 3.	- Description provided of optimization strategy for Ontario (1.4); - Information on current U.S. EPA water project (Section 1.2.1); - A CPE checklist (Section 2.3.2); - A sample letter to introduce a CPE (2.3); - Information on chemical sludge production (2.3.3.4); - Examples of CPE reports for Ontario STPs (Appendix C); - Typical design values for various unit processes, as provided by the "Ministry of the Environment and Energy's Design Guidelines for Water Treatment and Sewage Treatment Plants",(Appendix G); - Unit conversion tables (Appendix H); - Glossary of terms (Appendix L);

Information on selecting facility modifications for secondary treatment plants that have identified design limitations can be found in Chapter 4 of Handbook: Retrofitting POTWs (9) and other sources. A manual for conducting process audits is currently under preparation.

1.6 Using the Manual

This manual represents a revised and expanded update of Chapters 1 to 3 of the U.S. EPA's Handbook: Retrofitting POTWs (9) to make the Composite Correction Program more accessible to wastewater treatment professionals in Ontario. Table 1-3 lists the revisions and additions which were made to the original EPA handbook. The manual is intended to be used in whole or in part to pursue improved performance with existing secondary treatment facilities.

Text of the manual closely parallels the major steps depicted in Figure 1-1. Chapter 2 describes the Comprehensive Performance Evaluation protocol to identify reasons for noncompliance or performance and to assess the suitability of existing facilities for improved performance. At non-complying facilities, this evaluation procedure should be implemented before a decision is made to pursue the next phase of performance improvement.

The basic criteria for evaluating major unit processes listed in Chapter 2 were not changed from the original CCP Manual. It is important to note that these evaluation criteria are provided as a guideline and it is the judgement and experience of the evaluator that ultimately decides the capability of the unit processes. The evaluator's judgement is supported by information collected during the CPE from operator interviews, observations, performance data review etc. If the evaluation is to be submitted to the MOEE for comments or approval the evaluator should take particular note of the MOEE design guidelines listed in Appendix G.

Chapter 3 discusses the Comprehensive Technical Assistance approach which details methods of optimizing existing facilities without major capital expenditures. Procedures to address design, operation, maintenance, and administrative factors limiting performance are outlined. Implementation of technical assistance ensures optimization of existing facilities, and, if compliance is not achieved, the design factors limiting performance are identified.

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Chapter 2
Comprehensive Performance Evaluations

2.1 Introduction

This chapter provides information on the evaluation phase of a two-step process to economically improve the performance of existing sewage treatment plants (STPs). The evaluation phase, called a Comprehensive Performance Evaluation (CPE), is a thorough review and analysis of a STP's design capabilities and associated administrative, operational, and maintenance practices. It is conducted to provide information for STP 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 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 which can be corrected to improve performance.

The second step of the process is called Comprehensive Technical Assistance (CTA) and represents the performance improvement phase. It is a systematic approach to eliminating those factors that inhibit performance in existing STPs. A CTA focuses on optimizing the capability of existing facilities to perform better. This phase is described in Chapter 3.

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

2.2 Approach to Conducting CPEs

2.2.1 Methodology

A CPE involves several activities: assessment of plant performance; evaluation of the major unit processes; identification and prioritization of performance-limiting factors; assessment of the applicability of a follow-up Comprehensive Technical Assistance (CTA); and reporting results of the evaluation. Although these are distinct activities, some are conducted concurrently with others. For example, evaluation of the major unit processes and identification of performance-limiting factors are generally undertaken at the same time.

Although this chapter 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.

2.2.1.1 Assessment of Plant Performance

Typically the reason for conducting a CPE is to identify factors limiting the performance of an existing facility. As such, the past and current performance of a facility are of interest. As a first step recorded historical data can be assessed. Normally the most current one-year period is used for this performance assessment. Once historical data are reviewed, the evaluator should attempt to verify the accuracy of the reported plant performance. Flow and mass loadings can be checked by comparing plant information and current population served to typical per capita contributions. Additionally, a Sludge Accountability Evaluation is prepared by comparing expected sludge production to actual sludge production. This comparison has proven to be invaluable in conducting a CPE. Specific activities for completing an assessment of plant performance will be further described in this chapter.

2.2.1.2 Evaluation of Major Unit Processes

Major unit processes are evaluated to assess their <u>potential</u> to achieve desired performance levels. If the CPE indicates that the major unit processes are adequate or potentially adequate, a major plant expansion or upgrade may not be necessary and a properly conducted CTA should be implemented to achieve optimum performance. If, on the other hand, the CPE shows that major unit processes are inadequate, owners should consider modification of these processes as the focus for achieving desired performance.

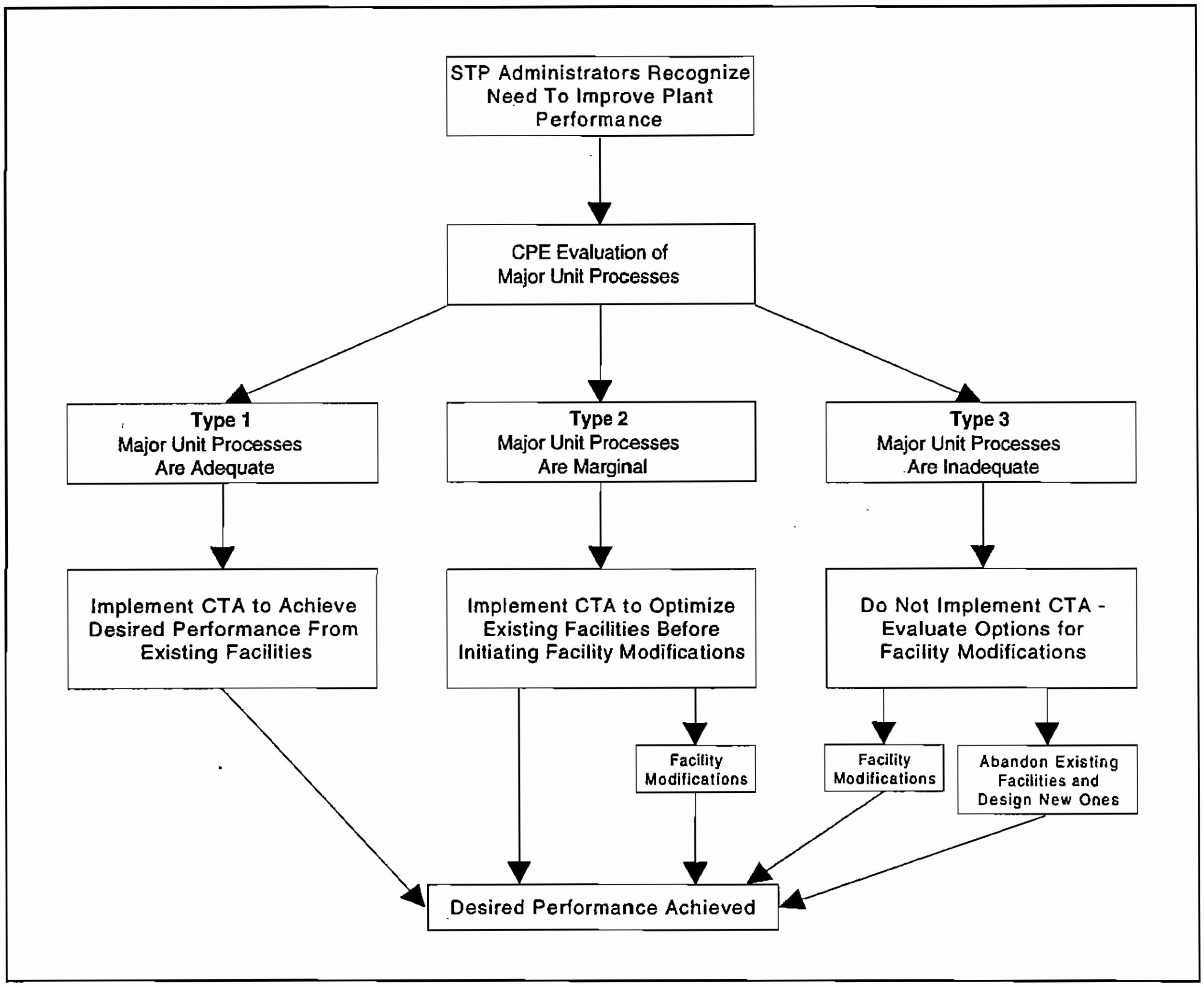
Results of evaluation of major unit processes can be summarized by categorization of plant type, as illustrated in Figure 2-1.

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

Identification of a STP 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 CTA will lead to improved performance but may not achieve required performance levels without facility modifications to the major treatment units.

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 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 CTA may only be of limited value and is not recommended. Owners with a Type 3 plant could

Figure 2-1. CPE/CTA schematic of activities.



meet their performance requirements by pursuing modifications of existing wastewater treatment facilities. However, depending on future waste loads, more detailed study of treatment alternatives and financing mechanisms may be warranted. CPEs that identify Type 3 facilities are still of benefit to STP administrators in that the need for construction is clearly identified. Additionally, the CPE provides an understanding of the capabilities and weaknesses of existing operation and maintenance practices and administrative policies. STP owners can use this information to evaluate use of existing facilities as part of any plant modification and as a guideline for optimizing operational, maintenance, and administrative practices.

2.2.1.3 Identification and Prioritization 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 STP's performance is provided in Appendix A (1). These factors are divided into the categories of administration, maintenance, design, and operation. Definitions for 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. 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 3 classification, these same limitations should be documented in the list of factors limiting the STP's performance.

Completing the identification of factors is difficult in that true problems in a STP 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 C of A. 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 practice of routinely wasting less sludge than was produced. It was determined that increased operator time and additional monitoring equipment would be required to properly control the sludge mass. It was further determined that the digester was undersized and would not provide adequate residence time for complete digestion of the waste activated sludge.
>
> 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 a less significant problem in this case because unlimited cropland for disposal of partially digested sludge was available. 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.

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 STP's performance. An actual link between poor plant performance and an identified factor must exist.

In almost all CPEs, several factors are identified as limiting performance. After these factors have been identified, they are prioritized as to their adverse effect on achieving desired plant performance. The purpose of this prioritization is to establish the sequence and/or emphasis of follow-up activities necessary to achieve compliance. 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 for their implementation. If the highest ranking factors are process control oriented, the initial emphasis of follow-up 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 and assigned an "A," "B," or "C" rating (Table 2-1). The checklist of factors in Appendix A includes a column to enter this rating. Second, those factors receiving "A" or " B" ratings are listed in order of priority, since typically all "A" and "B" factors must be eliminated before a plant will achieve consistent desired performance.

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

Factors that are assigned 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 (e.g., drying beds) that are too small to allow routine wasting of sludge from an activated sludge STP.

Factors are assigned a "B" if they fall in one of two categories:

1. Those that routinely contribute to poor plant performance but are not the major problems. An example would be a shortage of staff time 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 infiltration or inflow that cause periodic solids loss from final clarifiers, or marginal oxygen transfer capacity that causes an oxygen shortage only during the hottest month of the year.

Factors that receive a " C" rating can be shown to contribute to a performance problem, but their effect is minor. For example, if a critical process stream were accessible, but difficult to sample, it could indirectly contribute to poor performance by making process control testing less convenient and more time consuming. The problem would not be a major focus of a subsequent corrective program.

As a comparison of the different ratings, 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. The factor 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 on page 14, "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 routine 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 labour 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.

During the conduct of a CPE, the factors that are not identified as performance limiting also provide very useful information for STP owners. For example, in the illustration presented on page 14, the clarifier was not identified as a performance-limiting factor. Since it was not identified, plant personnel do not need to focus on the clarifier as a problem. Typically 5 to 15 factors are identified during a CPE. The remaining 55 to 65 factors outlined in Appendix

A that are not identified represent a significant finding and also a source of providing recognition to plant personnel for adequately addressing these sources of problems.

Once each identified factor is assessed individually and assigned an "A," "B," or "C" classification, those receiving "A" or "B" ratings are listed on a one-page summary sheet in order of priority. This requires that the evaluator assess all the "A" and "B" factors 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.

All factors limiting facility performance typically cannot be, nor are they intended to be, identified during the CPE phase. 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 performance improvement (CTA) 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 ("A").
> 2. Inadequate staffing to make operational adjustments ("B").
> 3. Inadequate maintenance program to keep equipment functioning continuously ("C").
>
> Based on these factors, a CTA 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 sludge solids predominated in the system. 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 performance improvement phase allows further definition and identification of factors during its implementation, is an important aspect of understanding the approach to conducting a CPE.

2.2.1.4 Assessing the Applicability of a Follow-up CTA

An assessment of the list of prioritized factors helps ensure that identified factors can realistically be addressed in a CTA given the unique set of factors noted at the facility being evaluated. On occasion, there are practical reasons why it is decided not to address identified factors using the CTA format. Examples of factors that may not be desirable to try and address during a CTA are replacement of key personnel, required increases in funding, or training of uncooperative owners or administrators. These factors represent a major time commitment if a recalcitrant situation exists.

Often recalcitrant factors can be addressed if there is an incentive to change the status quo. Enforcement of a plant's Certificate of Approval, (C of A), often serves as an adequate incentive.

If it appears desirable to pursue a CTA then this should be discussed during the CPE exit meeting. If a CTA does not appear feasible, such as in cases of facilities needing major construction, then this also should be presented. If a CTA is not desirable because of recalcitrant factors, then this should <u>tactfully</u> be presented.

2.2.1.5 CPE Report

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

- Facility background
- Performance assessment
- Major process evaluation
- Performance-limiting factors
- Assessment of impact of CTA activities

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. If appropriate, for Type 1 and 2 plants, the necessity of comprehensively addressing the combination of factors identified by the CPE through the implementation of a CTA should be stressed. For Type 3 plants, a recommendation for a facility modification or a more detailed study to support the anticipated upgrade may be warranted.

2.3 How to Conduct a CPE

2.3.1 Initial Activities

To determine the magnitude of the fieldwork required, and to make the on-site activities most productive, specific initial information should be gathered. This information includes basic data on the STP and sources for any needed additional information. If a person associated directly with the STP is the evaluator conducting the CPE, some of the steps may not be necessary.

2.3.1.1 Personnel

The evaluator should obtain the names of those persons associated with the STP who will be the primary sources of information for the CPE. The STP 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 STP budget should be identified by name, position, and physical location. A one- to two-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 or wastewater superintendent can usually provide the best information on the budget.

Key administrative personnel should also be identified. In many small communities or municipalities, 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 non-elected administrator. In all cases, the administrator(s) who has the authority to effect a change in policy or budget for the STP should be identified.

If a consulting engineer is currently involved with the STP, 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 conducting 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.

2.3.1.2 Wastewater Treatment Plant

The initial information outlined in Appendix D (Form D1) can be used to estimate field time required. The plant superintendent and/or chief operator typically would 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. As such, the data that a chief operator can provide from memory or from a readily available reference are sufficient at this time.

Figure 2-2 Example Letter to Introduce a CPE.

Date

Address to Public Official

Re: Evaluation of the XYZ Wastewater Treatment Plant on Date 1, 2, 3, 199X

Dear Official:

Thank you for agreeing to participate in an evaluation of the XYZ Wastewater Treatment Plant. This letter is intended to provide you with some information on the evaluation and describe the activities in which you will be involved.

The evaluation procedure that will be used is part of the Composite Correction Program (CCP) approach. The CCP approach has been successfully used in the US and Ontario to bring existing plants into compliance. During this evaluation, all aspects of design, operation, maintenance, and administration of the plant will be reviewed and evaluated with respect to their impact on performance. By evaluating the plant, you will obtain a good understanding of where your plant stands with respect to compliance with current and future regulations.

The evaluation will begin with a brief entrance meeting on ______________ at approximately 8:30 a.m. The purpose of the entrance meeting is to explain to the operations staff and plant administrators the conduct of the evaluation and the types of activities occurring during the three days. Any questions or concerns regarding the evaluation can also be raised at this time. It is important that the plant administrators and those persons responsible for plant budgeting and planning be present because this evaluation will focus a significant effort in reviewing these aspects of the plant. Following the entrance meeting, which should last approximately 30 minutes, the plant staff will be requested to take the evaluation team on an extensive plant tour. After the plant tour, the team will begin collecting performance and design data. Please make arrangements so that the operating records and any design information for the plant are available. These activities will be continued through the second day.

On the third day, the evaluation team will be involved in several different activities. The major involvement of the plant staff will be in individual interviews. The plant administrators will also be interviewed and the financial records of the plant reviewed. Several special studies may also be completed by the evaluation team to investigate the performance capabilities of the plant's different unit treatment processes. We request that each member of the operations staff be available some time during the day for the interviews. We would also appreciate having some staff member available to answer questions about the plant and operate the plant during the special studies. We will be flexible in working these interviews and special studies around the other required duties of you and your staff.

As far as the types of information and records that will be reviewed during the evaluation, we will first need to review your monitoring reports for the last 12 months. Any laboratory and plant log sheets covering this same period will also be useful as well as any drawings and specifications for the treatment plant. We will also need budget and financial information. This will centre around the budget for the treatment plant and information on salaries, outstanding bonds, operating funds available, etc. It is our experience that the information we need is usually readily available from existing reports. We usually work with the information available and do not request the administrative staff prepare additional summaries of the information.

The last day of the evaluation will consist of an exit meeting. During the exit meeting the results of the evaluation will be discussed with all of those who participated. The performance capabilities of the treatment processes will be presented and any factors found to limit the performance of the plant discussed. The evaluation team will also answer any questions regarding the results of the evaluation. The results presented in the exit meeting will form the basis of the final report, which will be provided in about six weeks. We tentatively expect to begin the exit meeting at 8:00 a.m. on ___________, and it should last approximately one hour. We may change this time depending on how the evaluation proceeds.

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.

An out-of-service single trickling filter, aeration basin, or final clarifier will probably necessitate postponing fieldwork in small plants. In plants with 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.

2.3.1.3 Scheduling

Interviews of personnel associated with the wastewater treatment facilities are a key component of conducting a CPE. As such, the major criterion for scheduling the time for a CPE should be local personnel availability. Usually, one-half to two-thirds of the time scheduled for fieldwork will require the availability and help of these persons.

Scheduling should be coordinated with the availability of at least the major process control decision-maker, the major administrative decision-maker, 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. 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 decision-maker should be prepared to devote at least half of his/her time to the evaluation. The administrative decision-maker should be available for one hour for a kickoff meeting, several hours for reviewing the budget, another several hours for an interview concerning plant administration issues, and one to two hours for a summary meeting.

Following the identification of suitable dates for the evaluation, a letter (see Figure 2-2, Figure 2-3) should be forwarded to the public officials responsible for the plant. The letter documents the evaluation approach and the agreed dates and times for the entrance and exit meetings.

2.3.2 On-Site Data Collection

Onsite CPE activities are largely devoted to collection and evaluation of data. As a courtesy to the facility owner, 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 STP are gathered and analyzed.

CPE Checklist

The following is a list of items that should be taken by the CPE team. These items can assist in the on-site data collection.

1. The Ontario Composite Correction Program Manual for Optimization of Sewage Treatment Plants.
2. IPSCO Handbook: for verifying flows.
3. Graph paper/eraser/pencil/calculator/ruler: for process calculations and performance potential graph.

4. Tape measure/metal yardstick.
5. Sludge judge.
6. Camera (disposable/regular).
7. Copies of Appendix D forms in a three ring binder.

2.3.2.1 Kickoff Meeting
A short meeting between key STP 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 for interviews with non-plant and plant 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; Certificate of Approval (C of A) for the STP; historical monitoring data (1 year); utility bills (1 year); sewer use by-laws (if applicable); and any facility plans or other engineering studies completed on the existing facility.

Clues to administrative factors that may affect plant performance should be noted during this meeting, such as the attitude toward C of A compliance, familiarity with plant needs, communication between administration and plant staff, and attitudes on plant funding. These initial perceptions often prove valuable when formally evaluating administrative factors later in the CPE effort.

2.3.2.2 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.

a. 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, it can become a significant factor. For example, if surface mechanical aerators must be shut down twice a day to remove rags in an activated sludge plant with marginal oxygen transfer capacity, screening could be a major limitation. Indications of screening problems are:

- Plugging (with rags) of raw sewage or primary sludge pumps
- Plugging of trickling filter distributors
- Rag build-up on surface mechanical aerators or submerged diffusers
- 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 and sludge processing equipment, resulting in excessive down-time which could impact plant performance and reliability.

Wastewater flow measurement facilities are important to accurately establish plant loadings. The plant tour should be used to observe the primary measuring devices and to ask several questions regarding plant flows. If flow is turbulent or non-symmetrical through flumes and over flow measurement weirs, the flow records are immediately questionable. If flow is non-turbulent and symmetrical, there is a good chance the flow measurement device is sufficiently accurate, provided the flow recorder and totalizer prove to be properly calibrated. The evaluator should always plan to verify the accuracy of flow measurement during the fieldwork.

Sources of wastewater and the nature of the waste contributions should initially be discussed when observing preliminary treatment facilities. Impacts of infiltration and inflow on plant flows should also be discussed.

b. 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. At 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 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) such that it adversely affects the capacity and/or performance of the sludge handling facilities. A primary sludge concentration of less than 3 percent total solids often indicates there is opportunity for improved sludge handling facilities performance with decreased sludge pumping. On the other hand, a primary sludge concentration of greater than 6 percent total solids can be an indication that primary clarifier performance may be improved by increased sludge pumping. The operational approach used to improve primary clarifier performance must be balanced with the capacity and performance requirements of the sludge handling processes.

The surface overflow rate (SOR), which is the daily average flow divided by clarifier surface area (CSA), can be used as an indicator to estimate the performance that can be expected from a primary clarifier handling typical domestic wastewater. A clarifier operating at an SOR of less than 24 $m^3/m^2 \bullet d$ (600 US gpd/sq ft) will typically remove 35-45 percent of the BOD_5 in domestic wastewater. A clarifier operating at an SOR of 24-40 $m^3/m^2 \bullet d$ (600-1,000 US gpd/sq ft) will typically remove 25-35 percent of the BOD_5.

c. Aerator
The term "aerator" is used in this manual 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. 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 step loading (or step feed) mode as well as a plug flow mode?

d. 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 often provides satisfactory performance. A long, narrow, shallow rectangular clarifier with effluent weirs only at the end often provides marginal solids separation and thickening capability. Clarifiers with a depth of 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 <u>roughly</u> estimate final clarifier performance capability. In a conventional activated sludge system, a SOR, based on average daily flow less than 24 $m^3/m^2 \bullet d$ (600 US gpd/sq ft), typically can be operated to achieve desired performance. A significantly higher SOR would mean that other processes would have to be fairly conservative to make the system perform adequately.

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 recycle rates; availability of return sludge flow measurement; and flexibility to direct return sludge to different aeration basins or points in the basins.

e. Disinfection
The evaluator should tour disinfection facilities 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, many STPs use chlorine as the disinfectant and incorporate a chlorine contact basin of sufficient size to provide 10 minutes to 2 hours of contact time.

Poorly performing biological wastewater treatment facilities periodically lose sludge solids over the final clarifier weirs. Chlorine contact basins generally will capture a portion of these 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.

f. Sludge Handling Capacity
During the tour of sludge handling facilities, the evaluator should become familiar with primary and secondary sludge management practices, including: 1) methods used to determine waste sludge quantities; 2) equipment used to thicken, stabilize, and dewater sludge; and 3) available options for final disposal and reuse. The evaluator's major concern with sludge handling facilities is identifying any potential "bottlenecks" and possible alternatives if problems that may limit performance are indicated.

All recycle streams should be identified during the tour and the plant personnel should be questioned regarding the availability of data concerning each stream's volume and strength. Return supernatant streams from anaerobic digesters and heat treatment conditioning processes are the most common return streams that cause performance problems. Supernatant from aerobic digesters and filtrate from dewatering operations typically have a lesser impact on plant performance.

g. Laboratory
The laboratory facilities should be included as part of the plant tour. Performance monitoring, process control testing, and quality control procedures should be discussed with laboratory personnel. Available analytical capability should also be noted. 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 during the CPE.

h. Maintenance Facilities
Maintenance facilities should be included as part of the plant tour. Tools, spare parts availability and storage, filing systems for equipment catalogues, general plant appearance, and condition of equipment should be observed during the tour. Questions on the preventive maintenance program, including methods of initiating work (e.g., work orders), are appropriate.

2.3.2.3 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 STP 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 to initially review documents such as O&M manuals and construction plans, to summarize notes and questions for STP 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). Items covered by these forms are listed below:

- Preliminary Plant Information, Form D-1
- Administration Data, Form D-2
- Design Data, Form D-3
- Operations Data, Form D-4
- Maintenance Data, Form D-5
- Performance Data, Form D-6
- Interview Data, Form D-7

When collecting information using these forms, the evaluator should be aware that the data are to be used to evaluate the performance capability of the existing STP. 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 the appearance of the grounds, the condition should be noted and efforts directed toward areas that specifically impact performance.

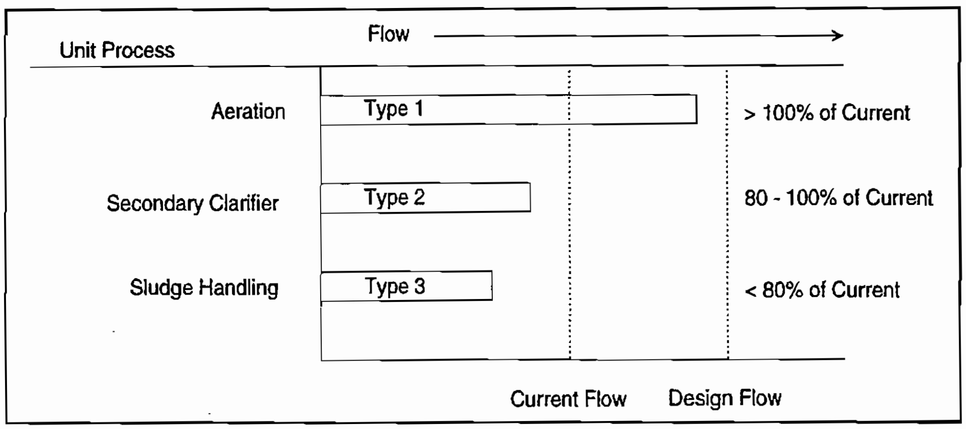
Completion of Form D-3 requires that values be selected to represent current plant hydraulic and BOD loadings. Typically, data for the most recent 12 months are used.

2.3.3 Evaluation of Major Unit Processes

Early in the on-site activities, an evaluation of the STP's major unit processes is conducted to determine the performance potential of existing facilities at current loadings (i.e., define the facility as Type 1, 2, or 3 as described in Figure 2-1). The three unit processes whose capabilities most frequently affect biological wastewater treatment plant performance are: the aerator, the secondary clarifier, and the sludge handling system (1,15,16).

These processes were selected based on the concept of determining if the "concrete" (e.g., basin size) is adequate. The potential capacity of a major unit process is not lowered if "minor modifications", such as converting to step loading capability or adding baffles to clarifiers could be accomplished. This approach is in line with the CPE intent of assessing adequacy of existing facilities to determine the potential of non-construction alternatives. Other components of the plant processes, such as return sludge pumping, or preliminary treatment facilities are not included in the major unit process evaluation, but rather are evaluated separately as factors that may be limiting performance. These components can most often be addressed through "minor modifications".

Figure 2-3. Conceptual Performance Potential Graph



An approach using a "performance potential graph" has been developed to evaluate the major unit processes. A comparison of major unit process capability to current and design flow rates is made in Figure 2-2, Figure 2-3. The processes evaluated are shown on the left of the graph and the various flow rates assessed are shown across the top. Horizontal bars on the graph depict projected capacity for each unit process, and the vertical lines represent current (e.g. most recent 12 month average) plant flow and design plant flow. Footnotes are typically used to explain the conditions used to rate each unit process.

The approach to determine whether a unit process is Type 1, 2, or 3 is based on the relationship of the horizontal bars to the current plant flow rate. As presented in Figure 2-3, a unit process would be rated Type 1 if its projected capacity exceeds the current plant flow (i.e., aeration in Figure 2-3), Type 2 if its capacity was 80 to 100 percent of current plant flow (secondary clarifier in Figure 2-3), or Type 3 if its projected capacity is less than 80 percent of current plant flow (sludge handling in Figure 2-3). The overall plant type is established by the "weakest link" among the unit processes evaluated. It must be remembered in using this performance potential system that this simplification can provide valuable assistance but it cannot replace the overall judgement and experience of the evaluator. Specific criteria by which each major unit process is assessed are described in the following sections.

2.3.3.1 Suspended Growth Major Unit Processes

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

a. Primary Clarifier

The parameter used for evaluating the capability of a primary clarifier is SOR. The typical values for evaluating SOR depend on whether waste activated sludge is co-thickened in the primaries.

Table 2-2 Guidelines for Assessing the Primary Clarifier

Current Operating Condition	Typical Unit Process Capability
SOR with WAS addition	
< 24	Type 1
24 - 30	Type 2
> 30	Type 3
SOR, without WAS addition	
< 32	Type 1
32 - 38	Type 2
> 38	Type 3

b. Aeration Basin

Parameters that are used for evaluating the capability of an aeration basin are: hydraulic detention time, BOD_5 loading, and oxygen availability. The typical values for evaluating these parameters are presented in Table 2-3. 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.

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 desired dissolved oxygen concentrations in the aeration basin
- Continuous operation of all blowers or all aerators set at high speed
- Design data showing less than 1.2 kg oxygen transfer capacity per kg actual BOD_5 load

Table 2-3 Guidelines for Assessing the Aeration Basin Unit Process Component in Suspended Growth STPs

Current Operating Condition		Typical Unit Process Capability
Hydraulic Retention Time, hr:		
Conventional Activated Sludge		
< 5 hrs		Type 3
5-6 hrs		Type 2
> 6 hrs		Type 1
Extended Aeration		
< 16 hrs		Type 3
16-24 hrs		Type 2
> 24 hrs		Type 1
BOD_5 Loading, $kg/m^3 \cdot d$:		
Conventional	Extended Aeration	
> 0.8	> 0.5	Type 3
0.5 - 0.8	0.2 - 0.5	Type 2
< 0.5	< 0.2	Type 1
Oxygen Availability:		
kg O_2/kg BOD_5 (only BOD_5 data available)		
w/o nitrification	with nitrification	Type 3
< 0.8	<1.2	Type 2
0.8 - 1.0	1.2-2.0	Type 1
> 1.0	>2.0	
kg O_2/(kg BOD_5 + kg Nitrogen(both BOD_5 and TKN data available):		
with nitrification		
<1.2		Type 3
1.2-2.0		Type 2
>2.0		Type 1

If design oxygen transfer numbers are unavailable or are believed suspect, oxygen transfer rates presented in Table 2-5 can be used to estimate oxygen transfer capacities.

Typically, the oxygen transfer efficiency (percent) is used when evaluating different diffused air systems, and oxygen transfer rate (lb O_2/hp-hr or kg O_2/kW-hr) is used when evaluating surface mechanical aerators. The evaluation of both diffused air and surface mechanical aerators is described in more detail below.

Table 2-4 Typical Values of Alpha (α) Used for Estimating AOTR/SOTR

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

When evaluating oxygen transfer capability of diffused aeration systems it is necessary to assess the capacity of the aeration blowers and the standard transfer efficiency of the diffusers. This information is often available from O&M manuals, specifications, and manufacturers literature. If questionable information is available, typical values for various systems are shown in Table 2-5. The blower capacity and diffuser transfer efficiency can then be utilized to determine the amount of oxygen (lb/d or kg/d) that can be transferred into the wastewater by the existing aeration system.

To determine the aeration system oxygen transfer in lb/day (kg/day), the diffuser standard transfer efficiency or standard oxygen transfer rate at standard conditions (14.7 psia, 20°C, and clean water) must be converted to transfer efficiency at actual site conditions including adjustments for site elevation, wastewater temperature, and wastewater characteristics. The procedure to convert standard oxygen transfer rates to actual oxygen transfer rates is presented in Appendix E.

In addition, blower capacity must be determined in standard cubic feet per minute (SCFM or standard m^3/min) to determine the mass of air/oxygen that the blowers are capable of discharging. [Note: 1 m^3/min = 35.31 CFM (ft^3/min)]. There is not a standard method of presenting blower output. Some manufacturers provide the blower rating in standard cubic feet per minute (SCFM), which is a term that describes airflow at standard conditions of 14.7 psia and 20°C. It is noted that different air temperatures, such as 70°F, are used by other manufacturers to describe standard conditions. Also, the blower output rating is often presented in terms of ICFM (inlet cfm) or ACFM (actual cfm), which is CFM at site conditions. ICFM, ACFM, or SCFM at standard conditions other than the conditions chosen for the evaluation must be converted to SCFM. The procedure to convert ICFM or ACFM

Table 2-5 Typical Clean Water Standard Oxygen Transfer Values

System	Oxygen Transfer Efficiency[a]	Oxygen Transfer Rate[b]	Oxygen Transfer Rate[b]
	percent	lb/wire hp-hr	kg/wire kW-hr
Fine bubble diffusers, total floor coverage	28-32	6.0-6.5	3.66-3.97
Fine bubble diffusers, side wall installation	18-20	3.5-4.5	2.14-2.75
Jet aerators (fine bubble)	18-25	3.0-3.5	1.83-2.14
Static aerators (medium-size bubble)	10-12	2.3-2.8	1.40-1.71
Mechanical surface aerators	-	2.5-3.5	1.53-2.14
Coarse bubble diffusers wide band pattern	8-12	2.0-3.0	1.22-1.83
Coarse bubble diffusers, narrow band pattern	6-8	1.5-2.0	0.92-1.22

[a] at 15 feet (4.57 m) submergence.
[b] 1 lb/hp-hr = 0.61 kg/kW-hr.

to SCFM for the standard condition of 14.7 psia, 20°C and clean water, is presented in the example below.

Utilization of the modified procedures to calculate the oxygen transfer capability of a diffused air system is shown in the following example. (The full calculations are illustrated in Appendix E).

Oxygen Transfer Calculations if airflow rate is known:
In Plant A there are four centrifugal blowers, each with a capacity of 1,550 acfm. Three are utilized, with one as standby. The standard oxygen transfer efficiency (SOTE) or efficiency of the coarse bubble diffusers is 12 percent at 15-ft water depth based on manufacturer's data. Plant A is located at 2,750 feet above sea level.

1. Convert SOTE = 12 percent to AOTE using:

Actual oxygen transfer efficiency, or AOTE, is calculated as follows:

$$\mathbf{AOTE = SOTE \times \alpha \times K}$$

Where,

SOTE is dependent on the aeration system and is obtained from Table 2-5 (in lieu of more specific information).

α is obtained from Table 2-4 (in lieu of more specific information).

K depends on the depth of submergence and elevation - see nomographs following these calculations (Figure 2-4 to Figure 2-7)

SOTE = 12 % = 0.12 (manufacturer's data or Table 2-5 in lieu of manufacturer's data)
α = 0.85 (Table 2-4)

K:

T = 25 °C (assume maximum summer temperature)
elevation = 2750 ft
submergence of diffusers = 15 ft
from Figure 2-4, K = 0.78

$$\begin{aligned} AOTE &= SOTE \times \alpha \times K \\ &= 0.12 \times 0.85 \times 0.78 \\ &= 0.080 \\ AOTE &= 8.0\ \% \end{aligned}$$

2. Convert blower output of 1,550 acfm (or icfm) to scfm:

$$acfm = scfm\ (\frac{T_a}{T_s})(\frac{P_s}{P_a})$$

$$scfm = acfm\ (\frac{T_s}{T_a})(\frac{P_a}{P_s})$$

Where,

acfm = 1,550 cfm
T_a = 100 °F + 460 °F = 560 °R (temperature at which manufacturer rated blowers).
T_s = 68 °F + 460 °F = 528 °R (standard temperature).
P_s = 14.7 psia (standard pressure).
P_a = 13.25 psia (pressure @ 2,750 ft above mean sea level); see Appendix E for figure.

scfm = (1,550) (528/560) (13.25/14.7) = 1,317 scfm

3. Calculate lb O_2/d from 3 blowers using diffuser actual oxygen transfer efficiency of 8.0 percent and blower capacity of 1,317 cfm:

Peak air flow = 3 × 1,317 = 3,951 scfm

R = 8.314 L·kPa/mol·K , 1 m³ of air = 1.2 kg @ 20°C, 1 atm.

$$
\begin{aligned}
\text{lb } O_2/\text{d} &= (\text{scfm})(1{,}440 \text{ min/d})(23.2 \text{ lb } O_2/100 \text{ lb air}) \times (0.075 \text{ lb air/cu ft air})(\text{AOTE}) \\
&= (3{,}951)(1{,}440)(23.2/100)(0.075)(8.0\%) \\
&= 7{,}920 \text{ lb/d} \times 0.45 \text{ kg/lb} \\
&= 3{,}564 \text{ kg/d}
\end{aligned}
$$

4. Therefore, 3 blowers @ 1,317 cfm each will transfer 3,564 kg O_2/d. Calculate the oxygen required based upon BOD_5 loading and nitrogen loading (if nitrification is required by C of A). Compare the oxygen transfer capability to the oxygen requirement to determine if the aeration system can provide enough oxygen for carbonaceous and nitrogenous (if required) removal. If the ratio of oxygen transfer capability to oxygen required is ≥ 1.0 then there is enough oxygen and this would be a "Type 1" aeration system. A Type 2 system would occur when the ratio is between 0.8 and 1.0, and a Type 3 facility is when the ratio < 0.8.

When evaluating the oxygen transfer capability of a surface mechanical aeration system, the power usage of the motor (whp) and the oxygen transfer rate of the aerator (lb O_2/whp-hr) must be determined. Various techniques for estimating motor power usage based on actual power measurements are presented in Appendix F. If power measuring equipment is not available, wire horsepower may be estimated by assuming the motor is 90 percent efficient and the surface mechanical aerator gear box is 85 percent efficient. Using these estimates, the evaluator may assume that 75 (appropriately 0.9 × 0.85) percent of the motor horsepower (mhp) is being converted to oxygen transfer energy, or wire horsepower. For example, if a surface mechanical aerator motor is rated at 50 mhp, the wire horsepower could be estimated to be 0.75 × 50 = 37.5 whp. Actual power measurements should be taken if the oxygen transfer capability of the system determined by estimating wire horsepower appears inadequate.

The aerator oxygen transfer rate may be determined from the O&M manual, specifications, and equipment manufacturer's literature. If questionable information is available, a typical value for surface mechanical aeration systems can be found Table 2-5. The standard oxygen transfer rate (SOTR) is typically provided and this must be converted to the actual oxygen transfer rate (AOTR) as shown in Appendix E. Utilization of the procedures simplified from those presented in Appendices E and F to determine actual oxygen transfer rate and motor wire horsepower are presented in the following example.

Oxygen Transfer Calculations if HP is known:

In Plant B there are two 50-hp surface mechanical aerators. Both units are utilized. The SOTR is 3 lb O_2/whp-hr based on manufacturer's data. Plant B is located at 2,750 ft above sea level.

1. Convert SOTR = 3 lb O_2/whp-hr to AOTR

Actual oxygen transfer rate, or AOTR, is calculated as follows:

$$\textbf{AOTR} = \textbf{SOTR} \times \alpha \times \textbf{K}$$

where,

SOTR is dependent on the aeration system and is obtained from Table 2-5 (in lieu of manufacturer's data).

α is obtained from Table 2-4 (in lieu of more specific information).

K depends on the depth of submergence and elevation - see nomographs following this section (Figure 2-4 to Figure 2-7).

SOTR = 3.0 lb O_2/whp•hr (manufacturer's data or Table 2-5)
α = 0.9 (Table 2-4)
K: T = 25 °C (assume maximum summer temperature)
elevation = 2,750 ft
submergence = 0
from Figure 2-4, K = 0.638

$$\begin{aligned} AOTR &= (SOTR) \times \alpha \times (K) \\ &= (3 \text{ lb } O_2/\text{whp-hr}) \times (0.9) \times (0.638) \\ &= 1.7 \text{ lb } O_2/\text{whp-hr} \end{aligned}$$

2. Determine surface mechanical motor power usage:

There are two methods to determine the power that is converted to O_2 transfer energy:

a. Assume that whp is 75 percent of mhp.

$$\begin{aligned} whp &= (\text{Assumed ratio of whp to mhp}) \times \text{actual mhp} \\ &= 0.75 \ (50 \text{ mhp}) \\ &= 37.5 \text{ whp} \end{aligned}$$

Total O_2 transfer energy = 2 motors × 37.5 whp = 75 whp

b. Use actual power measurements and assume that power factor is 0.90. (See Appendix F).

Voltage measurement = 480 volts   Amperage measurement = 37.4 amps
phase motor = 3 phases

i) Calculate the Power

$$kVa = \frac{(V)(A)(\#\ phase\ motor)^{1/2}}{1000} = \frac{480 \times 37.4 \times 3^{1/2}}{1000} = 31.1\ kW$$

ii) Calculate the actual power converted to O_2 transfer energy

kW = kVa × PF
= 31.1 kW × 0.9
= 28 kW

iii) Convert power from kW to whp

whp = kW × (1 hp/0.746 kW)
= 28 × (1/0.746)
= 37.5 whp

iv) Calculate total Oxygen transfer energy

Total whp = 2 motors × 37.5 whp = 75 whp

3.Determine oxygen transferred based on AOTR and whp (using one of the methods from above:

O_2 transfer = (1.7 lb O_2/whp-hr)(75 whp)(24 hr/d)
= 3,060 lb O_2/d × 0.45 kg/lb
= 1377 kg O_2/d

4. Calculate the oxygen required based upon BOD_5 loading and nitrogen loading (if nitrification is required by C of A). Compare the oxygen transfer capability to the oxygen requirement to determine if the aeration system can provide enough oxygen for carbonaceous and nitrogenous (if required) removal. If the ratio of oxygen transfer capability to oxygen required is ≥ 1.0 then there is enough oxygen and this would be a "Type 1" aeration system. A Type 2 system would occur when the ratio is between 0.8 and 1.0, and a Type 3 facility is when the ratio < 0.8.

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:

$$\textit{Aeration Hydraulic Retention Time} = \frac{\textit{Aeration Basin Volume } (m^3)}{\textit{Average Daily Flow } (m^3/d)}$$

Average daily wastewater flow is typically for the most recent 12 months.

$$\textit{BOD}_5 \textit{ Applied Loading } (kg/m^3 \cdot d) = \textit{Peak BOD}_5 \textit{ Concentration } (mg/L) \times \textit{Average Daily Flow } (m^3/d)$$

BOD_5 loading is typically the peak value for the most recent 12 months.

$$BOD_5\ Loading\ per\ unit\ volume\ of\ the\ Aeration\ basin = \frac{BOD_5\ Applied\ Loading\ (kg/m^3 \bullet d)}{Aeration\ Basin\ Volume\ (m^3)}$$

Nitrification required:

$$Oxygen\ Availability = \frac{Oxygen\ Transfer\ Capability}{BOD_5\ Applied\ Loading + Nitrogen\ Loading}$$

$$Nitrogen\ Loading = 4.57 \times Average\ Daily\ Flow \times Peak\ Raw\ Influent\ TKN$$

Raw influent TKN is typically the peak value for the most recent 12 months.

No nitrification required:

$$Oxygen\ Availability = \frac{Oxygen\ Transfer\ Capacity\ (kg\ O_2/d)}{BOD_5\ Applied\ Loading\ (kg\ BOD_5/d)}$$

When the above calculations have been completed for the subject STP, the results are plotted on the performance potential graph and compared to typical values as listed in Table 2-3. This method graphically displays the potential capability of these parameters. It is critical that site specific observations and the judgement of the evaluator be used when developing a performance potential graph.

Figure 2-4. K vs. Elevation 0′ to 3000′

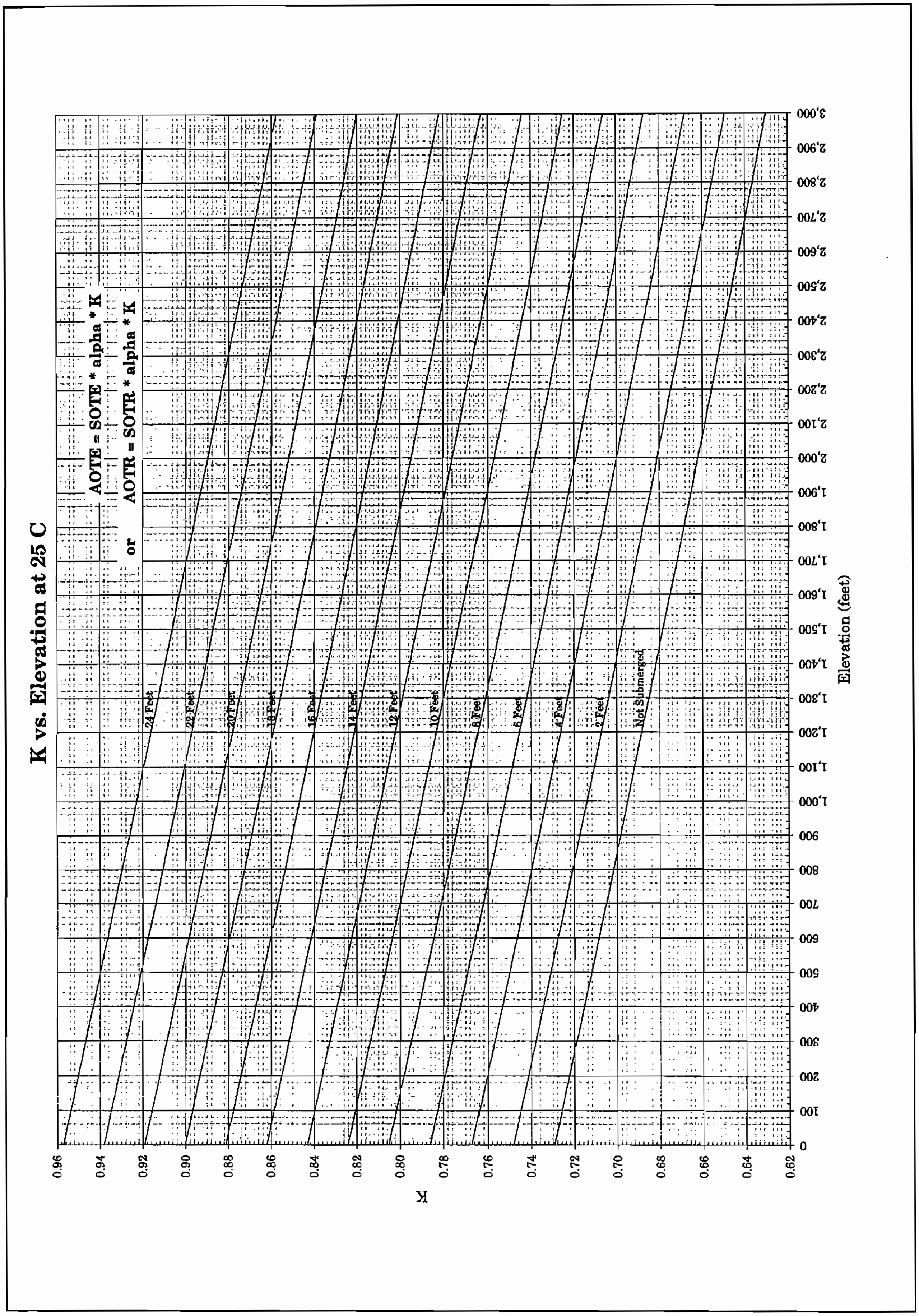


Figure 2-5. K vs. Elevation 3000′ to 6000′

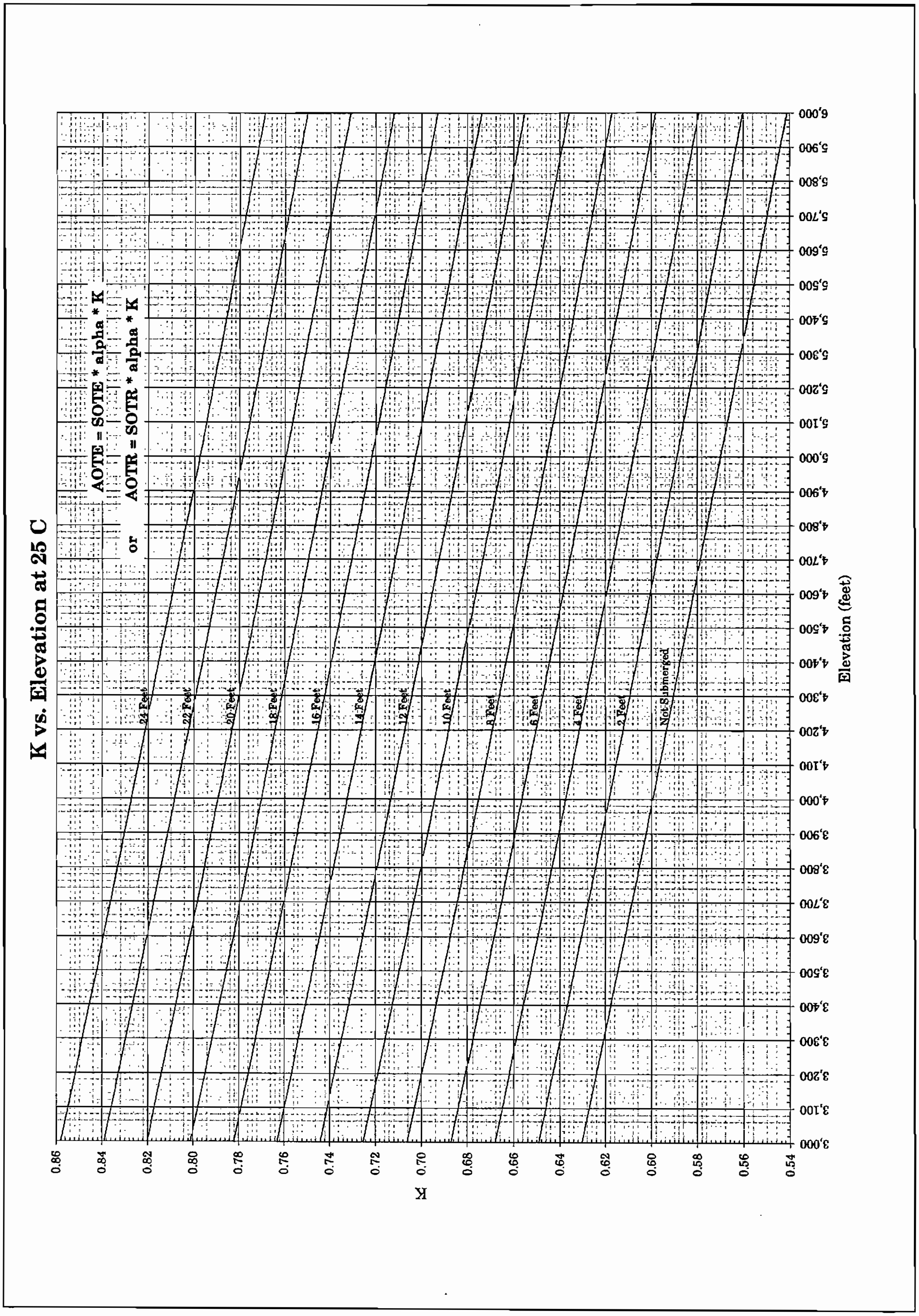


Figure 2-6. K vs. Elevation 6000′ to 9000′

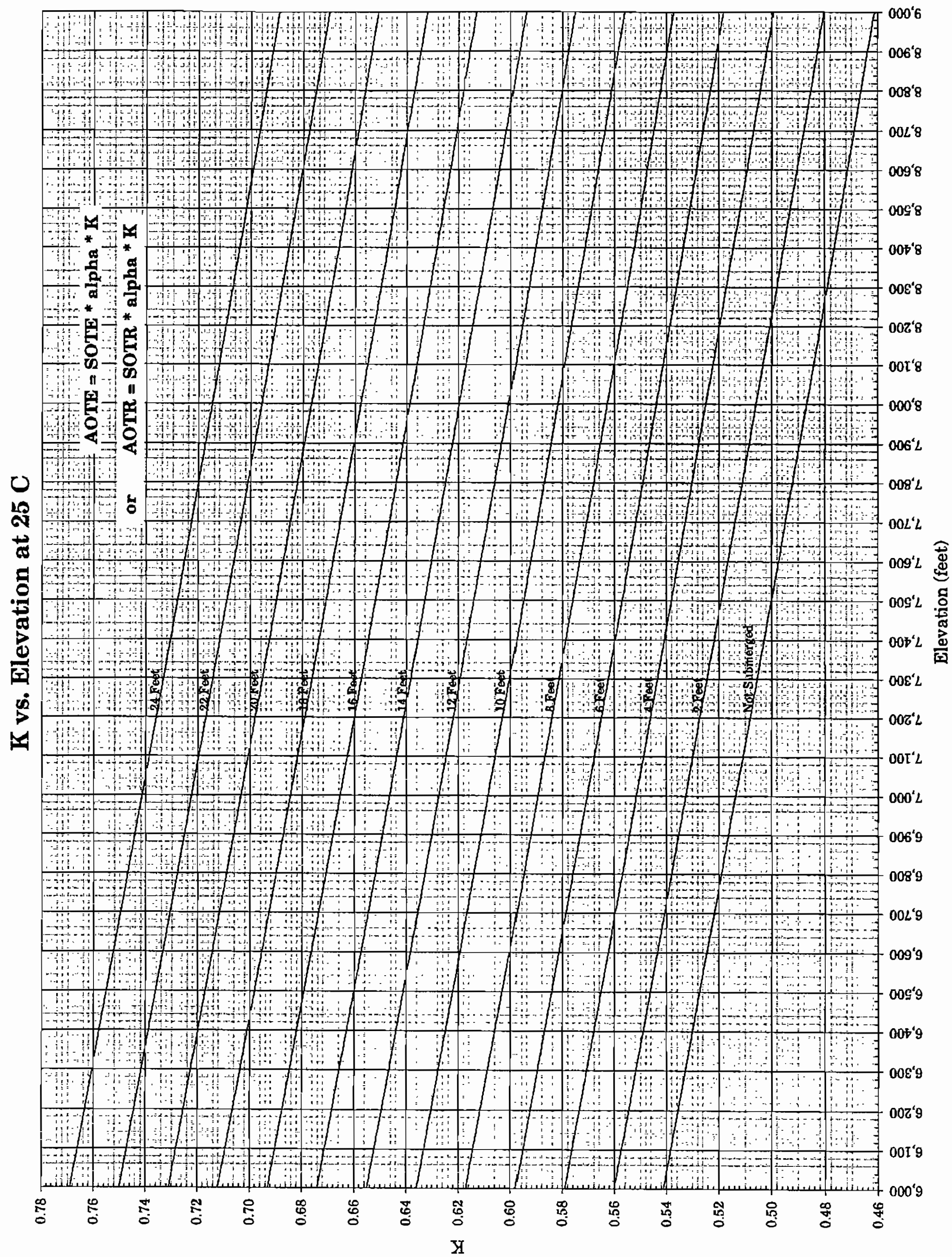
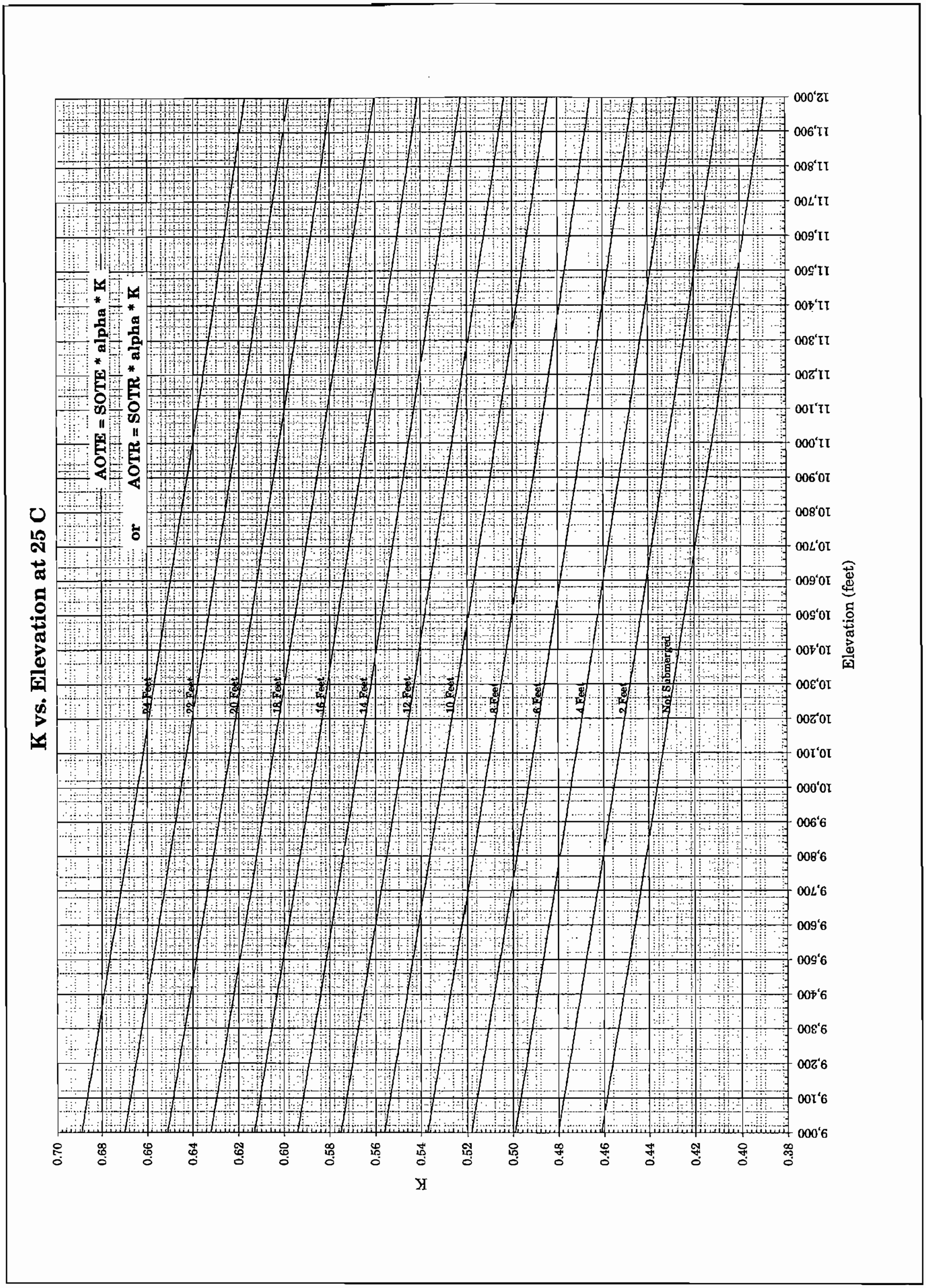


Figure 2-7. K vs. Elevation 9000′ to 12000′



c. Secondary Clarifiers

Parameters that are used for evaluating the capability of suspended growth secondary clarifiers are: configuration, surface overflow rate (SOR), and depth. Typical criteria for evaluating these parameters are presented in Table 2-6. SOR is evaluated at average daily flows.

Table 2-6 Guidelines for Assessing the Secondary Clarifier Unit Process Component in Suspended Growth STPs

Current Operating Condition		Typical Unit Process Capability
Surface Overflow Rate, $m^3/m^2/d$		
Activated Sludge	Extended Aeration	
< 24	< 12	Type 1
24 - 30	12 - 16	Type 2
> 30	> 16	Type 3
The above SORs are typically impacted by configuration and depth. The following can be used as a guide in rating various facilities:		
Configuration		
Circular with "donut" or interior weirs		Rate at SORs shown
Circular with weirs on walls		Rate at SORs shown
Rectangular with 33% covered with weirs		Rate at SORs shown
Rectangular with 25% covered with weirs		Derate to 80% of SORs shown
Rectangular with weir at or near end		Derate to 50% of SORs shown
Depth at Weirs, m (ft)		
≥ 3.0 (10)		Rate at SORs shown
< 3.0 (10)		Derate to 80% of SORs shown

The configuration of the clarifier is examined for poor weir locations or poor surface development with weirs. 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 weir coverage [(3 m wide) × (1 m + 1 m + 1 m)], or only 20 percent of the surface area developed. This clarifier's capability would be rate at a more conservative SOR because of the configuration.

Surface overflow rate is calculated independently of the configuration evaluation and is based on the total clarifier surface area and on the daily average flow, as follows:

$$SOR = \frac{Average\ Daily\ Flow}{Clarifier\ Surface\ Area}$$

There are a few items which must be noted when evaluating the SOR capacity. If diurnal flow variations are greater than 2:1 (peak daily flow:daily average flow) the capacity of the clarifier based on SOR must be reduced. Conversely, if a clarifier is loaded at a relatively constant rate due to the availability of flow equalization, the capacity of the clarifier based on SOR can be increased. It must be remembered that the assessment is not a design evaluation but an assessment of whether the clarifier can be made to perform under the desired conditions. In STPs where special allowance has been made for high infiltration/inflow, such as permitted bypassing above a certain flow, the flow at which secondary treatment is required should be used.

Depth of secondary clarifiers is a subjective evaluation. Shallow clarifiers (e.g. < 3 m [10 ft]) are typically marginal in handling sludge from suspended growth systems. Conservative SORs should be used with shallow clarifiers.

d. Sludge Handling Capability

The capability of sludge handling facilities associated with an activated sludge plant is evaluated based on the controllability of the wasting process and the capability of the available sludge treatment and ultimate disposal facilities. Evaluating sludge handling capability is not straightforward because of the variability that exists in design and operational "standards" for unit process capability. To evaluate the sludge handling capability, 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 expected sludge production.

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

- Determine current plant loadings and calculate expected sludge production.
- Determine chemical sludge produced based on type and dosage of metal salt for phosphorus removal.
- Establish capability of existing sludge handling unit processes.
- Identify the "weakest link" process as the overall capability of the existing sludge handling facilities.

Biological Sludge Production:

Expected biological sludge production is calculated using current BOD_5 loadings (unless believed inaccurate) and typical unit sludge production values and concentrations for the existing wastewater treatment processes (17). Typical unit sludge production values for various processes are shown in Table 2-7 and Table 2-9. 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 × 0.65 kg TSS/kg BOD_5 removed).

Chemical Sludge Production:

Most STPs in Ontario are required to remove phosphorus. If chemical removal is practised, then the additional sludge generated from this process must be included in

Table 2-7 Unit Biological Sludge Production Values for Projecting Sludge Production From Suspended Growth STPs

Process Type	kg TSS (sludge)/ kg BOD_5 removed
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 retention times < 10 hours.
[b] Includes oxidation ditch.

the evaluation of an STPs sludge handling capability.

There are several aluminum or iron salts which are used for phosphorus removal. These include:

- aluminum sulfate (alum)
- sodium aluminate
- ferric chloride
- ferrous chloride
- ferrous sulfate

Typical aluminum and iron salts reactions to remove phosphorus are as follows:

$$Al^{3+} + PO_4^{3-} \rightarrow AlPO_4$$

$$FeCl_3 + PO_4^{3-} \rightarrow FePO_4 + 3Cl^-$$

These equations illustrate that it is the aluminum or the iron that reacts with the phosphorus to form a precipitate which can be removed in the primary or secondary clarifier or subsequent filter beds.

Table 2-8 contains the chemical formula for a few common metal salts and some of their properties.

The calculation of chemical sludge production has been simplified. The basis for these calculations is stoichiometry, and sample calculations are presented in Appendix J.

In order to do calculation of projected chemical sludge, the following information is required:

- identification of type of metal salt used for phosphorus removal
- average volume of metal salt added per day (m^3/d) or average kg/d of metal salt added
- average wastewater flowrate in sewage treatment plant

Table 2-8 Characteristics of Aluminum and Iron Salts (24)

Common Name and Formula	Density (kg/m^3) average in brackets	Commercial Strength % by wt.	% Metal (%w/w)
Dry Alum $Al_2(SO_4)_3 \bullet 16H_2O$	600-1200 (900)	17% Al_2O_3	8.6% Aluminum
Liquid Alum $Al_2(SO_4)_3 \bullet 16H_2O$	1330 @16°C	8.3% Al_2O_3	4.3% Aluminum
Dry Sodium Aluminate $Na_2Al_2O_4$	640-800 (720)	43.5% Al_2O_3	23.0% Aluminum
Liquid Sodium Aluminate $Na_2Al_2O_4$	-	4.9-26.7% Al_2O_3	2.6-14.1% Aluminum
Liquid Ferric Chloride $FeCl_3$	1340-1490 (1415)	40% $FeCl_3$	13.8% Iron
Liquid Ferrous Chloride $FeCl_2$	1190-1250 (1220)	22.5% $FeCl_2$	9.9% Iron
Dry Ferrous Sulfate $FeSO_4 \bullet 7H_2O$	990-1060 (1025)	56.5% $FeSO_4$	11.4% Iron

Depending on whether the metal salt added is a liquid or a solid, there is a separate calculation of kg metal added. The two calculations are as follows:

i) Metal Added (solid)

Metal Added = Average kg of Metal Salt added/d × % metal (Table 2-8)

ii) Metal Added (liquid)

Metal Added = Avg. Volume of Metal Salt added/d × density of metal salt × % metal

A simplified ratio of chemical sludge production based on stoichiometry, as presented in the *US EPA Design Manual: Phosphorus Removal*, is as follows:

1 kg Aluminum produces 4.79 kg TSS 1 kg Iron produces 2.87 kg TSS

The detailed calculations are presented in Appendix J.

As an example calculation:

#	ITEM	VALUE
1	Type of metal salt	liquid alum
2	Average volume or mass of metal salt added/d	0.085 m^3/d
3	Average wastewater flow	650 m^3/d
4	Density of metal salt (Table 2-8)	1330 kg/m^3
5	% Metal (Table 2-8)	4.3 %

1. Metal Added (liquid) . . . . A

Metal Added = Avg. Volume of Metal Salt/d × density of metal salt × % metal
= (row 2) × (row 4) × (row 5)
= 0.085 m^3/d × 1330 kg/m^3 × 4.3/100
= 4.86 kg/d

2. Metal Dose . . . . B

$$Metal\ Dose = \frac{Metal\ Added}{Average\ Wastewater\ Flow} = \frac{A}{row\ 3} = \frac{4.86\ kg/d}{650\ m^3/d} = 0.00747\ kg/m^3 = 7.5\ mg/L$$

3. Projected Chemical Sludge Production C

= Avg. Wastewater Flow × Metal Dose × Chemical Sludge Production Ratio × 365 d/yr
Where chemical sludge production ratio = 4.79 mg TSS/mg Aluminum
= (row 3) × (B) × 4.79 mg TSS/mg Al × 365 d/yr
= 650 m^3/d × 7.5 mg/L × 4.79 mg TSS/mg Aluminum × 365 d/yr
= 8,523,206 mg•m^3/yr•L × 0.001 L•kg/m^3•mg
= 8,523 kg/yr

Therefore, on average, it is projected that there would have been 8,523 kg of chemical sludge produced per year.

The above calculations would be similar for iron salts, except the % iron value, specific gravity, and sludge production ratio would change.

When 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. If actual plant data fall within the 15 percent range, these data can be used for the evaluation of sludge handling capability. A detailed example of calculating expected sludge production and comparing it with plant data is included in Section 2.3.6.1.

Often plant sludge production data is not reliable and cannot be used to accurately assess sludge handling capability. 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_5 removed

Using the information on unit biological sludge production and chemical sludge production, the unit sludge production values and projected desired BOD_5 removals for the subject plant (desired effluent BOD_5 should meet effluent requirements), the projected mass of sludge produced per day can be calculated. To complete the evaluation of sludge handling capability, the expected volume of sludge produced per day must also be calculated. Typical waste sludge concentrations for activated sludge plants are presented in Table 2-9 and can be used to convert the expected mass of sludge produced per day to the expected volume of sludge produced per day.

Variations in sludge production values have been observed throughout the year. Additionally, operation decisions to lower sludge inventories in the plant can place increased requirements on the sludge handling facilities. It is not uncommon for these variations to require 125-150 percent of the long-term average sludge production value (17). <u>For this reason, a factor of 1.25 is applied to the calculated sludge mass and volume values to ensure reliable capability under most operational situations throughout the year.</u>

The capability of each of the components of the sludge handling process are evaluated with respect to its ability to handle the calculated sludge production based on current loadings (the mass and volume values adjusted by the 1.25 factor are used in this evaluation). Using this evaluation approach, sludge handling "bottlenecks" can be identified.

Typical components found in activated sludge facilities are: thickening, digestion, dewatering, hauling, and disposal. Guidelines for the capability evaluation of the

Table 2-9 Sludge Concentration for Projecting Sludge Production From Suspended Growth STPs

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).

components of the existing sludge handling processes are provided in Table 2-10 and Table 2-11. The guidelines provided in Table 2-10 are used to compare existing facility capability to calculated sludge production. For example, an existing aerobic digester with a volume of 380 m^3 (100,000 US gal) in a plant with a calculated waste sludge volume of 19 m^3/d (5,000 US gpd) would have a hydraulic detention time of 20 days. This is greater than the guideline of 15 days provided for aerobic digesters in Table 2-10. Thus, this component of the sludge handling process in this particular STP would be rated a Type 1. The sludge handling capability evaluation is illustrated as part of the CPE example presented in Section 2.3.10.

e. Suspended Growth Major Unit Process Analysis

Major unit processes are evaluated using the performance potential graph format. An example of this format is included as part of the example CPE presented in Section 2.3.10. This analysis results in the subject STP being rated a Type 1, 2, or 3 facility, as described in Section 2.2.1.2.

If the subject STP meets the criteria for a Type 1 plant, the evaluation has indicated that all major processes have adequate capability for the plant to provide desired performance. Type 3 plants will generally require major modifications before they can be expected to meet required effluent limits. It is again pointed out that the performance potential graph provides a good tool to assess the unit process capability but ultimately, the judgement and experience of the evaluator is the deciding factor in determining the capability of facilities to provide desired performance.

2.3.3.2 Fixed Film Major Unit Processes

Fixed film facilities covered in this manual include those trickling filter plants using rock or plastic media plus those using the RBC or activated bio-filter (ABF) variations of the basic 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

Table 2-10 Guidelines for Evaluating Capability of Existing Sludge Handling Processes

Process	Parameters That Can Be Used to Represent Type 1 Required Sludge Handling Capability[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	
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' HRT[b]
Anaerobic	
Single Stage	40 days' HRT
Two Stage	30 days' combined HRT
Drying Beds	Worst season turnover time (6 months storage)
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] Capability 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 $kg/m^3/d$ (5 lb/d/sq ft), the existing thickener should be considered to have the required capability.

[b] HRT = Hydraulic retention time = Volume of digester ÷ Volume of waste sludge calculated to be produced.

amount and type of trickling filter media, RBC media, etc.) Other significant unit processes are the secondary clarifier and sludge handling capability.

a. Aerator

<u>Trickling Filters</u>

An approach to develop "equivalency" is used to allow a comparable evaluation of the potential performance capability of trickling filters of varying media types. <u>It is not intended</u>

Table 2-11 Miscellaneous Unit Values Used in Evaluating Sludge Handling Capability[a]

	Digester HRT[b]	Total Solids Reduction	Output Solids Conc.
	days	%	mg/l
Aerobic Digesters Following Extended Aeration (SRT >20 d)	10	10	12,000
	15	20	15,000
	20	30	17,000
	>30	35	20,000
Aerobic Digesters Following Conventional A. S. (SRT <12 d)	10	20	12,000
	15	35	15,000
	>20	40	17,000
Anaerobic Digesters for Activated + Primary, and Fixed Film + Primary (Supernating Capability Usable)	<20	0	35,000
	20	25	25,000
	30	35	20,000
	40	45	15,000
WAS Volatile Solids Content			
Conv. (SRT < 12 d)		80%	
Ext. Aer. (SRT > 20 d)		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] HRT = Hydraulic retention time = Volume of digester ÷ Volume of waste sludge expected to be produced.

that this equivalency approach be used as a basis of design. The unit surface area for common rock media is typically 43 m^2/m^3 (13 sq ft/cu ft) (3). This information can be used to convert data from trickling filters with artificial media to roughly equivalent volumes of common rock media. For example, 1,000 m^3 (35,300 cu ft) of a plastic media with a specific surface area of 89 m^2/m^3 (27 sq ft/cu ft) is roughly equivalent to [(89/43) × (1,000 m^3)] or 2,070 m^3 (7,300 cu ft) of common rock media, (where 43 m^2/m^3 is the unit surface area for common rock media). Unit surface area information for various media types is generally available in manufacturers' literature.

Using the equivalency calculation, BOD_5 loadings can be calculated for all types of media. 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. Typical criteria for evaluating the volumetric loading to a trickling filter are presented in Table 2-12.

The capability of a trickling filter can be significantly decreased if plugging occurs. Ponding on the filter is a common indicator of plugging and can be due to overgrowth of

Table 2-12 Guidelines for Assessing the Trickling Filter Unit Process in Fixed Film STPs

Current Operating Condition	Typical Unit Process Capability: Freezing Trays	Typical Unit Process Capability: Covered Filter or Non-Freezing Trays
Organic Loading, kg $BOD_5/m^3/d$ (lb BOD_5/d/1000 cu ft):[a]		
> 0.8 (50)	Type 3	Type 2
0.48-0.8 (40-50)	Type 2	Type 1
< 0.48 (30)	Type 1	Type 1
Anaerobic Sidestreams:[c]		
Not returned to plant	Rate at loadings shown	
Returned to plant ahead of Trickling filter	Derate to 75% of loadings shown	

[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).

microorganism mass, disintegration of the media, or underdrain blockage or damage. The evaluator should inspect the filter in several places (removing media where possible) to ensure that ponding underneath the upper layer of rocks is not occurring.

RBCs

The key parameters to be evaluated for RBCs are: BOD_5 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. BOD_5 loading used for evaluating RBCs is soluble BOD_5 ($SBOD_5$) per unit of media. If data are not available, $SBOD_5$ can be estimated for typical domestic wastewater as 0.4 to 0.5 of the primary effluent total BOD_5 ($TBOD_5$). If significant industrial contributions are present in the system, $SBOD_5$ should be determined by testing. Table 2-13 presents typical criteria for evaluating the capability of an RBC unit process.

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 the first stage 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.

b. Secondary Clarifier

Table 2-13 Guidelines for Assessing the RBC Unit Process in Fixed Film STPs(18)

Current Operating Condition	Typical Unit Process Capability
First Stage Loading, g $SBOD_5/m^2/d$ (lb $SBOD_5$/d/1000 sq ft):	
< 16 (3.3)	Type 1
16-24 (3.3-5)	Type 2
> 24 (5)	Type 3
System Loading, g $SBOD_5/m^2/d$ (lb $SBOD_5$/d/1000 sq ft):	
< 0.8 (3.9)	Type 1
0.8-1.2 (3.9-5.9)	Type 2
> 1.2 (5.9)	Type 3
Number of Stages:	
> 2	Rate at loadings shown
2	Derate at 90% of loadings shown
Anaerobic Sidestreams:	
Not returned to plant	Rate at loadings shown
Returned to plant ahead of RBC	Derate to 75% of loadings shown

The calculations for evaluating secondary clarifiers require that wastewater flow rate and the clarifier configuration, surface area, and depth be known (see Section 2.3.3.1). Table 2-14 presents typical criteria for evaluating the capability of a secondary clarifier at Trickling Filter or RBC plants.

c. Sludge Handling Capability
The capability of sludge handling associated with fixed film facilities is evaluated using the same approach presented in Section 2.3.3.1d for suspended growth STPs. Different unit sludge production values are used in calculating expected sludge production from fixed film facilities. Typical unit sludge production values for the various types of fixed film plants are summarized in Table 2-15. A detailed example of calculating expected sludge production and comparing it with data is included in Section 2.3.10.

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 2-15 as well as sludge concentrations from the individual fixed film processes.

The guidelines presented in Table 2-10 and Table 2-11 can be used to help an evaluator assess the performance potential of existing sludge treatment and disposal facilities.

d. Fixed Film Major Unit Process Analysis
Major unit processes are evaluated using the performance potential graph format. An example of this format is included as part of the CPE example presented in Section 2.3.10. This analysis results in the subject STP being rated a Type 1, 2, or 3 facility, as described in Section 2.2.1.2.

Table 2-14 Guidelines for Assessing the Secondary Clarifier Unit Process Component in Trickling Filter and RBC STPs

Current Operating Condition	Typical Unit Process Capability
Surface Overflow Rate, $m^3/m^2/d$ (gpd/sq ft):	
< 29 (700)	Type 1
29-37 (700-900)	Type 2
> 37 (900)	Type 3
The above SORs are typically impacted by configuration and depth. The following can be used as a guide in rating various processes.	
Configuration:	
Circular with "donut" or interior weirs	Rate at SORs shown
Circular with weirs on walls	Rate at SORs shown
Rectangular with 33% covered with weirs	Rate at SORs shown
Rectangular with 35% covered with weirs	Rate at SORs shown
Rectangular with weir at or near end	Derate to 80% of SORs shown
Depth at Weirs, m (ft):	
≥ 2.1 (7)	Rate at SORs shown
< 2.1 (7)	Derate to 75% of SORs shown

Table 2-15 Unit Sludge Production and Sludge Concentration Values for Projecting Sludge Production From Fixed Film STPs (1, 20, 23)

Process Type	kg TSS (sludge)/ kg BOD_5 removed
Trickling Filter	0.9
RBC	1.0
<u>Sludge Type:</u>	<u>Waste Conc.,mg/l</u>
Primary	50,000
Primary + Trickling Filter	35,000
Primary + RBC	35,000
Trickling Filter	20,000
RBC	20,000

If the STP being evaluated meets the criteria for a Type 1 plant, the evaluation has indicated that the plant's major processes have adequate capability to provide the desired performance. Type 3 plants will generally require major modifications before they can be expected to meet required effluent limits. It is again pointed out that the performance potential graph provides a good tool to assess the unit process capability but it the judgement and experience of the evaluator is ultimately the deciding factor in determining the capability of facilities to provide desired performance.

2.3.4 Interviews

A key component of conducting a CPE is the use of interviews to verify and expand upon the data collection process. Interviews should be conducted with all of the plant staff, including the superintendent and foreman, and with key administrative personnel. Key administrators typically include the mayor, a council person or board member from the wastewater committee, and the public works director. The interviews are conducted privately with each individual. Information collected during interviews is considered confidential, but is used to contribute to the overall findings without specific reference to any individual. Approximately 30 minutes should be allowed for each interview.

It is beneficial to complete the data collection forms (Appendix D), the major unit process evaluation (Appendix I), and the performance assessment before initiating the formal interviews. This background information allows the interviewer to better focus the interview questions. Interviews can then be used to clarify information obtained from plant records and to ascertain differences between real or perceived problems.

Intangible items such as communication, administrative support, morale, and work attitudes are also assessed during the interview process. Administrative and plant staff are both interviewed in order to obtain both sides of the story. The performance focus of the CPE process must be maintained in the interviews. For example, an adamantly stated concern regarding supervision or communication is only of significance in a CPE if it can be directly related to plant performance.

2.3.5 Evaluation of Performance-Limiting Factors

Identification of performance-limiting factors should be completed at a location that allows all potential factors to be discussed openly and objectively (e.g., away from the plant staff). 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 STP. 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 inappropriate technical guidance) should be identified as performance-limiting factors, since both must be corrected 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, detailed data-gathering activities (including the completed forms from Appendix D), and interviews provide the resources for identifying factors.

Each factor identified as limiting performance should be assigned an "A," "B," or "C" rating as discussed in Section 2.2.1.3. Further prioritization is accomplished by completing the summary sheet presented in Appendix B. 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.

2.3.5.1 Administration Factors

Budgeting and financial planning are the mechanisms whereby STP owners/administrators generally implement their objectives. Therefore, evaluation and discussion of these aspects is an integral part of efforts to identify the presence of administrative performance-limiting factors. For this reason, early during the on-site fieldwork, the evaluator should schedule a meeting with the key STP decision-maker and the "budget person." This meeting should be scheduled after the evaluator is familiar with the plant.

Nearly every STP's financial information is set up differently so it helps to review the information with the assistance of plant personnel to realistically rearrange the line items into categories understood by the evaluator. Forms for collecting financial data are presented in Appendix D. Analysis of these data can be supported by comparison with typical values for wastewater treatment plants (16,20,21). STPs with flows greater than 88 L/s (2 US mgd) usually have separate financial information for the wastewater treatment facilities. Smaller STPs often have financial information combined with 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 assess the financial status for small STPs.

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 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 can't afford to spend another dime on that plant." STP administration can be judged by the following criteria:

Excellent: Reliably provides adequate wastewater treatment at lowest reasonable 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 STP 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 non-supportive 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, though indirectly, affect plant performance is through personnel motivation. A positive influence exists if administrators encourage professional growth through support of training, tangible awards for initial or upgrading certification, etc. 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 plant performance.

2.3.5.2 Design Factors

Data summaries, (completion of forms in Appendix D), and the completed evaluation of major unit process capabilities provide the basic information to identify and prioritize design-related performance-limiting factors. Often, to complete the evaluation of design factors, the evaluator must make field investigation of the operational flexibility of the various unit processes.

Field investigations should be completed in cooperation with the STP operator. <u>The evaluator must not make any changes unilaterally.</u> 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 ascertain 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 of implementing better process control. This is illustrated by the following discussion:

A 380 m^3/d (0.1 US 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 idea because the airlifts repeatedly plugged overnight when left at the lower rates. The evaluator convinced the operator to again try reducing the return rate so that the limits of return sludge flow control available could be defined.

Air flow 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. The return flow rate was reset by increasing the airflow substantially above the previous setting. An hour later the return flow rate was measured as 220 percent. 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 settling characteristics. To maintain a return sludge in the range of 125-150 percent required frequent checking, including an evening check not previously requested 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 STP that frequently require field investigations to determine process flexibility are:

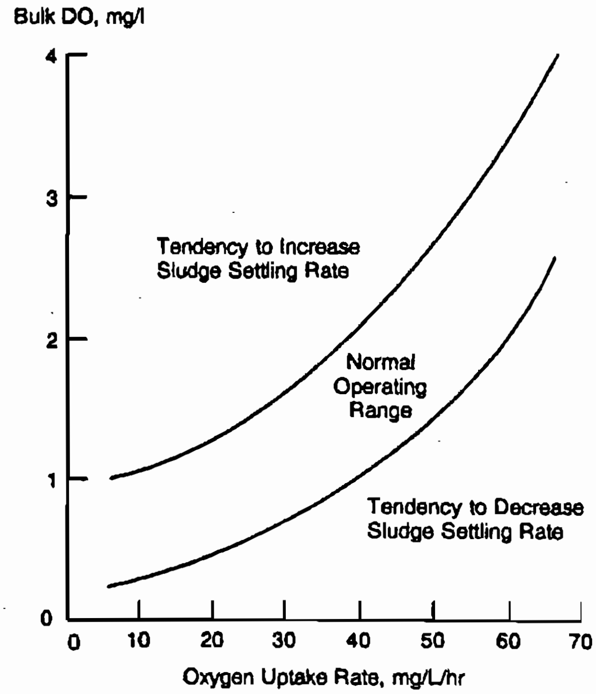
1. Suspended Growth Systems
   - Control of return sludge flow rate within typical ranges,
   - Control of aeration basin DO within the ranges presented in Figure 2-7,
   - Sludge mass control by wasting expected sludge production (mass and volume) presented in Table 2-7 and Table 2-9,
   - Flow splitting to prevent unnecessary overloading of individual process units,
   - Available mode changes to provide maximum use of existing facilities:

- Step feed or contact stabilization when the final clarifier appears to be a limiting unit process,
- Step feed when oxygen transfer is marginal.

2. Trickling Filters
   - Alternate disposal methods for anaerobic digester supernatant,
   - Ability to control sludge levels in clarifiers without adversely impacting sludge handling facilities,
   - 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 control sludge levels in clarifiers without adversely impacting sludge handling facilities,
   - Ability to redistribute individual stage loadings to provide unit loadings within the ranges shown in Table 2-13.

Table 2-16. Effect of aeration basin DO concentrations on sludge settling characteristics.



2.3.5.3 Operational Factors

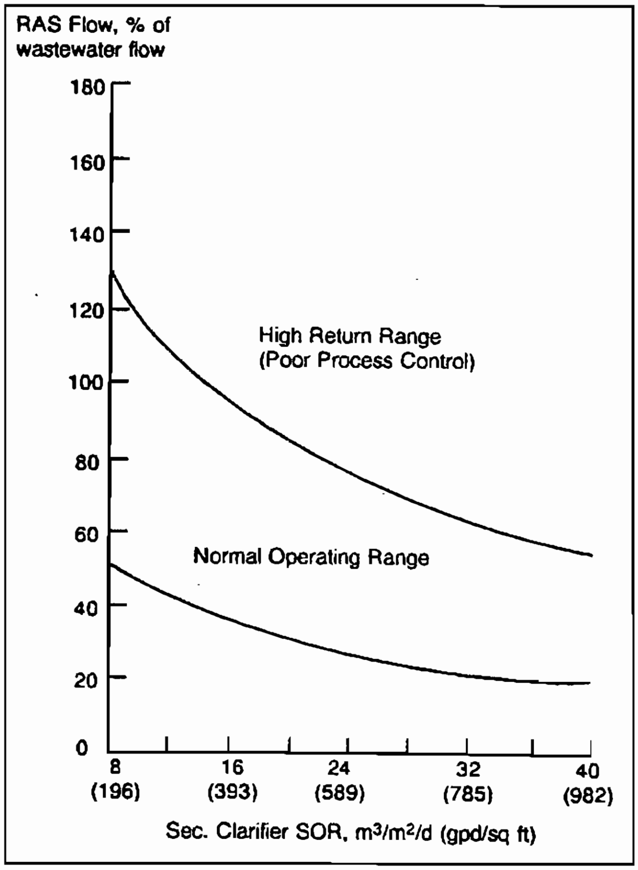
Operational factors are those factors that relate to the unit process control functions implemented at a STP. Significant performance-limiting factors often exist in these areas. The approach and methods used in maintaining process control can significantly affect the performance of plants that have adequate physical facilities. This section provides guidance to evaluators for identification and prioritization of operational factors that limit plant performance.

The evaluator should start collecting data for the process control evaluation by identifying the key STP 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 major unit process evaluation. If an operator recognizes the unit process functions and their relative influences on plant performance, a good grasp of process control is indicated. An approach to evaluating process control is discussed in the following sections.

a. Suspended Growth Facility Process Control
An operator of an activated sludge facility should be able to control sludge mass, aeration basin DO, and return sludge rate. Techniques and approaches for improving these controls are presented in Chapter 3.

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] or solids retention time [SRT], mixed liquor volatile suspended solids [MLVSS], plots of MLSS/MLVSS concentrations in the aeration basin, total mass of sludge in the plant, etc.).

Figure 2-8. Typical return sludge flow rates with various clarifier surface overflow rates.



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

- A sludge mass indicator parameter or calculation (MLVSS, SRT, total sludge units) is not obtained on a routine basis (21). "Routine" would be at least daily for an 88-L/s (2-US mgd) or larger plant and 2-3 times a week for a 4.4-L/s (0.1-US 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 mL/L).

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

- Significantly less mass is wasted than calculations indicate should be produced (i.e., the clarifiers lose solids over the weirs routinely).

- Poor perforпpersists and the mass of sludge maintained provides an SRT significantly the ranges in Table 2-17.

Table 2-17 TSolids Retention Times for Suspended Growth STPs

Process Type	Typical SRT
	days
Conventional on	4-12
Extended Aer	20-40
Contact Stabin	10-30

Aeration Basin ntrol

The aeration bO level is a significant factor in promoting the growth of either filamentous or al-type sludge organisms (22). Higher DO tends to speed up or slow down the relatiulations of these major organism types toward primarily zoogloeal. Conversely, low encourages the growth of filamentous organisms and a bulky, slow settling sludge. ral guideline for relating sludge characteristics to DO concentration in an aeration s presented in Figure 2-7. This information can be used to evaluate the DO control ch at the STP under study.

The following mmon indicators that aeration basin DO control is not properly practised at an ted sludge plant:

- DO testing is n routinely on the aeration basin. "Routine" ranges from daily for an 88-L/s (2 US r large plant to weekly for a 4.4-L/s (0.1 US mgd) plant.

- The operator ot understand or use the relationship between DO and sludge settling characteristic sludge settling is very slow and DO is very low, or sludge settling is very fast, effl turbid, and DO is very high).

Return Sludge Cl

The objective ofn sludge flow control is to optimize sludge distribution between the aeration basin aondary clarifier to achieve and maintain good sludge characteristics. Thus, return sllow rate control should be used to maximize the sludge mass and sludge detentio in the aeration basins and minimize the sludge mass and sludge detention time iclarifiers.

The following amon indicators that return sludge flow rate control is not properly practised at an ted sludge plant:

- Returns are opd outside the typical ranges (see Figure 2-8).

- The operator believes that a high sludge blanket condition in a final clarifier can be categorically lowered by increasing the sludge return rate. (e.g., 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.)

- 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.

b. 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 facility performance is so dependent on media loading, process control can in fact make a significant difference in plant performance. The following are common indicators that process control at a fixed film facility <u>is not</u> optimum (1):

- 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.

- Lack of good maintenance, indicated by:
  - Distributors on trickling filters are plugged, or leaky distributor seals are not fixed.
  - Filter media is partially plugged and measures such as chlorination, flooding, and recirculation are not used to address the problem.
  - 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 influent wastewater wet-well and must pass through the primary clarifier a second time. 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 practised.

2.3.5.4 Maintenance Factors

General information on STP 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 questions concerning the reliability and service requirements of pieces of equipment critical to process control and thus performance. If units are out of service routinely or for extended periods of time, maintenance practices may be a significant contributing cause to a performance problem. An adequate spare parts inventory is essential to 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 improper 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 record keeping systems. A good preventive maintenance program includes a schedule to distribute the workload evenly. Evaluation of these items provides a basis from which the specific results of maintenance, or lack thereof, can be assessed. This approach is illustrated by the following:

> A poorly performing trickling filter plant was assessed to have acceptable BOD_5 loadings to the filter, capable secondary clarifiers, and adequate sludge handling facilities. However, a large build-up of sludge was maintained in both the primary and secondary clarifiers. Questioning of the operator revealed that sludge was not removed adequately because the heated anaerobic digesters were upset if too much sludge is added. Further investigation indicated that adequate temperature control of the digester contents was not being achieved. The operator pointed out that the boiler for the heat exchanger was operated manually and just during the day because he had tried unsuccessfully to fix the automatic controls. Ultimately, inadequate maintenance was identified as a cause of poor plant performance.

The above discussion illustrates how a detailed evaluation of process control activities was necessary to properly identify a maintenance-related factor as a cause of poor plant performance. The evaluator must evaluate maintenance during all phases of the CPE and should not expect to identify these factors solely in a formal evaluation of maintenance procedures.

2.3.6 Performance Assessment

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

2.3.6.1 Magnitude of the Performance Problem

During the CPE, the evaluator should develop a clear understanding of the performance of the subject STP. As a first step of this assessment, recorded historical performance data, (typically the most recent 12 months of data), can be used. These data are available from copies of monthly monitoring summary sheets of samples which have been submitted to the MOEE.

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 plant staff, 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 STP is rated a Type 3 plant (inadequate major process capability), reported excellent effluent quality should be suspect. If reported 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.

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 0.07-0.11 kg (0.15-0.24 lb) /d for typical domestic wastewater. When estimating BOD_5 loads to a plant without actual data, or checking whether existing plant data is reasonable, loads from significant industrial contributors must be added to the calculated per capita loads.

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, 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 several hours. Effluent TSS may be less than 10 mg/L before and after bulking occurs, but may reach 1,000-2,000 mg/L while bulking. Samples collected to meet C of A monitoring requirements may miss bulking periods and indicate a good effluent quality.

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.

To verify good data or determine the magnitude of a performance problem, a comparison of expected vs. actual sludge production should be made during the CPE. This comparison has proven invaluable in conducting a CPE and is termed a Sludge Accountability Evaluation. A detailed example of this evaluation is presented.

a. Example Sludge Accountability Evaluation

An 810 m^3/d oxidation ditch activated sludge plant is being evaluated. The plant's MOEE discharge records indicate that the plant is in compliance. Information collected about the CPE is as follows:

- The plant has one oxidation ditch, 1 final clarifier, sludge holding tank, and 6 drying beds.

- The plant has limited infiltration and inflow problems, and limited industrial input. The plant services a closed loop type system.

- The population that the STP services approximately 1,000 people.

- Operators reported periods of washout from the secondary clarifier.

- The laboratory facilities were poorly equipped. The operators used a 30 minute settling test to determine when to waste solids from the system.

- Liquid Alum was added at a rate of 80 mL/min between the oxidation ditch and the secondary clarifier.

- There was a weir to measure WAS or RAS flow, but it was not utilized.

- Sludge drying beds were filled 40 times in total. Each sludge drying bed measures 13 m × 6 m × 1.5 m. About 29 m^3 of sludge was hauled off-site.

- Average concentration of wasted sludge based on 4 grab samples during the year = 12 g/L.

- The effluent flow was checked by measuring the depth of flow in the Parshall flume and comparing to the flow indicator. The readings were within 10% of the measured flow.

- The effluent limits for this STP are as follows:

Parameter	Limit
Effluent BOD_5	20 mg/L
Effluent Suspended Solids	25 mg/L
Effluent Fecal Coliforms (MF method)	400 per 100 mL
Chlorine Residual (after 30 minute contact)	0.5 mg/L minimum 1.0 mg/L maximum
pH	6-9
Oils & Grease	15 mg/L
Total Phosphorus	1.0 mg/L

- Plant performance data are as follows:

Performance Data for Example Sludge Accountability Evaluation

Date Month/Yr	Raw Sewage Flow m^3/d	Raw Sewage BOD_5 mg/L	Raw Sewage TSS mg/L	Raw Sewage TP mg/L	Final Effluent BOD_5 mg/L	Final Effluent TSS mg/L	Final Effluent TP mg/L
02/93	559	160	124	5.0	2	17	0.15
03/93	541	200	186	3.6	2	4	0.2
04/93	461	210	162	4.6	3	1	0.1
05/93	424	133	76.5	2.6	1	2	0.1
06/93	510	155	108	3.9	1.5	6.3	0.1
07/93	556	345	215	9.4	1.5	5	0.15
08/93	630	323	204	5.8	2	7	0.4
09/93	747	173	129	4.7	5	6	0.1
10/93	800	300	126	3.9	5	14	0.2
11/93	785	480	254	4.4	5	13	0.2
12/93	758	530	360	19.0	13	24	0.2
01/94	720	300	596	7.6	24	20	0.4
Average	653	250	212	6.2	5.4	9.9	0.2

Plant Loading Evaluation

Plant loadings should be verified by comparison to typical per capita contributions for domestic wastewater. Since industrial loadings can dramatically effect this evaluation, plants where significant industrial contributions are known to be present cannot be evaluated unless specific loading information from the industries is available.

1. Population Served

The population served is approximately 1,000 people. This can be checked if the number of taps are known, then assume that there are 2.5 persons/tap. If reported and calculated populations differ then use an average of the two numbers.

2. Plant Flow Evaluation

Assume per capita production of municipal wastewater

= 0.6 m^3/capita•d (150 US gal/capita•d)

Projected plant flow = 1,000 people × 0.6 m^3/capita•d

= 600 m^3/d

Measured Plant Flow = 653 m^3/d

Conclusion: Measured plant flow appears to be within expected range. Therefore can use actual plant flow in evaluation.

3. Organic Loading Evaluation

Assume that typical per capita domestic sewage BOD_5 = 0.08 kg BOD_5/capita•d

Projected plant organic load = 1,000 people × 0.08 kg BOD_5/capita•d
= 80 kg/d

Plant organic load (plant data) = 653 m^3/d × 250 mg/L × L•kg/1000 mg•m^3
= 163 kg/d

Conclusion: Plant BOD_5 loading is significantly higher than projected BOD_5 loading. A problem may exist with sampling and/or the BOD testing at this facility. The evaluator should continue to verify these suspicions during the CPE. Use the actual organic load for this evaluation.

<u>**Sludge Accountability Evaluation**</u>

1. Determine anticipated sludge production.

i.) Biological Solids

BOD_5 concentration removed = Influent BOD_5 - Effluent BOD_5
= 250 mg/L - 5.4 mg/L
= 244.6 mg/L

BOD_5 mass removed = BOD_5 concentration removed × Flow
= 244.6 mg/L × 653 m^3/d × 0.001 L•kg/m^3•mg
= 159.7 kg BOD_5/d

From Table 2-7, the expected solids production ratio for BOD_5 removed for oxidation ditch process is 0.65 kg TSS/kg BOD_5 removed.

Projected Biological Sludge = 0.65 kg TSS/kg BOD_5 removed × 159.7 kg BOD_5/d × 365 d/yr
= **37,894 kg/yr**

ii.) Chemical Solids

From Table 2-8, liquid alum has a density of 1330 kg/m^3, and an aluminum content of 4.3%.

$$Aluminum\ Added = Daily\ Alum\ Vol.\ x\ density\ x\ \%\ Aluminum\ content$$

$$= 80\ \frac{mL}{\min}\ x\ \frac{1\ L}{1000\ mL}\ x \frac{1\ m^3}{1000\ L}\ x\ \frac{60\ \min}{1\ hr}\ x\ \frac{24\ hr}{1\ day}\ x\ 1330 \frac{kg}{m^3}\ x\ \frac{4.3\ \%}{100\ \%}$$

$$= 0.1152\ \frac{m^3}{d}\ x\ 1330\ \frac{kg}{m^3}\ x\ \frac{4.3\ \%}{100\ \%}$$

$$= 6.59\ kg/d\ Aluminum$$

$$Aluminum\ Dose = \frac{Aluminum\ Added}{Wastewater\ Flowrate}$$

$$= \frac{6.59\ kg/d}{653\ m^3/d}$$

$$= 0.0101\ kg/m^3\ x\ \frac{1\ m^3}{1000\ L}\ x\ \frac{1x10^6\ mg}{1\ kg}$$

$$= 10.1\ mg/L$$

Projected Chemical Sludge = Wastewater Flow × Dose × Sludge Production Ratio(page 45)
= 653 m^3/d × 10.1 mg/L × 4.79 mg/mg × 365 d/yr
= 11.531 × 10^6 m^3•mg/L•yr x 0.001 L·kg/m^3·mg
= 11,531 kg/yr

iii.) Total Anticipated Sludge Production

Total Anticipated Sludge = Projected Biological Sludge + Projected Chemical Sludge
= 37,894 kg/yr + 11,531 kg/yr
= 49,425 kg/yr

2. Estimate the sludge that has been accounted for from the plant.

i.) Sludge that is unintentionally wasted in the effluent

Effluent "waste sludge" = 653 m^3/d × 9.9 mg/L × 0.001 L•kg/m^3•mg × 365 d/yr
= 2,360 kg/yr

ii.) Intentionally wasted sludge (sludge beds were filled 40 times and 29 m^3 was hauled off-site)

Sludge Bed Volume = 41 m^3 applied to each bed (operator)

Waste Sludge Volume = 40 beds/yr × 41 m^3/bed + 29 m^3/yr (hauled)
= 1,640 m^3/yr + 29 m^3/yr
= 1,669 m^3/yr

Assume that waste sludge concentration = 20 g/L.

Wasted Sludge = 1,669 m^3/yr × 20 g/L × 1000 L/m^3 × 0.001 kg/g
= **33,380 kg/yr**

Total Accounted-For Sludge = Intentional Wasted + Unintentional Wasted
= 33,380 kg/yr + 2,360 kg/yr
= **35,740 kg/yr**

The information calculated above can then be inserted into the following Performance Monitoring/Sludge Accountability Summary Sheet, as shown on the following page. There is a blank sludge accountability summary sheet in Appendix D.

This analysis reveals that the difference between predicted and reported sludge yield is 24%. This is an indication the there is a problem with sludge accountability. There may be several explanations for this difference: samples are not composited, effluent monitoring, etc.

As shown in this example, the sludge accountability analysis indicates that the plant effluent data are probably not a reliable indicator of true plant performance. Effluent quality could have been quite good when samples were collected, yet periodic solids loss could have been occurring during the relatively infrequent effluent monitoring events. Use of the sludge accountability evaluation often provides significant insight to the CPE effort.

Performance Monitoring/Sludge Accountability Summary Sheet

1. Sludge Accountability		Item
• Anticipated Sludge Production (see Table 2-7, note: unit production values include solids lost in plant effluent)		
- biological	37,894 kg/yr	1
- chemical	11,531 kg/yr	2
Total: **1 + 2**	49,425 kg/yr	3
• Accounted-for Sludge		
- wasted intentionally	33,380 kg/yr	4
- effluent sludge	2,360 kg/yr	5
Total: **4 + 5**	35,740 kg/yr	6
• Unaccounted-for Sludge: **3 - 6**	13,685 kg/yr	7
7 ÷ 365	37.5 kg/d	8
• Unaccounted-for Sludge Percentage: 100 × **7** ÷ **3**	28 %	9
if -15 < **9** < 15 then not possible to conclude that a problem with sludge wasting exists.		
if **9** > 15 then problem with effluent monitoring indicated.	← **CONDITION FOUND**	
if **9** < -15 then may indicate organic loading greater than typical domestic (ie, industrial loading).		
2. Performance Monitoring Assessment		
• Projected Actual Effluent TSS		
- recorded effluent TSS	9.9 mg/L	10
- projected increase in effluent TSS: **8** ÷ (flow)	57.4 mg/L	11
- estimated actual increase in effluent TSS: **10 + 11**	67.3 mg/L	
• Projected Actual Effluent BOD_5		
- recorded effluent BOD_5	5.4 mg/L	12
- projected increase in effluent BOD_5: 0.5 × **11**	28.7 mg/L	13
- estimated actual increase in effluent BOD_5: **12 + 13**	34.1 mg/L	
• Projected Actual Effluent TP		
- recorded effluent TP	0.2 mg/L	14
- projected increase in effluent TP: 0.04 × **11**	2.3 mg/L	15
- estimated actual increase in effluent TP: **14 + 15**	2.5 mg/L	

2.3.7 Assessing the Applicability of a Follow-up CTA

The plant performance that is achievable is initially estimated by evaluating the capability of major unit processes. This concept is schematically shown in Figure 2-1. If major unit processes are deficient in capacity, secondary treatment may not be achievable with the existing STP (i.e., it is a Type 3 plant).

If the evaluation of major unit processes shows that the major facilities have adequate capacity, then an approach like the CTA approach presented in Chapter 3, likely can be used to achieve improved STP performance (i.e., it is a Type 1 or 2 plant). For plants of these types, all performance-limiting factors may be corrected with adequate training of the appropriate STP personnel. The training is addressed toward the operational staff for improvements in plant process control and maintenance; toward the STP administration for improvements in administrative policies and budget limitations; and toward both operators and administrators to achieve minor facility modifications. "Training" as used in this context describes activities whereby information is provided to facilitate understanding and facilitate implementation of corrective actions.

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. 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 implementation of activities to optimize existing facilities (e.g., by implementing a CPE). Projecting costs for modifying a Type 3 plant are beyond the scope of a CPE effort.

2.3.8 Exit Meeting

Once the evaluation team has completed the fieldwork for the CPE, an exit meeting should be held with the STP administrators and staff. A presentation of preliminary CPE results should include brief descriptions of the following information developed during the field activities. Desirable hand-outs are noted in parentheses.

· Performance Assessment (Sludge Accountability Analysis)
· Evaluation of major unit processes (Performance Potential Graph)
· Prioritized performance-limiting factors (Factor Summary Sheet - Appendix B)

It is important to present all findings at the exit meeting with local officials. This approach eliminates surprises when the CPE report is received and begins the cooperative approach necessary for any follow-up activities. In situations where administrative or staff factors are difficult to present, the evaluator must be sensitive and use communication skills to successfully present 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 is emphasized that findings and not recommendations, are presented at the exit meeting. The CPE, while comprehensive, is conducted over a short period of time and is not a detailed engineering or design study. Recommendations made without appropriate follow-up could confuse operators and administrators and lead to inappropriate or incorrect actions on the part of the operations staff. For example, a recommendation to set the return sludge flow rate at a specific level could be followed literally to the extent that the next time the evaluator is at the plant, return rates may still be the same even though sludge settling characteristics may have changed significantly during the time frame.

It should also be made clear at the exit meeting that other factors are likely to surface during the conduct of any follow-up activities. These factors will also have to be addressed to achieve the desired performance. This understanding of the short-term CPE evaluation capabilities is often missed by local and regulatory officials, and efforts may be developed to address only the items prioritized during the CPE. The evaluator should stress that a commitment must be made to achieve the desired improved performance, not to addressing a "laundry list" of currently identified problems. An ideal conclusion for an exit meeting is that the facility owners fully recognize their responsibility to meet effluent criteria and that, empowered with the findings from the CPE, they are enthusiastic to pursue achievement of this goal.

2.3.9 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 decision-making 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. Three examples of CPE reports are presented in Appendix C. Typical contents are:

- Introduction
- Facility background
- Performance assessment
- Major unit process evaluation
- Performance-limiting factors
- Projected budget of a CTA
- Costs

As a minimum, the CPE report should be distributed to STP administrators and key plant personnel. 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.

2.3.9.1 Introduction

The introduction of the CPE report should cover the following topics:

- Reason(s) for the CPE
- Objectives of the CPE

2.3.9.2 Facility Background

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

- STP 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 processes diagram
- Plant effluent performance requirements

2.3.9.3 Performance Assessment

This section should document the performance of the facility. The following information should be included:

- Plant effluent performance requirements
- Historical performance (most recent 12 months)
- Results of sludge accountability analysis
- Data verification check
- Assessments of unit process performance

2.3.9.4 Major Unit Process Evaluation

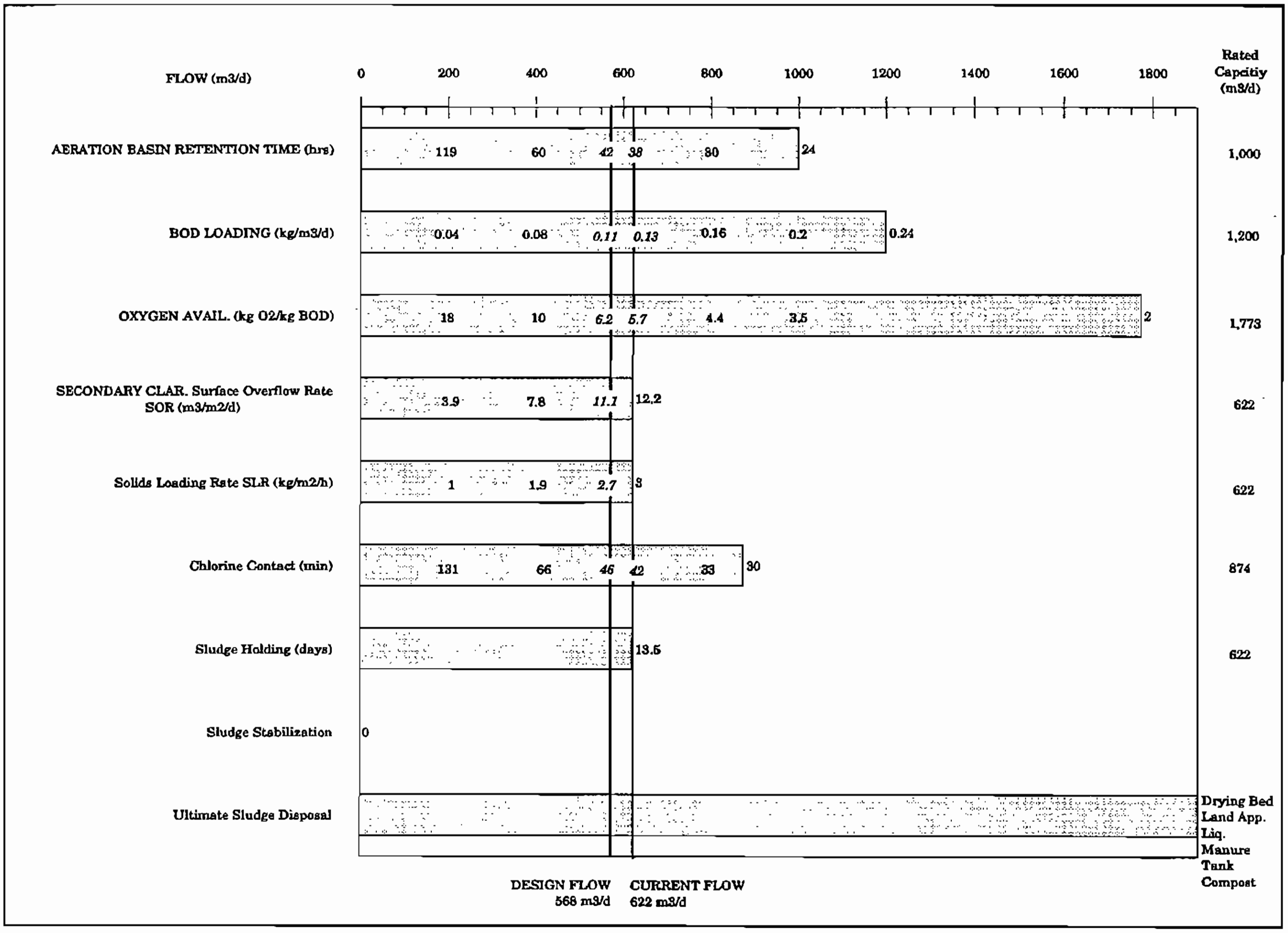
This section should include a description of the assessed plant type (Type 1, 2, or 3) and a summary of data sources for calculating current loading; for example, "current loadings were calculated using plant laboratory results for concentrations and plant flow records lowered by 10 percent to adjust for improper calibration of flow recording equipment." Other significant evaluations should be included in this section, such as calibration of flow measuring devices.

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

An effective method of presenting results of a plant's unit process evaluation relative to current and design loadings is the use of a *Performance Potential Graph.*

An example of this type of graph is shown in Figure 2-9. The plant's unit processes are listed in the left hand column. Plant flow is shown horizontally across the top of the graph. Current and design loadings are depicted by vertical lines. Rated capabilities of the various unit processes are projected using horizontal bars.

Figure 2-9. Example performance potential graph



PROCESS	BASIS
General	Total flow = 622 m^3/day; data evaluated was from 01/93 to 12/93.
Aeration Basin	Volume = 994 m^3; blower capacity = 27.6 m^3/min.; standard oxygen transfer efficiency = 10 %; secondary sludge production ratio = 0.65 kg SS produced per kg BOD_5 removed; chemical sludge = 3.0 mg/L sludge produced mg/L of aluminum added.
Secondary Clarifier	Surface Area = 50.7 m^2
Chlorine Contact Basin	Total Volume = 18.2 m^3
Sludge Storage Basin	Total volume = 88.9 m^3
Sludge Disposal	Land disposal; 3 sludge drying beds; liquid manure tank; composting operation (May, 1994)

Specific evaluation criteria are listed under each unit process. Assumptions for each set of calculations used to determine the values of the selected evaluation criteria are noted on the bottom of the graph. In addition, the value of the parameter used to project the unit's capability is shown.

The graph is time consuming to develop, but a great deal of clarity is provided to facility administrators and personnel when the plant's capabilities are thus depicted. It is important to note that the capabilities are not established using "typical" design values for unit process capacity. Judgment of the evaluator, each plant's unique circumstances, and experience with other similar facilities are factors that affect projections of the unit process capability to meet the plant's performance requirements.

As might be expected, rating a unit process' capabilities less than at its "design capacity" is something that requires full awareness of the possible ramifications. A first question of some administrators is "Why didn't I get what I paid for?" Many reasons may exist, such as industrial loadings not anticipated in design, inaccurate loading assumptions, changed criteria for capabilities of unit processes based on changes in regulations, etc. As such, the evaluator must be prepared to support the projections. Despite the potential ramifications, the effectiveness of the graph in presenting CPE results makes attempts to present information in this manner worthwhile.

2.3.9.5 Performance-Limiting Factors

Factors limiting performance that were identified during the CPE should be listed. The more serious factors (those receiving "A" or "B" ratings) are listed in order of priority and short, one- or two-paragraph explanations of each factor are included. Factors receiving a "C" rating are normally also listed. Often it is appropriate to summarize factors not identified as performance-limiting (i.e., areas where the STP was meeting or exceeding expectations) in this section of the report.

2.3.9.6 Performance Improvement Activities

Activities required to achieve required plant performance are briefly discussed. If a CTA activity could improve performance, this should be stated. If facility modifications are indicated (i.e., Type 3 plant), then a recommendation for a more detailed evaluation of treatment alternatives should be made.

2.3.9.7 Costs

On occasion it may be appropriate to identify costs associated with follow-up activities. Ranges of costs can be used if an evaluator does not feel comfortable projecting specific dollar amounts due to the complexity of the factors identified. Each cost projected should be indicated as a "one-time" or "annual" cost. Costs for a CTA 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.

2.3.10 Example CPE

A 4542 m^3/d (1.2 US mgd) oxidation ditch serves a primarily residential community with a population of 8,500. The municipality was notified by the MOEE that the self-monitoring reports indicated the STP is not meeting its Certificate of Approval requirements of 25 mg/L for BOD_5 and TSS on an annual average basis, and effluent TP of 1.0 mg/L on a monthly average basis.

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 was subsequently hired.

2.3.10.1 Plant Data

A flow diagram is presented in Figure 2-10. The following data were extracted from the completed data collection forms as presented in Appendix D.

DESIGN DATA

Design Flow:	4542 m^3/d
Hydraulic Capacity:	11356 m^3/d
Organic Loading:	900 kg BOD_5/d 900 kg TSS/d
Preliminary Treatment:	Mechanical Bar Screen, Aerated Grit Chamber
Flow Measurement:	Parshall Flume, Sonic Level Sensor, Strip Chart Recorder
Oxidation Ditch:	Volume - 4500 m^3 O_2 Transfer - Brush Rotors rated at 1,800 kg/d @ 38°C (100°F) with 2.0 mg/L residual DO
Final Clarifiers:	Number - 2 with Centre Feed and Peripheral Weirs Diameter - 15.35 m Surface Area - 370 m^2 Sidewater Depth - 2.7 m Centre Depth - 3.1 m Clarifier Scraper to Centre Hopper Liquid $FeCl_3$ addition prior to feed to final clarifier at 100 mL/min
Disinfection:	Number of Chlorinators - 2 Capacity - 113 kg/d each Contact Basin - 142 m^3
Sludge Return:	Number of Vortex Pumps - 2 Flow Control - 1.9-5.7 m^3/min Measurement - 90° V-notch Weir w/o Recorder Sampling - Manual @ Weir

Aerobic Digester:	Volume - 1150 m^3 Sludge Removal - Bottom Pipe to Drying Beds Supernatant Removal - Multiple-Port Draw-off to Oxidation Ditch
Sludge Drying Beds:	Number of Beds - 12 Size - 18.29 m × 36.6 m Summer Drying Time - 3 weeks Winter Drying Eliminated - Storage Required for December-March Subnatant Returned to Head of Plant Depth of beds - 0.46 m

CURRENT LOADING

Flow:	
Annual Average	3594 m^3/d
Minimum Month	3240 m^3/d
Peak Month	4320 m^3/d
Influent BOD_5:	190 mg/L
Effluent BOD_5:	10 mg/L
Influent TSS:	205 mg/L
Effluent TSS:	15 mg/L
Influent TKN:	12.0 mg/L
Influent TP:	5.0 mg/L
Effluent TP:	0.8 mg/L

2.3.10.2 Major Unit Process Evaluation

A performance potential graph similar to that shown in Figure 2-9 should be constructed for an exit meeting. The following approach can be used to establish the plant type.

Aerator

Hydraulic Retention Time:

$$HRT = \frac{Aeration\ Basin\ Volume}{Average\ Daily\ Flow}$$

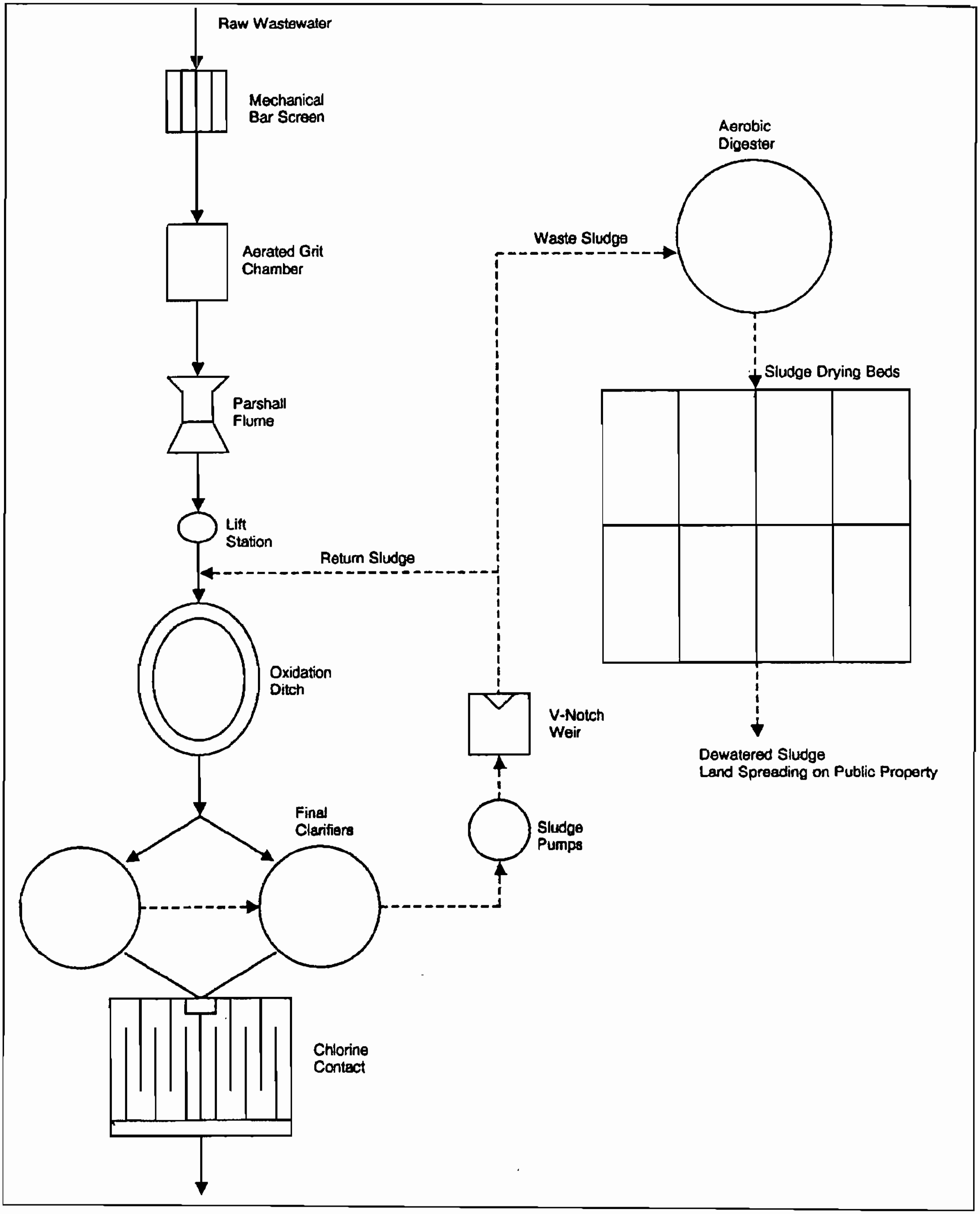
$$= \frac{4500\ m^3}{3594 m^3/d} \times 24 \frac{h}{d}$$

$$= 30\ h$$

<u>From Table 2-3, project a Type 1 capability</u>

Rearrange the HRT equation to solve for rated flow to achieve the design HRT of 24 hours.

Figure 2-10. Flow diagram of STP in example CPE.



$$Rated\ Flow = \frac{Aeration\ Basin\ Volume}{HRT}$$
$$= 4500\ m^3/d$$

BOD_5 Loading per unit volume of the aeration basin:

$$BOD_5\ Loading\ per\ unit\ vol.\ of\ aeration\ basin = \frac{BOD_5\ Loading}{Aeration\ Basin\ Volume}$$
$$= \frac{190\frac{mg}{L} \times 3594\frac{m^3}{d} \times 1000\frac{L}{m^3} \times \frac{1\ kg}{1\ x\ 10^6\ mg}}{4500\ m^3}$$
$$= 0.15\ kg/m^3{\cdot}d$$

From Table 2-3, project a Type 1 capability

Rearrange the BOD_5 loading per unit volume equation to solve for the rated flow to achieve the design value of 0.20 kg/m^3·d (see Table 2-3, Extended Aeration, Type 1):

$$Rated\ Flow = \frac{BOD_5\ loading\ per\ unit\ volume \times Aeration\ Volume}{BOD_5\ Concentration \times 1000 \times \frac{1}{1 \times 10^6}}$$
$$= \frac{0.20 \times 4500}{190 \times \frac{1}{1000}}$$
$$= 4737\ m^3/d$$

Oxygen Availability (with nitrification):

$$Oxygen\ Availability = \frac{Oxygen\ Transfer\ Capacity}{BOD_5\ Applied\ Loading + Nitrogen\ Loading}$$
$$= \frac{1800\ kg\ O_2/d}{190\frac{mg}{L} \times 3594\frac{m^3}{d} \times \frac{L{\cdot}kg}{1000\ m^3{\cdot}mg} + 4.57 \times 3594\frac{m^3}{d} \times 12.0\frac{mg}{L} \times \frac{L{\cdot}kg}{1000m^3{\cdot}mg}}$$
$$= \frac{1800\ kg\ O_2/d}{683\ kg\ O_2/d + 197\ kg\ O_2/d}$$
$$= 2.0$$

From Table 2-3, project a Type 1 capability

Rearrange the oxygen availability calculation to solve for the rated flow to achieve the desired ratio of 2.0 (see Table 2-3, Oxygen Availability with Nitrification Type 1 rating):

$$Rated\ Flow = \frac{Oxygen\ Transfer\ Capacity}{Oxygen\ Availability \times (BOD_5\ Conc. + 4.57 \times TKN\ Conc.) \times 0.001 \frac{L \cdot kg}{m^3 \cdot mg}}$$

$$= \frac{1800\ kg\ O_2/d \times 1.0}{2.0 \times (190\ mg/L + 4.57 \times 12.0\ mg/L) \times 0.001 \frac{L \cdot kg}{m^3 \cdot mg}}$$

$$= 3676\ m^3/d$$

Secondary Clarifier

Configuration: Circular With Weirs on Wall

Depth at Weirs: 2.7 m

NOTE: Derate SOR evaluation criteria (Table 2-6) by 80% of values shown due to shallow depth of clarifier. For example, the type 1 evaluation criteria SOR of 12 $m^3/m^2 \cdot d$ becomes 9.6 $m^3/m^2 \cdot d$.

Surface Overflow Rate:

$$SOR = \frac{Average\ Daily\ Flow}{Clarifier\ Surface\ Area}$$

$$= \frac{3594\ m^3/d}{370\ m^2}$$

$$= 9.7\ m^3/m^2 \cdot d$$

From Table 2-6 (derated by 80%), project a Type 2.

Rearrange SOR equation to solve for the type 1 evaluation criteria of 9.6 $m^3/m^2 \cdot d$ (12 × 0.8).

$$Rated\ Flow = SOR \times Clarifier\ S.A.$$

$$= 9.6\ m^3/m^2 \cdot d \times 370\ m^2$$

$$= 3552\ m^3/d$$

Sludge Handling Capability

Capacity:

a. Expected Biological Sludge Production

Unit sludge production, from Table 2-7, is 0.65 kg TSS/kg BOD_5 removed.

BOD_5 Removed = (Influent BOD_5 - Effluent BOD_5) × Flow
= (190 mg/L - 10 mg/L) × (3594 m^3/d) × 0.001
= 647 kg BOD_5/d

Expected Sludge Mass = (0.65 kg TSS/kg BOD_5) × 647 kg BOD_5/d
= 421 kg TSS/d
= 153,665 kg/yr

b. Expected Chemical Sludge Production

#	ITEM	VALUE
1	Type of metal salt	$FeCl_3$
2	Average volume or mass of metal salt added/d	0.144 m^3/d
3	Average wastewater flow	3594 m^3/d
4	Density of metal salt (Table 2-8)	1415 kg/m^3
5	% Metal (Table 2-8)	13.8 %

1. Metal Added (liquid) . . . . A

Metal Added = Avg. Volume of Metal Salt/d × density of metal salt × % metal
= (row 2) × (row 4) × (row 5) / 100
= 0.144 m^3/d × 1415 kg/m^3 × 13.8 / 100
= 28.1 kg/d

2. Metal Dose . . . . B

$$Metal\ Dose = \frac{Metal\ Added}{Average\ Wastewater\ Flow} = \frac{A}{row\ 3} = \frac{28.1\ kg/d \times 1000}{3594\ m^3/d} = 7.8\ mg/L$$

3. Projected Chemical Sludge Production C

= Avg. Wastewater Flow × Metal Dose × Chemical Sludge Production Ratio × 365 d/yr
Where chemical sludge production ratio = 2.87 kg TSS / kg Iron (from production ratio box on page 45)
= (row 3) × (B) × 2.87 kg TSS/kg Iron ×364 d/yr
= 3,594 m^3/d × 7.8 mg/L × 2.87 kg TSS/kg Iron × 365 d/yr × 0.001 L·kg/m^3·mg
= 29,366 kg/yr

Therefore, the projected chemical waste sludge is **29,366** kg/yr or **80** kg/d.

c. Expected Total Sludge

Expected Total Sludge = Expected Biological Sludge + Chemical Sludge
= 421 kg/d + 80 kg/d = 501 kg/d

Expected Sludge Concentration, From Table 2-9: 7,500 mg/L.

Expected Sludge Volume = (501 kg/d ÷ 7500 mg/L) × 1000 = 66.8 m^3/d

Increase by 25 percent to allow operational flexibility:

Expected Sludge Volume = 1.25 × 66.8 = 83.5 m^3/d

d. Reported Sludge

Unintentional Wasting = Effluent TSS × Flow × 0.001 × 365 d/yr
= 15 mg/L × 3594 m^3 × 0.001 × 365 d/yr
= 19,677 kg TSS/yr

Intentional Wasting

It was reported that approximately 10,700 m^3 of WAS was wasted to the digester over the last 12 months. The average WAS concentration was 12,000 mg/L.

Intentional Wasting = Volume wasted/yr × WAS concentration × 0.001
= 10,700 m^3/yr × 12,000 mg/L × 0.001
= 128,400 kg/yr

A sludge accountability can now be performed as shown below:

Performance Monitoring/Sludge Accountability Summary Sheet

1. Sludge Accountability		Item
• Anticipated Sludge Production (see Table 2-7, note: unit production values include solids lost in plant effluent)		
- biological	153,300 kg/yr	1
- chemical	29,366 kg/yr	2
Total: **1** + **2**	182,666 kg/yr	3
• Accounted-for Sludge		
- wasted intentionally	128,400 kg/yr	4
- effluent sludge	19,677 kg/yr	5
Total: **4** + **5**	148,077 kg/yr	6
• Unaccounted-for Sludge: **3** - **6**	30,589 kg/yr	7
7 ÷ 365	95 kg/d	8
• Unaccounted-for Sludge Percentage: 100 × **7** ÷ **3**	19 %	9
if -15 < **9** < 15 then — not possible to conclude that a problem with sludge wasting exists.		
if **9** > 15 then — problem with effluent monitoring indicated.	← **CONDITION FOUND**	
if **9** < -15 then — may indicate organic loading greater than typical domestic (ie, industrial loading).		
2. Performance Monitoring Assessment		
• Projected Actual Effluent TSS		
- recorded effluent TSS	15 mg/L	10
- projected increase in effluent TSS: **8** ÷ (flow)	26.4 mg/L	11
- estimated actual increase in effluent TSS: **10** + **11**	41.4 mg/L	
• Projected Actual Effluent BOD_5		
- recorded effluent BOD_5	10 mg/L	12
- projected increase in effluent BOD_5: 0.5 × **11**	13.2 mg/L	13
- estimated actual increase in effluent BOD_5: **12** + **13**	23.2 mg/L	
• Projected Actual Effluent TP		
- recorded effluent TP	0.8 mg/L	14
- projected increase in effluent TP: 0.04 × **11**	1.1 mg/L	15
- estimated actual increase in effluent TP: **14** + **15**	1.9 mg/L	

e. Percentage of Expected Sludge Production Each Process Can Handle

1. Aerobic Digester

From Table 2-10, standard for evaluating aerobic digesters is a hydraulic retention time of 15 days.

From sludge accountability it was projected that there was approximately 182,700 kg/yr of sludge production. If it is assumed that the wasting concentration is 7500 mg/L (Table 2-9).

Volume of Sludge to Digester = 182,700 kg/yr ÷ 7500 mg/L
= 24.4 kg·L/mg·yr × 1 yr/365 d × 1000 mg·m^3/L·kg
= 66.7 m^3/d

To account for variances in sludge production need to increase the calculated sludge production by 25% (page 46)

Expected Sludge Volume = 1.25 x 66.7 m^3/d = 83.4 m^3/d

$$Digester\ HRT = \frac{Total\ Digester\ Volume}{Sludge\ Flow}$$
$$= \frac{1150\ m^3}{83.4\ m^3/d}$$
$$= 13.8\ d$$

% Capability = 13.8 d ÷ 15 × 100 % = 92 %

From Table 2-10, project a Type 2 capability.

To determine rated flow capacity of digesters at design HRT of 15 days requires an interim step.

Expected Sludge flow = λ × Average daily flow
where λ = sludge flow factor

λ = Sludge Flow ÷ Average Daily Flow
= 83.4 m^3/d ÷ 3594 m^3/d
λ = 0.023

Rearrange digester HRT equation to solve for rated flow at 15 d HRT:

$$Sludge\ Flow = \frac{Total\ Digester\ Volume}{Digester\ HRT}$$
$$\lambda \times Average\ Daily\ Flow = \frac{Total\ Digester\ Volume}{Digester\ HRT}$$
$$Rated\ Flow = \frac{Total\ Digester\ Volume}{\lambda \times Digester\ HRT}$$
$$= \frac{1150\ m^3}{0.023 \times 15}$$
$$= 3333\ m^3/d$$

2. Drying Beds

From Table 2-10, 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 Retention Time (HRT) = Digester Volume/Sludge Volume

HRT = 1150 $m^3 \div 83.4\ m^3/d$ = 13.8 days

Interpolating from Table 2-11, for HRT = 13.8 days, total solids reduction of 18% and output solids concentration of about 14,400 mg/L is expected.

Sludge to Drying Beds = (501 kg TSS/d) × (1.00 - 0.18) = 411 kg/d

Expected Sludge Volume = 411 kg/d ÷ 14,400 mg/L × 1000 x 1.25 = 35.7 m^3/d

Storage Capacity of Existing Beds = # of beds × width × length × depth
= 12 × 18.29 m × 36.6 m × 0.46 m
= 3695 m^3

Storage Capacity Available = 3695 $m^3 \div 35.7\ m^3/d$ = 104 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 86% (104 ÷ 121) of required storage capacity is available during the winter 4 months.

Rate at Type 2 capability.

Rated Flow = 86% x Avg. daily Flow = 0.86 x 3594 m^3/d = 3091 m^3/d

3. Hauling

From discussions with the STP 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 *Rate at Type 1.*

4. Land Application

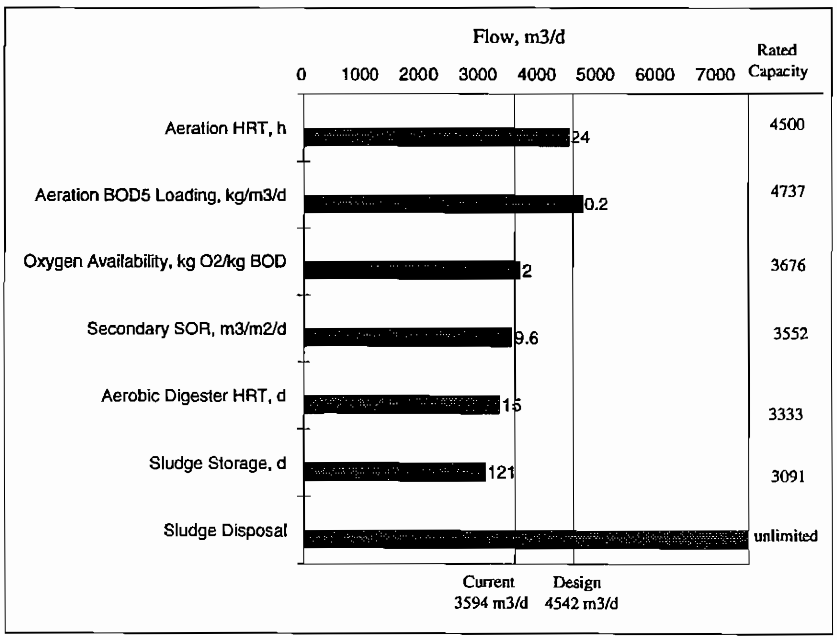
From discussions with the STP staff and administrators, "If we can get it through the beds, we can get rid of it. We can go to the landfill if we have to."

Land Application Adequacy = 100 percent   *Rate at Type 1.*

From the capacity evaluation, the drying beds are the "weakest link" at 86 percent capacity.

The results are shown in the performance potential graph, Figure 2-11.

Figure 2-11 Performance Potential Graph for Example CPE



The data indicate that the aerator capability is sufficient to receive a Type 1 rating. However, the secondary clarifier, sludge handling capability, and the total plant are only sufficient for a Type 2 rating. Therefore, the overall plant rating is Type 2. This rating indicated that improvement in plant performance without any upgrade of major processes may be likely. Attempts to address performance-limiting factors should be evaluated before construction is pursued.

2.3.10.3 Performance-Limiting Factors

The following performance-limiting factors were identified during the CPE and given rankings of "A" or "B". Further prioritization 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 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. Performance Monitoring ("B")
Performance monitoring samples were collected routinely in the morning hours. Periods when solids loss occurred from the clarifiers were generally in the afternoon.

4. Familiarity With Plant Needs ("B")
Administrators were not familiar enough with the plant requirements for performance and operations to adequately make decisions on the plant budget yet they did not allow the plant superintendent to have input to the budgeting process.

5. 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.

6. Secondary Clarifier ("B")
The shallow depth of the secondary clarifier aggravates control of effluent solids on a routine basis.

2.3.10.4 Performance Improvement Activities

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 deficient, sludge handling capability, (hauling was an available option). The STP appears to be a good candidate for improved performance through implementation of a CTA. This recommendation should be presented to the City Council. 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.

2.3.11 CPE Results

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

2.4 Personnel Capabilities for Conducting CPEs

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

- Regulatory requirement
- Process control
- Process design
- Sampling
- Laboratory testing
- Microbiology
- Hydraulic principles
- Operator training
- Wastewater facility budgeting
- Safety
- Maintenance
- Management

Consulting engineers who routinely work with STP design and start-up, and regulatory agency personnel with experience in evaluating wastewater treatment facilities, represent the types of personnel with adequate backgrounds to conduct CPEs.

Table 2-17 Typical Costs for Conducting CPEs

Type and Size of Facility	Person Days Onsite	Typical Cost (1993 $)[a]
Suspended Growth[b]		
< 760 m^3/d (0.2 mgd)	2	2,600-6,500
760 - 7600 m^3/d (0.2-2 mgd)	5	3,900-16,000
7600 - 37850 m^3/d (2-10 mgd)	7	5,200-23,500
Fixed Film[c]		
<18900 m^3/d (0.5 mgd)	2	2,600-6,500
18900 - 37850 m^3/d (0.5-10 mgd)	5	3,900-16,000

[a] For contract consultant.
[b] Includes all variations of activated sludge.
[c] Includes trickling filters with both plastic and rock media as well as RBCs.

2.5 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 2-17. 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 2-17. 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.

2.6 References

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Chapter 3
Conducting Comprehensive Technical Assistance Programs

3.1 Objective

The objective of a Comprehensive Technical Assistance (CTA) is to improve the performance of an existing STP (1). If the results of a Comprehensive Performance Evaluation (CPE) indicate a STP 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 CTA focuses on systematically addressing performance-limiting factors to achieve the desired effluent quality. This can be done without 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 CTA, and the STP may or may not meet performance objectives without major facility modifications. For these plants, the CTA focuses on clearly defining the optimum capability of existing facilities. Even if the CTA does not achieve the desired effluent quality, unit process deficiencies will be identified and plant administrators can be confident in pursuing the facility modifications indicated.

For Type 3 plants, major construction is often indicated and a more comprehensive study is warranted. A study of this type could look at long-term needs, treatment alternatives, potential location changes, and financing mechanisms. Chapter 4 of the US EPA's "Handbook: Retrofitting POTWs", provides alternatives for making facility modifications at existing facilities where specific design deficiencies have been identified. Typically, a CTA would not be implemented at a Type 3 facility until adequate modifications have been completed.

3.2 CTA Methodology

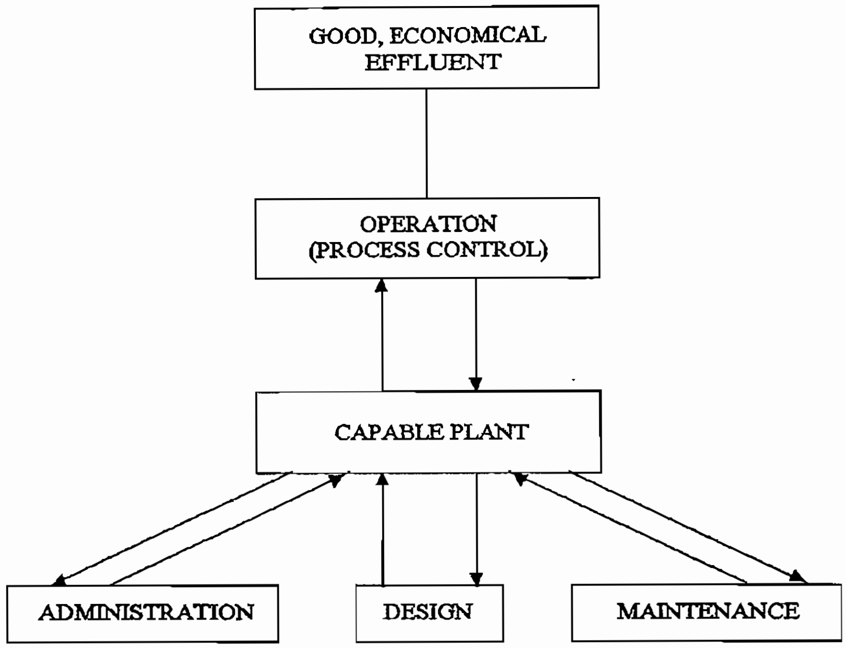
The methodology for conducting a CTA is a combination of: 1) implementing activities that support process requirements; and 2) systematically training the staff and administrators responsible for wastewater treatment (2-4).

3.2.1 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 2.2.1.3). The list provides a plant-specific outline of activities that must be addressed during the CTA. It is important to note, however, that performance-limiting factors not identified in a CPE often become apparent during conduct of the CTA and must be addressed to achieve the desired level of performance (3).

3.2.2 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. However, when implementing a CTA, the

relationship of these areas to achieving the goal of an effluent in compliance must be understood. 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 activities, that take a physically capable plant and produce adequately treated wastewater, as indicated in Figure 3-1. By focusing on the needs of the biological treatment process, as established through process control efforts, priorities for changes to achieve improved performance are thus developed.

Figure 3-1. Relationship of performance-limiting factors to achieving a performance goal.



For example, if good performance in an extended aeration activated sludge plant cannot be maintained because bulking sludge has developed as a result of inadequate oxygen transfer capability, better performance requires meeting the oxygen deficiency (5). In this case, limitations in meeting process needs (inadequate DO) establish a high priority for design changes (i.e., oxygen transfer equipment). This example illustrates 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 improve performance is implemented. Non-performance related improvements can be delayed properly until the plant has achieved the treatment objective for which it is intended.

3.2.3 Long-Term Involvement

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

- *Greater effectiveness of repetitive training techniques.* Operator and administrator training can be conducted under a variety of actual operating (e.g., seasonal) and administrative experiences. Time is also necessary for the staff to develop confidence in new techniques.

- *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. For example, for activated sludge systems, some changes can be accomplished in the period of three to five SRTs, but it is not uncommon for some changes to take weeks and even several 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 administrative (e.g., city council) and/or MOEE approval is necessary.

- *Attitude of staff*. If the staff is not supportive of the CTA approach, the CTA will require additional effort and may have to include some personnel changes to be successful.

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

3.3 CTA Activities

3.3.1 General

This section presents techniques that have been successfully used in implementing CTA programs. The methods presented should not be considered as the only workable methods, since experience has shown that no single approach will work at every STP (7). The concept of correcting performance-limiting factors, until the desired STP performance is achieved, must remain the controlling guidance when implementing a CTA. Details of implementation are, of necessity, site-specific and should be left to the individual implementing the CTA.

The individual that implements a CTA is called a facilitator. This individual is typically an "outsider" and accomplishes the CTA objectives utilizing periods of on-site involvement interspersed with off-site limited involvement. The facilitator assumes a leadership role in making process control decisions, assigning responsibilities, training STP staff, and checking progress. When not on-site, STP personnel are responsible for this leadership and the CTA facilitator monitors their progress as well as the process control and performance of the plant.

The following tools have been successfully used in implementing a CTA:

- *Telephone calls* to routinely monitor CTA progress. Routine telephone contact can be used to train and encourage STP personnel concerning their responsibility for making critical plant observations, interpreting data, and summarizing important indicators and conclusions. The effectiveness of telephone calls is limited in that the CTA facilitator must rely on observations of the STP personnel rather than his/her own. To ensure common understanding of the telephone conversations, the CTA 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 STP personnel should keep written phone logs.

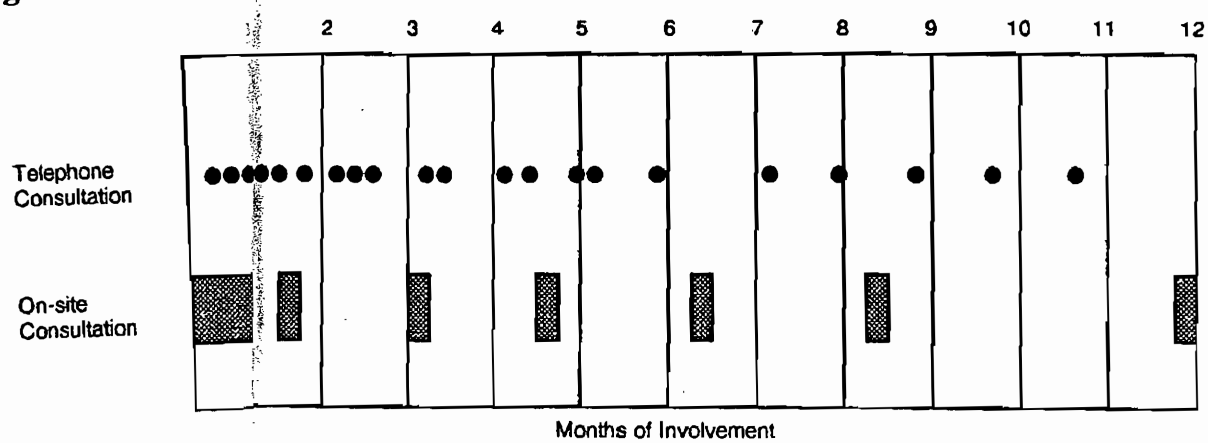
- *Site visits* to verify or clarify plant status, initiate major process control changes, test completed facility modifications, provide on-site operator training, and report progress to STP administrators. Specific dates for site visits should be scheduled as indicated by the plant status and training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

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

- *Final CTA report* to summarize activities. Since all major recommendations should have been implemented during the CTA, only current status of the STP performance should be presented in this report.

The approach of intrspersing on-site with off-site involvement is illustrated in Figure 3-2. As the CTA progress, fewer site visits and telephone calls will typically be necessary. This is in line with the ansfer of responsibility to the permanent STP staff. Typical levels of effort required by CP facilitators are presented in Table 3-1. For any STP, the level of effort is dependent the specific performance-limiting factors.

Figure 3-2. Typicascheduling of CCP activities.



3.3.2 Initial Siteit

The working relathip between the CTA facilitator and the STP staff and administration is established du the first site visit. A good working relationship based on mutual respect, communin, and understanding of the CTA, greatly enhances the potential for success.

3.3.2.1 CPE Results

A CTA is often implemented by individuals more experienced in identifying and correcting factors limiting STP performance than those who conducted the CPE. During the initial site visit, the CTA facilitator should allow time to confirm and/or modify the original performance-limiting factors identified in the CPE. Time to assess the Type 1 or 2 "rating" of the STP should also be allowed.

Table 3-1 Typical CTA Facilitator Involvement

Facility Size and Type*	Site Visit	Telephone Consultation number/week		Initial Site Visits
	days	initial	end	days
Suspended Growth:				
44 L/s (1 mgd)	3-5	2-6	2-4	4-12
440 L/s (10 mgd)	4-10	3-8	3-8	6-20
Fixed Film:				
44 L/s (1 mgd)	2-5	1-3	1-4	3-8
440 L/s (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 CTA facilitator.

The initial site visit is used to begin activities for addressing all major performance-limiting factors (rated "A" or "B" in the CPE). The process control focus of the CTA activities should be made apparent during this visit. 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 reviewed and, if necessary, standardized so that data collected can be used for evaluating progress. New or modified sampling or analyses procedures should be demonstrated by the CTA facilitator and then performed by plant personnel under the supervision of the CTA facilitator.

3.3.2.2 Monitoring Equipment

Any needed sampling or testing equipment should be obtained as quickly as possible. Rental or "loaner" equipment should be made available immediately. The CTA facilitator should assist the STP personnel in obtaining administrative approvals.

3.3.2.3 Process Control Summaries

The CTA facilitator should, with the help of plant personnel, draft a precise 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. STP personnel should provide data from the summaries to the CTA facilitator throughout the CTA. Often, weekly summaries of data are used. However, if computer capability is available, electronic transfer of data can be used to allow daily data exchange.

In small plants, where process control and monitoring activities are not conducted on a daily basis, a single page can often be used to record results. A sample process control form for a small plant used both for in-plant records and as a summary sent to the CTA facilitator is shown in Figure 3-3. Terms used in this figure are defined in Table 3-2.

3.3.2.4 Process Control Adjustments

The CTA facilitator should begin directing process control adjustments during the site visit. Where process control adjustments are grossly out of line (e.g., 300 percent estimated return sludge flows), the CTA facilitator should direct changes toward more reasonable values. Fine tuning of process control procedures and training of the STP staff cannot legitimately progress until this first level of effort is initiated .

When implementing major changes in process control adjustments, the facilitator must be very aware of the potential adverse impact on the STP operators' morale. All recommendations for process control changes should be thoroughly explained prior to implementation. Even with this approach, a CTA facilitator should not expect to obtain immediate support from STP personnel. A response such as "well, let's try it then and see" is often the best that can be expected. Some changes may have to be made with only the degree of consensus expressed by the statement: "I don't think it'll work, but we can try it."

3.3.2.5 Minor Design Changes

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

3.3.2.6 Action Lists

An important aspect of a CTA program is implementation of activities to improve plant performance. As such, it is helpful to "inventory" the action items to be accomplished. A summary of this inventory is developed and updated throughout the CTA by the CTA facilitator. The summary is distributed to the plant staff and administration. An example format for an action list is shown in Figure 3-4.

3.3.3 Improving Design Performance-Limiting Factors

The performance of Type 1 and 2 STPs can often be improved by making modifications or additions to the original design. A detailed discussion of facility modifications that can be used to improve plant performance is presented in Chapter 4 of the US EPA's "Handbook: Retrofitting POTWs". Only the conceptual approach to improving design performance-limiting factors will be presented here.

Figure 3-3. Sample process control and performance monitoring program form for a small plant.

PROCESS CONTROL SUMMARY

OPERATIONAL OBJECTIVES:

DATE ________
TIME ________
INITIALS ______

TSU ________ DO ________ $SSC_{60(min)}$ ________
RSP ________ DC_{min} ________ DC_{max} ________

RSP - lowest possible setting without plugging

PROCESS CONTROL TEST INFORMATION:

TIME (min.)	SSV (cc/L)	SSC (%)
0	1,000	
5		
30		
60		

ATC ________ RSC ________ CSC ________
DC ________ DOB ________ TEMP ________ °C
DO ________ FLOW ______________

WASTING INFORMATION:

ASU = ATC x 264,000 = ________ ASU

CSU = CSC x 37,700 = ________ CSU

SDR = ASU ÷ CSU = ________

RSP = 100 x ATC ÷ (RSC - ATC) = ________ %

Current TSU = ASU + CSU = ________ TSU

Objective WSU = Current ASU - Objective TSU = ________ - ________ = ________ WSU

WSU ÷ WSCE = ________ ÷ ________ = ________ Gallons Needed to Waste

Gallons ÷ Gallons per Inch = ________ ÷ ________ = ________ Inches Estimated to Waste

Gallons per Inch	Actual Inches	Gallons	Actual WSC, %	WSU, Gal x %
306				
306				
306				
			Total Actual WSU	

ULTIMATE DISPOSAL INFORMATION:

DATE ______________
Gal/Load ________ LOADS ________
Total Gals ______________
Avg. UDC ________
App. Rate (Gal/Acre) ________

PLANT MONITORING INFORMATION:

DATE ______________
Inf. BOD_5 ________ Eff. BOD_5 ________
Inf. TSS ________ Eff. TSS ________
MLSS ________ RATIO ________
Eff. FC ________

NOTES:

Table 3-2 Acronyms Used in Figure 3-3

Term	Definition	Calculation
Operational Objectives		
TSU	Total Sludge Units	ASU + CSU
DO	Dissolved Oxygen	
SSC_{60}	Settled Sludge Concentration in 60 Minutes	1000 x ATC ÷ SSV_{60}
RSP	Return Sludge Percentage	100 x ATC ÷ (RSC - ATC)
DC	Digester Concentration	Centrifuge Spin
Process Control Test Information		
SSV	Settled Sludge Volume	cc/L from Mallory Settleometer
ATC	Aeration Tank Concentration	Centrifuge Spin
RSC	Return Sludge Concentration	Centrifuge Spin
CSC	Clarifier Sludge Concentration	Centrifuge Spin or Clarifier Core Sample
DOB	Depth of Sludge Blanket in Clarifier	
Wasting Information		
ASU	Aerator Sludge Units	Total Aeration Tank, Volume x ATC
CSU	Clarifier Sludge Units	Total Clarifier Tank, Volume x CSC
SDR	Sludge Distribution Ratio	ASU ÷ CSU
WSU	Waste Sludge Units	WSC x Waste Flow
WSCE	Estimated Waste Sludge Conc.	
Gallon/inch	Incremental Volume of Waste Receiving Tank	
Ultimate Disposal Information		
UDC	Ultimate Disposal Conc.	Centrifuge Spin
Plant Monitoring Information		
MLSS	Mixed Liquor Suspended Solids Concentration	
Ratio		MLSS ÷ % Centrifuge Spin (mg/L per %)
FC	Fecal Coliform	# per 100 mL

3.3.3.1 Identification and Justification

Initially, proper identification of a design performance-limiting factor is required. CPE results or findings during the conduct of a CTA are excellent methods to identify design limitations. Once design factors have been identified, the process of selecting facility modification alternatives for implementation can begin. An indexed guide is presented in Chapter 4 (Table 4-2) of the US EPA's "Handbook: Retrofitting POTWs" to assist in evaluating alternatives.

The CTA facilitator and STP personnel must be able to justify each proposed modification based on the resulting increased performance capability that the modification will provide. A sound basis is to relate design modifications to the items needed to provide a capable plant such that process control objectives can be met (see Figure 3-1). The degree of

Figure 3-4. Example format for summarizing CCP action items.

PROCESS CONTROL COMMUNICATIONS NOTE

Date of Site Visit: ______________________________

Present:

Topics Discussed:

<u>Operations</u>

<u>Management</u>

Action Items Proposed or Decided:

<u>Operations</u>

<u>Management</u>

Decisions to be communicated and discussed with ______________, Others? - specify

Copy this note to

justification required usually varies with the associated costs and specific plant circumstances. For example, little justification may be required to add a sampling tap in a sludge line. Whereas justification for modifications to the aeration basin to allow use of several modes of the activated sludge process would require much more emphasis. Additionally, extensive justification may be required for a facility where sewer rates are high and have recently been raised, yet there is no money available for an identified modification.

3.3.3.2 Implementation

The CTA facilitator should ensure that each modification is formally documented in writing. This documentation is more valuable in terms of training and commitment if it is completed by STP personnel. It should include:

- Purpose of the proposed change (Identification/Justification)
- 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 CTA facilitator is to assist STP personnel in understanding and implementing their responsibility in regard to the modification. Ideally, the CTA facilitator should be a technical and managerial reference throughout the implementation of the modification, and the STP 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 CTA facilitator must become more aggressive in assuring completion of the modification.

3.3.3.3 Assessment

Following completion of a facility modification, the CTA facilitator should ensure that an evaluation of the improved STP capability is completed and documented. This assessment should compare the quantitative criteria established for the project with the capability of the actual modification. A short summary (1-2 pages) is helpful in informing and maintaining support from STP personnel and administrators.

3.3.4 Improving Maintenance Performance-Limiting Factors

Plant maintenance can generally be improved in nearly all STPs, but it is a significant performance-limiting factor in only a small percentage of plants (1,4,8). Nevertheless, adequate maintenance is essential to achieve consistent effluent quality. As such, a CTA facilitator may end up improving the maintenance program to ensure that improved performance achieved during a CTA is maintained.

The first step in addressing maintenance factors is to document any undesirable results of the current maintenance effort. If plant performance is degraded as a result of maintenance-related equipment breakdowns, the problem is easily documented. Likewise, if extensive emergency maintenance events are experienced, a need for improved preventive maintenance is easily recognized. Ideally, these factors should have been previously identified and prioritized during a CPE. However, most STPs do not have such obvious evidence directly correlating poor maintenance practices with poor performance. For these STPs, maintenance factors would not have been identified as limiting performance.

Simply formalizing recordkeeping will generally improve maintenance practices to an acceptable level in many STPs, 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 schedule. Equipment lists can be developed by touring the STP. 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 name plate) or from local equipment representatives. An information sheet should be filled out for each piece of equipment. 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.

The above system for developing a maintenance recordkeeping system has worked successfully at several STPs. However, there are many other good maintenance references available for use by CTA facilitators and STP staff (9-11).

3.3.5 Improving Administrative Performance Limiting Factors

Administrators who are unfamiliar with plant needs and thus implement policies that conflict with plant performance are a commonly identified factor. For example, such items as implementing minor modifications, purchasing testing equipment, or expanding operator coverage may be recognized by plant operating personnel as needed performance improvement steps but changes cannot be pursued due to lack of support by non-technical administrators. Administrative support and understanding is essential to the successful implementation of a CTA. The following techniques have proven useful in overcoming administrative limitations:

- *Involve plant administrators from the start of the CTA.* The initial site visit should include time with key administrators to explain the CTA process and possibly include a joint plant tour to increase their understanding of plant processes and problems.

- *Focus administrators on their responsibility to produce a "product" that meets regulatory requirements.* Administrators may be reluctant to pursue corrective actions because of lack of understanding of <u>their</u> responsibilities in producing clean water from the plant's treatment processes.

- *Listen carefully to the concerns of administrators* so that they can be addressed during the CTA. Some of their concerns or ideas may be technically unimportant, but are very important "politically." Political influence as well as technical limitations must be addressed and are considered to be an integral part of the activities of a CTA facilitator.

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

- *Initiate a process control coordination committee.* In larger plants it is often advantageous to establish a process control coordination committee. The purpose of this committee is to meet routinely (weekly) to discuss process control decisions and direction. It should include, as a minimum, one representative each from operations, maintenance, laboratory, and administration. These meetings encourage communication and understanding since each party has a different perspective yet is focused on the common objective of effluent quality.

- *Encourage intimate involvement of plant staff in the budgeting process.* Budget involvement has been effective in motivating plant staff as well as encouraging more effective communication.

- *Include a plant-specific "management audit" as a portion of the CTA.* An example audit that has been used to more effectively describe administrative factors is shown in Appendix L. Results from an audit of this type have been used to effectively encourage improvement of administrative factors that are limiting performance, since the plant staff has an opportunity to provide constructive, confidential feedback on many topics that are often sensitive.

- *Encourage financial planning for modification and replacement of STP equipment structures.* This type of planning encourages communication between administrators and plant staff through the need to accomplish both short- and long-term planning. Many reference materials are available to assist the CTA facilitator in guiding activities in this area (12,13).

3.3.6 Improving Operational Performance Limiting Factors

Improvement of STP operations during a CTA 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 decision-makers. In most plants with flows less than 22 L/s (0.5 US 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. If possible in plants of this size, a "back-up" person should also be trained. 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 Section 3.2, process control is a key aspect of implementing a CTA because it represents the essential step that enables a capable plant to achieve the ultimate goal of producing a plant effluent in compliance with regulatory requirements. A detailed discussion of process control for suspended growth and fixed film facilities is presented.

3.3.6.1 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
· Aeration basin configuration

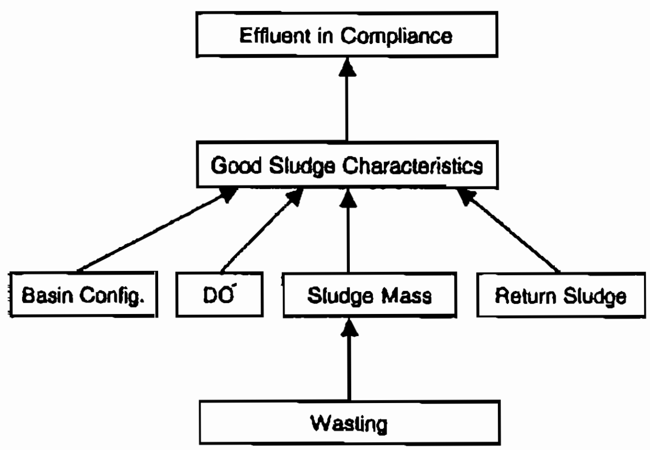
These items can be utilized to apply "pressure" to the biological environment. If a particular pressure is held for an adequate length of time to get biological system response, a desired change in activated sludge characteristics - such as settling velocity - will result.

The relationships between sludge characteristics, pressure, and time for biological system response relative to process control parameters are graphically depicted in Figure 3-5.

a. Suspended Growth Characteristics

The primary objective of suspended growth process control is achieving good performance by maintaining proper sludge characteristics (e.g., those physical and biological characteristics of a sludge that determine its ability to remove organic material from wastewater). Obtaining good sludge characteristics requires that filamentous and zoogloeal bacteria 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.

Figure 3-5. Relationship between suspended growth process control parameters and effluent quality.



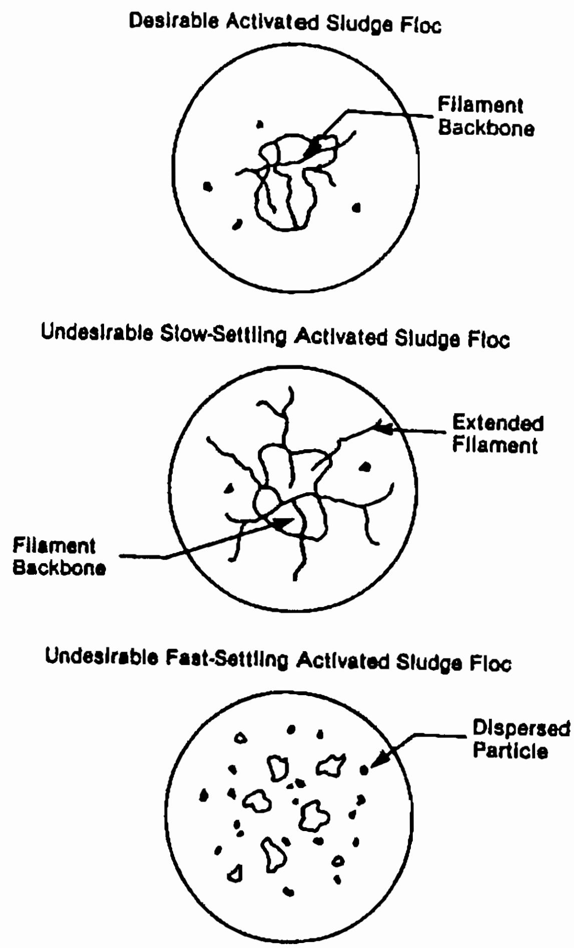
More filaments tend to produce a slower settling, larger sludge floc that produces a clearer supernatant. Too many filaments, however, produce a sludge that will not adequately settle and thicken in the final clarifier, often causing sludge to be carried over the clarifier weirs. Having fewer filaments 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 3-6 (14).

It is desirable to obtain good solids/liquid separation 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 process control to obtain the best balance of fast- and slow-settling characteristics. Settling tests and microscopic examinations can be used to monitor the sludge conditions shown in Figure 3-6.

b. Suspended Growth Mass Control

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

Figure 3-6. Representations of activated sludge floc.



A common mass control technique is based on maintaining a relatively constant MLSS 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, (e.g., SRT).

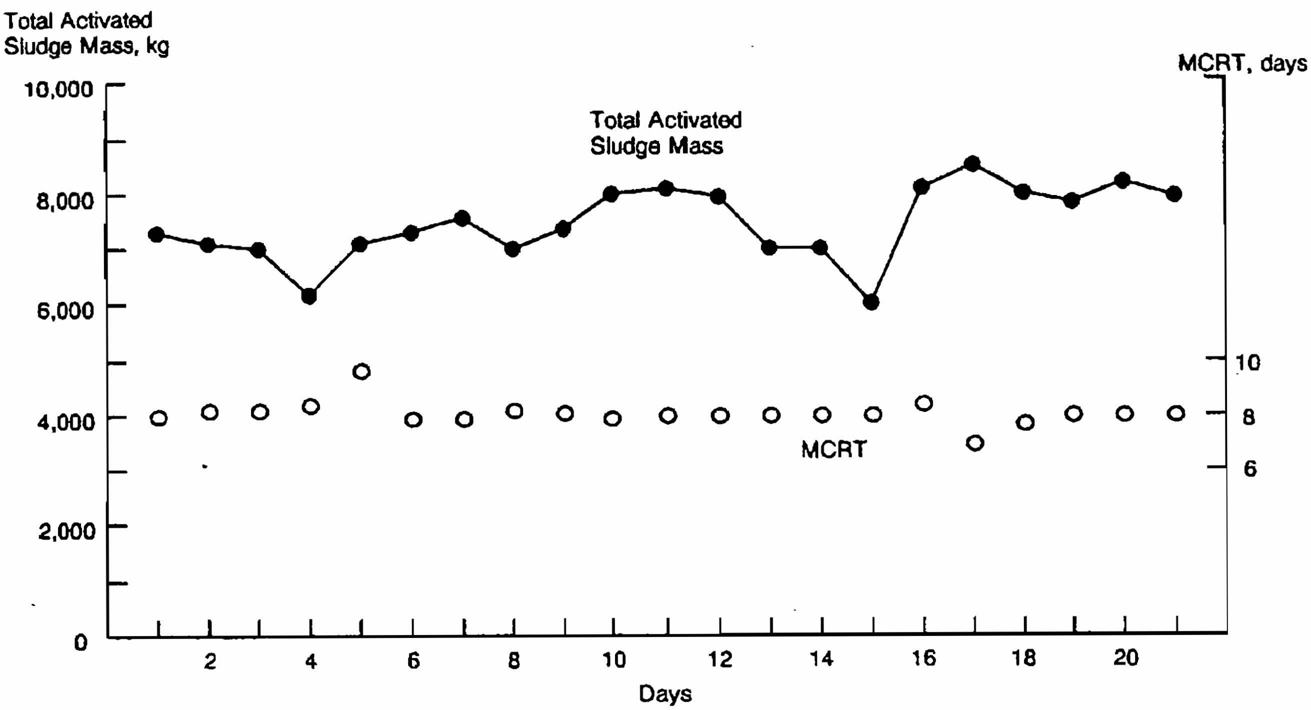
Mass control schemes based on the mass of sludge in the aeration basin (e.g., MLSS control) assume that variations in the amount of sludge in the secondary clarifiers is insignificant. A preferred approach includes secondary clarifier sludge in the mass control monitoring program.

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 SRT approach can be set up to include the mass of sludge in the aeration basin and the secondary clarifier (6). A variation of this technique is to select a desired level of total mass for the system (e.g., 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.

Suspended growth mass control using the SRT approach requires that the total sludge mass be measured each day and that total be divided by the target SRT to estimate a mass to be wasted. Actual SRTs 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 SRT (MCRT) approach are shown in Figure 3-7. During this period the target SRT was kept constant at 8 days. The data in Figure 3-7 show that fairly constant SRT can be maintained. From a process control viewpoint, an advantage of mass control by this method is that it requires daily wasting.

Figure 3-7. Activated Sludge Mass Control Using SRT (MCRT).

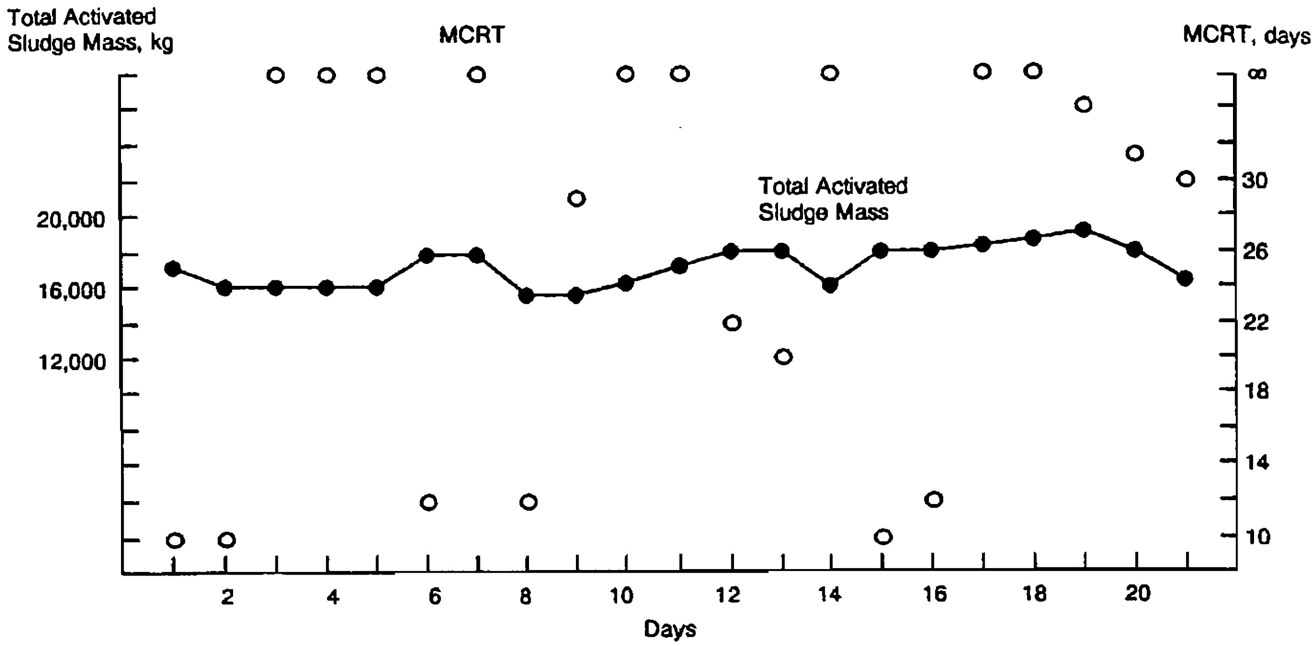


Sludge mass control using the total mass in the system approach requires that wasting be varied depending on increases or decreases in the total sludge mass. For example, if the total sludge mass was increasing above the selected target level, wasting would be increased until the desired sludge mass was again achieved. Actual data for a 3-week period of sludge mass control using the target total mass approach are shown in Figure 3-8. An important observation from Figure 3-8 is that total mass was held relatively constant despite individual SRTs 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 cannot be completed every day.

c. Return Sludge Flow Rate Control

The distribution of sludge between the aeration basin and secondary clarifier can be controlled by adjusting the return sludge flow rate. In general, return sludge flow rate control should be used to maximize the sludge mass and sludge retention time in the aeration basin and minimize the sludge mass and sludge retention time in the final clarifier.

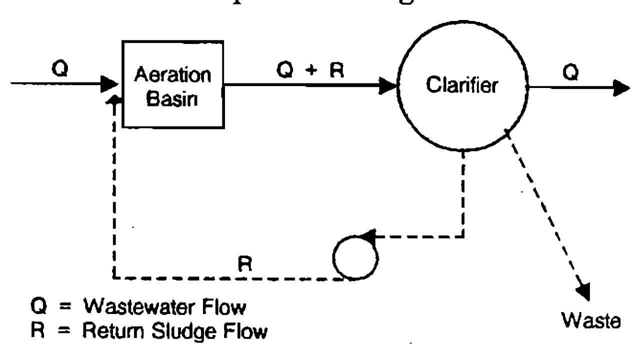
Figure 3-8. Activated Sludge Mass Control Using Total Sludge Mass.



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 since the return sludge ultimately contributes to the total hydraulic and total solids load to the clarifier (see Figure 3-9). 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. If sludge settling characteristics are such that the mass of sludge in the clarifier is increased as a result of increasing the return sludge flowrate, the objective of maximizing the sludge distribution ratio is not achieved.

Figure 3-9. Simplified activated sludge process diagram.



Two levels of improved sludge return control are typically encountered when implementing a CTA: gross adjustments to achieve normal operating ranges followed by fine tuning to further optimize the sludge distribution ratio. Thus, a grossly out-of-line return rate should first be adjusted to at least fall within the appropriate range presented in Table 3-3. Most suspended growth plants with design flows of less than 88 L/s (2 US mgd) are designed conservatively enough (e.g., Type 1 plants) that gross adjustments to bring the return sludge flow rate within normal ranges often provide sufficiently improved control. The applicability and results of gross sludge return adjustments are illustrated by the following example:

> An activated sludge plant was experiencing almost continuous problems with solids loss in the final clarifier effluent. This continued despite repeated efforts by the plant superintendent to control the filamentous nature of the sludge. The superintendent had tried chlorinating the aeration basin contents and had even dumped the entire contents of the aeration basin to polishing ponds. Review of plant operation records 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 the filamentous sludge problem, but it did significantly improve plant 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 clarifier surface overflow rates were not affected, retention time in the clarifier for settling was increased by 67 percent and solids loading to the clarifier was reduced by 40 percent. These changes greatly enhanced the solids/liquid separation capabilities of the clarifier to be more compatible with the existing sludge settling characteristics.

Table 3-3 Typical Ranges for Return Activated Sludge Pumping Capacities.

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

Plants where gross return sludge flow adjustments do not produce the desired results require a higher level of return sludge flow control. Return sludge flow adjustments need to be compatible with changes such as diurnal variations in wastewater flow and/or variations in sludge settling characteristics that occur due to diurnal variations in STP loadings. The selection of a specific fine-tuning technique, and evaluation of the results, is best left to the skill and judgment of an experienced CTA facilitator and is not discussed in this document.

d. Aeration Basin DO Control

Oxygen levels in an aeration basin can be used to promote or hinder the growth rates of filamentous organisms in suspended growth processes (5,6,14,15). DO control can therefore be used to promote the desired balance between filamentous and zoogloeal microorganisms, which controls sludge settling characteristics and ultimately leads to improved plant performance.

In activated sludge plants, 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 discussed 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 developing a DO process control approach. Oxygen demand is the mass of oxygen required to meet BOD_5 and nitrification demands and to maintain a viable microorganism population. The required residual DO is that mass of oxygen needed to provide the environment that produces desired sludge settling characteristics. 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 BOD_5 loading rate on the activated sludge system, the higher the aeration basin oxygen uptake rates and the higher the residual DO. A general guideline for residual bulk DO is shown in Figure 2-7.

Operating experience has shown that DO becomes a growth-limiting factor for zoogloeal-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, proper testing is essential to ensure that adequate oxygen is being transferred. Tests that will be most beneficial are residual DO measurements and oxygen uptake rate tests (16). 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 BOD_5 loading variations. 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 zoogloeal and filamentous organisms.

The oxygen uptake test can also be used as a measure of adequacy of oxygen transfer (17). 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. For example, 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-US gal] aeration basin was 30 mg/L/hr, or 550 kg (1,200 lb) O_2/d (150 percent of the calculated oxygen demand). These results 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 CTA facilitator.

e. Aeration Basin Configuration

Sludge characteristics and thus plant performance can often be improved by utilizing different aeration basin loading configurations. For example, the adverse impacts of extremes in flow and BOD_5 loading variations can be minimized by operating in the step feed or contact stabilization mode as opposed to plug flow. For a more detailed discussion of utilizing aeration basin configurations to improve process performance, see Section 4.4.2 of the US EPA's "Handbook: Retrofitting POTWs".

f. Process Control Pressure

As discussed in Section 3.3.6.1a, overall suspended growth process performance is primarily a function of the sludge characteristics. Process control tests and adjustments should be made with the purpose of achieving desired sludge characteristics. The specific process controls discussed earlier (sludge mass, sludge returns, aeration basin loading configuration, and aeration basin DO) are used to apply "pressure" to develop desired sludge characteristics by changing the environment for the sludge mass. A combination of operational adjustments may be necessary to provide enough pressure to achieve the desired changes. For example, if sludge settling had slowed to an undesirable level and a wet weather season (which will cause higher average and peak clarifier hydraulic loadings) was approaching, it would be advantageous to expedite efforts to increase the settling rate. Simultaneous adjustments of several process control parameters could be used to provide more pressure in the desired direction. In general, a raise in aeration basin DO, more frequent return rate adjustments to minimize sludge mass and sludge retention time in the clarifier, and converting to a step loading mode would all be appropriate to achieve faster settling.

g. Time for Biological System Response

When making process control adjustments at suspended growth facilities, it is important to realize that, although some changes take place quite rapidly, some changes in sludge characteristics develop slowly and adequate time must be allowed for the biological system to respond to the pressures applied. Adjustments change the environment of the activated sludge very quickly, but a considerably longer period of time may be required before sludge characteristics change 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.

A tendency to return to status quo if a desired result is not achieved quickly has been observed at many plants. In the above example, a person using a trial and error approach may decide after 3 days of higher DO concentration in the aeration basin that additional aeration was the wrong adjustment and a waste of energy. However, a person directing a CTA 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 characteristics has not started to take place in a length of time equal to two or three SRTs, additional pressure should be applied. As a general reference, a time equal to three to five SRTs is necessary to establish changes in sludge characteristics.

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

h. Suspended Growth Testing

Several references are available for selecting tests and their frequency for suspended growth plants (15,18,19). To achieve adequate 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

Figure 3-3 illustrates a process control test recording sheet for an 11-L/s (0.25-US mgd) extended aeration package plant. Process control tests for this plant were conducted once per day, 2 days per week. Larger activated sludge STPs require that similar parameters be monitored. However, since larger plants are often designed less conservatively, they require more frequent monitoring and more frequent process adjustments. For example, at a 241-L/s

(5.5 US mgd) activated sludge plant, settling and mass control tests were conducted once per 8-hour shift, 7 days per week.

As a further example, Table 3-4 illustrates a testing schedule for a 2-L/s (50,000-US gpd) plant that is subjected to highly variable conditions due to drastic climate changes and wide seasonal population fluctuations. 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 (e.g., peak seasonal populations), the "critical" frequency is appropriate.

Table 3-4 Process Control Monitoring at a Small Activated Sludge Plant

Test Parameter or Evaluation	Frequency	
	Routine	Critical*
Activated Sludge:		
Control Tests	3/week	Daily
Centrifuge Spins (Aeration Tank Conc./ Return Sludge Conc./Clarifier Core Sample Conc.), Settleometer Test, Depth to Blanket, Aeration Basin DO		
Control Calculations	3/week	Daily
Total Sludge Mass, Aerator Sludge Mass, Clarifier Sludge Mass, Return Sludge Percentage, Sludge Distribution Ratio, Clarifier Solids Loading, MCRT		
Control Plots	3/week	Daily
Graph 1: Settling Results, Return Sludge Conc., Aerator Conc.		
Graph 2: Total Sludge Mass (Aerator and Clarifier), Wasted Sludge Mass		
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.

3.3.6.2 Fixed Film Process Control

Fixed film (trickling filter and RBC) STPs are not impacted to the same degree by process adjustments as are suspended growth facilities (7,8) since there are only a limited number of process adjustments that can be optimized. The potential improvement in effluent quality due to improved process control is accordingly less. Areas of process control that can be optimized to improve fixed film facility performance are discussed below.

a. Reducing Return Process Stream Loadings

The CTA facilitator should strive to reduce the BOD_5 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 BOD_5 loadings. This practice has been implemented most frequently in smaller STPs where sludge disposal is by liquid haul to nearby farmland. Another way to achieve partial BOD_5 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 minimized to lower costs. If a low solids capture is being accomplished, increased chemical usage to increase capture and reduce the impact of return flow on the plant should be considered. A more detailed description of alternatives for reducing sidestream loading is included in Chapter 4 of the US EPA's "Handbook: Retrofitting POTWs".

b. Optimizing Clarifier Operation
Process control adjustments can be used to optimize primary clarifier performance (e.g., decrease BOD_5 loading on subsequent fixed film processes). Similarly, process control adjustments can be used to optimize secondary clarifier performance. BOD_5 and TSS removals in both primary and secondary clarifiers can be typically improved by minimizing surface overflow rates and controlling sludge quantities in the clarifiers.

Surface overflow rates can be minimized by eliminating any unnecessary flow through the clarifiers. A common situation occurs when trickling filter recycle is directed through either the primary or secondary clarifier. In this case, a facility modification to provide recirculation only through the fixed film process is typically justified.

Keeping sludge blanket levels and sludge retention times low in both primary and secondary clarifiers typically enhances BOD_5 and TSS removals. These operational objectives can often be accomplished by increasing sludge pumping. Care must be exercised to ensure that removed sludge is not so thin that it adversely affects sludge treatment processes. Experience and judgment of the CTA facilitator must be used to achieve the best compromise.

c. Media Cleaning / Flushing
Solids accumulation in fixed film facilities can decrease BOD_5 removal efficiency and result in uncontrolled sloughing events that can overload secondary clarifiers. Various process control procedures can be used to regulate these occurrences.

Varying the recycle rate, and thus the hydraulic application rate, can promote sloughing. Additionally, increased recycle can help distribute the BOD_5 load throughout the filter depth. At plants having multiple filters, all of the wastewater flow can be directed to one filter on a periodic basis (e.g., weekly). Another practice, called "walking the filter," hydraulically overloads a section of the filter by physically restraining the rotational speed of the distributor arm. One method of accomplishing this procedure involves the plant operator tying a rope or cable to the arm and slowly "walking" the arm around the filter on a periodic basis.

In addition to increasing the hydraulic loading, "flooding" of fixed film filters has been used to aid in controlling solids accumulation. Also, if the media is in good condition, it can be removed and cleaned and then placed back in service (20).

d. Fixed Film Testing
Process control monitoring for fixed film facilities is generally less extensive than for suspended growth systems. 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 since this test directly measures the unit's capability to convert dissolved and colloidal organics to microbial solids.

3.4 Example CTA

An example CTA is difficult to present because many of the performance-limiting factors are addressed through training, interpersonal 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 (3). Despite these limitations, an overview of a CTA is presented based on the example CPE presented in Section 2.3.10. Also, a full CTA report is contained in Appendix K.

3.4.1 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 CTA was directed at improving plant operations (process control).

1. Operation (Process Control)

- A process control testing schedule to monitor sludge settling, sludge mass, sludge wasting, sludge return concentration and flow, and aeration basin DO was established using the guidelines in Table 3-4. On-the-job training was provided in the areas of specific process control sampling and testing requirements (see Section 3.3.6).

- A process control summary sheet was developed and process control calculations were implemented.

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

- Sludge wasting requirements were documented to 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. This actual value was higher than the projected sludge production of 0.65 kg TSS/kg BOD_5 removed used for evaluation in the CPE, further aggravating the capacity limitation of the anaerobic digester.

- STP administrators were presented with the sludge production results by using the following explanation: "Your STP treats about 1.3 million m^3 of wastewater a year which results in about 17.9 thousand m^3 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 STP at a charge of $0.22/L ($0.06/US 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, (9.072-11.34 kg 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 facility modifications, such as enlarging the aerobic digester, were avoided.

3. Maintenance

- Suggested preventive maintenance forms (similar to those in Appendix G) were provided the plant superintendent. However, lack of a documented preventive maintenance program had not been a significant performance-limiting problem and consequently, no additional emphasis was placed on plant maintenance.

4. Administration

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

3.4.2 Plant Performance

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

	Effluent BOD_5, mg/L	Effluent TSS, mg/L
Before CTA		
Reported	10	15
Estimated Actual	21	38
After CTA		
Actual	14	17

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

3.4.3 CTA Costs

The costs for the example CPE and CTA described in Sections 2.3.9 and 3.4 are summarized below:

Item	$
CPE Consultant	3,500 (one-time)
CTA 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 and annual costs)

3.4.4 Summary

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

- The primary objective of a CTA is attaining adequate performance. A secondary objective can be 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 CTA. This was true of the digester design limitations in this plant.

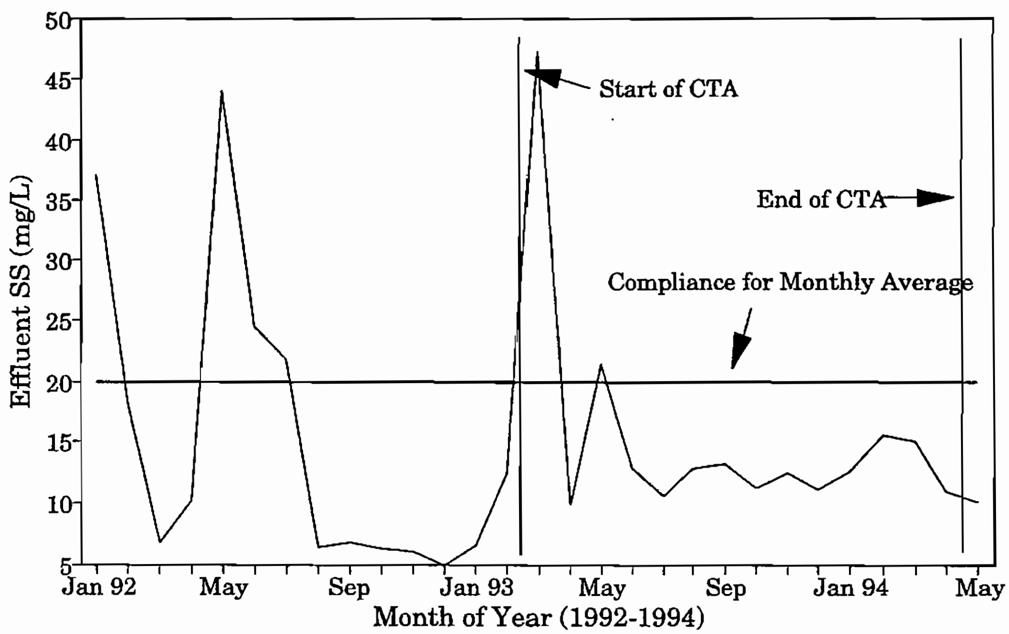
- The degree of administrative support is sometimes difficult to assess during a CPE but often becomes a major concern during a CTA. This was true when the administrators were faced with supporting dramatically increased sludge handling costs in the example CTA.

- A Type 2 STP was brought into compliance without major plant modifications.

3.5 CTA Results

The success of conducting CTA activities can be measured by a variety of parameters, such as improved operator capability, cost savings, improved maintenance, etc. However, the true success of a CTA should be documented improved performance to the degree that the plant has achieved compliance. Given this measure, the results of a successful CTA effort can be easily depicted in graphical form. Results from an actual CTA are presented in Figure 3-10. It is desirable to present CTA results in this format.

Figure 3-10. Final Effluent TSS Quality 1992 to 1994



3.6 Personnel Capabilities for Conducting CTAs

Persons responsible for conducting a CTA must have a comprehensive understanding of wastewater treatment (see Section 2.4), extensive hands-on experience in biological wastewater treatment operations, and strong capabilities in personnel motivation. Comprehensive understanding of, and experience in, biological wastewater processes are necessary because the current state-of-the-art in biological treatment leaves room for individual judgement 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 CTA must have sufficient process experience to determine appropriate application of a strategy to the personnel capabilities of the STP in question. Leadership and motivational skills are required to fill the multi-faceted "facilitator" role required of individuals responsible for implementing a CTA.

Individuals who routinely work in the area of improving wastewater treatment plant performance likely will be best qualified to be CTA 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 CTA 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 CTA is greatly enhanced by experience.

By the very nature of the CTA approach, the CTA 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 STP staff is trying to prove that "the facilitator can't make it work either." The CTA facilitator must be able to deal with this personal issue in such a manner that allows all parties involved to focus on the common goal of achieving desired plant performance.

A CTA 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 decision-makers. Some may be inexperienced and uncertified; others may have considerable experience and credentials. Administrative "training" is often a matter of <u>clearly</u> providing information to justify or support CTA 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.

CTA facilitators can be either consultants, including provincial and federal personnel, or utility employees. When local administrators decide to use a consultant to implement the CTA, they should conduct interviews and check references thoroughly. A substantial construction cost could be incurred if an inexperienced facilitator is not capable of bringing a capable STP to the desired level of treatment. Another important attribute of a consultant providing CTA services is the ability to explain problems and potential solutions clearly in a non-threatening manner.

When local administrators decide to conduct a CTA without the services of outside personnel, they should recognize that some inherent problems may exist. The individuals implementing the CTA, 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 STP initiate a CTA.

3.7 Estimating CTA Costs

CTA costs vary widely depending on: 1) the size and complexity of the facility; 2) who implements the CTA; 3) the number and nature of performance-limiting factors; and 4) the capability and cooperation available from the STP technical and administrative staff. The cost of a CTA falls into two main areas: 1) cost of a consultant to implement the CTA; and 2) cost of implementing activities to support the CTA effort, such as minor plant modifications, additional staffing, more testing equipment, and certain process changes. Estimated costs for using a CTA consultant are presented in Table 3-5.

Wide ranges are presented in Table 3-5 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 CTA effort and for operating the STP at a higher level of performance are difficult to generalize. They must be developed on an individual STP basis since they are more dependent on the particular performance-limiting factors than the size or type of facility. In most CTAs these costs equal or exceed the typical costs of a CTA consultant, as presented in Table 3-5.

Table 3-5 Typical Costs for Conducting a CTA[a]

Type and Size of Facility	CTA Consultant Cost (1993 $)
Suspended Growth:[b]	
< 9 L/s (0.2 mgd)	4000-26,000
9-88 L/s (0.2-2 mgd)	6,500-65,000
88-440 L/s (2-10 mgd)	19,500-130,500
Fixed Film:[c]	
< 22 L/s (0.5 mgd)	4000-32,500
22-440 L/s (0.5-10 mgd)	6,500-104,500

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

3.8 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, Factors Checklist, and Definitions for Assessing 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
NR	No Rating - factor has no adverse effect on plant performance (i.e., satisfactory assessment of this potentially performance-limiting item)

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* Factors are assessed based on their adverse effect on achieving desired effluent quality.

Checklist of Performance-Limiting Factors

Factor	Rating*	Comments
A. Administration	xxxxx	
1. Plant Administrators	xxxxx	
a. Policies		
b. Familiarity with Plant Needs		
c. Supervision		
d. Planning		
2. Plant Staff	xxxxx	
a. Manpower	xxxxx	
1) Number		
2) Plant Coverage		
3) Workload Distribution		
4) Personnel Turnover		
b. Morale	xxxxx	
1) Motivation		
2) Pay		
3) Work Environment		
4) Working Conditions		
c. Staff Qualification 1) Aptitude 2) Level of Education 3) Certification		
d. Productivity		
3. Financial		
a. Insufficient Funding		
b. Unnecessary Expenditures		
c. Bond Indebtedness		

* 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.
NR - No rating.

Checklist of Performance-Limiting Factors (continued)

Factor	Rating*	Comments
B. Maintenance	xxxxx	
1. Preventative	xxxxx	
a. Effective/Formal Program		
b. Spare Parts Inventory		
2. Corrective	xxxxx	
a. Procedures		
b. Critical Parts Procurement		
c. Technical Guidance (maintenance)		
3. General	xxxxx	
a. Housekeeping		
b. References Available		
c. Staff Expertise		
d. Technical Guidance (Maintenance)		
e. Equipment Age		
C. Design	xxxxx	
1. Plant Loading	xxxxx	
a. Organic		
b. Hydraulic		
c. Industrial		
d. Toxic		
e. Seasonal Variation		
f. Infiltration/Inflow		
g. Return Process Streams		

* 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.
NR - No rating.

Checklist of Performance-Limiting Factors (continued)

Factor	Rating*	Comments
2. Unit Design Adequacy	xxxxx	
a. Preliminary		
b. Primary		
c. Secondary	xxxxx	
1) Process Flexibility		
2) Process Controllability		
3) "Aerator"		
4) Clarifier		
d. Advance Waste Treatment	xxxxx	
1)		
2)		
3)		
e. Disinfection		
f. Sludge Wasting Capability		
g. Sludge Thickening/Dewatering		
h. Sludge Treatment		
i. Ultimate Sludge Disposal		

* 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.
NR - No rating.

Checklist of Performance-Limiting Factors (continued)

Factor	Rating*	Comments
3. Miscellaneous	xxxxx	
a. Plant Location		
b. Unit Process Layout		
c. Lack of Unit Bypass		
d. Flow Proportioning to Units		
e. Alarm Systems		
f. Alternate Power Sources		
g. Process Automation		
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. Equipment Malfunction		
D. Operation	xxxxx	
1. Testing	xxxxx	
a. Performance Monitoring		
b. Process Control Testing		

* 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.
NR - No rating.

Checklist of Performance-Limiting Factors (continued)

Factor	Rating*	Comments
3. Process Control Adjustments	xxxxx	
a. Wastewater Treatment Understanding		
b. Application of Concepts and Testing to Process Control		
c. Technical Guidance (Operations)		
d. Training		
e. Plant Familiarity		
4. O&M Manual/Procedures	xxxxx	
a. Adequacy		
b. Use		
E. Miscellaneous	xxxxx	
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		

* 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.
NR - No rating.

Definitions for Assessing Performance-Limiting Factors

Category	Explanation
A. Administration	
1. Plant Administrators	
a. Policies	Do staff members have authority to make required operation (e.g., adjust valve), maintenance (e.g., hire electrician), and/or administrative (e.g., purchase critical piece of equipment) decisions, or do 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 (e.g., non-support of training; industrial contributions not being controlled; or plant funding too low because of campaign to avoid rate increases)?
b. Familiarity With Plant Needs	Do administrators have a first-hand knowledge of plant needs through plant visits or discussions with operators? 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.?
c. Supervision	Do the management styles, organizational capabilities, motivational skills, budgeting skills, or communication practices at any management level adversely impact the plant to the extent that performance is affected?
d. Planning	**Does the lack of long range plans for facility replacement, emergency response, etc., adversely impact plant performance?**
2. Plant Staff	
a. Manpower	
1) Number	Does a limited number of people employed have a detrimental effect on plant operations or maintenance (e.g., not getting the necessary work done)?
2) Plant Coverage	Is plant coverage adequate such that necessary operation activities are accomplished? Can appropriate adjustments be made during the evenings, weekends, or holidays?
3) Workload Distribution	Does the improper distribution of adequate manpower (i.e., a higher priority on maintenance tasks) prevent process adjustments from being made or cause them to be made at inappropriate times, resulting in poor plant performance?

4) Personnel Turnover — Does a high personnel turnover rate cause operation and/or maintenance problems that affect process performance or reliability?

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 pay scale or benefits package discourage more highly qualified persons from applying for operator positions or cause operators to leave after they are trained?

3) Work Environment — Does a poor work environment create a condition for more "sloppy work habits" and lower operator morale?

c. Staff Qualifications

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

2) Level of Education — Does a low level of education result in poor O&M decisions? Does a high level of education cause needed training to be felt unnecessary?

3) Certification — Does the lack of adequately certified personnel result in poor O&M decisions?

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

3. Financial

a. Funding — Does the lack of available funds (e.g., inadequate rate structure) cause poor salary schedules, insufficient spare parts that results in delays in equipment repair, insufficient money for capital outlays for improvements or replacement, etc.?

b. Expenditures — Does the manner in which available funds are used 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. Preventative	
a. Effective/Formal Program	Does the absence or lack of an effective scheduling and recording procedure cause unnecessary equipment failures or excessive downtime that results in plant performance or reliability problems?
b. 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?
2. Corrective	
a. Procedures	Are procedures available to initiate maintenance activities on observed equipment operating irregularities (e.g., work order system)? Does the lack of emergency response procedures result in activities that fail to protect process needs during breakdowns of critical equipment (e.g., maintaining oxygen supply to organisms during blower breakdowns)?
b. Critical Parts Procurement	Do delays in getting replacement parts caused by procurement procedures result in extended periods of equipment downtime?
c. Technical Guidance (Maintenance)	Is technical guidance for repairing or installing equipment necessary to decrease equipment downtime, is it available and retained?
3. 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. References Available	Does the absence or lack of good equipment reference sources result in unnecessary equipment failure and/or downtime for repairs (includes maintenance portion of O&M Manual, equipment catalogues, pump curves, etc.)?
c. Staff Expertise	Does the plant staff have the necessary expertise to keep the equipment operating and to make equipment repairs when necessary?
d. Technical Guidance (Maintenance)	Does inappropriate guidance for repairing, maintaining or installing equipment from a technical resource (e.g., equipment supplier or contract service) result in equipment downtime that adversely affects performance?
e. 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. 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 — (e.g., high-volume on-off lift station pumps)

c. Industrial

d. Toxic

e. Seasonal Variation — (e.g., winter flows at ski resort)

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 problems in downstream equipment or processes that have led to degraded plant performance?

b. Primary — Does the performance of the primary treatment unit contribute to problems in downstream equipment or processes that have degraded plant performance? Do the units have any design problem areas that have caused less than required performance to meet overall treatment objectives?

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 existing plant can be utilized to improve performance (e.g., operate activated sludge plant in plug, step, or contact stabilization mode; operate RBC's in step loading mode)?

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 does inadequate scum removal adversely affect performance?

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 unit have any design limitations that contribute to its inability to accomplish disinfection (i.e., proper mixing, detention time, feed rates, feeding rates proportional to flow, etc.)?

f. Sludge Wasting Capability*

Does the inability to waste sludge adversely affect plant performance? Can desired volume of sludge be wasted? Can sludge wasting be adequately controlled? Can sludge wasted be sampled without extreme difficulty?

g. Sludge Thickening/ Dewatering*

Does the type or size of the sludge thickening/dewatering process hinder sludge wasting capability or sludge treatment such that plant performance is adversely affected?

h. 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., odours, limited sludge wasting, poor quality recycle streams, etc.)?

i. 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 the any specific areas that limit ultimate sludge disposal such as seasonal weather variations or crop harvesting?

* For the purposes of this manual, these factors are assessed on their impact on a plant to achieve final effluent requirements and are not assessed relative to meeting sludge regulation criteria.

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 cause plant upset and long-term poor treatment when a short-term bypass could have minimized pollutional load to the receiving waters; cause necessary preventive or emergency maintenance items to be cancelled or delayed; or cause more than one unit to be out of service when maintaining only one unit?

d. Flow Proportioning 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 an alarm system for critical pieces of equipment or processes cause degraded process performance?

f. Alternate Power Source

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

g. Process Automation

Does the breakdown or improper workings of automatic process monitoring or control features cause degradation of process performance? Could the availability of automatic monitoring or control devices enhance process control and improve plant 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 during necessary preventive maintenance activities?

i. Laboratory Space and Equipment — Does the absence of an adequately equipped analytical and/or process control laboratory limit plant performance?

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 no operate at all or do not operate as efficiently as necessary to achieve required performance?

m. Equipment Malfunction — Does malfunctioning equipment (i.e., not functioning in accordance with design) cause deteriorated process performance?

D. Operation

1. Testing

a. Performance Monitoring — Are the monitoring tests truly representative of plant performance (e.g., does a sludge accountability analysis support plant performance records)?

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

2. Process Control Adjustments

a. Wastewater Treatment Understanding — Is the operator's lack of a basic understanding of wastewater treatment (e.g., limited exposure to terminology, lack of understanding of the function of unit processes, etc.) a factor in poor operational decisions and poor plant performance or reliability?

b. Application of Concepts and Testing to Process Control — Is the staff deficient in the application of their knowledge of wastewater treatment and interpretation of process control testing such that improper process control adjustments are made?

c. Technical Guidance (Operations) — Does inappropriate operational information received from a technical resource (e.g., design engineer, equipment representative, state trainer)

d. Training — Does inattendance at available training programs result in poor process control decisions by the plant staff or administrators?

e. Plant Familiarity — Does the short time on the job and associated unfamiliarity with plant needs result in the absence of process control adjustments or in improper process control adjustments being made (e.g., opening or closing a wrong valve, turning on or off a wrong pump, etc.)?

4. O&M Manual/ Procedures

a. Adequacy — Does inappropriate guidance provided by the O&M Manual/Procedures result in poor or improper operational decisions?

b. Use — Does a good O&M Manual/Procedures, not used by the operator, cause poor process control and poor treatment that could have been avoided?

E. Miscellaneous

The "miscellaneous" category allows addition of factors not covered by the above definitions. Space is available in the Checklist to accommodate these additional items.

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:
Plant Performance Summary:

RANKING TABLE

Ranking	Rating	Performance-Limiting Factor
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 activated sludge with aerobic sludge digestion and drying beds).
DESIGN FLOW	Daily average plant design flow rate as of most recent upgrade.
ACTUAL FLOW	Daily average wastewater flow rate for current operating condition (e.g., for past year).
PLANT PERFORMANCE SUMMARY	Brief description of plant performance as related to discharge permit requirements (e.g., for past year).
RANKING TABLE	A list of the major causes of decreased plant performance and reliability.
RANKING	Causes of decreased plant performance and reliability, with the most critical factors listed first. (Typically only "A" and "B" factors are listed).
RATING PERFORMANCE-LIMITING FACTORS	Items identified from the Checklist (Appendix A).

APPENDIX C
Example CPE Reports

RESULTS OF THE
COMPREHENSIVE PERFORMANCE EVALUATION
OF
WASTEWATER TREATMENT PLANT A
SOUTHWESTERN, ONTARIO

April 1992

Prepared by:

Joint MOE/WTC Technical Evaluation Team

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FACILITY BACKGROUND

Plant A Water Pollution Control Plant (WPCP) in southwestern Ontario is operated by the Ministry of the Environment. The treatment plant has a rated flow capacity of 681 m^3/day (.15 MIGD) and a specified design BOD loading of 116 kg/day. The plant efficiency is rated at 90+% removal of SS and BOD.

The Smith and Loveless Model R, factory-built sewage treatment plant was commissioned in April 1974. The treatment plant is classified as a extended aeration process with phosphorous removal and chlorination capabilities. The plant is equipped with raw sewage and secondary bypasses (Figure 2).

Flow to the plant comes from a lift station equipped with 3 transfer pumps which are capable of pumping up to 700% of the design flow. This at times causes severe hydraulic overloading of the plant. Flow entering the plant passes through a comminutor or manually cleaned bar screen and into a 3 m^3 aerated grit tank. At present, the grit removal equipment is out of service and grit removal can only be accomplished by draining the grit tank. The flow then enters the circular extended aeration tank where it is aerated and mixed by coarse bubble diffusers mounted on the inner wall of the tank. Air is presently supplied by two 268 cfm positive displacement blowers which are housed in the control building. The blowers also supply air to the return activated sludge and grit chamber airlift pumps. Waste sludge flow is taken off the return activated sludge line and transferred to the 42.5 m^3 sludge holding tank every two or three days. Supernatant from the sludge holding tank is airlifted back into the aeration system prior to sludge haulage. Alum is pumped by one of two metering pumps into the discharge of the aeration tank. Mixed liquor is discharged into the centre well of a circular clarifier with a surface area of 46.8 m^2. The clarifier is equipped with an outer perimeter weir and scum removal system. Scum flows by gravity into the sludge holding tank. Final effluent is chlorinated in a 14.2 m^3 contact tank before being discharged through a 90 degree V-notch weir. Total plant flow is measured using an ultrasonic level detector and the 90 degree V-notch weir.

The waste sludge is gravity thickened in the sludge holding tank before being pumped and trucked to either approved land disposal sites or sludge storage lagoons. The sludge storage lagoons were designed to handle sludge from at least two activated sludge facilities. Sludge is presently hauled once weekly with the contractor available to haul more frequently if required.

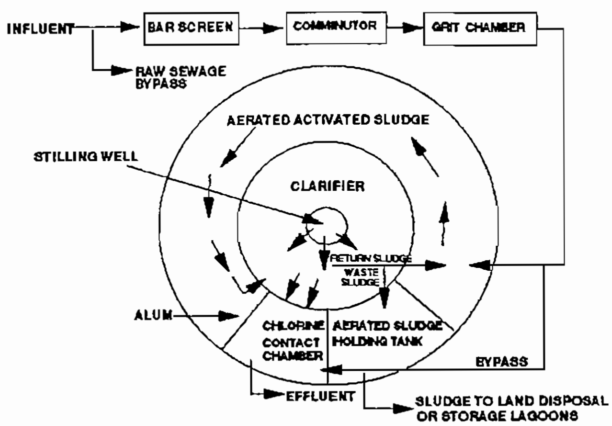

FIGURE 2. Flow Schematic Plant A WPCP.

PERFORMANCE ASSESSMENT

Historical Performance

Plant A WPCP is required under the Ministry of the Environment Policy No. 08-01, (Guidelines for the Determination of Treatment Requirements for Municipal and Private Sewage Treatment Works, Discharging to Surface Waters), to achieve annual average effluent criteria of 25 mg/L for BOD_5, SS and a monthly average of 1 mg/L for Total Phosphorous. Exceedance of these criteria constitutes non-compliance. In view of the objectives of this research study, the CPE examined the plant performance in terms of monthly average effluent quality, for BOD_5, SS, and Total Phosphorus of 15 mg/L, 20 mg/L and 1 mg/L, respectively.

Plant performance data was reviewed for the period January 1991 to December 1991. Average monthly effluent concentrations were plotted for BOD, SS and Total Phosphorus. The respective graphs are represented in Figures 3, 4, and 5 respectively.

The annual average BOD_5 concentration for the period was 5.2 mg/L. As illustrated in Figure 3 the reported plant effluent quality met the monthly average BOD_5 criteria of 15 mg/L in all months.

The annual average SS concentration for the period was 7.6 mg/L. As illustrated in Figure 4 the reported plant effluent quality met the monthly average SS criteria of 20 mg/L in all but one month (May).

The annual average Total Phosphorus concentration for the period was 0.22 mg/L. As illustrated in Figure 5 the reported plant effluent quality met the monthly average criteria of 1.0 mg/L in all months.

For the parameters reported there was only one incident of non-compliance, (SS of 29.5 mg/L) for the period January to December 1991.

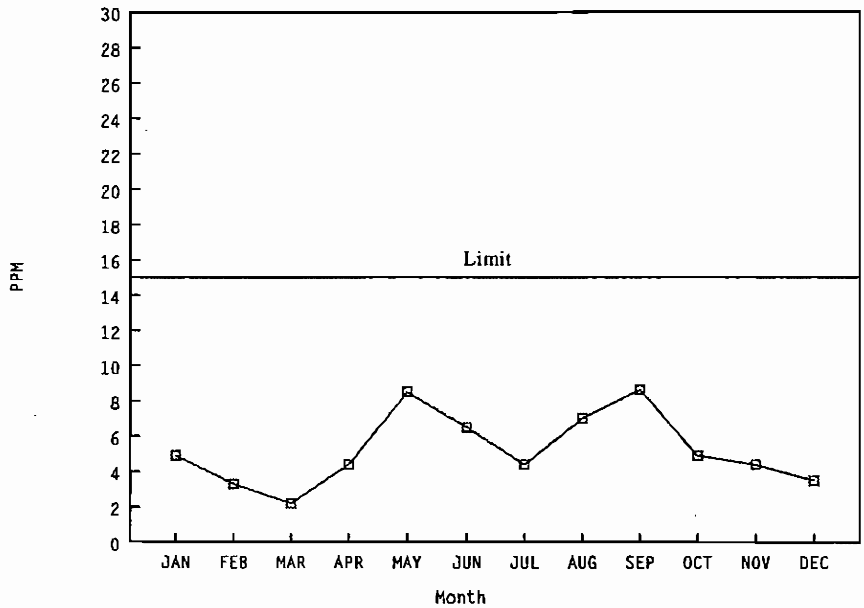

FIGURE 3. Monthly Average Effluent BOD_5.

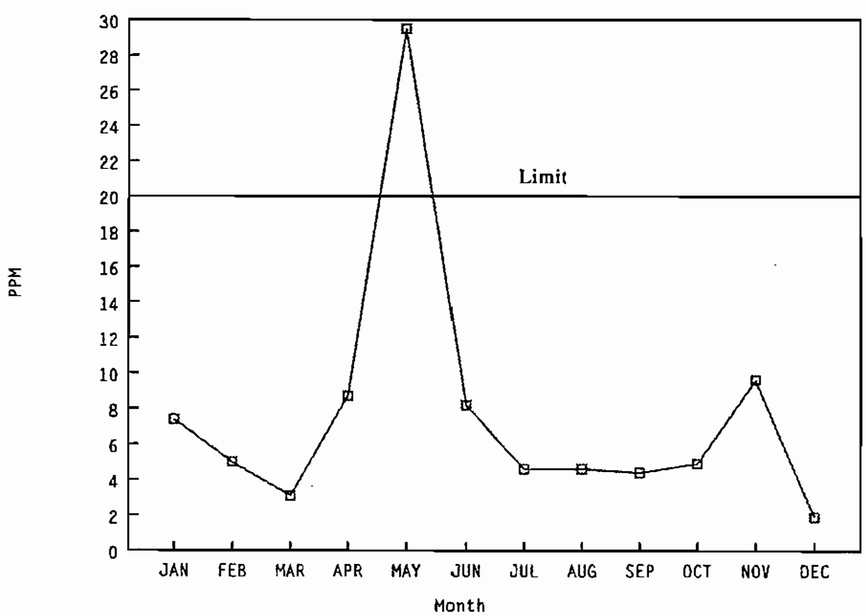

FIGURE 4. Monthly Average Effluent SS.

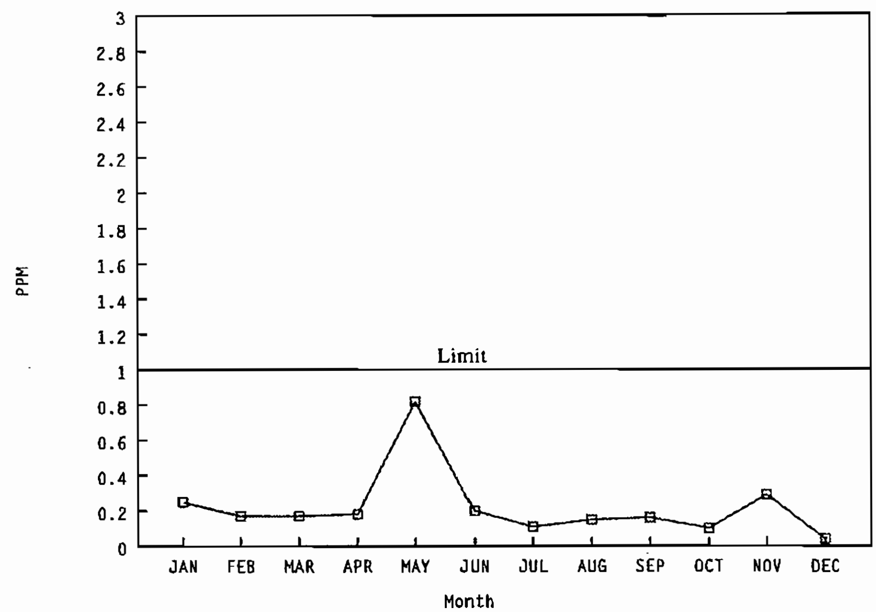

FIGURE 5. Monthly Average Effluent Total Phosphorous.

Sludge Accountability Analysis

A sludge accountability analysis was performed as part of the performance assessment. The actual sludge mass wasted from the plant over the last year was compared to an anticipated sludge mass that would have been produced by this type of treatment process over the same period. Typical sludge production data from similar processes[1] was used to calculate the anticipated sludge mass produced over the same period. If the projected sludge mass and the reported sludge mass wasted for the year are within (+/- 15%) then the reported effluent quality is probably an accurate representation of plant performance. The calculations for the sludge accountability analysis at Plant A (WPCP) are included in the Appendix at the end of this section. The projected yearly sludge mass production is about 26% greater than the actual mass wasted for the year. The reported plant data probably does not accurately reflect plant performance over the period evaluated.

MAJOR UNIT PROCESS EVALUATION

The major unit process evaluation component of the CPE projects the capability of the existing major unit processes to meet effluent standards. This evaluation was based on a review of plant drawings, equipment information, performance data as well as operation and maintenance practices. The "Performance Potential Graph" illustrates the major unit process capabilities (Figure 6).

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[1]Hegg B.A., L.D. DeMers, and J.B. Barber, Handbook - Retrofitting POTWs, EPA 625/6-89-020, U.S. Environmental Protection Agency, Centre for Environmental Research Information, Cincinnati, Ohio (July 1989).

The major unit processes included in the evaluation are shown on the left hand column. Unit processes were rated against a combination of design and operational parameters. The horizontal bars in the Performance Potential Graph represent the estimated capacity for the parameters associated with each major unit process.

Vertical dashed lines indicate the current and design flows for comparison relative to the estimated capacity.

1. The aeration basin capacity was rated on hydraulic detention time, organic loading expressed in kg BOD/day/m^3 of aeration capacity and the capability of the aeration equipment to transfer sufficient oxygen. Based on the operation of the plant As an extended aeration activated sludge process, a detention time of 24 hours and an organic loading of 0.24 kg BOD/m^3/day were used to determine the capacity rating of this process. The oxygen supply provided by diffused aeration was rated at its ability to transfer 2.0 kg of O_2/kg BOD. The aeration detention time is the most limiting factor of the aeration design parameters; however, each of the rated parameters indicate the capability of the unit process to handle present plant flows.

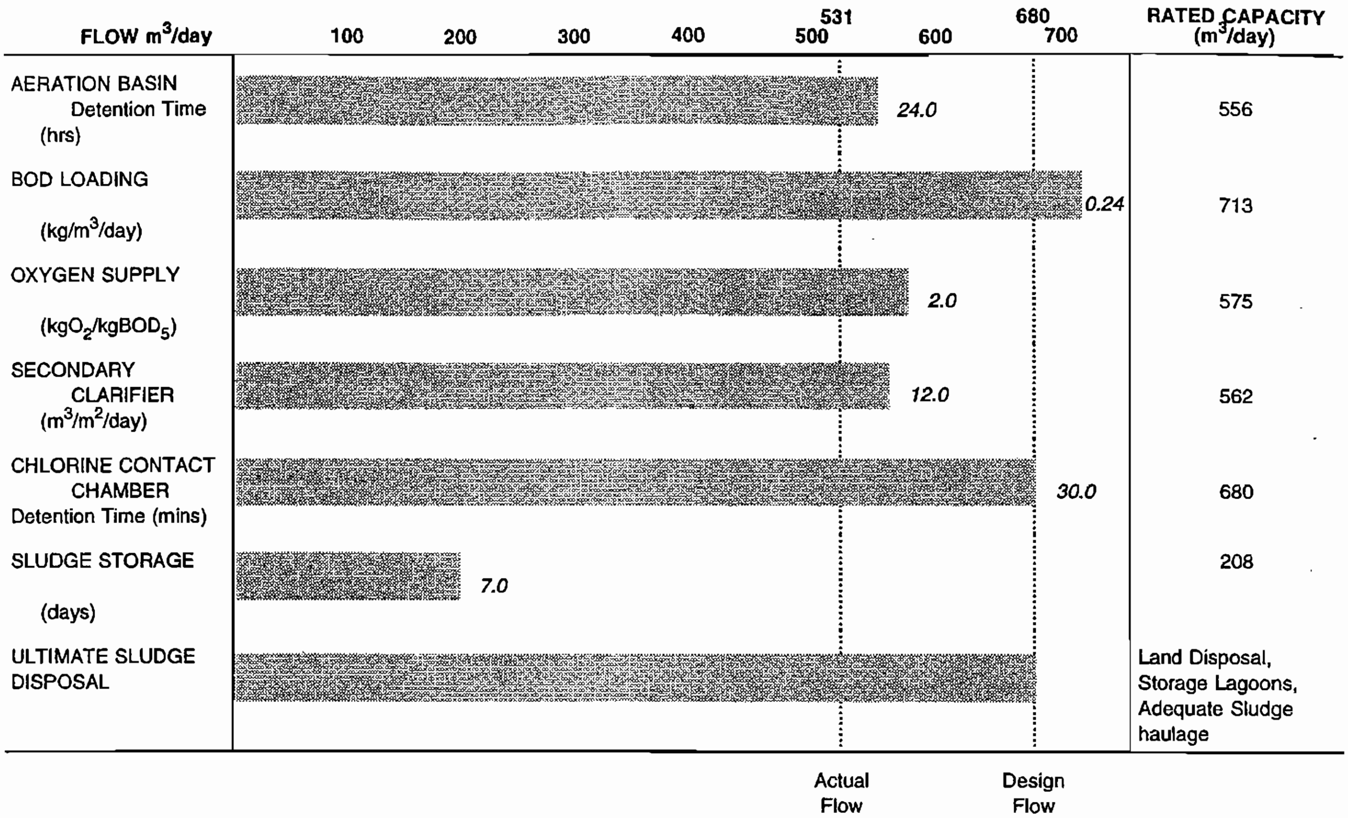
2. The secondary clarifier surface overflow rate was rated at 12 m^3/m^2/day. This surface overflow rate equates to a hydraulic capacity of 562 m^3/day based on a clarifier surface area of 46.8 m^2. This data indicates that the clarifier is capable of treating flow in excess of present hydraulic flow rates.

3. The chlorine contact tank was rated to supply 30 minutes contact time at average day flow. This would allow the plant to treat up to 680 m^3/day which is greater than current plant flow.

4. The waste sludge storage tank was rated to supply 7 days of sludge storage based on the present once weekly sludge haulage from the facility. Calculations were based on 34 m^3 of sludge storage tank capacity, an unthickened waste sludge concentration of 6 206 mg/l, 0.65 kg of solids produced per kg of BOD removed and 3.0 mg sludge produced per mg of alum added as aluminum. The resultant treatment capacity of 208 m^3 indicates that the size of the sludge holding tank could be a limiting major unit process.

5. Sludge disposal does not appear at present to be a limiting major unit process because of the availability of approved land disposal sites, the use of two sludge storage lagoons and readily available sludge haulage.

An overview of the Performance Potential Graph shows that the sludge storage tank capacity could at present, be a limiting major unit process. Additional routine sludge hauling will be required to overcome the sludge storage limitations if optimum plant performance is to be achieved. The other major unit processes indicate adequate capability to handle present flows.



PROCESS	BASIS
General	Total flow = 531 m^3/day; data evaluated was from 01/91 to 12/91.
Aeration Basin	Volume = 556 m^3; blower capacity = 15.2 m^3/min.; standard oxygen transfer efficiency = 10%; secondary sludge production ratio = .65 lb SS produced per lb BOD_5 removed; chemical sludge = 3.0 mg/L sludge produced per mg/L of alum added.
Secondary Clarifier	Surface area = 46.8 m^2
Chlorine Contact Basin	Total volume = 14.2 m^3
Sludge Storage Basin	Total volume = 34.0 m^3
Sludge Disposal	Land disposal; 2 sludge storage lagoons

FIGURE 6. Performance Potential Graph

FACTORS LIMITING PERFORMANCE

During the CPE, factors limiting performance were identified. Seventy potential factors were evaluated, and identification of applicable factors were based on the results of the major unit process evaluation, review of plant operational and maintenance data and practices, and interviews with plant Administrators and staff. These potential factors examine the areas of design, operation, maintenance, and administration.

Factors having a major effect on plant performance on a continuous basis are given an "A" rating. Factors having a major effect on performance on a periodic basis, or a minor effect on a continuous basis are given a "B" rating. Factors having a minor effect on plant performance were also identified and given a "C" rating. Descriptions of the factors identified during the Plant A CPE are presented in the following paragraphs.

Policies - A Rating (Administration)

Current staffing policy regarding the number of plant personnel available to operate Plant A, and affiliated projects is inhibiting optimum plant operation and performance. Operation of another WPCP, maintenance of two sludge storage lagoons, and servicing of ten pumping stations is preventing the allocation of adequate operational and performance monitoring time at Plant A to allow for adequate process control and sludge handling to be implemented.

Supervision - A Rating (Administration)

Currently plant supervision, is focused on housekeeping and maintenance, and not performance-based process control. This practice allows little time for operations staff to apply process monitoring and control. Staff interaction and communication is not stressed, and consequently the morale of all staff has deteriorated.

Application of Concepts and Testing to Process Control - A Rating (Operation)

The maintenance and housekeeping focus has resulted in low priority on process control, and limited application of process control techniques to optimize performance. Optimization of the activated sludge process requires attention to key concepts, such as sludge mass control, sludge distribution through return sludge flow adjustment and process sampling. Data and trend development of related parameters is required to determine short-term and long-term effects on process performance. Adequate process sampling and proper sampling point selection of process streams are also crucial. These concepts and related parameters are not being utilized or correctly applied by plant staff at the present time.

Performance Monitoring - B Rating (Operation)

During the CPE, a sludge accountability analysis was performed in which the actual and projected sludge mass produced was compared. The sludge accountability analysis for Plant

A revealed that the facility produced 26 percent less sludge than the projected value; therefore, the monitoring data probably does not accurately reflect true performance of the facility.

Hydraulic Surging - B Rating (Design)

When high flow conditions persist, the pumping capacity of two of the three submersible pumps, located at the plant's lift station, creates hydraulic surging in the plant. When three pumps are operating, the pumping capacity exceeds the plant physical hydraulic capability and the plant becomes surcharged. This can result in degraded process performance, as the aeration tank solids inventory is flushed through the clarifier.

Alarm Systems - B Rating (Design)

Absence of adequate alarming to alert personnel of the lift station pump status could potentially lead to degraded plant performance. Adequate alarming would enable personnel to determine that surging is occurring, and if bypassing is required to protect the integrity of the biological process.

Minor Performance Limiting Factors - C Rating (Design)

Minor performance limiting factors identified during the CPE include adjustment and measurement of return and waste activated sludge flow.

The current return sludge airlift system is difficult to regulate, and plugs when the supply air flow is lowered. This promotes operation of the system with maximum air supply, and could result in too high a return sludge flow rate. The return sludge stream has no flow measuring device to allow accurate measurement of volume returned. The return line is presently concealed beneath the surface of the aeration cell contents, making it impossible to measure the return sludge flow rate or sample its concentration.

Waste sludge flow from the return sludge line, has no flow measuring device to provide accurate measurement of volumes wasted.

Adequate process control is not achievable without improved measurement of return and waste sludge flows.

SUMMARY OF EVALUATION FINDINGS

Examination of the data during the CPE conducted at Plant A WPCP showed that the plant has been in compliance with its annual effluent criteria over the period from January 1 to December 31 1991. However, the plant would have had one suspended solids violation under the proposed MISA monthly effluent standards. A sludge accountability analysis showed that the data evaluated probably does not accurately represent true plant performance.

The evaluation of the major unit processes established that the sludge holding tank capacity could limit the performance of the facility if waste sludge is not hauled on a demand basis. At present, it was determined that the contract hauler was able to fulfil this requirement and based on this it was not rated as a limiting factor. The other major unit processes were rated as capable of treating present flows.

The major factors limiting performance are related to administrative and staffing policies, and the lack of process control focus by the plant staff. By allocating more time for plant operation and re-directing the plant staff activities to a performance-based process control program, it is anticipated that Plant A could meet the proposed new MISA regulations for BOD_5, suspended solids, and total phosphorus without major construction.

The second part of the CCP program, Comprehensive Technical Assistance (CTA), would be applicable to Plant A, because the high ranking performance limiting factors were Administration and Operations oriented. The efforts of the CTA would be directed at addressing the performance limiting factors identified during the CPE, providing staff training and transfer of skills to achieve process control. This effort would optimize the use of existing facilities.

APPENDIX

SLUDGE ACCOUNTABILITY ANALYSIS
PLANT A WATER POLLUTION CONTROL PLANT
FEBRUARY 26, 1992

Step 1 - Sludge Mass Wasted From Final Clarifier To Sludge Holding Tank

Avg. Volume Wasted Daily = 9.19 m^3/day
Avg. Concentration of Return Activated Sludge SS = 6206 mg/l

Mass Wasted =

9.19 m^3/day x 6206 mg/L x 365 days/yr x 0.001 kg·L/mg·m^3
= 20817 kg/yr

Step 2 - Projected Chemical Sludge

Avg. Wastewater Flow = 531 m^3/day (01/91 - 12/91)
Avg. Aluminum Dose = 8.96 mg/L
Sludge Production Ratio = 3.0 mg sludge produced/mg Aluminum added[2]

Chemical Waste Sludge =

531 m^3/day x 8.96 mg/L x 3.0 mg/mg x 365 days/yr x 0.001 kg·L/mg·m^3
= 5209 kg/yr

Step 3 - Projected Secondary Sludge

Avg. Wastewater Flow = 531 m^3/day
Avg. BOD Removed Across Secondary System
= 187 mg/L - 5 mg/L = 182 mg/L
Sludge Production Ratio = 0.65 kg SS produced/kg BOD_5 removed
(ref. U.S. EPA Handbook Retrofitting POTWs)

Secondary Waste Sludge =

531 m^3/day x 182 mg/L x 0.65 kg/kg x 365 days/yr x 0.001 kg·L/mg·m^3
= 22,928 kg/yr

Step 4 - Total Projected Sludge Produced
(Chemical Sludge & Secondary Sludge)
= 5209 kg/yr + 22,928 kg/yr = 28,137 kg/yr

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[2]Bowker, R.P.G. and H.G. Stensel, Design Manual for Phosphorous Removal, EPA/625/1-87-001, U.S. Environmental Protection Agency, Center for Environmental Research, Cincinnati, Ohio (September 1987).

Step 5 - Evaluation

$$= \frac{\text{Total Projected Sludge Produced - Reported Sludge Wasted}}{\text{Total Projected Sludge Produced}} * 100$$

$$= \frac{28{,}137 \text{ kg/yr} - 20{,}817 \text{ kg/yr}}{28{,}137 \text{ Kg/yr}} \times 100$$

= 26.1%

The projected total sludge mass produced is not within ±15% of the actual sludge mass produced. Therefore, the data probably does not reflect the current level of treatment.

RESULTS OF THE

COMPREHENSIVE PERFORMANCE EVALUATION

OF

WASTEWATER TREATMENT PLANT C

March 1992

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FACILITY BACKGROUND

The Plant C Water Pollution Control Plant (WPCP) in southwestern Ontario has a mechanical design capacity of 22,727 m^3/d (5.0 MIGD).

The original conventional activated sludge plant was constructed in 1965. Six lagoons operated as two parallel systems in series were added in 1968 to treat high strength wastewaters from nearby industry during seasonal canning. Mechanical surface aeration of the first two lagoons of each system is provided. A quiescent zone to assure solids settling, prior to discharge is provided by the third lagoon in series.

By using the lagoon system to alleviate hydraulic and organic overloading of the secondary treatment process unit, the plant capacity was upgraded to 24,970 m^3/d (5.49 MIGD) in 1978. At this time, the Certificate of Approval (C of A)specified that all secondary clarifier effluent must pass through the lagoon system prior to discharge. An amendment to Plant C WPCP C of A, just prior to the CPE, allowed secondary clarifier effluent, when in compliance, to be discharged after chlorination directly to the receiving stream. This new discharge option is shown in the plant flow schematic illustrated in Figure 2.

The influent liquid stream passes through a single, spiral flow aerated grit tank. Ferrous chloride is added at the grit removal tank to ensure that all secondary bypassed primary effluent entering the lagoon systems during high flow conditions ($<$25,500 m^3) (5.61 MIGD) is treated for phosphorus removal. Raw sewage flows from the grit removal tank through two barminutors to two rectangular primary clarifiers. Primary effluent is then directed to two equally sized three-pass aeration tanks. Diffused fine bubble aeration is used for mixing and aeration. Five blowers provide aeration, with aeration dissolved oxygen levels being controlled by an on-line DO sensor that automatically controls additional blower on, off operation. Secondary process sludge wasting is done by wasting a portion of the return sludge flow to the primary clarifiers. Two rectangular clarifiers provide secondary clarification. Three variable speed pumps (one on stand-by) provide sludge return. Two Parshall flumes provide secondary effluent flow measurement. The secondary effluent historically has been pumped to the lagoons for polishing before chlorination and discharge to the receiving stream.

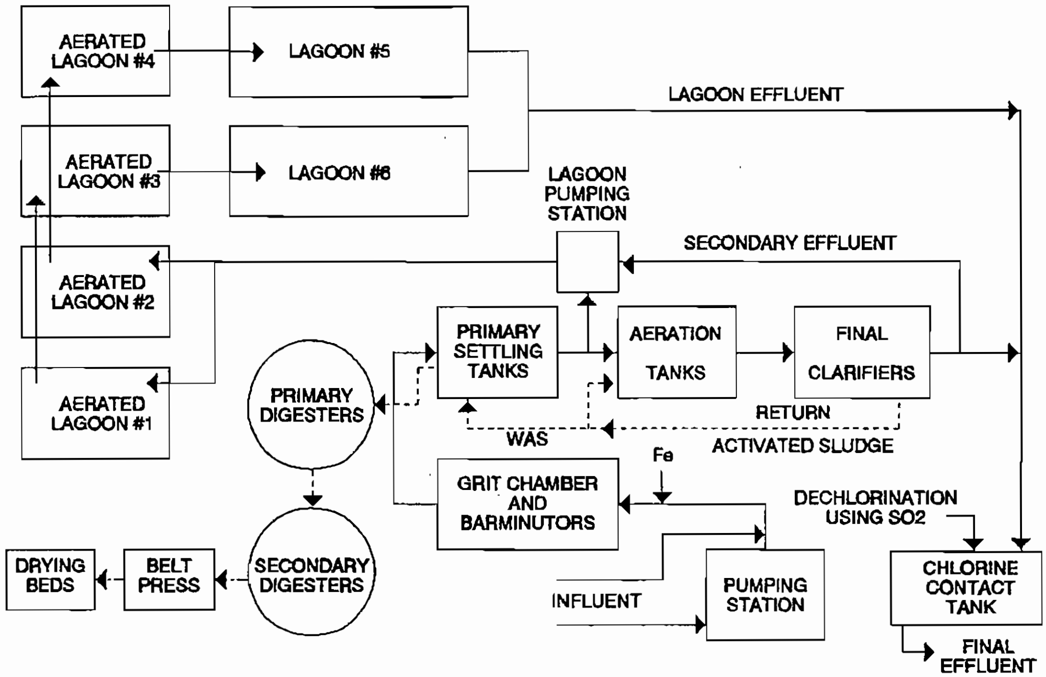


FIGURE 2. Flow Schematic.

Sludge from the primary clarifiers is pumped to a gas mixed primary digester with a fixed cover. Primary digested sludge is transferred to a non-heated fixed cover secondary digester. Secondary digester supernatant is returned to the primary clarifiers.

A two meter belt filter press dewaters the stabilized sludge prior to air drying in drying beds on-site. The belt press is operated eight hours per day, which results in a normal capacity of about 220 m^3/d. The air dried sludge from the drying beds is transported and used as a top dressing at a landfill site.

PERFORMANCE ASSESSMENT

Historical Performance

Plant C WPCP is required by their C of A to achieve monthly average effluent criteria of 25 mg/L, 25 mg/L, and 1.0 mg/L for BOD_5, SS and Total Phosphorus, respectively. Exceedance of these criteria constitutes non-compliance with the C of

A. In addition, the plant is required to meet monthly effluent compliance criteria of 4.5 mg/L total ammonia (non-freezing period), 7.5 mg/L total ammonia (freezing period), 1.0 mg/L total phosphorus, 200 organisms/100 mL E Coli, and 0.03 mg/L for total chlorine residual. For the purpose of performance assessment, the CPE limited examination to BOD_5, SS and Total Phosphorus.

The proposed MISA regulations will require the plant to meet these effluent criteria on a monthly average rather than annual basis. Since one of the purposes of the CCP program is to assess the ability of Ontario sewage treatment plants to meet the new regulations , the monthly criteria was used during the CPE to evaluate current plant performance.

Plant performance data was reviewed for the previous twelve month period (November 1990 - October 1991). Average monthly concentrations for BOD_5, SS, and Total Phosphorus, were plotted for this period, for both the total plant effluent and the mechanical plant effluent. The respective graphs are represented in Figures 3, 4, 5, 6, 7, and 8.

The average BOD_5 concentration for the period was 7 mg/L and 8 mg/L for the total plant effluent and mechanical plant effluent, respectively (Figures 3,4). Both plant effluents met the monthly average BOD_5 compliance criteria of 25 mg/L.

The annual average SS concentration for the period was 21 mg/L and 9 mg/L for the total, and mechanical plant effluents, respectively (Figures 5,6). The total plant effluent failed to meet the monthly average compliance criteria of 25 mg/L during March, September, and October, and would have had three monthly violations under the new C of A. The mechanical plant effluent exceeded this criteria during September.

The average Total Phosphorus concentration for the period was 0.35 mg/L and 0.64 mg/L for the total, and the mechanical plant effluents, respectively (Figures 7,8). The total plant effluent consistently met the monthly compliance criteria of 1.0 mg/L. Therefore, the total plant effluent would have had no monthly violations under the new C of A. The mechanical plant effluent failed to meet the monthly average compliance criteria of 1.0 mg/L during September and October. Therefore, the plant would have had two monthly violations under the new C of A.

Sludge Accountability Analysis

As part of the performance assessment, a sludge accountability analysis is performed. The analysis compares the actual sludge mass wasted from the plant over the last year with the projected mass over the same period. The sludge projections are based on typical sludge production data from similar plants. If the reported waste sludge mass compares favorably with the projected waste sludge mass (i.e., ±15%), the reported effluent quality is probably an accurate representation of plant performance.

The calculations for the sludge accountability analysis at Plant C Water Pollution Control Plant (WPCP) are included in the Appendix. All sludge produced (i.e., primary, secondary, chemical) at Plant C WPCP is wasted from the primary clarifiers to the anaerobic digesters. The average primary sludge flow rate and concentration over the past year were used to determine the sludge mass produced from the plant during this period (step 1).

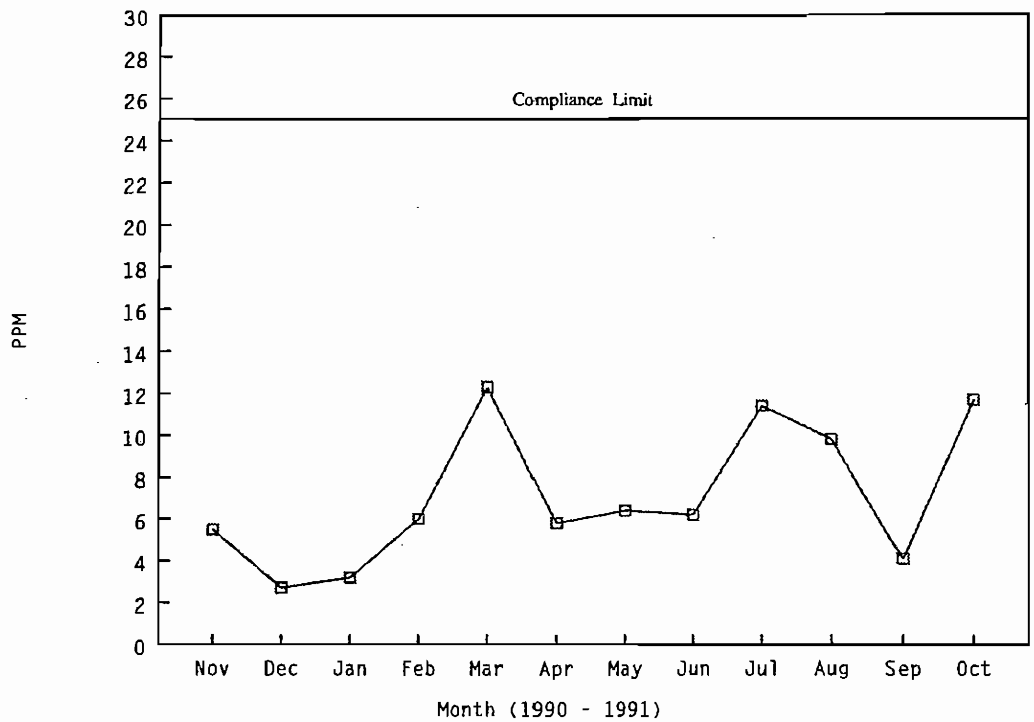


FIGURE 3. Total Plant Monthly Average Effluent BODs.

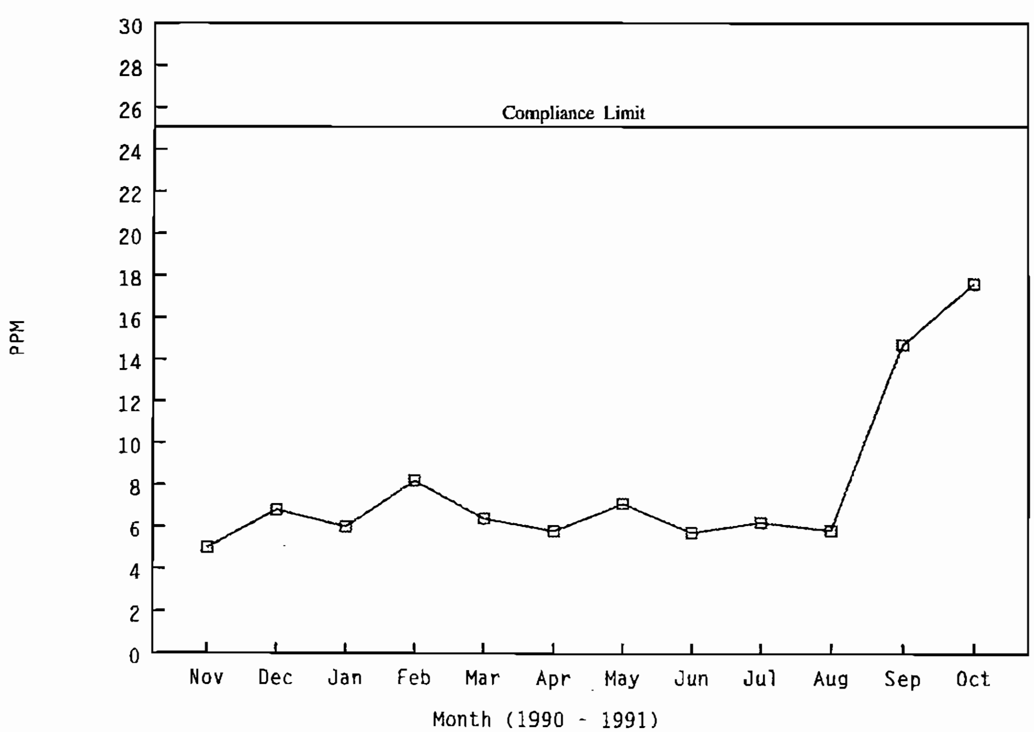


FIGURE 4. Mechanical Plant Monthly Average Effluent BODs.

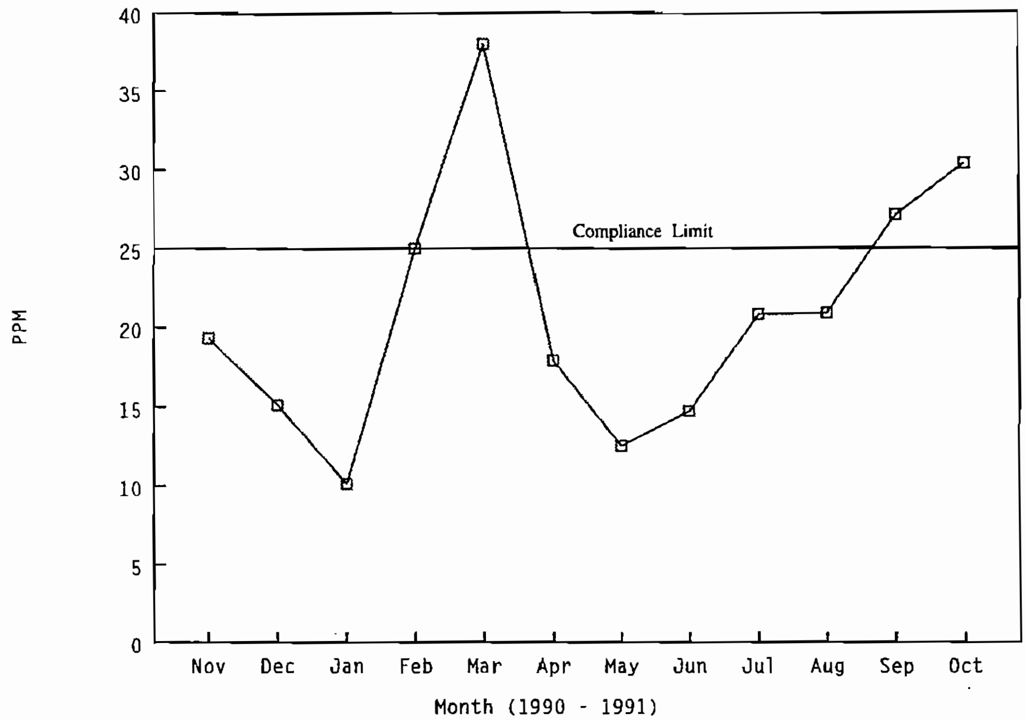


FIGURE 5. Total Plant Monthly Average Effluent SS.

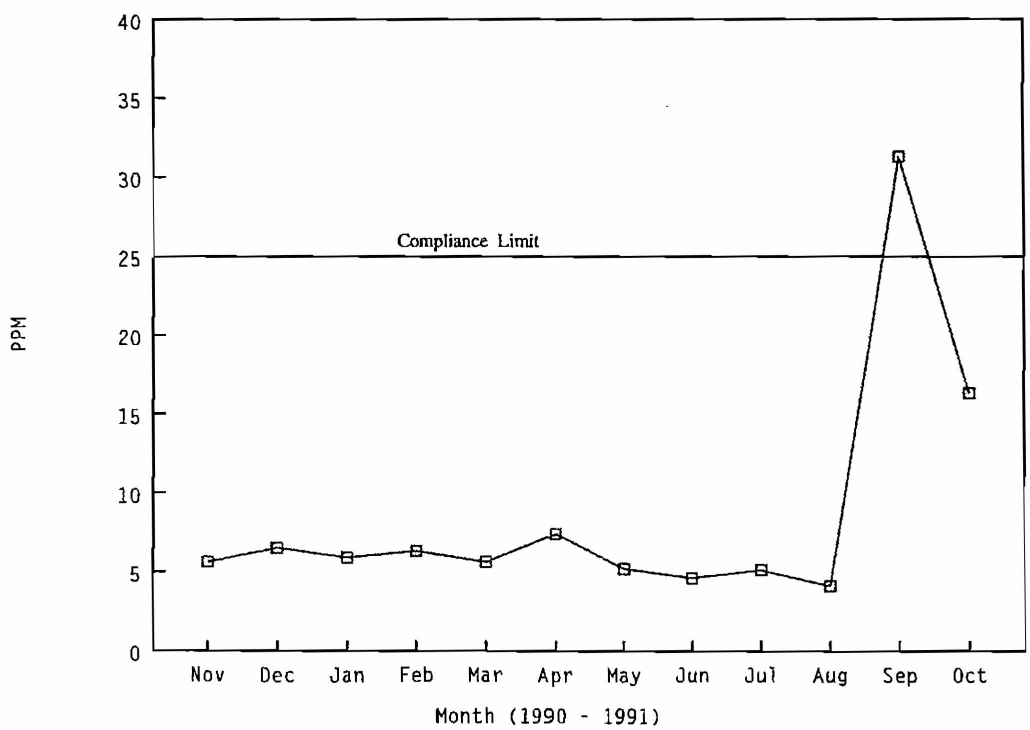


FIGURE 6. Mechanical Plant Monthly Average Effluent SS.

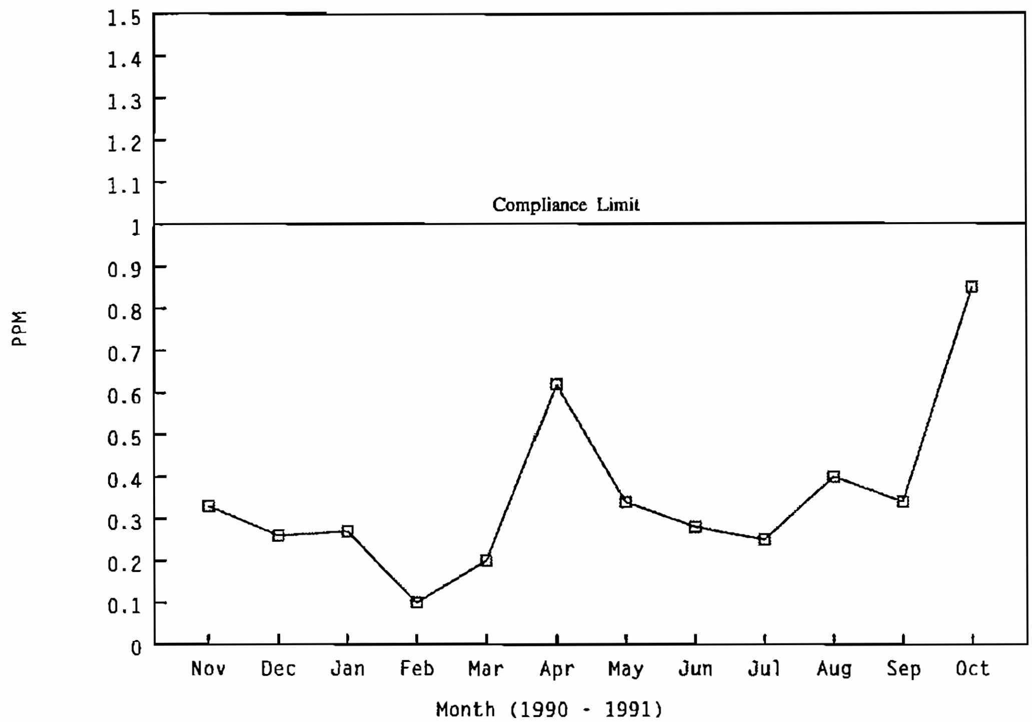


FIGURE 7. Total Plant Monthly Average Effluent Phosphorous.

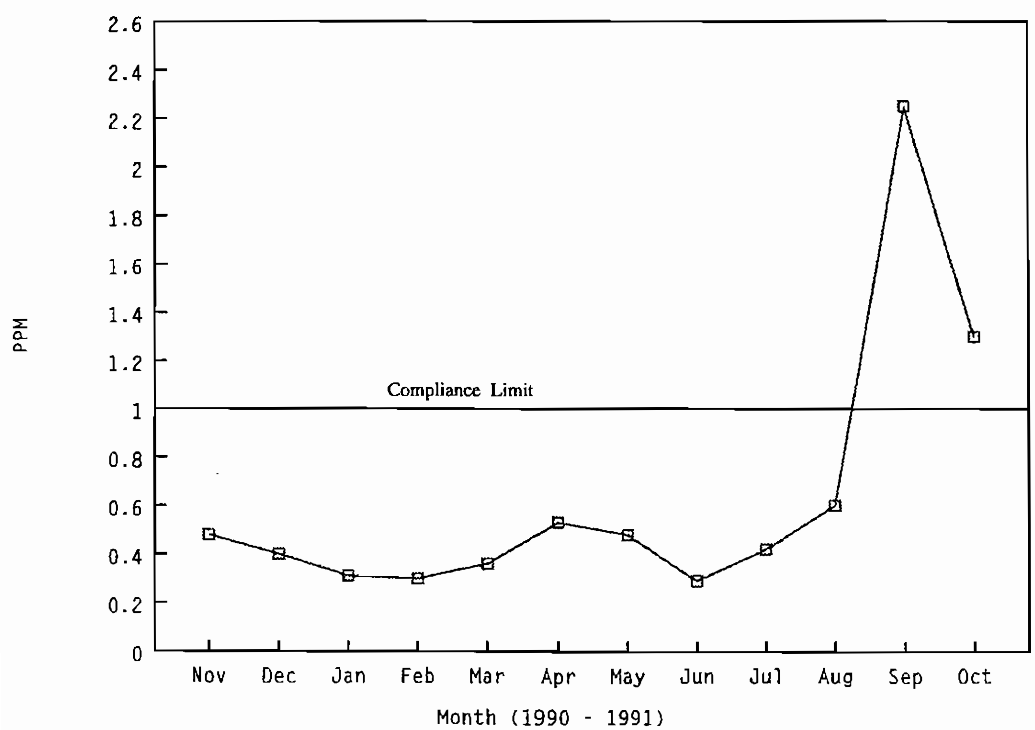


FIGURE 8. Mechanical Plant Monthly Average Effluent Phosphorous.

Projections of the primary, chemical and secondary sludge masses were determined from plant records (steps 2-4). The primary, chemical and secondary sludge masses were added together to give the total projected sludge mass (step 5). The projected total sludge mass produced is approximately equal to the actual sludge mass pumped to the primary digesters. This would indicate that Plant C WPCP staff have wasted the expected sludge mass for a plant of this type. Given the close comparison between the actual and projected sludge masses it is believed that the effluent quality accurately reflects the plant performance over the last year.

MAJOR UNIT PROCESS EVALUATION

The major unit process evaluation component of the CPE projects the capability of the existing major unit processes to meet the proposed MISA effluent standards. This evaluation was based on a review of plant drawings, equipment information, performance data as well as operation and maintenance practices. The "performance potential graph" indicates the major unit process capabilities and includes the background data used in the associated calculations (Figure 9).

The major unit processes included in the evaluation are shown in the left hand column. Unit processes were rated based on a combination of design and operational parameters. The horizontal bars in the performance potential graph represent the estimated capacity for the parameters associated with each major unit process. Vertical dashed lines indicate the current and design flows for comparison relative to the estimated capacity.

1. The primary clarifiers were rated at a flow of 5.12 MIGD based on a surface overflow rate of 1,000 Igal/d/ft^2.

2. The aeration basin capacity was assessed using hydraulic detention time, organic loading expressed in lbs BOD_5/day/1,000 ft^3 of aeration capacity and oxygen supply. Based on operation of the plant as a conventional activated sludge process, a detention time of 6 hours and an organic loading rate of 30 lbs BOD_5/day/1,000 ft^3 a capacity rating of this process was determined. As can be observed from the performance potential graph, hydraulic detection time was the most limiting criteria for the aeration parameters. The aeration basin was rated at 5.7 MIGD. The aeration basins do have the flexibility to implement step feed aeration in times of hydraulic overload.

3. The secondary clarifier capacity was rated using the surface overflow rate of 650 Igal/d/ft^2. The secondary clarifier capacity is the limiting factor of all the major unit processes at 5 MIGD.

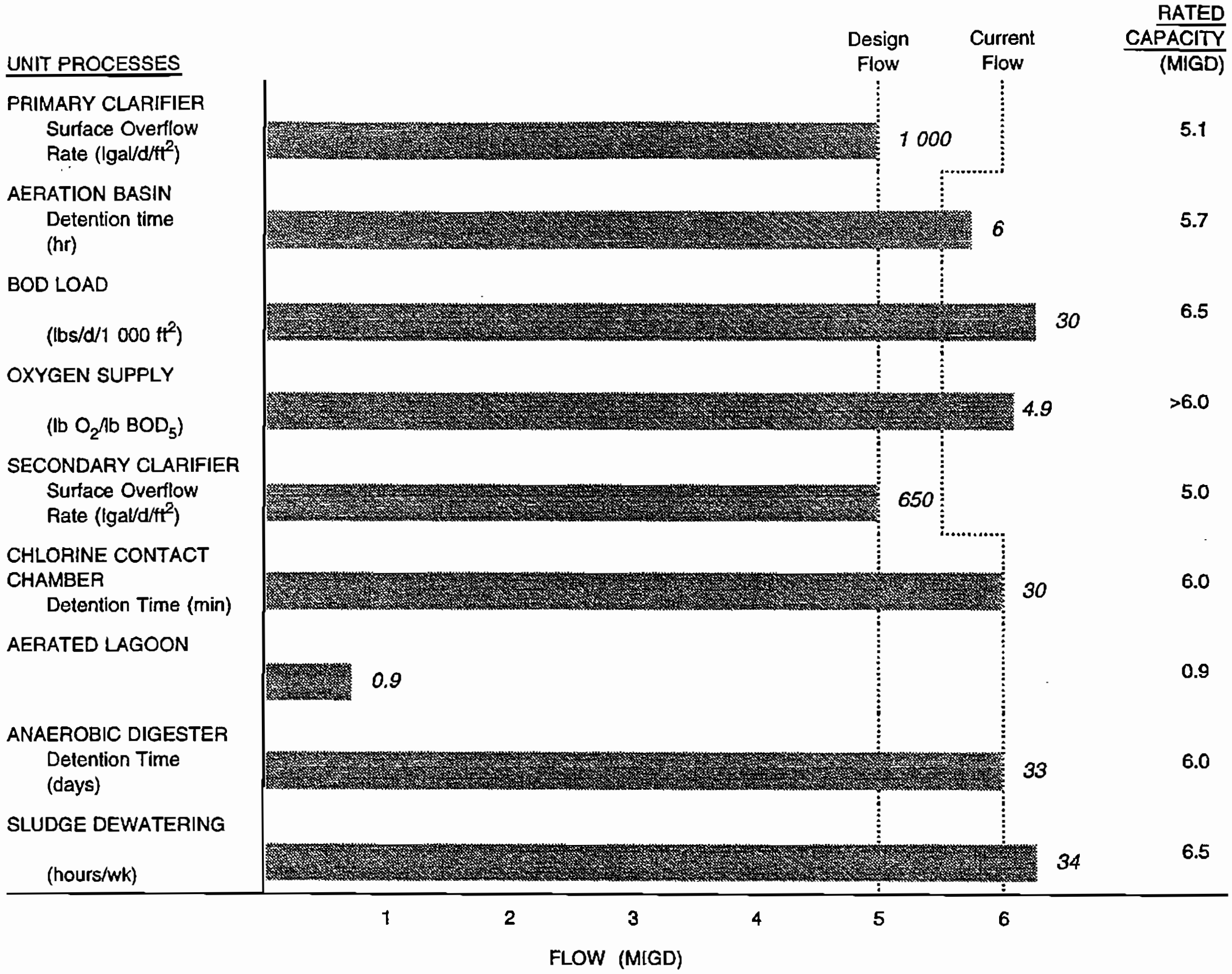
4. The chlorine contact tank was rated at 30 minutes contact time at average day flow. This would limit the plant hydraulically to approximately 6.0 MIGD.

5. The aerated lagoons are presently receiving an average flow of primary effluent in the order of 0.3 MIGD plus a average mechanical plant flow of 5.52 MIGD. The total organic loading equates to approximately 760 lbs (345 Kg) BOD_5/day. Based on an aeration volume of 263,536 m^3, this 345 kg BOD_5/day equates to 0.0013 kg BOD_5/day/m^3 which is only a fraction of normal allowable loading rate to aeration cells.
   Until recently, the plant was limited in its flexibility of operation by a Certificate of Approval which ensured that all the plant effluent would be pumped through the lagoons. As a consequence of this, the plant would inevitably fail the suspended solid criteria when algae blooms would prevail. It is not uncommon for the biomass of algae to yield 40-50 mg/L suspended solids in the final effluent.

   In light of the algae blooms, the lagoons were hydraulically rated at 0.88 MIGD such that the segregated flows, when recombined would not exceed a suspended solid concentration of 15.0 mg/L. This evaluation assumed that the mechanical plant would be base loaded at 5.0 MIGD.

6. The sludge handling capability was established by calculating the available detention time in the anaerobic digestors. Based on 33 days detention time, the anaerobic digestion capacity was rated at 6.0 MIGD. As there is plenty of on site storage for belt press cake, the only limiting factor of the sludge handling facility could be the belt press operation itself. As the performance curve would indicate, the belt press operation is capable of a rated capacity of 6.5 MIGD based on its solids handling capability when operated at 34 hours per week.

   An overview of the performance potential graph, shows that the plant is capable of treating 5.0 MIGD with the primary and secondary clarifiers being the limiting major unit processes.



Criteria for Major Unit Process Evaluation

PROCESS	BASIS
General	Total flow = 5.82; mechanical plant flow = 5.52; influent BOD_5 = 161 mg/L; influent SS = 220 mg/L; influent P = 9.0; these parameters are used to calculate loadings at all flows; data evaluated was from 11/90 - 10/91.
Primary Clarifiers	Combined surface area = 5 120 ft^2; BOD_5 removal = 35%; SS removal = 55%; primary sludge concentration = 3.62% dry weight.
Aeration Basins	Combined volume = 229 053 ft^3; total blower capacity = 10 600 scfm based on 4 blowers; site oxygen transfer efficiency = 11.7%; secondary sludge production = 0.7 lb SS produced per lb BOD_5 removed; chemical sludge = 2.5 mg/L sludge produced per mg/L of iron added.
Secondary Clarifiers	Combined surface area = 7 680 ft^2.
Chlorine Contact Basin	Total volume = 30 673 ft^3.
Lagoons	Allowable flow to lagoon to maintain a 15.0 mg/L SS concentration = Q MIGD; lagoon effluent SS on occasion reaches 50 mg/L; average plant flow = 5.82 MIGD; mechanical plant effluent SS = 8.7 mg/L. (5.82 MIGD - Q MIGD)(10 lb/gal)(8.7 mg/L) + Q MIGD(50 mg/L)(10 lbs/gal) = (15 mg/L)(5.82 MIGD)(10 lbs/gal) Q = 0.9 MIGD
Anaerobic Digesters	Combined volume of primary and secondary digesters = 165 682 ft^3
Sludge Dewatering	Press capacity rated at 2 400 lbs dry solids per hour; feed sludge concentration = 4% at 100 IGPM.

FIGURE 9. Major Unit Process Evaluation.

FACTORS LIMITING PERFORMANCE

During the CPE, factors limiting performance of the facility were identified to achieve present effluent requirements. Seventy potential factors were evaluated based on the results of the major unit process evaluations, together with a review of plant operation and maintenance practices, and interviews with plant administrators and staff. These potential factors cover the areas of design, operation, maintenance and administration.

Factors having a major effect on performance on a continuous basis are given an "A" rating. Factors having a major effect on performance on a periodic basis, or a minor effect on a continuous basis are given a "B" rating. Factors having a minor effect on plant performance are also identified, and given a "C" rating. A description of the factors identified during the Chatham CPE is presented in the following paragraphs.

Application of Concepts and Testing to Process Control - A Rating (Operation)

Optimization of an activated sludge processes requires close attention to key process control adjustments such as sludge mass control and distribution. These items receive a low priority at Plant C. Data processing and trending of related parameters is not conducted routinely, such that short and long term impacts on process performance are determined. Pending plant modifications do not support identified process limititations (secondary clarifier, return sludge etc.).

Process Flexibility - B Rating (Operation)

Flexibility to control storm flows to the lagoons for storage and flow equalization does not exist. Currently, flows can be diverted to the lagoons, but cannot be returned for treatment. This flexibility could allow for base loading of the mechanical plant, and provide process protection during high flow conditions, thus protecting the integrity of the activated sludge process.

Plant Coverage - B Rating (Operation)

The plant is currently staffed for 10 hours per day. Since the actual loading is equal to or greater than the projected treatment capability of one or more of the major unit processes, additional attention is necessary to maintain the desired performance through routine process adjustments of return sludge flow and wasting, throughout the diurnal flow variations. Also, because of variable industrial loading adjustments (i.e, step feed) may be required at any time. Extended coverage does not necessarily imply that additional staff are required. Re-allocation of existing staff could enable additional monitoring and process adjustments.

Process Control Testing - B Rating (Operation)

Process control testing to optimize performance should include mass concentrations throughout the liquid train (aeration basin, secondary clarifier, return sludge), blanket depths in secondary clarifier, respiration rates, and microscopic sludge examination. Monitoring of these parameters would allow for increased data development, more directed process adjustments, and improved process control and performance.

Secondary Clarifier - B Rating (Design)

The surface overflow rates are too high to consistently meet the solids requirements at higher hydraulic loading conditions and variable sludge settling characteristics. Process control to encourage faster sludge settling suppported by chemical (polymer) addition capability may be required if construction is to be avoided.

Process Controllability - C Rating (Operation)

Flow metering installed in the Return Activated Sludge transfer line was removed as it was causing flow restrictions. Accurate return activated sludge flow measurement is essential to enable continuous process control adjustments to be made, in response to load variations, and to changing sludge distribution throughout the day.

SUMMARY OF EVALUATION FINDINGS

The CPE performed at the Plant C treatment plant shows that the plant has been in compliance with its annual average effluent quality objectives. However it would have had several SS violations under the proposed MISA monthly effluent regulations. The evaluation of the major unit processes established that the treatment processes in the plant are capable of treating flows up to the rated design capacity of 5 MIGD. The evaluation identified the secondary clarifier as limiting in treating existing flows to the level required by the new C of A. This limitation can be alleviated by several methods other than construction, e.g. reducing the hydraulic loading through the mechanical plant by diverting this flow through the lagoon system, changing the sludge settling characteristics, chemical addition.

The Plant C mechanical plant is capable of treating flow up to 5 MIGD. The lagoons would allow an additional 0.9 MIGD giving a total plant capacity of 5.9 MIGD. The major factor limiting performance is related to inadequate focus on process control by the operations staff. By focussing plant staff attention to a performance-based process control program, supported by some minor modifications and additional testing and coverage, it is anticipated that the Plant C facility can meet the proposed new regulations for BOD_5, SS, and total phosphorus without major construction changes.

The second part of the CCP program, Comprehensive Technical Assistance (CTA), would be applicable at Plant C, because the high ranking performance limiting factors were operations oriented. The efforts of the CTA would be directed at addressing the performance limiting factors identified during the CPE, providing staff training and transfer of skills to achieve process control.

APPENDIX

SLUDGE ACCOUNTABILITY ANALYSIS

PLANT C WATER POLLUTION CONTROL PLANT

DECEMBER 4th, 1991

Total Waste Sludge Evaluation

Step 1 - Sludge Mass Wasted From Primary Clarifiers To Primary Digester

Avg. Sludge Flow = 30 575 Igpd (11/90 - 10/91) = 138.7 m^3/d
Avg. Sludge Conc.= 3.62% dry weight

Waste Sludge Mass =

138.7 m^3/d x 36 200 mg/L x 365 days/yr x 0.001 kg·L/mg·m^3
= 1,832,643 kg/yr

Step 2 - Projected Primary Sludge

Avg. Wastewater Flow = 5.82 mIgpd (11/90 - 10/91) = 26,400 m^3/d
Avg. Influent SS = 220 mg/L
Primary SS Removal = 54% (assumed)

Primary Waste Sludge =

26,400 m^3/d x 220 mg x 0.54 x 365 days/yr x 0.001 kg·L/mg·m^3
= 1,144,757 kg/yr

Step 3 - Projected Chemical Sludge

Avg. Wastewater Flow = 5.82 mIgpd (11/90 - 10/91)= 26,400 m^3/d
Avg. Iron Dose = 7.1 mg/L
Sludge Production Ratio = 2.5 mg sludge/mg Fe
Reference U.S. EPA Phosphorous Removal Handbook[3]

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[3] Bowker, R.P.G. and H.D. and Stensel, Design Manual Phosphorous Removal, EPA/625/1-87/001, U.S. Environmental Protection Agency, Center for Environmental Research, Cincinnati, Ohio (Setpember, 1987).

Chemical Waste Sludge =

26,400 m^3/d x 7.1 mg/L x 2.5 mg/mg x 365 days/yr x 0.001 kg·L/mg·m^3
= 171,039 kg/yr

Step 4 - Projected Secondary Sludge

Avg. Wastewater Flow (mech. plant) = 5.52 mIgpd (11/90 - 10/91)
= 25,039 m^3/d
Avg. BOD Removed Across Secondary System = 102 mg/L - 8mg/L
= 98 mg/L
Sludge Production Ratio = 0.7 kg SS produced/kg BOD5 removed
(ref. U.S. EPA Handbook Retrofitting POTWs)

Secondary Waste Sludge =

25,039 m^3/d x 98 mg/L x 0.7 kg/kg x 365 days/yr x 0.001 kg·L/m^3·mg
= 626,952 kg/yr

Step 5 - Projected Total Sludge to Digesters

Projected Prim. Solids + Projected Chem. + Projected Sec. = Total Sludge Produced

1,144,757 kg/yr + 171,039 kg/yr + 626,952 kg/yr = 1,942,748 kg/yr

The estimated total sludge mass produced is approximately equal to the actual sludge mass pumped to the primary digester. The data accurately reflects the current level of treatment.

RESULTS OF THE COMPREHENSIVE PERFORMANCE EVALUATION OF WASTEWATER TREATMENT PLANT N

March 1994

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FACILITY BACKGROUND

Plant N Water Pollution Control Plant (WPCP) has a design flow capacity of 810 m^3/day (0.18 MIGD).

The original oxidation ditch sewage treatment plant was commissioned in 1967, and was expanded in 1992 to about twice the original capacity. The treatment plant is classified as an extended aeration process with chemical phosphorous removal and ultraviolet disinfection capabilities. The plant design incorporates flexibility. The raw sewage can by-pass the oxidation ditch and be directed to the final clarifiers. The final clarifiers would then act as a primary clarifier and the effluent from the clarifier would be disinfected prior to discharge to the receiver. As well, the oxidation ditch can be operated in a batch mode. The ditch can be filled with raw wastewater, which is treated during the fill phase. The biological solids are then allowed to settle in the ditch by turning off the aerators. The effluent is then disinfected and discharged to the receiver (**Figure 2**).

Flow to the plant is primarily by gravity, but there are two low lift pump stations (low flow, and visitors building). Flow entering the treatment plant is either directed to the treatment facility or by-passed through a manually cleaned bar screen to the final clarifier. Normally, the flow passes through an automatic bar screen. This screen has been cleaned manually since December 1993 due to maintenance problems. The flow then passes through a second, smaller, bar screen prior to passing through a comminutor. The wastewater then feeds into the oxidation ditch. Filtrate from the drying beds are added to the influent wastewater prior to entering the ditch.

The oxidation ditch is aerated and mixed by two 10 HP mechanical aerators each located at approximately the midpoint of the straight sections of the ditch (**Figure 2**). Aeration is controlled by either raising or lowering a control gate located on the discharge of the oxidation ditch. Alum is added into the mixed liquor as it leaves the oxidation ditch prior to entering the final clarifier.

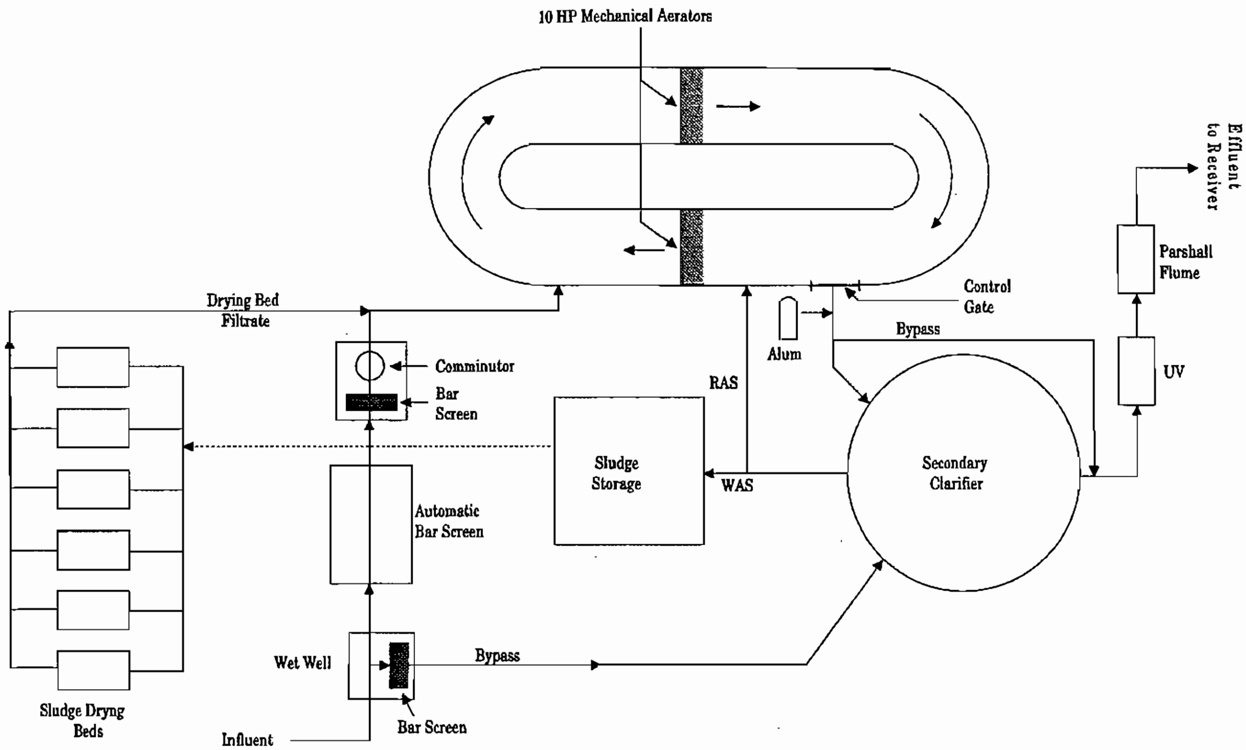


FIGURE 2. Flow Schematic of Plant N.

The final clarifier is a perimeter feed design housed in its own building. The clarifier has a surface area of 68.6 m^2 and the weirs are located at approximately mid radius. The scum is manually removed from the clarifier. There is a sludge blanket sensor fixed to the final clarifier located at about one-quarter the clarifier radius. The blanket level can be read from a display in the laboratory workroom. The accuracy of the sludge blanket depth meter was also evaluated. It was found that the depth meter was calibrated properly. The sludge removal from the bottom of the clarifier is on a timer that varies throughout the day (10 minutes on, 5 minutes off from 6 am to 10 pm, 10 minutes off, 5 minutes on from 10 pm to 12 am, and 3 minutes on, 7 minutes off from 12 am to 6 am). The sludge blanket sensor can override the timed cycles if blanket levels are above or below set-points. The return sludge pump operates approximately 65% of the time. There are two 1 1/2 HP centrifugal sludge pumps.

The return activated sludge flow enters a splitter box from which the sludge can be returned to the oxidation ditch or wasted directly to a 50.7 m^3 aerated sludge holding tank. Supernatant from the sludge holding tank is pumped back into the aeration system.

Final effluent is disinfected by an ultraviolet treatment system, then discharged to the receiver through a 3 inch Parshall flume. Total plant flow is measured using an ultrasonic level detection device. A calibration check of the plant flow measurement during the CPE indicated that the recorded flow was within 5%.

The waste sludge is gravity thickened in the sludge holding tank before being pumped to the sludge drying beds or hauled off-site to a sludge storage lagoon or another STP for disposal. Sludge from the drying beds is applied to the land surrounding the institution. Sludge was not wasted from the system from January 1993 to June 1993.

PERFORMANCE ASSESSMENT

Historical Performance

Plant N is required to achieve annual average effluent criteria of 20 mg/L for BOD_5, and 25 mg/L for TSS and a monthly average of 1.0 mg/L for Total Phosphorous (TP) as outlined in the Federal legislation - *Guidelines for Effluent Quality and Wastewater Treatment at Federal Establishments* (April, 1976). As well, the Bay of Quinte Remedial Action Plan (RAP) has recommended that Plant N limit its discharge of TP since this facility discharges into the watershed that feeds into the Bay of Quinte. The RAP objective for Plant N is a monthly average effluent of 0.5 mg/l TP. For purposes of the CPE, performance of Plant N was evaluated in terms of its ability to meet both effluent criteria and RAP objectives.

Plant performance data was reviewed on a monthly basis for the period of February 1993 to January 1994. Average monthly effluent concentrations were plotted for BOD, SS and Total Phosphorus. The graphs are represented in **Figures 3, 4, and 5** respectively.

The reported annual average BOD_5 concentration for the period was 5.4 mg/L. As illustrated in Figure 3 the reported plant effluent quality met a monthly average BOD_5 of 20 mg/L in all months except January 1994.

The reported annual average TSS concentration for the period was 9.9 mg/L. As illustrated in Figure 4, the reported plant effluent quality met a monthly average SS of 25 mg/L in all months.

As illustrated in Figure 5, the reported plant effluent quality met the monthly average criteria of 0.5 mg/L Total Phosphorus in all months.

The reported data for the 12 months evaluated met the compliance criteria

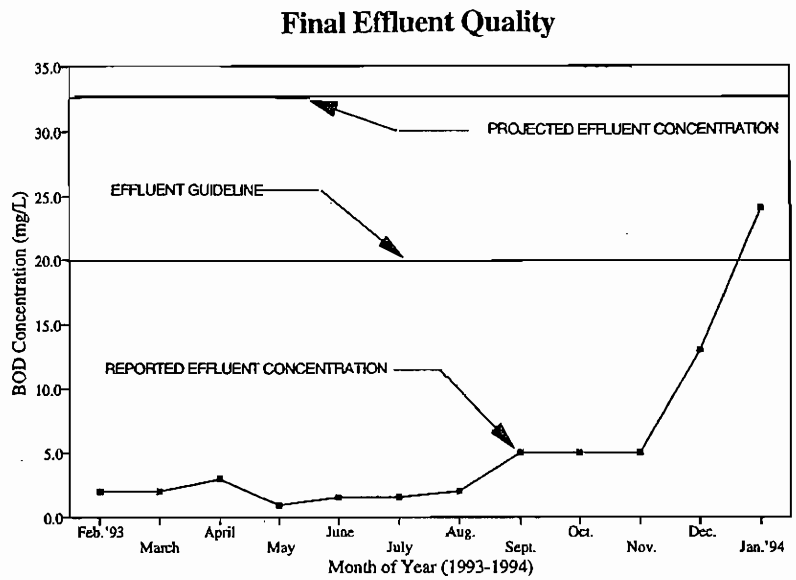


FIGURE 3. Monthly Effluent BOD_5 Concentrations for February, 1993 to January, 1994.

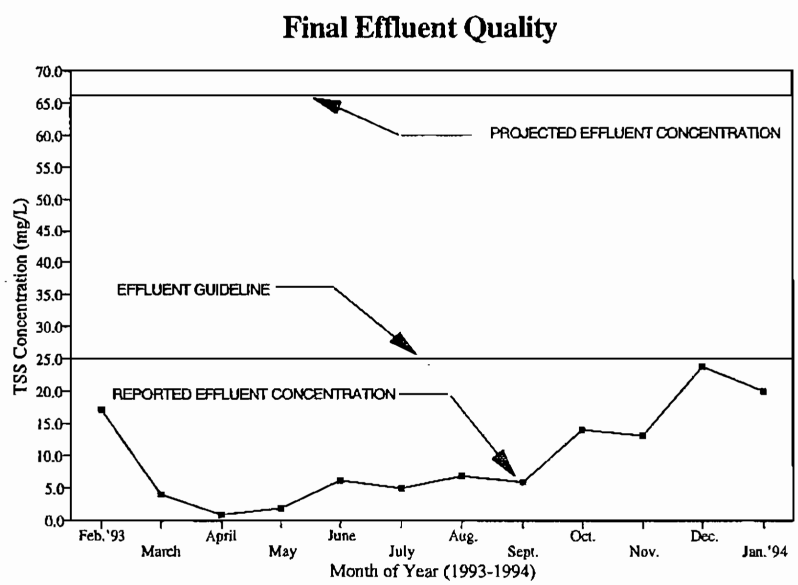


FIGURE 4. Monthly Effluent TSS Concentrations for February, 1993 to January, 1994.

Final Effluent Quality

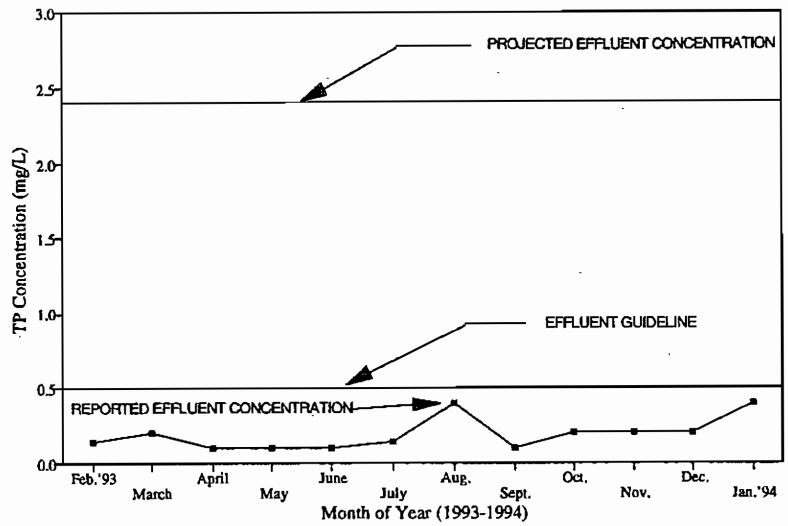


FIGURE 5. Monthly Effluent TP Concentrations for February, 1993 to January, 1994.

Sludge Accountability Analysis

A sludge accountability analysis was performed as part of the performance assessment. The actual sludge mass wasted from the plant over the last year was compared to a projected sludge mass that would typically have been produced by this type of treatment process over the same period. Typical sludge production data from similar processes[4] was used to calculate the projected sludge mass produced over the same period. If the projected sludge mass and the reported sludge mass wasted for the year are within (+/- 15%) then the reported effluent quality is probably an accurate representation of plant performance. The calculations for the sludge accountability analysis at Plant N are included in the Appendix.

The projected yearly sludge mass production is about 27% greater than the actual mass wasted for the year. Plant records indicate that no sludge was wasted from the system from January 1993 to June 1993. The reported plant performance data probably does not accurately reflect true plant performance over the period evaluated.

[4]Hegg B.A., L.D. DeMers, and J.B. Barber, Handbook - Retrofitting POTWs, EPA 625/6-89-020, U.S. Environmental Protection Agency, Centre for Environmental Research Information, Cincinnati, Ohio (July 1989).

Due to the non-accountable sludge the projected average daily effluent concentration for BOD_5, SS and TP were derived. These calculations are detailed in the Appendix. The projected effluent BOD_5 was 33 mg/L, effluent SS was 66 mg/L and effluent TP was 2.4 mg/L. The projected values are shown in Figures 3 to 5. These projected concentrations would exceed effluent guidelines for all parameters for the 12 month period evaluated.

MAJOR UNIT PROCESS EVALUATION

The major unit process evaluation component of the CPE projects the capability of the existing major unit processes to meet effluent standards. This evaluation was based on a review of plant drawings, equipment information, performance data as well as operation and maintenance practices. The "Performance Potential Graph" illustrates the major unit process capabilities (**Figure 6**).

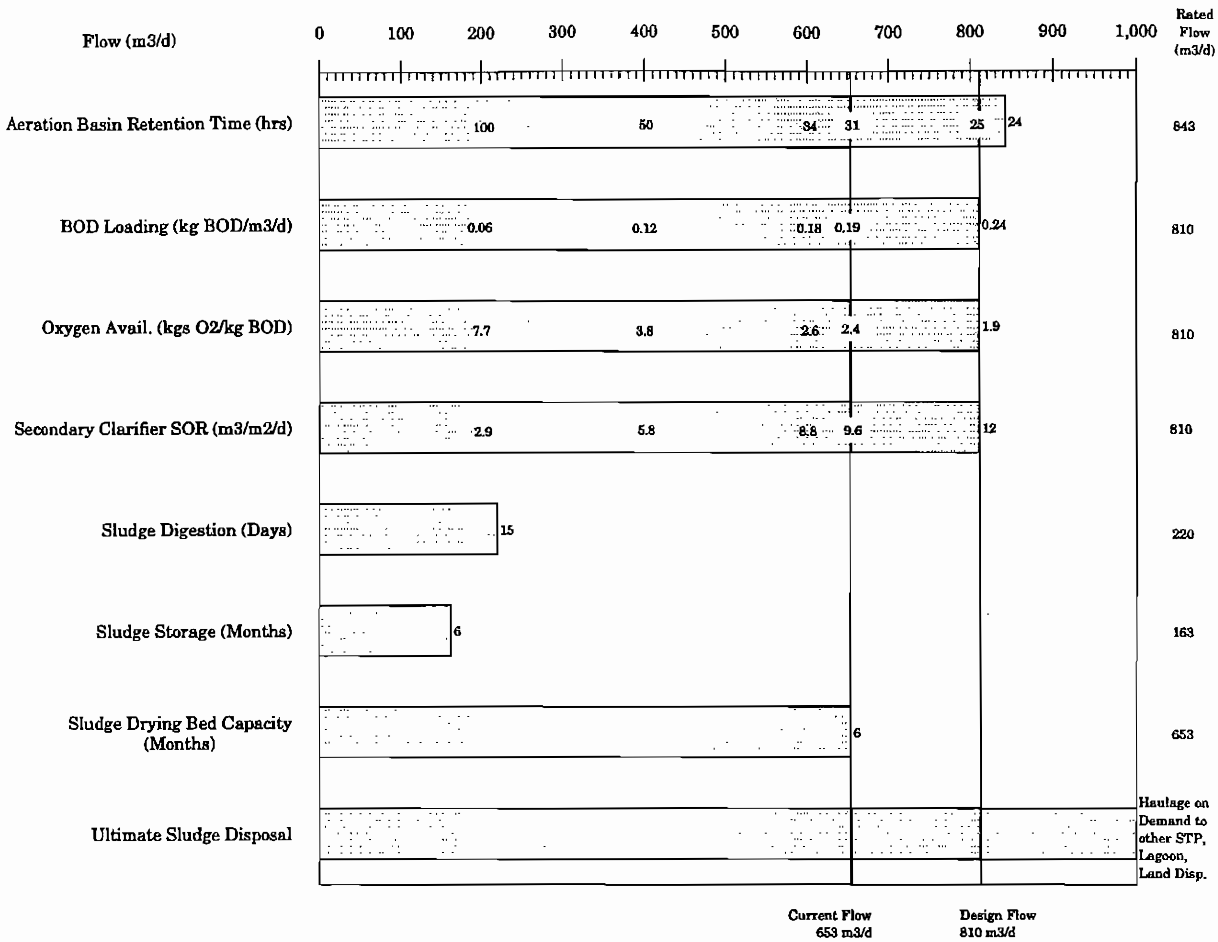
The major unit processes included in the evaluation are shown on the left hand column. Unit processes were rated against a combination of design and operational parameters. The horizontal bars in the Performance Potential Graph represent the projected capacity for the parameters associated with each major unit process.

Vertical lines identify the current and design flows for comparison relative to the projected capacity.

1. The aeration basin capacity was rated on hydraulic detention time, organic loading expressed in kg BOD/day/m^3 of aeration capacity and the capability of the aeration equipment to transfer sufficient oxygen. Based on the operation of the plant as an extended aeration activated sludge process, a detention time of 24 hours and an organic loading of 0.24 kg BOD/m^3/day were used to determine the capacity rating of this process. The mechanical aerators were rated at their ability to transfer 2.0 kg of O_2/kg BOD. The BOD_5 loading and oxygen availability parameters were designed to meet the average design requirements at the design flow of 810 m^3/d. The retention time was rated for a flow of 843 m^3/d, a slightly greater capacity than required for the design flow. The aeration basin was rated as being capable of handling flows at its design.

2. The secondary clarifier surface overflow rate was rated at 12 m^3/m^2/day. This surface overflow rate equates to a hydraulic capacity of 810 m^3/day based on a clarifier surface area of 68.6 m^2. This data indicates that the clarifier is capable of treating flows at the design hydraulic flow rates.

3. Sludge digestion was rated at a plant flow rate of 220 m^3/d in order to fulfil the requirement of 15 days aerobic digestion to obtain a stabilized sludge[1]. The volume of the sludge storage tank does not provide adequate retention time to stabilize the sludge based on current projected sludge production. Provincial guidelines indicate that sludge must be stabilized prior to application to land or sludge drying beds. Sludge must be stabilized in order to reduce the pathogenic bacteria that can cause diseases in humans.



PROCESS	BASIS
General	Total flow = 653 m^3/day; data evaluated was from 02/93 to 01/94.
Aeration Basin	Volume = 840 m^3; Mechanical mixer = 10 HP; secondary sludge production ratio = 0.65 kg SS produced per kg BOD_5 removed; chemical sludge = 3.0 mg/L sludge produced per mg/L of aluminum added.
Secondary Clarifier	Surface area = 68.6 m^2
Sludge Storage Basin	Total volume = 50.7 m^3
Sludge Disposal	Land disposal; 6 sludge drying beds; haulage to another STP, haulage to a sludge lagoon

FIGURE 6. Performance Potential Graph

4. Plant N has two operating periods in terms of sludge disposal or treatment. These are as follows:

   Summer: Sludge drying beds used for treatment

   Winter: Storage (sludge storage tank plus sludge drying beds) or Haulage off-site to another STP or sludge lagoon

   The waste sludge storage tank plus the sludge drying beds (used as storage tanks) were rated to supply 6 months of sludge storage capacity during winter conditions when land application is not available. This 6 months represents the time that sludge would have to be stored on-site since the sludge drying beds are the only source of on-site treatment and these beds can only be used during the warmer 6 months of the year. Based on the projected sludge production there would be 6 months of storage capacity if the average daily flow was 163 m^3/d. Calculations were based on 50.7 m^3 of sludge storage tank volume, 246 m^3 of drying bed volume, a thickened waste sludge concentration of 20 000 mg/l, 0.65 kg of solids produced per kg of BOD removed and 3.0 mg sludge produced per mg of aluminum added as alum.

5. The sludge drying beds were rated at 6 months at current flow for the projected sludge production. However, it must be noted that this is based upon the fact that drying beds can only be used in warmer months (May to October) and that no interruptions would occur due to excessive rainfall during that period. If there was greater amounts of rain then the drying beds will not work as efficiently.

6. Ultimate sludge disposal is not considered to be limiting because of the availability of off-site disposal at the Campbellford STP or the sludge lagoon. However, it must be noted that the sludge is not currently stabilized, and that anaerobic or aerobic digestion is required for stabilization of sludge before application to land.

An overview of the Performance Potential Graph shows that the liquid train is adequate up to the design capacity of 810 m^3/d, but there is a short-fall on the plant's sludge handling capability. Sludge digestion and sludge storage capacity at present is not adequate at current flows. There is currently limited stabilization of the sludge which will be important if haulage to another STP or sludge lagoon is stopped.

FACTORS LIMITING PERFORMANCE

During the CPE, factors limiting performance were identified. Seventy potential factors were evaluated, and identification of applicable factors were based on the results of the major unit process evaluation, review of plant operational and maintenance data and practices, and interviews with plant administrators and staff. These potential factors examine the areas of design, operation, maintenance, and administration.

Factors having a major effect on plant performance on a continuous basis are given an "A" rating. Factors having a major effect on performance on a periodic basis, or a minor effect on a continuous basis are given a "B" rating. Factors having a minor effect on plant performance were also identified and given a "C" rating.

The performance limiting factors of the Plant N CPE are listed and discussed in the following paragraphs.

Performance Monitoring - A Rating (Operation)

During the CPE, a sludge accountability analysis was performed in which the actual and projected sludge mass produced was compared. The sludge accountability analysis for Plant N revealed that the facility produced 27 percent less sludge than the projected value. The operators comments indicated that reported effluent data based on one grab sample per month may not be representative of true plant performance. There is a need to improve performance monitoring to accurately assess true plant performance. Projected performance of the plant for the 12 months evaluated indicates that the compliance criteria was not achieved for BOD_5, SS or TP.

Familiarity With Plant Needs - A Rating (Administration)

There is a lack of first-hand knowledge of the plant needs by the administration. Insufficient awareness of the requirements to operate a sewage treatment plant is reflected in no budget allocation for sludge haulage disposal. The operators have not received adequate training to apply concepts to implement process control at the wastewater treatment plant. There is no source of technical guidance or support for wastewater treatment activities.

Application of Concepts and Testing to Process Control - A Rating (Operations)

Optimization of activated sludge processes requires attention to key concepts such as sludge mass control and sludge mass distribution through sludge return flow control. Data development and trending of related parameters is required to determine their short and long term effects on process performance. Most of these concepts and parameters are not being applied by the plant staff at the present time.

Process Control Equipment - B Rating (Design)

Basic lab equipment is not provided in order to monitor and control the biological treatment process properly.

Sludge Storage/Stabilization - B Rating (Design)

The volume of the aerated sludge storage is inadequate to stabilize the current volume of sludge being produced. It is general practice to stabilize sludge prior to application to drying beds. Stabilization of sludge by either aerobic or anaerobic digestion is required by the MOEE to reduce organic material and destroy disease causing organisms prior to application of the sludge to land or drying beds. This is important to note because the sludge from the drying beds is applied to the property around the institution. The sludge storage/treatment was rated a B factor because currently the facility has the ability to haul sludge off-site for further treatment at another STP or application to a sludge lagoon. However, if at any time the alternative to haul sludge is eliminated then this factor will be an A factor, and must be addressed immediately.

Ultimate Sludge Disposal - B Rating (Design)

Currently, Plant N has three options for ultimate sludge disposal: sludge drying beds with application to land, haulage of sludge to a local municipal STP for further treatment, and haulage to a sludge drying lagoon. Also, the sludge drying beds can only be used during the warmer months (May to October) and the beds were rated under ideal conditions (i.e. normal amount of rainfall). Ultimate sludge disposal was left open-ended on the performance potential graph because currently the staff have the ability to haul sludge off-site for further treatment at a local STP or application to a sludge lagoon. However, it must be noted that if only on-site facilities were available for ultimate sludge disposal this would lead to a factor limiting performance.

Minor Performance Limiting Factors - C Rating

Plant Coverage

The wastewater treatment process operates every day therefore it requires a level of attention by skilled personnel 7 days a week to ensure the proper operation of the biological treatment process. There is currently a stationary engineer who checks the facility on weekends for any obvious mechanical problems, but this person does not perform any monitoring or process control adjustments to ensure the performance of the process.

Alarm Systems

Absence of adequate alarming to alert personnel could potentially lead to degraded plant performance. A high flow alarm or sludge depth alarm would enable personnel to respond and take appropriate action to protect the integrity of the biological process.

SUMMARY OF EVALUATION FINDINGS

Examination of the reported data during the CPE conducted at Plant N showed that the plant has been in compliance with its effluent criteria and RAP objectives over the period from February 1, 1993 to January 30, 1994. However, a sludge accountability analysis showed that the data evaluated probably does not accurately represent true plant performance.

The evaluation of the major unit processes established that the sludge digestion (stabilization) and sludge storage capacity could limit the performance of the facility. In order to aerobically stabilize sludge would require 15 days in the aerobic sludge storage tank. This would require that the total plant flow only be 220 m^3/d, rather than the current flow of 653 m^3/d. Currently, Plant N has 6 months of sludge treatment capacity using sludge drying beds. However, if there is no alternative other than storage for the remaining 6 months then the solids storage facilities could only handle a plant flow of 163 m^3/d over those 6 months. Using the multiple sludge disposal options overcomes these limitations and as such facilities exist for Plant N to consistently achieve compliance at current loadings.

The major factors limiting performance are primarily related to operations and administrative factors. By re-directing the plant staff activities to a performance-based process control program, it is anticipated that Plant N performance could be improved significantly using the existing facilities.

The second part of the CCP program, Comprehensive Technical Assistance (CTA), would be applicable to Plant N because the high ranking performance limiting factors were operations and administration related. The efforts of the CTA would be directed at addressing the performance limiting factors identified during the CPE, providing staff training and transfer of skills to achieve process control. This effort would optimize the use of existing facilities.

APPENDIX

SLUDGE ACCOUNTABILITY ANALYSIS
PLANT N SEWAGE TREATMENT PLANT
MARCH 11, 1994

Step 1 - **Reported Sludge Mass Produced** (February 1993 - January 1994)

Hauled Sludge Volume = 29 m^3/yr
Hauled Sludge Concentration = 20 g/L = 20 kg/m^3 (assumed)
Hauled Sludge Mass = 29 m^3/yr * 20 kg/m^3 = 580 kg/yr

Sludge Drying Bed Volume = 40 beds/yr * 9000 IG = 40 * 40.8 m^3 = 1632 m^3
Sludge Concentration = 20 g/L = 20 kg/m^3 (assumed)
Sludge Drying Bed Mass = 1632 m^3 * 20 kg/m^3 = 32,640 kg/yr

Average Plant Flow = 622 m^3/d
Average Effluent SS = 9.9 mg/L = 0.0099 kg/m^3
Sludge Mass in Effluent = 653 m^3/d * 0.0099 kg/m^3 * 365 d/yr = 2,360 kg/yr

Total Reported Sludge Mass Produced = 580 kg/yr + 32,640 kg/yr + 2,360 kg/yr = 35,580 kg/yr

Step 2 - **Projected Chemical Sludge**

Average Wastewater Flow = 653 m^3/day
Aluminum Dosage = 58.8 ml/min = 0.085 m^3/d
Specific Gravity of Alum = 1330 kg/m^3
Aluminum as a percentage of Alum = 9.1%
Average Aluminum Dose = (0.085 m^3/d * 1330 kg/m^3 * 0.091)/653 m^3/d = 0.0156 kg/m^3
Sludge Production Ratio = 3.0 mg sludge produced/mg Alum added[5]

Chemical Waste Sludge = 653 m^3/d * 0.0156 kg/m^3 x 3.0 mg/mg x 365 d/yr = 11,154 kg/yr

Step 3 - **Projected Secondary Sludge Mass Produced**

Average Wastewater Flow = 653 m^3/d
Average BOD Removed Across Secondary System = 250 mg/L - 5.4 mg/L = 244.6 mg/L = 0.2446 kg/m^3
Sludge Production Ratio = 0.65 kg SS produced/kg BOD_5 removed
(ref. U.S. EPA Handbook Retrofitting POTWs)

Secondary Waste Sludge = 653 m^3/d x 0.2446 kg/m^3 x 0.65 kg/kg x 365 days/yr = 37,894 kg/yr

---

[5]Bowker, R.P.G. and H.G. Stensel, Design Manual for Phosphorous Removal, EPA/625/1-87-001, U.S. Environmental Protection Agency, Center for Environmental Research, Cincinnati, Ohio (September 1987).

Step 4 - **Total Projected Sludge Produced**
Step 2 + Step 3 (Chemical Sludge + Secondary Sludge)
= 11,154 kg/yr + 37,894 kg/yr = 49,048 kg/yr

Step 5 - **Evaluation**

$$= \frac{\text{TOTAL PROJECTED MASS (STEP 4) - REPORTED MASS (STEP 1)}}{\text{TOTAL PROJECTED MASS}} * 100$$

$$= \frac{49,048 - 35,580}{49,048} * 100$$

$$= 27\%$$

The projected total sludge mass produced is not within ±15% of the actual sludge mass produced. Therefore, the data probably does not reflect the current level of treatment.

Step 6 - **Projected Effluent SS Concentration**

Projected Mass - Reported Mass = 49,048 kg/yr - 35,580 kg/yr = 13,468 kg/yr
Average Wastewater Flow = 653 m^3/d
Average Reported Effluent SS = 9.9 mg/L

Projected Effluent SS = 13,468 kg/yr / (653 m^3/d*365 d/yr)*1000 = 56 mg/L
Average Projected Effluent SS = 56 mg/L + 9.9 mg/L = 66 mg/L

Step 7 - **Projected Effluent BOD_5 Concentration**

Projected Effluent SS = 56 mg/L
Reported Average Effluent BOD_5 = 5.4 mg/L
Assume 0.5 mg/L BOD_5/1.0 mg/L TSS

Projected Effluent BOD_5 = 0.5*Projected Effluent SS + Reported Effluent BOD_5
= 0.5*56 mg/L + 5.4 mg/L
= 33 mg/L

Step 8 - **Projected Effluent TP Concentration**

Projected Effluent SS = 56 mg/L
Reported Average Effluent TP = 0.2 mg/L
Assume 0.04 mg/L TP/1.0 mg/L TSS

Projected Effluent TP = 0.04*Projected Effluent SS + Reported Effluent TP
= 0.04*56 mg/L + 0.2 mg/L
= 2.4 mg/L

The estimated performance of the facility indicates that compliance criteria for this facility was probably not achieved for the 12 month period evaluated.

Appendix D
Data Collection Forms Used in Conducting CPEs

Form	Title
D-1	Preliminary Plant Information
D-2	Administration Data
D-3	Design Data
D-4	Operations Data
D-5	Maintenance Data
D-6	Performance Data
D-7	Interview Data

Form D-1

Preliminary Plant Information to Collect by Phone

Plant Name ______________________________

Phone Contact ______________________________

Position ______________________________

Phone Number ______________ 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 ______________________________

Unusual Processes or Equipment

____

____

____

Any processes or equipment currently not operational

____

Who does performance monitoring tests? ______________________

Who does process control test? ______________________

What process control and laboratory 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 ______________________

Process control records ______________________

Form D-2
Administration Data

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. ______________________________

B. Kickoff Meeting

Purposes of CPE

- Background
- Assess plant potential for achieving compliance
- Identify current factors limiting performance
- Outline follow-up activities

Schedule of Events	Day	Time
a. Kickoff Meeting	____	____
b. Plant Tour	____	____
c. Review Budget/User Charge Ordinance/Revenues	____	____
d. On-site Data Collection/Review O&M Manual/C of A Permit/Design Data/Operating Records	____	____
e. Conduct Personnel Interviews	____	____
f. Exit Meeting	____	____

B. Kickoff Meeting (continued)

Personnel Interviews Scheduling Sheets (includes off-site administrators/owners, budgeting personnel, laboratory, maintenance personnel, plant administrators, shift personnel, operators, etc.)

Person	Title	Day	Time

B. Kickoff Meeting (continued)

Attendance List

Organization ______________________ Date ______________________

Name	Title/Dept	Telephone No.

C. Permit Information (attach copies of pertinent pages from actual permit if available)

Permit Number ____________________

Date Permit Issued ____________________

Date Permit Expires ____________________

Receiving Stream ____________________

Effluent Limits and Monitoring Requirements:

Parameter*	Maximum Monthly Average	Maximum Weekly Average	Monitoring Frequency Required	Sample Type Required
Flow, m^3/d				
BOD_5, mg/L				
BOD_5, kg/d				
TSS, mg/L				
TSS, kg/d				
Fecal Coliform, No./100 ml				
Chlorine Residual, mg/L				
pH, units				
Phosphorus, mg/L				
Phosphorus, kg/d				
Ammonia, mg/L				
Ammonia, kg/d				
Oil & Grease mg/L				
Others				

* Note: if seasonal limit

Note: 1 mgd = 3785 m^3/d

1 lb = 0.4536 kg

D. Organization

Governing Body (name and scheduled meetings)

Structure

From Governing Body to STP

STP Staff

Staff Meetings (formal/informal)

Reporting Requirements (formal/informal)

D. Organization (continued)

Service Area (general description - residential, industrial, seasonal influences, etc.)

Compliance Schedule

Observations (openness, awareness of plant needs, management style, etc.)

E. Personnel

Plant

No.	Title/Name	Certification	Pay Scale	% of Time at STP

Off-Site

No.	Title/Name	Pay Scale	% of Time Allocated to STP

F. Training

Operator Training Budget ______________________________

____

____

Training Incentives ______________________________

____

____

Training Over Last Year ______________________________

____

____

G. Plant Coverage

Weekdays

Shifts (times/overlap?/number per shift)

Weekends & Holidays

Alarms (on what processes? dialer?)

H. Plant Budget/Expenditures (attach a copy of actual budget and/or expenditures if available)

Budget Year: ____________________ to ____________________

Expenditure Period: ____________________ to ____________________

Category	Budget Amount	Expenditure Amount
Administrative Salaries (including fringes)	________	________
Plant Staff Salaries (including fringes)	________	________
Utilities Electric (see Part I)	________	________
Gas (see Part I)	________	________
Chemicals	________	________
Vehicles	________	________
Training	________	________
____________________	________	________
____________________	________	________
____________________	________	________
____________________	________	________
____________________	________	________
____________________	________	________
Operations Subtotal	________	________
Capital Outlay (See Part J) Bond Debt Retirement	________	________
Reserve	________	________
Capital Improvement Subtotal	________	________
Plant Total	________	________

Observations

Budget Prepared By:

I. Energy Consumption

Electricity

Source of Information ________________________________

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

Demand Cost __________

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

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

I. Energy Consumption (continued)

Natural Gas/Fuel Oil/LPG

Source of Information ______________________________

Unit Cost __________ (attach rate schedule if available)

Month/Year	Days in Billing Period	Usage	Cost
Total			
Average			

Miscellaneous (Fuel Oil, Digester Gas, etc.):

J. Capital Outlays

Bond Retirement

Bond Type	Year Issued	Duration	Int. Rate	Annual Payment	Description of Project Financed

Capital Improvement Reserve (Self sustaining utility? Exceed bond requirements? Replacement philosophy?)

Capital Replacement Plan (Available? Items scheduled for replacement? Attach if available)

Observations

K. Revenue

User Charges

Type of Connection	Fee	User Fee Revenue
Residential	______	______
Non-Residential (Industry, Commercial, Government Institutions)	______	______
Other	______	______

Connection Fee

Type of Connection	Fee	Connection Fee Revenue
Residential	______	______
Non-Residential	______	______

Other Sources of Revenue

Total Revenue for Evaluation Period (see Part H)

Miscellaneous

Are rates and budgets reviewed annually?

When was last rate increase? (How much?)

Proposed increases?

L. Exit Meeting

Attendance List

Organization ______________________ Date ______________

Name	Title/Dept.	Telephone No.

Attach Copy of Exit Meeting Handouts

Form D-3
Design Data*

*** Note: All references to gallons in this form are US Gallons.**

A. Plant Flow Diagram (attach if available)

B. Plant Solids Handling Diagram (attach if available)

C. Upgrading and/or Expansion History (historical studies, proposed modifications, etc.)

D. Influent Characteristics

Average Daily Flow:	Design ______	mgd[1] x 3,785 =	______	m^3/d
	Current ______	mgd x 3,785 =	______	m^3/d
Maximum Daily 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

Name	Flow	BOD_5 Load	TSS Load	Other
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______

[1] mgd in US gallons; if Imperial gallons mgd (Imp) x 4,546 = ______ m^3/d.

Collection System

Lift Stations

Number of Residential Taps Served

Population Served

E. Unit Processes

Flow Measurement
(Form for each flow measuring device)

Flow Stream Measured ______________________________

Control Section:
Type and Size ______________________________

Location ______________________________

Comments (operational problems, maintenance problems, unique features, preventative maintenance procedures, etc.):

Recorder
Name ______________ Model ______________

Flow Range ______________________________

Calibration Frequency ______________________________

Date of Last Calibration ______________________________

Totalizer ______________________________

Comments (operation and design problems, unique features, etc.):

Accuracy Check During CPE
Method of Check:

Results:

E. Unit Processes (continued)

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, etc.)

Comments:

Comments:

E. Unit Processes (continued)

Preliminary Treatment

Mechanical Bar Screen

Name ______________________________

Model ______________ Horsepower ______________

Bar Screen Width __________ inch x 2.54 = __________ cm

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

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

Cleaning Frequency ______________________________

Within Building? __________ Heated? __________

Description of Operation:

Screenings Volume:

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

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

Screenings Disposal

Comments

E. Unit Processes (continued)

Preliminary Treatment

Comminutor

Name ____

Model ____________________ Horsepower ________________________

Within Building? __________ Heated? __________

Maintenance:

Comments:

Grit Removal

Description of Unit:

Grit Volume:

Normal ______________ cu yd x 0.76[2] = ______________ m^3/d

Peak ______________ cu yd x 0.76[2] = ______________ m^3/d

Disposal of Grit:

Comments:

---

[2] If using ft^3/d, conversion is **ft^3/d x 0.028 =** __________ **m^3/d**

E. Unit Processes (continued)

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 (US) x 3,785[3] = __________ m^3/d

(Operating) ____________ mgd (US) x 3,785[3] = __________ m^3/d

Weir Overflow Rate

(Design) ______________ gpd/ft (US) x 0.013[4] = __________ $m^3/m^2/d$

(Operating) ____________ gpd/ft (US) x 0.013[4] = __________ $m^3/m^2/d$

Surface Settling Rate

(Design) ______________ gpd/ft^2 x 0.041[5]= ______________

$m^3/m^2 \cdot d$

(Operating) ____________ gpd/ft^2 x 0.041[5]= ______________ m^3/m^2d

Collector Mechanism Name ______________________________

Model ______________ Horsepower ______________

Scum Collection and Treatment:

Scum Volume:

Scum Treatment/Disposal:

---

[3] If using Imperial gallons, conversion is **mgd(Imp) x 4,456 =** _______ **m^3/d**

[4] For Imperial gallons, conversion is **gpd(Imp)/ft x 0.015 =** _______ **$m^3/m^2/d$**

[5] For Imperial gallons, conversion is **gpd(Imp)/ft^2 x 0.049 =** _______ **$m^3/m^2 \cdot d$**

E. Unit Processes (continued)

Secondary Treatment (Activated Sludge)

Aeration Basin(s)

Number ______________ Surface Dimensions ____________________

____

Water Depth ______________ ft x 0.3 = __________ m

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

Flow (Design) ______________ mgd(US) x 3,785[6] = ________ m^3/d

(Operating) ______________ mgd(US) x 3,785[6] = ________ m^3/d

Covered? ____

Comments:

Modes of Operation (current and other options; i.e., complete mix, plug flow, step loading, tapered aeration - sketch options):

[6] For Imperial gallons, conversion is **mgd(Imp) x 4,546 =** ________ **m^3/d**

E. Unit Processes (continued)

Secondary Treatment (Contact Stabilization)

Contact Basin

Surface Dimensions (ea unit) ____________ No. of Units ________

Water Depth ________ ft x 0.3 = ________ m

Volume (ea) ________ cu ft x 0.028 = ________ m^3

Flow (Design) ________ mgd x 3,785[7]= ________ m^3/d

(Operating) ________ mgd x 3,785[7]= ________ m^3/d

Wastewater Detention Time (Design) ________ hr

(Operating) ________ hr

Covered?

Comments:

Reaeration Basin

Surface Dimensions (ea unit) ____________ No. of Units ________

Water Depth ________ ft x 0.3 = ________ m

Volume (ea) ________ cu ft x 0.028 = ________ m^3

Hydraulic Retention Time at 100 Percent Return

(Design)________ hr

(Operating)________ hr

Flexibility to Operate as Conventional or Step Feed:

Covered?

Comments:

[7] For Imperial gallons, conversion is **mgd(Imp) x 4,546 = ________ m^3/d**

E. Unit Processes (continued)

Secondary Treatment (Oxygen Supply)

Surface Mechanical Aeration

No. of Aerators ______________ Name ______________________________________

Model ______________________ Horsepower ______________________________

Rated Capacity ________________ lb/hr x 0.454 = ______________ kg/hr

Speed Control:

Submergence Control:

Diffused Aeration

Blowers

No of Blowers ______________________ Name ____________________________

Model ______________________ Horsepower ______________________________

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

Minimum Inlet Air Temperature ______________

Diffusers

Types of Diffusers (coarse, fine, ceramic, stainless steel, etc.):

Manufacturer ____________________________Name __________________________

Water Depth ____

Rated Standard Transfer Efficiency

Water Temperature (maximum)

Plant Elevation

Jet Aeration

No. of Aerators ______________ Name ______________________________________

Model _________________________ Horsepower ____________________________

Rated Capacity _______________________ lb/hr x 0.454 = ____________ kg/hr

Controls:

Comments

E. Unit Processes (continued)

Secondary Treatment (Trickling Filter)

Filter(s)

Number ____________ Covered? ______________________________

Surface Dimensions ______________________________

Media Type ______________________________

Specific Surface Area ____________ sq ft/cu ft x 3.32 = ____________ m^2/m^3

Media Depth ____________ ft x 0.3 = ____________ m

Surface Area ____________ sq ft x 0.093 = ____________ m^2

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

Flow

(Design) ____________ mgd(US) x 3,785[8] = ____________ m^3/d

(Operating) ____________ mgd(US) x 3,785[8] = ____________ 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(US)/sq ft x 0.041 = ____________ $m^3/m^2/d$

(Operating) ____________ gpd(US)/sq ft x 0.041 = ____________ $m^3/m^2/d$

Recirculation (description, ranges, current operation, sketch relative to clarifiers)

Mode of Operation

Climate (freezing in winter?)

Comments

---

[8] For Imperial gallons, conversion is **mgd(Imp) x 4,546 =** ________ **m^3/d**

E. Unit Processes (continued)

Secondary Treatment (Rotating Biological Contactor - RBC)

RBC

Manufacturer ______________________________

No. of Shafts ______________ No. of Stages ______________

Length of Shafts __________ ft x 0.3 = __________ m

Disk Diameter __________ ft x 0.3 = __________ m

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

Type of Drive (air, mechanical): ______________________________

Covered? ______________ Heated? ______________

Flow

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

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

Hydraulic Loading

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

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

Temperature (Design) __________ °C Operating __________ °C

First Stage 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 System 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

Flexibility to Distribute Load to Stages (sketch)

Load Cells Available?

Comments

E. Unit Processes (continued)

Secondary Treatment (Activated Biofilter - ABF)

Biocell

Manufacturer ______________________ No. of Cells ______________________

Surface Dimensions ____

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

Media Depth __________________ ft x 0.3 = ___________ m

Total Media volume ____________ cu ft x 0.028 = __________ m^3

Media Type ____

Specific Surface Area __________ sq ft/cu ft x 3.32 = ___________ m^2/m^3

BOD_5 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 = ___________ $kg/m^3/d$

Recirculation Tank

Dimensions (LxWxD) ______________ ft x 0.3 = ____________ m

Volume __________________ cu ft x 7.48 = ______________ m^3

Aeration Basin

Surface Dimensions ____

Depth _________________ ft x 0.3 = ___________ m

Volume __________________ cu ft x 7.48 = ______________ m^3

Hydraulic Retention Time (Design) _________ min (Operating) _________ min

Comments

E. Unit Processes (continued)

Secondary Treatment (Secondary Clarifiers)

Number ______________ Surface Dimensions ______________________________

____

____

Water Depth (Shallowest) __________ ft x 0.3 = __________ m

Water Depth (Deepest) __________ ft x 0.3 = __________ m

Weir/Launder Location(s) ______________________________

Percent of Clarification Developed by Launders ______________________________

Weir Length ______________ ft x 0.3 = __________ m

Weir Overflow Rate

(Design) ______________ gpd/ft x 0.013 = __________ m^3/m/d

(Operating) __________ gpd/ft x 0.013 = __________ m^3/m/d

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

Total Volume ______________ cu ft x 0.028 = __________ m^3

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

(Operating) __________________ mgd(US) x 3,785 = __________ m^3/d

Surface Settling Rate

(Design) __________________ gpd/sq ft x 0.041 = __________ m^3/d

(Operating) __________________ gpd/sq ft x 0.041 = __________ m^3/d

Hydraulic Retention Time (Design) __________ hr (Operating) __________ hr

(Actual From Dye Test) __________ hr

Collector Mechanism Name ______________________________

Model ______________________ Horsepower ______________________________

Return Sludge Collector Mechanism Type ______________________________

Mechanical Seal Location (centre well?/collector arm?):

Scum Collection and Removal:

Scum Volume:

Normal ________________ cu yd x 0.76 = ________________ m^3/d

Peak ________________ cu yd x 0.76 = ________________ m^3/d

Scum Treatment/Disposal:

E. Unit Processes (continued)

Secondary Treatment (Stabilization Ponds)

Number ______________ Surface Dimensions ______________________________

____

____

Water Depth #1 ________ ft x 0.3 = ________ m Length:Width Ratio ________

Water Depth #2 ________ ft x 0.3 = ________ m Length:Width Ratio ________

Water Depth #3 ________ ft x 0.3 = ________ m Length:Width Ratio ________

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

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

Hydraulic Detention Time (Design) _________ days (Operating) _________ days

BOD_5 Loading

(Design) ____________ lb/ac/d x 1.12 = __________ kg/ha/d

(Operating) __________ lb/ac/d x 1.12 = __________ kg/ha/d

Type of Aeration ______________ No. of Aerators/Pond #1 ______________

Type of Aeration ______________ No. of Aerators/Pond #2 ______________

Type of Aeration ______________ No. of Aerators/Pond #3 ______________

Name _____________ Model _____________ Horsepower _______________

No. of Blowers ______ Name ____________ Model ______________________

Horsepower ____________ Air Capacity ______________________________

Mixing Pond #1 ____________ $hp/10^6$ gal(US) x 0.0002[9]= __________ kW/m^3

Mixing Pond #2 ____________ $hp/10^6$ gal(US) x 0.0002[9]= __________ kW/m^3

Mixing Pond #3 ____________ $hp/10^6$ gal(US) x 0.0002[9]= __________ kW/m^3

---

[9] For Imperial gallons, conversion is **$hp/10^6$·gal(Imp) x 0.00016 =** _____ **kW/m^3**

Recirculation Description ____

____

____

Ratio of Recirculation to Flow: (Design) __________ (Operating) __________

Flexibility (series/parallel operation; discharge structure) ____________________

____

____

Comments (short-circuiting?, etc.)

E. Unit Processes (continued)

Chlorine Disinfection

Contact Basin(s)

Number ______________________________

Surface Dimensions ______________________________

Channel Length-to-Width Ratio __________ No. of Bends __________

Water Depth __________ ft x 0.3 = __________ m

Total Volume __________ cu ft x 7.48 = __________ m^3

Retention Time: (Design) __________ min (Operating) __________ min

Drain Capability:

Scum Removal Capability:

Comments:

Chlorinators

Name ______________________________ Number __________

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

Comments:

E. Unit Processes (continued)

Ultra-Violet Disinfection

Number ______________________________

Length of Flow Path __________ ft x 0.3 = __________ m

Lamp Type ______________________________

Number of Lamps per Unit ______________________________

Lamp Length __________ ft x 0.3 = __________ m

Effective Arc Length __________ ft x 0.3 = __________ m

Nominal UV Output __________ (W/ft arc) x 3.281 = __________ W/m arc

Lamp Horizontal Spacing (centre-to-centre) __________ in x 2.54 = __________ cm

Lamp Vertical Spacing (centre-to-centre) __________ in x 2.54 = __________ cm

Flow (Design) ______________ mgd(US) x 3,785[10]= __________ m^3/d

(Operating) ______________ mgd(US) x 3,785[10]= __________ m^3/d

Maximum Influent Bacterial Density __________ No./100 mL

Average Influent TSS __________ mg/l

Comments:

[10] For Imperial gallons, conversion is **mgd(Imp) x 4,546 =** _______ **m^3/d**

E. Unit Processes (continued)

Sludge Handling Facilities

Primary Sludge

Description of Pumping Procedure (time clocks; variable speed pumps; etc)

Method of Sludge Volume Measurement

Sampling Location

Sampling Procedure

Comments

Return Sludge

Description of Sludge Movement (scrape to clarifier hopper; pump to aeration basin inlet channels; etc)

Controllable Capacity Ranges

(Low) ____________ mgd(US) x 3,785[11]= ____________ m^3/d

(High) ____________ mgd(US) x 3,785[11]= ____________ m^3/d

Method of Control

Method of RAS Volume Measurement

Sampling Location

Sampling Procedure

Comments

---

[11] For Imperial gallons, conversion is **mgd(Imp) x 4,546 =** ________ $\mathbf{m^3/d}$

Waste Sludge

Description of Waste Procedure (variable-speed pump wastes from separate clarifier hopper; continuous or by time clock; etc.)

Method of Waste Volume Measurement

Sampling Location

Sampling Procedure

Comments

E. Unit Processes (continued)

Treatment (Aerobic Digestion)

Digesters

Number of Basins ____________ Surface Dimensions ______________________________

Water Depth ____________ ft x 0.3 = ____________ m

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

Covered? ________________ Heated? ______________

Mode of Operation

Oxygen Supply [Complete Form "Secondary Treatment (Oxygen Supply)"*]*

Decanting Procedure

Scum Removal

Comments

E. Unit Processes (continued)

Treatment (Anaerobic Digestion)

Primary Digesters

Number of Digesters ____________ Diameter ____________ ft x 0.3 = ____________ m

Sidewall Depth ____________ ft x 0.3 = ____________ m

Centre Depth ____________ ft x 0.3 = ____________ m

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

Floating Cover? ____________

Flow (Design) ____________ mgd(US) x 3,785[12] = ____________ m^3/d

(Operating) ____________ mgd(US) x 3,785[12] = ____________ m^3/d

Detention Time (Design) ____________ days (Operating) ____________ days

Volatile Solids Loading (Design) ____________ lb/cu ft x 16.2 = ____________ kg/m^3

(Operating) ____________ lb/cu ft x 16.2 = ____________ kg/m^3

Heating

Manufacturer ____________ Model Number ____________

Capacity ____________ 10^6 Btu/hr x 0.29[13] = ____________ 10^6 W

Mixing

Manufacturer ____________ Type ____________

Number of Units ____________

Sampling Ports

Mode of Operation

Gas System

Comments

---

[12] For Imperial gallons, conversion is **mgd(Imp) x 4,546 =** ________ **m^3/d**

[13] For measurements in seconds, the conversion is **Btu/s x 1005.1 =** _____ **10^6 W**

E. Unit Processes (continued)

Treatment (Anaerobic Digestion)

Secondary Digesters

Number of Digesters ____________ Diameter ____________ ft x 0.3 = ____________ m

Sidewall Depth ____________ ft x 0.3 = ____________ m

Centre Depth ____________ ft x 0.3 = ____________ m

Total Volume ____________ cu ft x 0.28 = ____________ 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

Volatile Solids Loading (Design) ____________ lb/cu ft x 16 = ____________ kg/m^3

(Operating) ____________ lb/cu ft x 16 = ____________ kg/m^3

Heating

Manufacturer ______________________________ Model Number ________________

Capacity ________________________ 10^6 Btu/hr x 0.29 = ____________ 10^6 W

Mixing

Manufacturer ______________________________ Type ________________________

Number of Units ______________________________

Sampling Ports

Mode of Operation

Gas System

Comments

E. Unit Processes (continued)

Dewatering

Sludge Drying Beds

Number of Beds _____ Dimensions (ea) __________ Surface Area (Total) __________

Covered? (Glass?)(Plastic?) _______________ Subnatant Drain To _______________

Dewatered Sludge Removal:

Mode of Operation (depth of sludge draw; seasonal operation; etc.)

Comments:

Other Dewatering Unit(s)

Type(s) of Unit(s) ______________________________

Number of Units _______________ Manufacturer _______________

Model ______________________ Horsepower _______________

Loading Rate (Design) _____________ lb/hr x 0.454 = _____________ kg/hr

(Operating) _____________ lb/hr x 0.454 = _____________ kg/hr

Polymer Used ______________________________

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

Cake Solids (Design) ____________ percent solids

(Operating) ____________ percent solids

Hours of Operation (Design) ____________ hr/wk

(Operating) ____________ hr/wk

Comments:

E. Unit Processes (continued)

Ultimate Disposal

Describe Procedure

Options

Seasonal Operation

Comments

E. Unit Processes (continued)

Summary of Plant Horsepower

Item	HP	Usage, %	Weighted HP
Total			

F. 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.)

Plant Automation (description of any plant automation not covered under more specific topics)

Miscellaneous (see miscellaneous design factors list in Appendix A)

Form D-4
Operations Data

A. Process Control Strategy and Direction

Who Sets Major Process Control Strategies?

Who Sets Daily Adjustments?

Where is Help Sought When Desired Performance is Not Achieved?

How is Staff Input Utilized (Opinions, etc.)?

B. Specific Process Control Procedures

Sampling and Testing
Automatic Sampling

Sampling Locations

Composites (flow proportioned?)

Flow Measurement and Recording

	Influent	Prim. Sludge	RAS	WAS	To Digesters
Meter Calibration					
Readings Taken					
Onsite Accuracy Check					

B. Specific Process Control Procedures (continued)

Primary Clarification
Sludge Removal (method of control/adjustment?)

Performance Monitoring (tests used? solids balance?)

Other

A. S. Secondary Systems
Sludge Mass Control (tests used? method of control/adjustment?)

Return Sludge Control (tests used? method of control/adjustment?)

Microscopy Used? Filament Identification Capability?

DO Control (monitoring locations; frequency; control/adjustment?)

Mode Changes (capability; changed?)

Other

Fixed Film Secondary Systems
Secondary Clarifier Sludge Removal (adjustments?)

Soluble BOD Removal (monitored? recycle adjustments?)

Sidestream Returns (monitored? options?)

Other

B. Specific Process Control Procedures (continued)

Sludge Handling and Disposal
Purpose Relative to Other Processes

Sludge Thickening (monitored? process control/optimization?)

Sludge Stabilization (monitored? process control/optimization?)

Sludge Dewatering (monitored? process control/optimization?)

Sludge Disposal (meet requirements? monitoring? options?)

Miscellaneous
Unit Process Monitoring

Data Development / Interpretation

Trend Charts

C. Process Control References (Specifically note references that are the source of poor process control decisions or strategies, suspected or definitely identified)

D. Operations and Maintenance Manual

Manual Contents
Manual Located at Treatment Plant? Yes _______ No _______

Adequate Coverage? Yes _______ No _______

Operator/Manager Responsibilities Defined? Yes _______ No _______

Design Criteria Listed? Yes _______ No _______

Process Control Covered? Yes _______ No _______

Manual Used? Yes _______ No _______

Operating Staff
Specified in Manual? Yes _______ No _______

Present Staffing Meets/Exceeds Specified Staffing Requirement? Yes _______No _______

Operator Qualifications
Specified in O&M Manual? Yes _______ No _______

Operator Possesses Specified Qualifications? Yes _______ No _______

Certification? Yes _______ No _______

Experience? Yes _______ No _______

Comments:

E. Pretreatment Program

Is There An Active Pretreatment Program? Yes ______ No ______

Significant Industries

Problems

Staffing

Sampling Frequency (announced? unannounced?)

Comments:

F. Sewer Use Ordinance

Are There Problems At The Plant Related To Wastewater Influent?

Does The Ordinance Contain Provisions Necessary To Solve The Problem?

Is The Sewer Use Ordinance Being Enforced?

Comments:

G. Laboratory Capability

Facilities

	Adequate (Yes/No)	Comments
Bench Space		
Storage Space		
Floor Area		
Lighting		
Electricity		
Potable Water Supply		
Compressed Air		
Vacuum		
Chemical Fume Hood		
Air Conditioning		
Desk		
Records Storage		

Equipment and Instruments

	Available (Yes/No)	Comments
Portable DO Meter		
Settleometer		
Graduated Cylinder		
Turbidimeter		
Core Sampler (Sludge Depth)		
pH meter		
Centrifuge		
Distilled Water (Source)		
BOD Incubator		
TSS Drying Oven		

FC Water Bath Incubator		
Hot Air Oven		
Refrigerator		
Autoclave		
Analytical Balance		
Microscope		
Desiccator		
Automatic Samplers		

Analytical Capabilities

	Available (Yes/No)	Method/Comments
Total Solids		
TSS		
VSS		
Volatile Solids		
Alkalinity		
Temperature		
pH		
Turbidity		
BOD		
COD		
TKN		
Ammonia		
NO_2-NO_3-N		
Total Phosphorus		

Total Coliform		
Fecal Coliform		
Oxygen Uptake Rate (OUR)		
Specific OUR		

Miscellaneous

Quality Control

EPA Reference Samples

Duplicate Tests

Other

Standard Procedures/References

Standard Methods

Site-Specific Procedures

Training

Form D-5

Maintenance Data

A. Preventative Maintenance Program

Program Description

Method of Scheduling

Method of Documenting Work Completed

Small Spare Parts (fuses, belts, bearings, packing diffusers, etc.)

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

References

O&M Manual

Accurate As-Builts

Manufacturer's Literature

Adequacy of Resources Available

Outside Support

Tools/Lubricants

Work Area

B. Emergency Maintenance Program

Priority Setting (relationship to process control decisions)

Expertise

On-Site

Technical Support

Method of Initiating Work Activities (work order?)

Method of Documenting Work Completed

Control Parts Procurement (policy restrictions? sources?)

Comments

C. General

Housekeeping

Method of Factoring Costs For Parts/Equipment Into Budgeting Process

Equipment Age

Equipment Accessibility For Maintenance

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 12 months (list and explain)

Form D-6
Performance Data

A. Source of Data

B. Reported Monitoring Data for Previous 12 Months (flows in mgd or L/s; others in mg/L, except as noted)

	Raw						Primary Effluent				
Mo/Yr	Flow	BOD5	TSS	___	___	___	BOD5	TSS	___	___	___
___	___	___	___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___	___	___	___
AVG.	___	___	___	___	___	___	___	___	___	___	___

B. Reported Monitoring Data for Previous 12 Months (flows in mgd or L/s; others in mg/l, except as noted)

	Final						Other				
Mo/Yr	Flow	BOD5	TSS				BOD5	TSS			
AVG.											

Influent Quality Control Checks

Population:

Per Capita BOD_5 Contribution (0.17-0.22 lb/capita typical):

Service Taps:

Persons per Tap (2-4 typical):

C. Selected Data for Previous 12 Months

Parameter									
Units									
Mo/Yr									
AVG.									

D. Permit Performance Violations Within Last 12 Months (30-day averages, 7-day averages, instantaneous violations, effluent mass violations, percent removal violations)

E. Reasons, (if any), Reported Monitoring Data are Not Believed to Represent Actual Effluent Quality (unrepresentative sampling, improper lab analyses, selective reporting, unaccounted-for sludge loss [see attached sludge accountability evaluation], etc.)

F. Performance Monitoring/Sludge Accountability Summary Sheet

1. Sludge Accountability			**Item**
• Anticipated Sludge Production (see Table 2-6; Note: unit production values include solids lost in plant effluent)	________	kg/yr	1
• Accounted-For Sludge			
- wasted intentionally	________	kg/yr	2
- effluent sludge	________	kg/yr	3
Total: **2** + **3**	________	kg/yr	4
• Unaccounted-For Sludge: **1** - **4**	________	kg/yr	5
5 ÷ 365	________	kg/yr	6
• Unaccounted-For Sludge Percentage: 100 x **5** ÷ **1**	________	%	7
if -15 < **7** < 15 then — not possible to conclude that a problem with sludge wasting exists.			
if **7** > 15 then — problem with effluent monitoring indicated.			
if **7** < -15 then — may indicate organic loading greater than typical domestic (i.e., industrial loading).			
2. Performance Monitoring Assessment			
• Projected Actual Effluent TSS			
- recorded effluent TSS	________	mg/L	8
- projected increase in eff. TSS: **6** ÷ [flow(m^3/d) x 1000L/m^3]	________	mg/L	9
- estimated actual effluent TSS: **8** + **9**	________	mg/L	
• Projected Actual Effluent BOD_5			
- recorded effluent BOD_5	________	mg/L	10
- projected increase in effluent BOD_5: 0.5 x **9**	________	mg/L	11
- estimated actual effluent BOD_5: **10** + **11**	________	mg/L	
• Projected Actual Effluent TP			
- recorded effluent TP	________	mg/L	12
- projected increase in effluent TP: 0.04 x **9**	________	mg/L	13
- estimated actual effluent TP: **12** + **13**	________	mg/L	

Form D-7
Interview Data

A. Interview Concerns

Interviews are used to obtain feedback in the four categories of administration, design, operation, and maintenance. The following items are presented to assist the interviewers in obtaining this feedback.

1. Administration

Owner Responsibility?
Attitude toward staff?
Attitude toward regulatory agency?
Self-sustaining facility agency?
Attitude toward consultants?
Policies?
Communications (Formal/Informal)?

Performance Goal
Is plant in compliance?
If yes, what is making it that way?
If no, why not?
Is regulatory pressure felt for performance?
What are performance requirements?
What is stated performance goal?

Administrative Support
Budget
Within range of other plants?
"Drained" to general fund?
Unnecessary expenditures?
Sufficient?
Attitude toward rates?

Sewer Use Ordinance / Pretreatment Programs
Available?
Enforced?

Personnel
Within range of other plants?
Allows adequate time?
Motivation, pay/comparison with other municipal units, supervision, working conditions?
Productivity?

Turnover?
Training Support?

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

2. Design

Influent problems?
Equipment problems?
Status of warranties?
Return process streams?
Preliminary treatment?
Secondary treatment?
Disinfection?
Advanced waste treatment?
Sludge handling and disposal?
Flow measurement?
Flow splitting?
Alarms or alternate power?

3. Operation

Communication of decisions?
Key control parameters?
Involvement of staff?
Laboratory quality?
Administrative support?
Staffing?
Performance problems?
Unit process optimization?
External support?
Process control testing/adjustments?
O&M Manual/references?

4. Maintenance

How are priorities set?
Attitude toward program?
Emergency versus preventative?
Reliability? (spare parts or critical part procurement)
Staffing?
Equipment assessibility?

B. Personnel Interviews

Name ____

Title ____

Certification ____

Years at Plant ____________________ Years Experience ______________

Area of Responsibility ____

Education ____

Training ____

Concerns/Recommendations (Administration, Design, Operation, Maintenance):

Appendix E

Procedures for Converting Oxygenation Rates and Flows

The procedure for converting the manufacturers standard oxygen rates or standard oxygen efficiencies to actual oxygen transfer rates (or efficiencies) are calculated as follows:

$$AOTR = SOTR\,(\alpha)[\frac{BC_{sw} - C_L}{C_s}]\theta^{(T-20)}$$

or

$$AOTE = SOTE\,(\alpha)[\frac{BC_{sw} - C_L}{C_s}]\theta^{(T-20)}$$

Where:

AOTR = Actual oxygen transfer rate, lb O_2/hp-h
AOTE = Actual oxygen transfer efficiency, percent
SOTR = Standard oxygen transfer rate, lb O_2/hp-h
SOTE = Standard oxygen transfer efficiency, percent
α = Relative rate of oxygen transfer in wastewater compared to water. Estimate from Table 2-4.
β = Relative oxygen saturation value in wastewater compared to water. β = 0.95 for mixed liquor.
θ = Temperature correction constant, $\theta = 1.024$.
C_s = Oxygen saturation concentration of clean water at standard conditions, C_s = 9.17 mg/L
C_L = mixed liquor D.O. concentration, mg/L
T = Temperature of the liquid, °C
C_{sw} = Oxygen saturation concentration of clean water at site conditions of temperature and pressure, mg/L:

$$C_{sw} = C_{14.7}[\frac{P}{14.7}]$$

$C_{14.7}$ = oxygen saturation value of clean water at standard pressure of 14.7 psi and actual water temperature (see Table E-1).

P = actual pressure at oxygen transfer point:
a) For surface aerators use atmospheric pressure (see Figure E-1).
b) For others, use atmospheric pressure from Figure E-1, plus the

pressure at one third depth of the tank from the surface of the diffusers (i.e. aerator depth in feet x 0.33 x 0.434 psi/ft). [NOTE: the one-third depth is an approximation. Actual pressure at oxygen transfer point may vary depending on such factors as type of diffusers and tank geometry. To be more conservative, utilize atmospheric pressure.]

Figure E-1. Atmospheric Pressure at Various Altitudes.

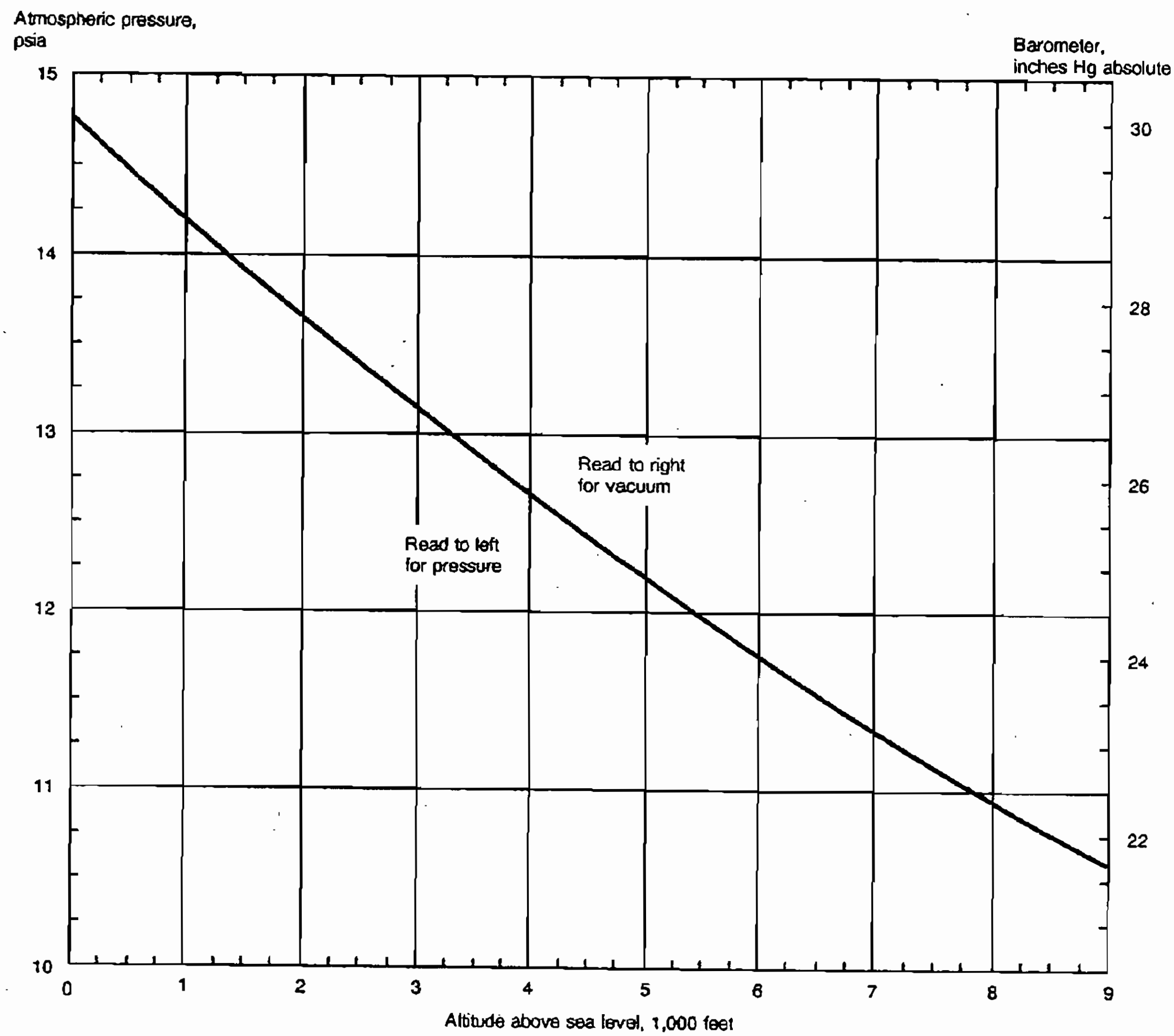


Table E-1. Oxygen Saturation at Standard Pressure and Actual Water Temperature

Temperature	Dissolved Oxygen Saturation Level
°C	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

The above calculations were simplified to make it easier for the CPE team to calculate the oxygen supply capability. Investigation of the AOTR and AOTE equation revealed the SOTR/SOTE and α values would vary depending upon system. However, if the maximum summer temperature of the wastewater was assumed to be 25°C, and the mixed liquor D.O. concentration was assumed to be 2.0 mg/L the remaining variables could be grouped into one term, which is now called the constant.

$$AOTR = SOTR \times \alpha \times constant$$

or

$$AOTE = SOTE \times \alpha \times constant$$

The constant can be found using the graphs presented in Figures 2-4 to 2-7. These graphs contain all the information that was previously calculated out in several steps. The information required to locate the constant value is the elevation of the STP, and the depth of submergence of the aerators (assume depth = 0 feet for surface aeration).

Appendix F
Guidelines for Field Estimating Equipment Power Usage

The power that a particular piece of equipment is drawing can be estimated in the field by measuring the current power 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 F-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:

$kVA = V \times A \times (3)^{1/2} \div 1{,}000$ (3-phase power)

$kW = KVA \times PF$

$whp = kW \div 0.746$

Table F-1. Worksheet for Calculation of Power Supply

Apparent Power

Line-to-Line Voltage on Incoming Power:

$V_{1\text{-}2}$ =____________Volts

$V_{2\text{-}3}$ =____________Volts

$V_{1\text{-}3}$ =____________Volts

V_{avg} =____________Volts

Amperage for Each Phase on Incoming Power:

I_1 = ____________ Amps

I_2 = ____________ Amps

I_3 = ____________ Amps

I_{avg}= ____________ Amps

Actual Power

K_h = ________________________ watthours/revolution (from meter)

CTR[a] = _________ : _________

PTR[a] = _________ : _________

TR[c] = CTR × PTR = _______________ × _______________ = _______________

Disc Speed = _______________ Seconds/ _______________ Revolution(s)

kW = K_h × TR × (Disc Rev/sec) × (3600 sec/hour) × (1 kW/1000 Watts) = __________

Power Factor

PF = kW ÷ kVA = _______________ × _______________ = _______________

---

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

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

Appendix G
Typical Design Values for Various Unit Processes
(From the MOEE Green Book)

Primary Sedimentation Tank Design Parameters

PLANT TYPE	TANK DEPTH (m)		SURFACE SETTLING RATE ($L/m^2 \cdot s$)[1]		WEIR OVERFLOW RATE ($L/m \cdot s$)[1]	
	No P Removal[2]	With P Removal[2]	No P Removal[2]	With P Removal[2]	No P Removal[2]	With P Removal[2]
Primary Treatment Plant	3.0-4.6	3.0-4.6	≤0.81	0.41-0.46 (with Alum or Ferric) 0.52 (with Lime)	1.74-5.21	1.74-5.21
Secondary Treatment Plant with W.A.S. Handling in Primaries	3.0-4.6	3.0-4.6	0.58-0.69	--	--[3]	--[3]
Secondary Treatment Plant Without W.A.S. Handling in Primaries	3.0-4.6	3.0-4.6	0.93-1.39	--	--[3]	--[3]

NOTES:
1. At peak flow rate.
2. Status of phosphorous removal refers to whether the primary sedimentation tank itself is used for P removal.
3. Weir overflow rates not generally critical provided tank depth is sufficient and weirs are located away from the area of upturn of the sludge density currents.
4. $L/m^2 \cdot s \times 86.4 = m^3/m^2 \cdot d$

Aeration System Design Parameters

TREATMENT PROCESS	ORGANIC LOADING RATE (kg BOD_5/m·d)	F/Mv (d^{-1})[1]	MINIMUM DETENTION TIME (h, Based on Q Avg.)	RETURN SLUDGE RATE (% Q Avg)[2]	OXYGEN DEMAND IN TYPICAL MUNICIPAL SEWAGE AT STANDARD CONDITIONS[10] (kg O_2/kg BOD_5 Applied of Nitrogen Applied Loading)	SOLIDS RETENTION TIME (SRT) (Days)	MINIMUM DISSOLVED OXYGEN LEVEL (mg/L)	MINIMUM RESIDUAL ALKALINITY (mg/L as $CaCO_3$)
CONVENTIONAL A. S.[3]								
-without nitrification	0.31-0.72	0.2-0.5	6	25-100	1.0 kg/kg BOD_5	4-8	2.0	-
-with nitrification[4]	0.31-0.72	0.05-0.25	6	25-100	1.0 kg/kg BOD_5 +4.6 kg/kg NH_4-N	>4 at 20 °C >10 at 5 °C	2.0	50
EXTENDED AERATION								
-without nitrification	0.17-0.24	0.05-0.15	15	50-200	1.5 kg/kg BOD_5	>15	2.0	-
-with nitrification	0.17-0.24	0.05-0.15	15[11]	50-200	1.5 kg/kg BOD_5 +4.6 kg/kg TKN	>15	2.0	50
HI-RATE								
-without nitrification	0.72-0.96	0.3-0.5	4	50-200	1.0 kg/kg BOD_5	4-6	2.0	-
-with nitrification[5]	-	-	-	-	-	-	-	-
CONTACT STABILIZATION								
-without nitrification	0.31-0.72[6]	0.2-0.5[6]	0.33[7] 4[8]	50-150	1.0 kg/kg BOD_5	4-10	2.0	-
-with nitrification[5]	-	-	-	-	-	-	-	-
AERATION LAGOONS[9]								
-without nitrification	0.031-0.048	-	-	-	1.0 kg/kg BOD_5	-	2.0	-

NOTES:

1. "F" is the mass loading to the aeration tank of BOD_5 per day and "Mv" is the mixed liquor volatile suspended solids mass under aeration.
2. Return sludge pumpage should be variable over the full range given.
3. Including step aeration.
4. Refer to "Nitrification in Activated Sludge Plants, Guidelines on Some Operation and Design Aspects", research publication W62 Revised July, 1977.
5. Hi-rate and contact stabilization not considered suitable for nitrification.
6. Considering contact and re-aeration tankage.
7. Based on Q Peak + 100% Q Avg return sludge rate, (Contact).
8. Based on 100% Q Avg return sludge rate, (Re-aeration).
9. Aerobic-Facultative Lagoons without separate clarification and without sludge return) providing pre-treatment prior to conventional lagoons.
10. The designer must adjust these values to the necessary O_2 transfer rate of the chosen aeration equipment by applying factors for alpha, beta, DO, and non-standard conditions such as altitude and temperature.
11. If nitrification is required year round, a longer detention time may be required.
12. Deviations from the recommended design parameters may be permitted if the designer can demonstrate through operating data or test that such deviations can be tolerated and still achieve the required treatment efficiency.

Secondary Sedimentation Basin Design Parameters

MIXED LIQUOR TYPE	TANK DEPTH (m)	SURFACE SETTLING RATE ($L/m^2 \cdot s$) (At Peak Overflow Rates)	WEIR LOADING RATE ($L/m \cdot s$)	SOLIDS LOADING ($kg/m^2 \cdot d$) (At Peak Flow)
Activated Sludge (No Chemical Addition to ML for P Removal)	3.6-4.6	0.58	2.9	≤240 (Including 50% Return Sludge)
Activated Sludge (With Chemical Addition to ML for P Removal)	3.6-4.6	0.41	2.9	≤240 (Including 50% Return Sludge)
Activated Sludge (With Nitrification Requirement)	3.6-4.6	0.34	2.9	≤120 (Including 100% Return Sludge)
Extended Aeration (With or Without P Removal)	3.6-4.6	0.41	2.9	≤120 (Including 100% Return Sludge)

NOTES:

1. Weir loading rates for weirs located away from the upturn of the density current should not exceed 2.9 $L/m \cdot s$, and for weirs located within the upturn zone the rate should not exceed 2.2 $L/m \cdot s$.
2. Peak overflow rate is the peak flow rate entering the sedimentation basin excluding the return sludge flow rate.
3. $L/m^2 \cdot s \times 86.4 = m^3/m^2 \cdot d$

Typical Sludge Qualities and Generation Rates for Different Unit Processes

UNIT PROCESS	LIQUID SLUDGE (L/m³)[1]	SOLIDS CONCENTRATION Range (%)	SOLIDS CONCENTRATION Average (%)	VOLATILE SOLIDS (%)	DRY SOLIDS (g/m³)[2]	DRY SOLIDS (g/cap)
PRIMARY SEDIMENTATION WITH ANAEROBIC DIGESTION						
Undigested (No P Removal)	2.0	(3.5-8)	5.0	65	120	55
Undigested (With P Removal)	3.2	(3.6-7)	4.5	65	170	77
Digested (No P Removal)	1.1	(5-13)	6.0	50	75	34
Digested (With P Removal)	1.6	(5-13)	5.0	50	110	50
PRIMARY SEDIMENTATION AND CONVENTIONAL ACTIVATED SLUDGE WITH ANAEROBIC DIGESTION						
Undigested (No P Removal)	4.0	(2-7)	4.5	65	180	82
Undigested (With P Removal)	5.0	(2-6.5)	4.0	60	220	100
Digested (No P Removal)	2.0	(2-6)	5.0	50	115	52
Digested (With P Removal)	3.5	(2-6)	4.0	45	150	68
CONTACT STABILIZATION AND HIGH RATE WITH AEROBIC DIGESTION						
Undigested (No P Removal)	15.5	(0.4-2.8)	1.1	70	170	77
Undigested (With P Removal)	19.1	(0.4-2.8)	1.1	60	210	95
Digested (No P Removal)	6.1	(1-3)	1.9	70	115	52
Digested (With P Removal)	8.1	(1-3)	1.9	60	155	70
EXTENDED AERATION WITH AERATED SLUDGE HOLDING TANK						
Waste Activated (No P Removal)	10.0	(0.4-1.9)	0.9	70	90	41
Waste Activated (With P Removal)	13.3	(0.4-1.9)	0.9	60	120	55
Sludge Holding Tank (No P Removal)	4.0	(0.4-4.5)	2.0	70	80	36
Sludge Holding Tank (With P Removal)	5.5	(0.4-4.5)	2.0	60	110	50

NOTES:

1. (L/m^3) denotes litres of liquid sludge per cubic metre of treated sewage.
2. (g/m^3) denotes grams of dry solids per cubic metre of treated sewage.
3. The above values are based on typical raw sewage with Total BOD_5 = 170 mg/L, Soluble BOD_5 = 50 %, SS = 200 mg/L, P = 7 mg/L, NH_4^+ = 20 mg/L.

Sludge Thickening Methods and Performance with Various Sludge Types

THICKENING METHOD	SLUDGE TYPE	PERFORMANCE EXPECTED
GRAVITY	Raw Primary	Good, 8-10% Solids
	Raw Primary and Waste Activated	Poor, 5-8% Solids
	Waste Activated	Very Poor, 2-3% Solids (Better results reported for oxygen excess activated sludge).
	Digested Primary	Very Good, 8-14% Solids
	Digested Primary and Waste Activated	-
DISSOLVED AIR FLOTATION	Waste Activated (Not generally used for other sludge types)	Good, 4-6% Solids and ≥ 95% Solids Capture with Flotation Aids.
CENTRIFUGATION	Waste Activated	8-10% and 80-90% Solids Capture with Basket Centrifuges; 4-6% and 80-90% Solids Capture with Disc-nozzle Centrifuges; 5-8% and 70-90% Solids Capture with Solid Bowl Centrifuges.

APPENDIX H
Unit Conversion Tables

Unit Conversion Tables

Abbreviations

min	minute	psi	pounds/square foot
mL	millilitre	psia	pounds/square inch, absolute
mm	millimetre		
mph	miles per hour	psig	pounds/square inch, gauge
kph	kilometres per hour	sec	second
No.	number	sq	square
p.	page	UK	United Kingdom
pp.	pages	US	United States
ppm	parts per million	Vol.	volume
psf	pounds per square foot	yd	yard
m	metre		

Weights and Measures

Units of Length

Inches	Feet	Yards	Centimetres	Metres
1	0.083	0.028	2.540	0.025
...	1	0.333	30.48	0.305
...	...	1	91.44	0.914
...	...	...	1	0.01

Units of Area

Square Inches	Square Feet	Square Miles	Square Centimetres	Square Metres
1	0.007	2.491×10^{-10}	6.45	6.45×10^{-4}
...	1	3.587×10^{-8}	929.03	0.093
...	...	1	25 900	2.59
...	...	...	1	1.0×10^{-4}

Units of Volume

Cubic Feet	Imperial Gallons	U.S. Gallons	Cubic Inches	Litres
1	6.23	7.481	1728	28.32
...	1	1.2	277.4	4.546
...	...	1	231	3.785
...	...	...	1	0.016

1 m^3 = 35.31 cu ft = 264.2 US gal
1 Imperial (UK) gal weighs 10 lb
1 cu ft of water weighs 63.43 lb
1 $m^3 = 10^3$ l and weighs 1000 kg
1 US gal weighs 8.34 lb
1 m^3 weighs 2283 lb

Discharge		
Cubic Feet per Second	Million Gallons per Day (mgd)	Gallons per Minute
1	0.6436	448.8
...	1	694.4

1 in. per hour per acre = 1.008 cfs
1 m^2/s = 22.83 mgd = 35.32 cfs

Units of Velocity

Miles per Hour	Feet per Second	Inches per Minute	Centimetres per Second	Kilometres per Hour
1	1.467	1056	...	1.609
...	1	720	30.48	...
...	...	1	0.423	...

Units of Weight

Tons	Pounds	Grams	Grains	Metric Tons
1	2000	...	...	0.9078
...	1	454	7000	...
...	...	1	15.43	...

1 long ton = 2240 lb
1 ppm = 1 mg/L = 8.34 lb per mg

Units of Pressure

Pounds per Square Inch	Feet of Water	Inches of Mercury
1	2.307	2.036
0.4335	1	0.882
0.4912	1.133	1

1 atm = 14.70 psia = 29.92 in. Hg = 33.93 ft water = 76.0 cm Hg

Units of Power

Kilowatts	Horsepower	Foot-Pounds per Second	Kilogram-Metres per Second
1	1.341	737.6	102.0
0.7457	1	550	76.04

Kilowatt-Hours	Horsepower-Hours	British Thermal Units (BTU's)
1	1.341	3412
0.7457	1	2544

Temperature

$$\text{Degrees Fahrenheit} = 32 + \frac{9}{5} \times \text{degrees Centigrade}$$

0	5	10	15	20	25	30	35	40	45	50	55	60	C
32	41	50	59	68	77	86	95	104	113	122	131	140	F

Viscosity and Density of Water

Temperature, C	Density ρ, γ (grams/cm^3), also s	Absolute Viscosity, μ centipoises*	Kinematic Viscosity ν, centistokes**	Temperature, F
0	0.99987	1.7921	1.7923	32.0
2	0.99997	1.6740	1.6741	35.6
4	1.00000	1.5676	1.5676	39.2
6	0.99997	1.4726	1.4726	42.8
8	0.99988	1.3872	1.3874	46.4
10	0.99973	1.3097	1.3101	50.0
12	0.99952	1.2390	1.2396	53.6
14	0.99927	1.1748	1.1756	57.2
16	0.99897	1.1156	1.1168	60.8
18	0.99862	1.0603	1.0618	64.4
20	0.99823	1.0087	1.0105	68.0
22	0.99780	0.9608	0.9629	71.6
24	0.99733	0.9161	0.9186	75.2
26	0.99681	0.8746	0.8774	78.8
28	0.99626	0.8363	0.8394	82.4
30	0.99568	0.8004	0.8039	86.0

* 1 centipoise = 10^{-2} (gram mass)/(cm)(sec). To convert to (lb force)(sec)/(sq ft) multiply centipoise by 2.088×10^{-5}.
** 1 centistoke = 10^{-2} cm^2/sec. To convert to (sq ft)/(sec) multiply centistoke by 1.075×10^{-5}.

1 gram/cm^3 = 62.43 lb/cu ft.

Vapour Pressure of Water and Surface Tension of Water in Contact with Air

Temperature, C	0	5	10	15	20	25	30
Vapour Pressure (p_w), mm Hg*	4.58	6.54	9.21	12.8	17.5	23.8	31.8
Surface Tension (σ), dyne/cm**	75.6	74.9	74.2	73.5	72.8	72.0	71.2

* To convert to in. Hg, divide by 25.4.
** To convert to (lb force)/ft divide by 14.9.

APPENDIX I
Unit Process Evaluations for Suspended Growth Systems
(As Developed for Severn Sound)

PLANT UNIT PROCESS ASSESSMENT

Suspended Growth Major Unit Process Evaluation

This worksheet is used to evaluate the capability of existing major unit process, 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:

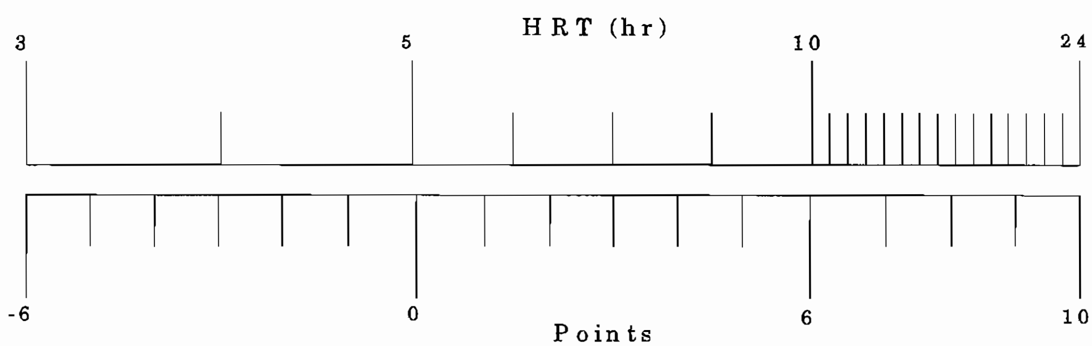
- Proceed through the steps contained in this worksheet *in order*.
- Use actual values in lieu of calculations if such data are available and appear reliable, e.g., waste sludge volume.
- When assigning points, interpolate and use the nearest whole number.
- Minimum and maximum point values are indicated - do not exceed the range illustrated.

Aeration Basin **Calculate Hydraulic Retention Time (HRT):**

$$HRT = \frac{\text{Aeratin Basin Volume}}{\text{Peak Month Average Daily Flow}}$$

$$HRT = \frac{(\qquad\qquad m^3)}{(\qquad\qquad m^3/d)} \times 24 = \underline{\qquad\qquad} \text{ hr}$$

Determine HRT Point Score:



HRT Point Score = 1

Calculate BOD_5 Loading

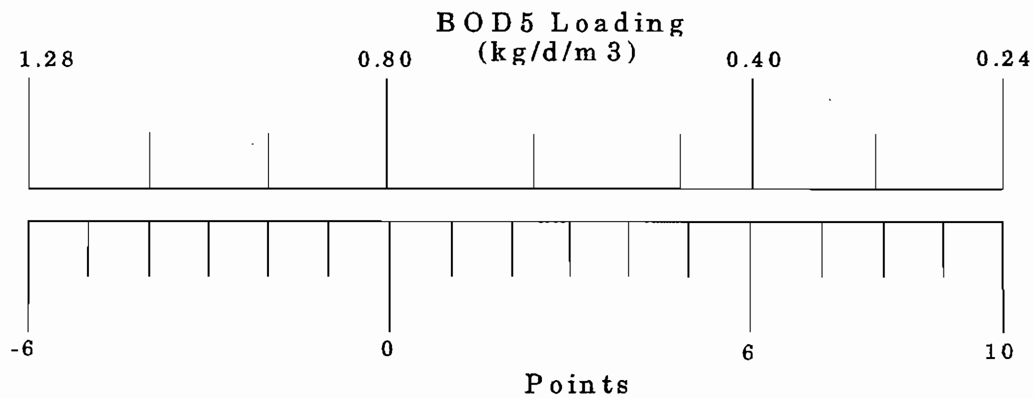
$$BOD_5 \text{ Loading} = \frac{\text{Average Daily } BOD_5 \text{ Loading}}{\text{Aeration Basin Volume}}$$

$$BOD_5 \text{ Loading} = \frac{\text{Average Influent } BOD_5 \text{ Concentration x Average Daily Flow}}{\text{Aeration Basin Volume}}$$

$$BOD_5 \text{ Loading} = \frac{(\quad mg/L) \times (\quad m^3/d) \times 0.001 \text{ L kg / mg } m^3}{(\quad m^3)}$$

$$BOD_5 \text{ Loading} = \quad kg\ BOD_5\ / m^3 \bullet d$$

Determine BOD_5 Loading Point Score:



***BOD_5 Loading Point Score =* __________ 2**

Calculate Oxygen Availability :

These calculations determine the amount of oxygen available. Actual oxygen transfer rate, or AOTR, is calculated as follows:

AOTR = (SOTR) α (constant), lb O_2/wire hph

where SOTR is dependant upon the aeration system and must be looked up in Table A;
α must be looked up in Table B
constant depends on the depth of submergence and elevation - see Table C

Table A Typical Clean Water Standard Oxygen Transfer Values

System	Oxygen Transfer Efficiency[a]	Oxygen Transfer Rate[b]	Oxygen Transfer Rate[b]
	percent	lb/wire hphr	kg/wire kWhr
Fine bubble diffusers, total floor coverage	38-32	6.0-6.5	3.66-3.97
Fine bubble diffusers, side wall installation	18-20	3.5-4.5	2.14-2.75
Jet aerators (fine bubbles)	18-25	3.0-3.5	1.83-2.14
Static aerators (medium-size bubble)	10-12	2.3-3.8	1.40-1.71
Mechanical surface aerators	-	2.5-3.5	1.53-2.14
Coarse bubble diffusers wide band pattern	8-12	2.0-3.0	1.22-1.83
Coarse bubble diffusers, narrow band pattern	6-8	1.5-2.0	0.92-1.22

[a] at 15 feet (4.572 m) submergence.
[b] 1 lb/hp-hr = 0.61 kg/kW-hr

Note: For the following calculations, use the average of the values found in the second column, (Oxygen Transfer Rate, lb/wire hp-hr.

Table B Typical Values of Alpha (α) Used for Estimating AOTR/SOTR

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

See Appendix 1 for Table C.

AOTR = (SOTR) α (constant)

AOTR = (lb O_2/wire hp-h) x (   ) x (   ),

= ______________ lb O_2/wire hp-h

Oxygen Transfer Capacity

= AOTR x HP x efficiency (75%) x 10.886 kg h/lb d

= (lb O_2/wire hp-h) x (hp) x (0.75) x 10.866

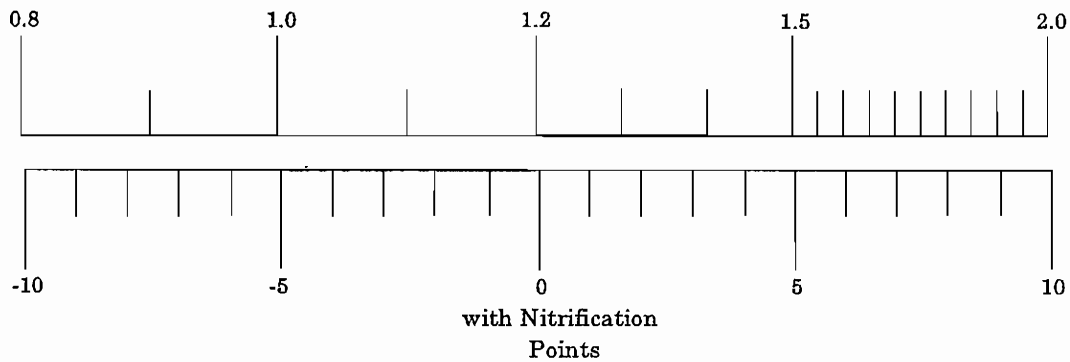
=   kg O_2/d

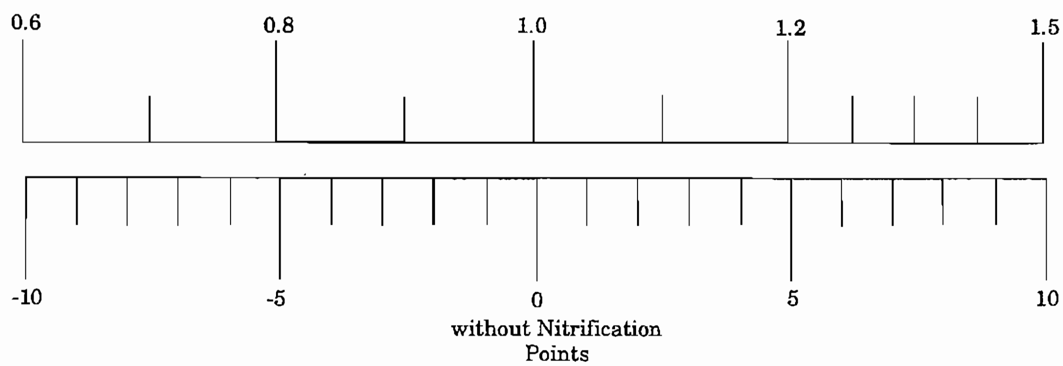
$$\text{Oxygen Availability} = \frac{\text{Oxygen Transfer Capacity}}{\text{BOD}_5\text{ Loading}}$$

$$\text{Oxygen Availability} = \frac{(\qquad \text{kg } O_2 / \text{d})}{(\qquad \text{kg } O_2 / \text{d})} = \_\_\_\_\_\_\_\_ \text{kg } O_2 / \text{kg BOD}_5$$

Determine Oxygen Availability Point Score (use top scale if plant nitrifies, and bottom scale if plant does <u>not</u> nitrify):

Oxygen Availability (kg O2/kg BOD5)





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 weirs	10
Circular with weirs on walls	5
Rectangular with 33% covered with weirs	5
Rectangular with 20% covered with weirs	0
Rectangular with weir at or near end	-10

Clarifier Configuration Point Score = ________ **5**

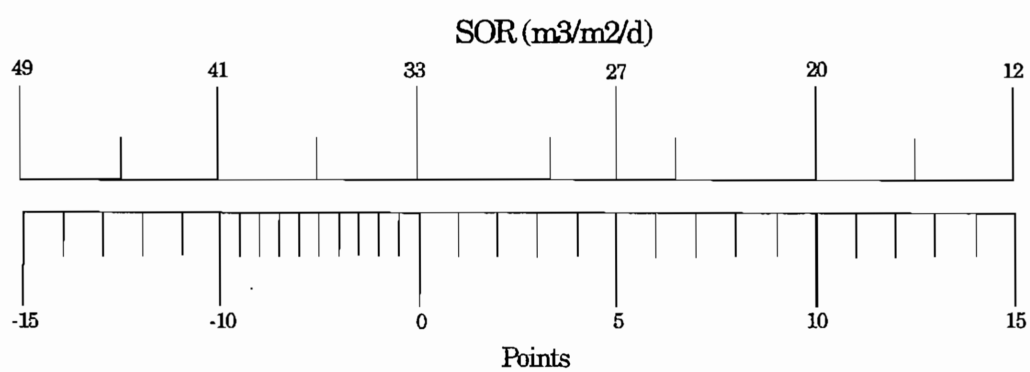
Calculate Clarifier Surface Overflow Rate (SOR):

$$SOR = \frac{\text{Peak Month Average Daily Flow}}{\text{Clarifier Surface Area *}}$$

$$SOR = \frac{(\qquad\qquad m^3/d)}{(\qquad\qquad m^2)} = \_\_\_\_\_\_\_\_ \ m^3/m^2 \bullet d$$

* Area of a circle= $\pi r^2 = \pi d^2/4$
Volume of a cylinder = $h\pi r^2 = h\pi d^2/4$
Volume of a cube = l x w x h

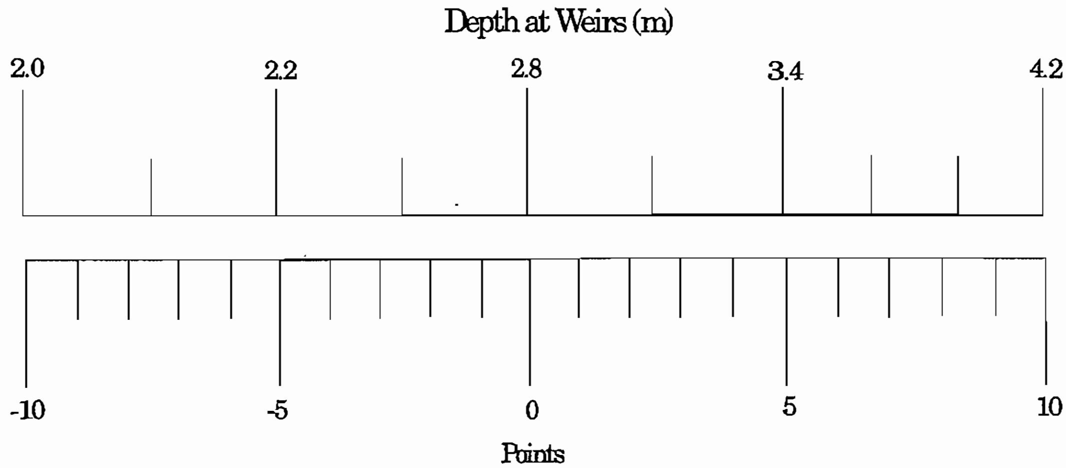
Determine SOR Point Score:



SOR Point Score ________ **6**

What is the depth of the secondary clarifier at the weirs? _______ m

Determine Depth at Weirs Point Score:



Depth at Weirs Point Score = ________________ 7

Determine Return Activated Sludge Point Score:

RAS Removal	Points
Circular, rapid withdrawal	10
Circular, scraper to hopper	8
Rectangular, co-current scraper	2
Rectangular, counter-current scraper	0
No mechanical removal	-5

RAS Removal Point Score = ________________ 8

Determine Typical RAS Rate from Following:

Process Type	RAS Rate, % of Average Daily Wastewater Flow	
	Minimum	Maximum
Conventional (plug flow or complete mix)	25	100
Extended Aeration (including oxidation ditches)	50	100
Contact Stabilization	50	125

For this facility, what are the values from the above table for the following:

Minimum Typical RAS Rate = ______________ %, and

Maximum Typical RAS Rate = ______________ %,

Calculate Typical RAS Flow Range:

Minimum Typical RAS Rate x Minimum Month STP Flow
=Minimum Recommended RAS Flow
(____________%) x (____________m^3/d) x (0.01) = ____________ m^3/d

Maximum Typical RAS Rate x Maximum Month STP Flow
= Maximum Recommended RAS Flow
(____________%) x (____________m^3/d) x (0.01) = ____________ m^3/d

Determine Possible RAS Flow Range for Existing Facilities:

Minimum Possible RAS Flow = __________ m^3/d (Pump design flow and controllability)

Maximum Possible RAS Flow = __________ m^3/d (Pump design flow and controllability)

Determine RAS Control Point Score (Compare Calculated Typical RAS Flow Range with Possible RAS Flow Range):

RAS Control	Points
The possible RAS flow range is completely within the typical RAS flow range and the capability to measure RAS flow exists	10
The possible RAS flow range is completely within the typical RAS flow range but the capability to measure RAS flow does not exist	7
50% of the typical RAS flow range is covered by the possible RAS flow range and the capability to measure RAS flow exists	5
50% of the typical RAS flow range is covered by the possible RAS flow range but the capability to measure RAS flow does not exist	0
The possible RAS flow range is completely outside the typical 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 Scores:

Waste Sludge Sampling	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**

Calculated Expected BOD_5 Mass to be Removed (in the following calculations, 1.25 is a variability factor, described in the following paragraph:

> Variations in sludge production values have been observed throughout the year. Additionally, operation decisions to lower sludge inventories in the plant can place increased requirements on the sludge handling facilities. It is not uncommon for these variations to require 125-150 percent of the long-term average sludge production value. For this reason, a factor of 1.25 is applied to the calculated sludge mass and volume values to ensure reliable capability under most operational situations throughout the year.)

STP with Primary Clarification:

Primary BOD_{5in} - Primary BOD_{5out} = Primary BOD_5 Conc. Removed **A**

(________ mg/L) - (________ mg/L) = ________ mg/L ÷ 1000

= ________ kg/m^3

Primary BOD_{5out} - STP Effluent BOD_5 = Secondary BOD_5 Conc. Removed **B**

(________ mg/L) - (________ mg/L) = ________ mg/L ÷ 1000

= ________ kg/m^3

Primary BOD_5 Concentration Removed (**A**)x Average Daily STP Flow x 1.25.

= Primary BOD_5 Mass Removed **C**

(________ kg/m^3) x (________ m^3/d) x 1.25 = ________ kg

Secondary BOD_5 Concentration Removed (**B**) x Average STP Flow x 1.25

= Secondary BOD_5 Mass Removed **D**

(________ kg/m^3) x (________ m^3/d) x 1.25 = ________ kg

STP without Primary Clarification:

BOD_{5in} - STP Effluent BOD_5 = Total BOD_5 Concentration Removed **E**
(_________ mg/L) - (_________ mg/L) = _________ mg/L ÷ 1000
= _________ kg/m^3

Total BOD_5 Concentration Removed x Average Daily STP Flow x 1.25
= Total BOD_5 Mass Removed **F**
(_________ kg/m^3) x (_________ m^3/d) x 1.25 = _________ kg

Typical Unit Sludge Production From the Following:

Process Type	kg TSS (sludge)/ kg BOD_5 Removed
Primary Clarification	1.7
Activated Sludge with Primary Clarification	0.7
Activated Sludge without Primary Clarification	
Conventional[1]	0.85
Extended Aeration[2]	0.65
Contact Stabilization	1.0

[1] Includes tapered aeration, step feed, plug flow, and complete mix with wastewater times < 10 hr.
[2] 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:

STP with Primary Clarification:

Unit Sludge Prod. x Prim. BOD_5 Mass Removed = Prim. Sludge Mass **G**
(_______ kg TSS/kg BOD_5 removed) x (________ kg/d) (**C**) = _________ kg/d

and/or Unit Sludge Prod x Sec. BOD_5 Mass Removed = Secondary Sludge Mass **H**
(_______ kg TSS/kg BOD_5 removed) x (________ kg/d) (**D**) = _________ kg/d

Expected Total Sludge Mass (**G** + **H**) = __________ kg/d **I**

STP without Primary Clarification

Unit Sludge Prod. x Total BOD_5 Mass Removed = Total Sludge Mass **J**

(________ kg TSS/kg BOD_5 removed) x (________ kg/d) (**C**) = ________ kg/d

Typical Unit Sludge Production From the Following:

Sludge Type	Sludge Concentration, kg/m^3
Primary	50
Activated	
Return Sludge/Conventional	6
Return Sludge/Extended Aeration	7.5
Return Sludge/Contact Stabilization	8.0
Return Sludge/small plant with low SOR[1]	10.0
Separate waste hopper in secondary clarifier	12.0

[1] Returns can often be shut off for short periods to thicken waste sludge in clarifiers with surface overflow rates < 500 gpd/sq ft or 20.4 m^3/m^{2}d

Calculated Expected Sludge Volume:

STP with Primary Clarification:

$$\text{Sludge Volume} = \frac{\text{Total Sludge Mass (G)}}{\text{Primary Sludge Concentration}}$$

$$\text{Sludge Volume} = \frac{(\qquad\qquad \text{kg / d})}{(\quad 50 \quad \text{kg / m}^3)} = \_\_\_\_\_\_\_\_ \text{ m}^3\text{/d}$$ **K**

$$\text{Sludge Volume} = \frac{\text{Secondary Sludge Mass (H)}}{\text{Secondary Sludge Concentration (see above table)}}$$

$$\text{Sludge Volume} = \frac{(\qquad\qquad \text{kg / d})}{(\qquad\qquad \text{kg / m}^3)} = \_\_\_\_\_\_\_ \text{ m}^3\text{/d}$$ **L**

Expected Total Sludge Volume (**K** + **L**) = _______ m^3/d **M**

STP without Primary Clarification:

$$\text{Total Sludge Volume} = \frac{\text{Total Sludge Mass (J)}}{\text{Waste Sludge Concentration (see above table)}}$$

$$\text{Sludge Volume} = \frac{(\qquad\qquad\qquad \text{kg / d})}{(\qquad\qquad\qquad \text{kg / m}^3)} = \_\_\_\_\_\_ \text{ m}^3\text{/d}$$

N

Calculated Capability of Sludge Handling Unit Processes:

1. Establish capability 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

Aerobic Digestion:

HRT of Aerobic Digestion Process

$$\text{Calculated Aerobic Digestion HRT} = \frac{\text{Total Volume of Aerobic Digestion Units}}{\text{Flow of Waste Sludge to Unit}}$$

$$= \frac{(\qquad\qquad\qquad \text{m}^3)}{(\qquad\qquad\qquad \text{m}^3\text{ / d})}$$

$$= \qquad \text{days}$$

$$\text{\% Capability} = \frac{\text{Calculated Digester HRT}}{\text{Typical Digester HRT}} x100\%$$

$$= \frac{(\qquad\qquad \text{days})}{\text{15 days}} x100\%$$

$$= \qquad \%$$

Anaerobic Digestion:

HRT of Anaerobic Digestion Process

$$\text{Calculated Anaerobic Digestion HRT} = \frac{\text{Total Volume of Anaerobic Digestion Units}}{\text{Flow of Waste Sludge to Unit}}$$

$$= \frac{(\qquad\qquad m^3)}{(\qquad\qquad m^3/d)}$$

$$= \qquad\qquad \text{days}$$

$$\%\ \text{Capability} = \frac{\text{Calculated Digester HRT}}{\text{Typical Digester HRT}} x100\%$$

Typical Digester HRT Values: Single Stage Anaerobic Digestion 40 days

Two Stage Anaerobic Digestion 30 days

$$\%\ \text{Capability} = \frac{(\qquad \text{days})}{(\qquad \text{days})} x100\%$$

$$= \qquad \%$$

Gravity Thickening:

$$\text{Thickener Loading} = \frac{\text{Total Sludge Mass}}{\text{Thickener Surface Area}}$$

$$= \frac{(\qquad kg/d)}{(\qquad m^2)}$$

$$= \qquad kg/m^2 \cdot d$$

Typical Loading Rates

Primary Sludge	125 kg/m^2d
Activated Sludge	20 kg/m^2d
Primary & Activated Sludge	50 kg/m^2d
Fixed Film	40 kg/m^2d
Primary & Fixed Film	75 kg/m^2d

$$\% \text{ Capacity} = \frac{\text{Calculated Loading}}{\text{Typical Loading}} x100\%$$

$$= \frac{(\qquad \text{kg/m}^2 \cdot \text{d})}{(\qquad \text{kg/m}^2 \cdot \text{d})} x100\%$$

$$= \qquad \%$$

Mechanical Dewatering:

# of hours that unit is in operation per week: ____________________

Typical Dewatering Unit Usage

Single Unit	30 hours of operation per week
Multiple Units (with one unit out of service)	60 hours of operation per week

$$\% \text{ Capacity} = \frac{\text{\# hours usage per week}}{\text{Typical Usage}} x100\%$$

$$= \frac{(\qquad \text{hours / week})}{(\qquad \text{hours / week})} x100\%$$

$$= \qquad \%$$

Drying Beds:

Worst season Turnover time? _______________________ days

Liquid Haulage:

Estimate the percentage of time that the STP is limited in its ability to haul sludge off-site (i.e. due to lack of budget, no where to take sludge etc.) _____________________________%

Guidelines for Evaluating Capability of Existing Sludge Handling Processes

Process	Parameters That Can Be Used to Represent 100% of Required Sludge Handling Capability[a]
Gravity Thickeners	
Primary Sludge	125 kg/m²/d (25 lb/d/sq ft)
Activated Sludge	20 kg/m²/d (4 lb/d/sq ft)
Primary + Activated	50 kg/m²/d (10 lb/d/sq ft)
Fixed Film	40 kg/m²/d (8 lb/d/sq ft)
Primary + Fixed Film	75 kg.m²/d (15) lb/d/sq ft)
Dissolved Air Flotation	
Activated Sludge	50 kg/m²/d (10 lb/d/sq ft)
Primary + Activated	100 kg/m²/d (20 lb/d/sq ft)
Fixed Film	75 kg/m²/d (15 lb/d/sq ft)
Primary + Fixed Film	125 kg/m²/d (25 lb/d/sq ft)
Digesters	
Aerobic	15 days' HRT[b]
Anaerobic	
Single Stage	40 days' HRT
Two Stage	30 days' combined HRT
Drying Beds	Worst season turnover time
Mechanical Dewatering	
Single Unit	30 hours of operation/week
Multiple Units	80 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] Capability 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/m²/d (5 lb/d/sq ft), the existing thickener should be considered to have 100% of required capability.

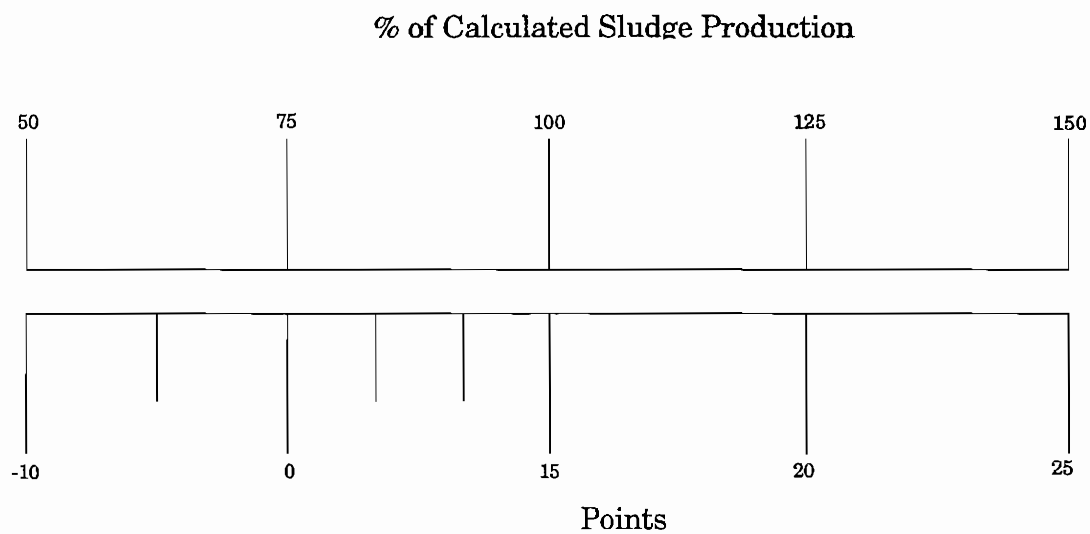
[b] HRT = Hydraulic Retention Time = Volume of digester ÷ Volume of waste sludge calculated to be produced.

List Each Process and its Associated Sludge Handling Capability and Identify the Lowest Percentage Capability:

Process	Percentage
______________	______________
______________	______________
______________	______________
______________	______________
______________	______________
______________	______________
______________	______________

Lowest Capability = ______________

Determine Sludge Handling Capability Point Score (Plot the lowest percentage capable sludge handling process):



***Sludge Handling Capability 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 STP 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	________

Select the Worst Case: STP is Type ________

Type 1 Current performance difficulties are not caused by limitations in the size or capabilities of the existing major unit processes.

Type 2 The marginal capacity of major unit processes will potentially prohibit the ability to achieve the desired performance level.

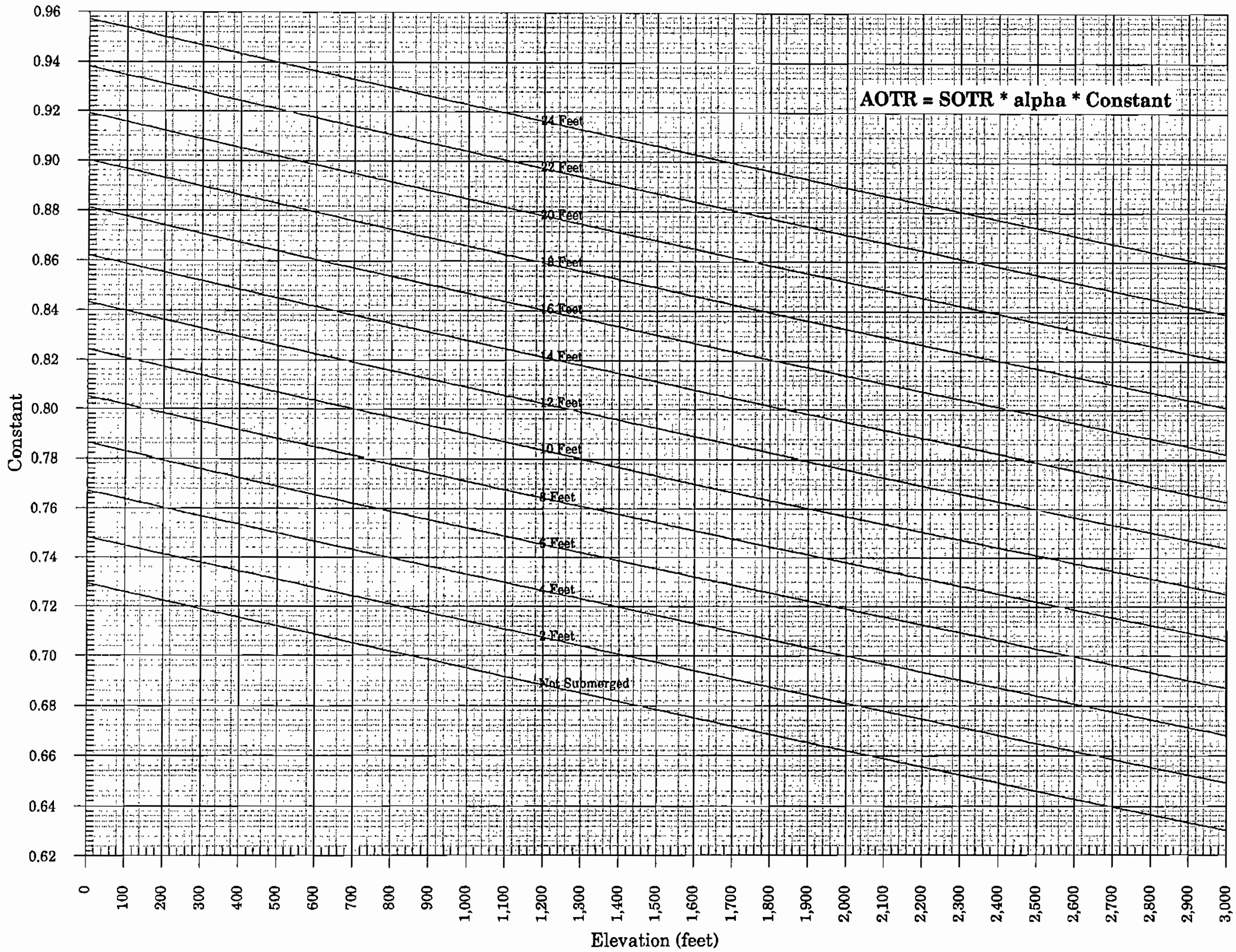
Type 3 The existing major unit processes are inadequate.

Appendix

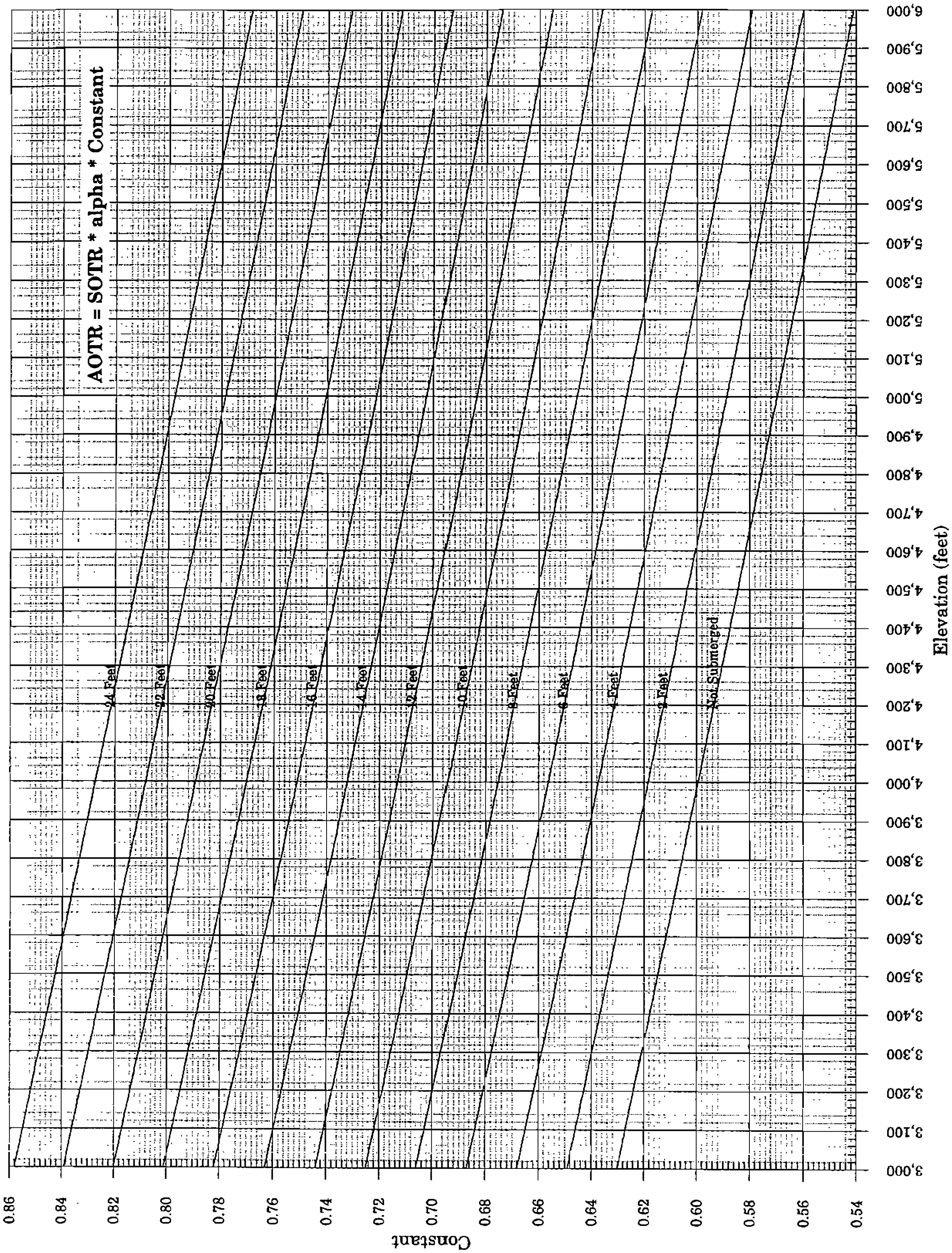
Table C **Graphs of Constant vs. Elevation**

To obtain the value for the constant, the elevation of the plant as well as the submergence of the aerators must be known. To find the value of the constant, follow the values on the graph for submergence and elevation to where they intersect. Then draw a straight horizontal line (i.e., parallel to the x-axis) so that it intersects the y-axis. The value read off the y-axis where the horizontal line intersects is the value for the constant. For example, an elevation of 6,450 feet and a submergence of 12 feet would give a constant of 0.640.

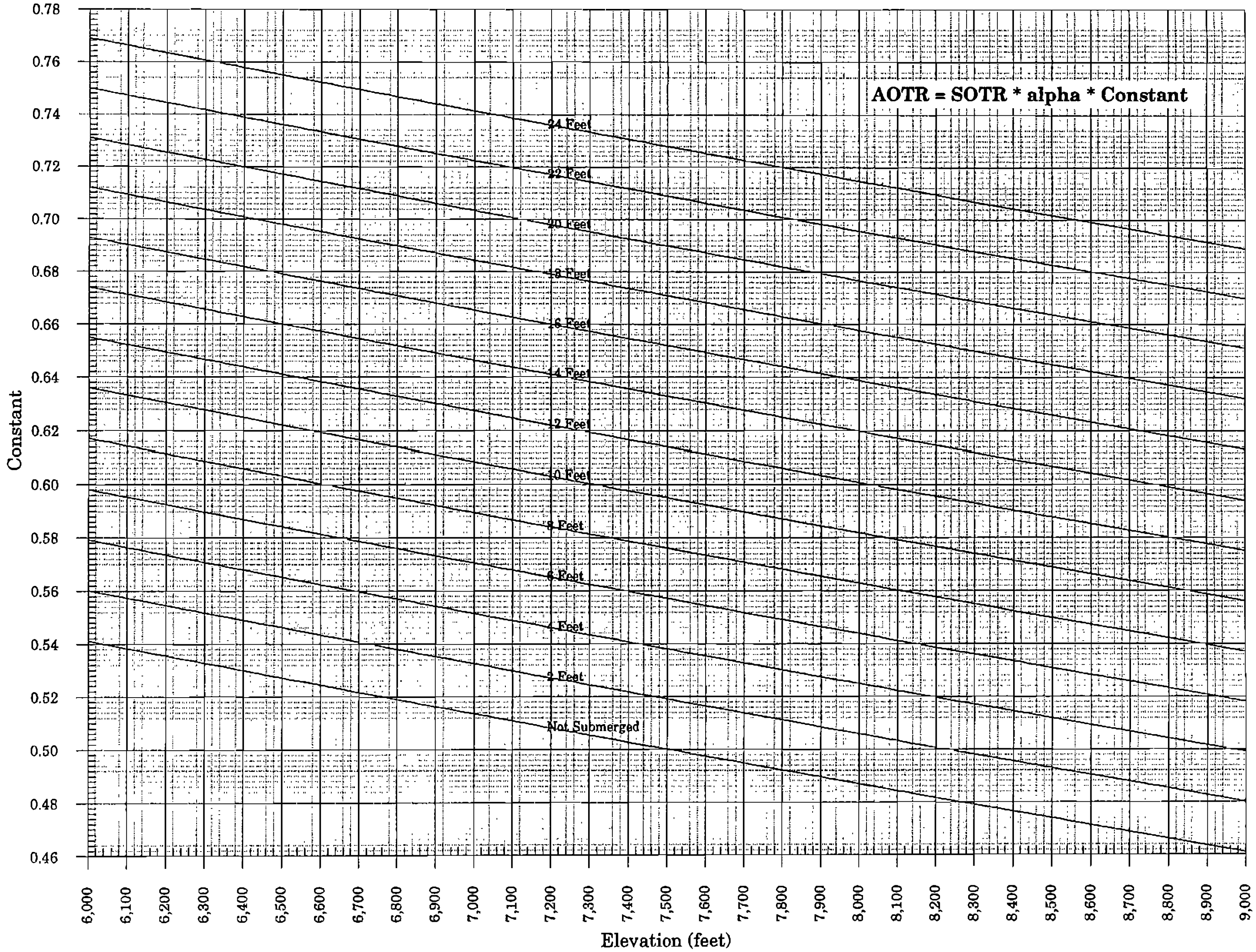
Constant vs. Elevation at 25 C



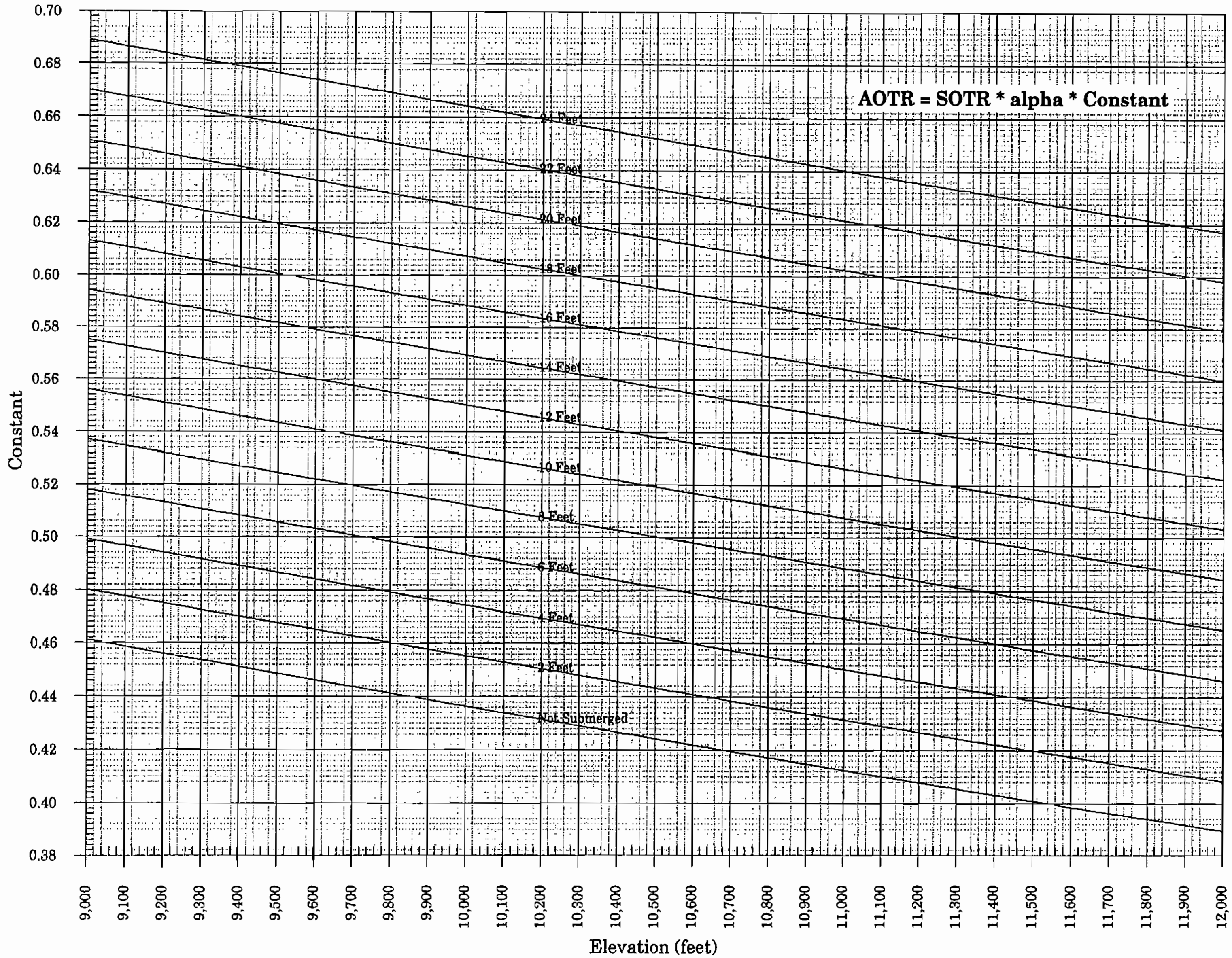
Constant vs. Elevation at 25 C



Constant vs. Elevation at 25 C



Constant vs. Elevation at 25 C



APPENDIX J

PROJECTED CHEMICAL SLUDGE BY STOICHIOMETRY

The projected chemical waste sludge produced per year could be calculated by stoichiometry. This method is detailed below.

1. Fill out the information in this table.

Summary Data for Calculations:

#	ITEM	VALUE
1	Type of metal salt?	Liq. Alum
2	Density of metal salt (Table 2-7)?	1330
3	% metal (Table 2-7)	4.4
4	Points of addition?	pre
5	Average volume of metal salt added per day, m^3/d	0.085
6	Average Wastewater Flow, m^3/d	650
7	$BOD_{5,raw}$, mg/L	150
8	$BOD_{5,out}$, mg/L	10
9	R, % (BOD_5 Removal across primary, if no primary R=0)	30
10	TP_{raw}, mg/L	9.0
11	TP_{out}, mg/L	0.5
GIVEN VALUES		
12	f_b, mg P/mg VSS	0.04
13	Y_{obs}, mg VSS/mg BOD_5	0.5

2. Calculate the Metal Dose

The amount of metal salt added must be determined, then the dosage rate can be calculated.

a) Metal added..A

$$Metal\ Added = Avg.\ Volume\ of\ Metal\ salt/d * density\ of\ metal\ salt * \%\ metal$$

$$Metal\ Added = (\ row\ 5\ )*(\ row\ 2\ )*(\ row\ 3\ )$$

$$= (\ 0.085\ \ m^3/d)*(\ 1330\ \ kg/m^3)*\frac{(\ 4.4\ \%)}{100}$$

$$= \ 4.97\ \ kg\ metal/d$$

b) Metal Dose..B

$$Metal\ Dose = \frac{Metal\ Added}{Average\ Wastewater\ Flow}$$

$$= \frac{(\ A\ )}{(\ row\ 6\ )}$$

$$= \frac{(\ 4.97\ \ kg/d)*1x10^6 mg/kg}{(\ 650\ 000\ L/d)}$$

$$= \ 7.6\ \ mg/L$$

3. Calculate Phosphorus Removed Chemically

a.) Phosphorus concentration required for Biological Uptake in Aeration System

$$TP_b = f_p * \Delta VSS$$

$$but\ require\ \Delta VSS\ first$$

ΔVSS .... **C**

$$\Delta VSS = \Delta BOD_5 * Y_{obs}$$

$$\Delta VSS = ((1-R) * BOD_{5,raw} - BOD_{5,out}) * Y_{obs}$$

$$= ((1-\frac{(\ row\ 9\ )}{100})*(\ row\ 7\ )-(\ row\ 8\ ))*(\ row\ 13\ )$$

$$=((1-\frac{30\ \%}{100})*(\ 150\ \ mg/L)-(\ 10\ \ mg/L))*(\ 0.5\ \ mg\ VSS/mg\ BOD)$$

$$= 47.5\ \ mg\ VSS/L$$

Therefore, TP_b = f_p * ΔVSS

= (row 12)*(D)

= (0.04 mg P/mg VSS)*(47.5 mg VSS/L)

= 1.9 mg/L... **D**

b.) Phosphorus Removed by Chemical Means

TP_r = TP_{raw}-TP_b-TP_{out}

= (row 10) - (E) - (row 11)

= (9.0 mg/L) - (1.9 mg/L) - (0.5 mg/L)

= 6.6 mg/L... **E**

4.0 Calculate Chemical Sludge Production Using Stoichiometry

Given: Atomic weight of P = 31
Atomic weight of Al = 27
Atomic weight of $AlPO_4 \cdot 2H_2O$ = 158
Atomic weight of $Al(OH)_3$ = 78

$$\mathbf{Al + PO_4 = AlPO_4 \cdot 2H_2O}$$
$$\mathbf{Al + 3OH = Al(OH)_3}$$

The following calculations quantify the amount of $AlPO_4 \cdot 2H_2O$ and $Al(OH)_3$ that will be produced based upon the metal dose and the amount of phosphorus removed chemically. The aluminum not used to produce $AlPO_4 \cdot 2H_2O$ will then be in excess and used to form $Al(OH)_3$.

(TP_r)/atomic wt of P = E/31 = (6.6)/31 = 0.21 mmole/L $AlPO_4 \bullet 2H_2O$ produced

Al dose/atomic wt. of Al = B/27 = (7.6 mg Aluminum/L)/27 = 0.28 mmole/L Al added

Al added - $AlPO_4$ produced = 0.28 - 0.21 = 0.07 mmole/L Al in excess to $Al(OH)_3$

$AlPO_4$ sludge:$AlPO_4$ produced*atomic wt. of $AlPO_4 \bullet 2H_2O$ = 0.21*158
= 33.18 mg/L $AlPO_4 \bullet 2H_2O$

$Al(OH)_3$ sludge: Al in excess* Atomic wt. of $Al(OH)_3$ = 0.07*78 = 5.46 mg/L $Al(OH)_3$

Total Sludge = $AlPO_4 \bullet 2H_2O$ sludge+$Al(OH)_3$ sludge = 33.18 + 5.46 = 38.64 mg/L

a.) Chemical Sludge Production Ratio

Using this total sludge concentration (as calculated above) and the aluminum dose, the chemical sludge production ratio can be calculated.

Chemical Sludge Production Ratio = (38.64 mg/L sludge)/(7.6 mg/L Aluminum)
= 5.1 mg sludge/mg aluminum

To account for sludge production due to other reactions the sludge production ratio is increased by 35% (US EPA, 1987). Therefore,

Chemical Sludge Production Ratio = 5.7 mg sludge/mg aluminum * 1.35
= 6.8 mg sludge/mg aluminum

5.0 Projected Chemical Waste Sludge Produced (per year)

= Avg. Flow * Aluminum Dose * Total Chemical Sludge Production Ratio* 365 d/yr

= 650 m^3/d * 7.6 mg Aluminum/L * 6.8 mg sludge/mg aluminum * 365 d/yr

= 1.226×10^7 g/yr * 1×10^{-3} kg/g

= 12 261 kg/yr

Therefore, on average it is projected that there would have been 12 261 kg of chemical sludge produced per year.

To simplify the stoichiometric calculations, summary graphs were created. These summary graphs replace all of the calculations in step 4.

The following are the same calculations as above except that the summary graphs of sludge production are utilized.

1. Fill out the information in this table.

Summary Data for Calculations:

#	ITEM	VALUE
1	Type of metal salt?	Liq. Alum
2	Density of metal salt (Table 2-7)?	1330
3	% metal (Table 2-7)	4.4
4	Points of addition?	pre
5	Average volume of metal salt added per day, m^3/d	0.085
6	Average Wastewater Flow, m^3/d	650
7	$BOD_{5,raw}$, mg/L	150
8	$BOD_{5,out}$, mg/L	10
9	R, % (BOD_5 Removal across primary, if no primary R=0)	30
10	TP_{raw}, mg/L	9.0
11	TP_{out}, mg/L	0.5
	GIVEN VALUES	
12	f_b, mg P/mg VSS	0.04
13	Y_{obs}, mg VSS/mg BOD_5	0.5

Using the information in the above tables in the following calculations.

2. Calculate the Metal Dose

The amount of metal salt added must be determined, then the dosage rate can be calculated.

a) Metal added..A

$$Metal\ Added = Avg.\ Volume\ of\ Metal\ salt/d * density\ of\ metal\ salt * \%\ metal$$

$$Metal\ Added = (\ row\ 5\ )*(\ row\ 2\ )*(\ row\ 3\ )$$

$$= (\ 0.085\ m^3/d)*(\ 1330\ kg/m^3)*\frac{(\ 4.4\ \%)}{100}$$

$$= 4.97\ kg\ metal/d$$

b) Metal Dose..**B**

$$Metal\ Dose = \frac{Metal\ Added}{Average\ Wastewater\ Flow}$$

$$= \frac{(\ A\ )}{(\ row\ 6\ )}$$

$$= \frac{(\ 4.97\ kg/d)*1x10^6 mg/kg}{(\ 650\ 000\ L/d)}$$

$$= 7.6\ mg/L$$

3. Calculate the Chemical Sludge Production Ratio

a.) Phosphorus concentration required for Biological Uptake in Aeration System

$$TP_b = f_p * \Delta VSS$$

but require ΔVSS *first*

ΔVSS..**C**

$$\Delta VSS = \Delta BOD_5 * Y_{obs}$$

$$\Delta VSS = ((1-R) * BOD_{5,raw} - BOD_{5,out}) * Y_{obs}$$

$$= ((1-\frac{(\ row\ 9\ )}{100})*(\ row\ 7\ )-(\ row\ 8\ ))*(\ row\ 13\ )$$

$$=((1-\frac{30\ \%}{100})*(\ 150\ \ mg/L)-(\ 10\ \ mg/L))*(\ 0.5\ \ mg\ VSS/mg\ BOD)$$

$$=\ 47.5\ \ mg\ VSS/L$$

Therefore, $TP_b = f_p \times \Delta VSS$

$= (\text{ row 12 }) \times (\text{ D })$

$= (\ 0.04\ \text{mg P/mg VSS}) \times (\ 47.5\ \text{mg VSS/L})$

$=$ 1.9 mg/L..**D**

b.) Phosphorus Removed by Chemical Means

$TP_r = TP_{raw} - TP_b - TP_{out}$

$= (\text{ row 10 }) - (\text{ E }) - (\text{ row 11 })$

$= (\ 9.0\ \text{mg/L}) - (\ 1.9\ \text{mg/L}) - (\ 0.5\ \text{mg/L})$

$=$ 6.6 mg/L..**E**

Using Figure 1-4 or, depending upon whether aluminum or iron salts are used, the chemical sludge production ratio can be estimated.

The steps to using this chart are as follows:

1. Locate the concentration of phosphorous that was removed chemically across the treatment system (TP_r) along the X-axis. In this case TP_r=6.6 mg/L.

2. From the phosphorus concentration move upwards until you locate the line (may need to interpolate) that represents the dosage rate of aluminum (or iron) as calculated in previous step (in this case 7.6 mg Al^{3+}/L).

3. Using these two data points read across to the Y-axis to find the chemical sludge production ratio. In this example it would be 7.1 mg sludge/mg aluminum.

∴ Total Chemical Sludge Production Ratio = 7.1 mg sludge/mg Al^{3+}

4.0 Projected Chemical Waste Sludge Produced (per year)

= Avg. wastewater flow × Aluminum Dose × Total Chemical Sludge Prod. Ratio × 365 d/yr
= 650 m^3/d × 7.6 mg Aluminum/L × 7.1 mg sludge/1.0 mg aluminum × 365 d/yr
= 1.2802×10^7 g/yr × 1 × 10^{-3} kg/g
= 12 802 kg/yr

Therefore, on average it is projected that there would have been 12 802 kg of chemical sludge produced per year.

A comparison between the 2 methods of calculating chemical sludge production presented in this appendix reveals that there is only a 4.4% difference between the sludge production.

% difference = (12,261-12,802)/12,261 × 100%
= 4.4%

Therefore, it is reasonable to use the charts in place of the extended calculations.

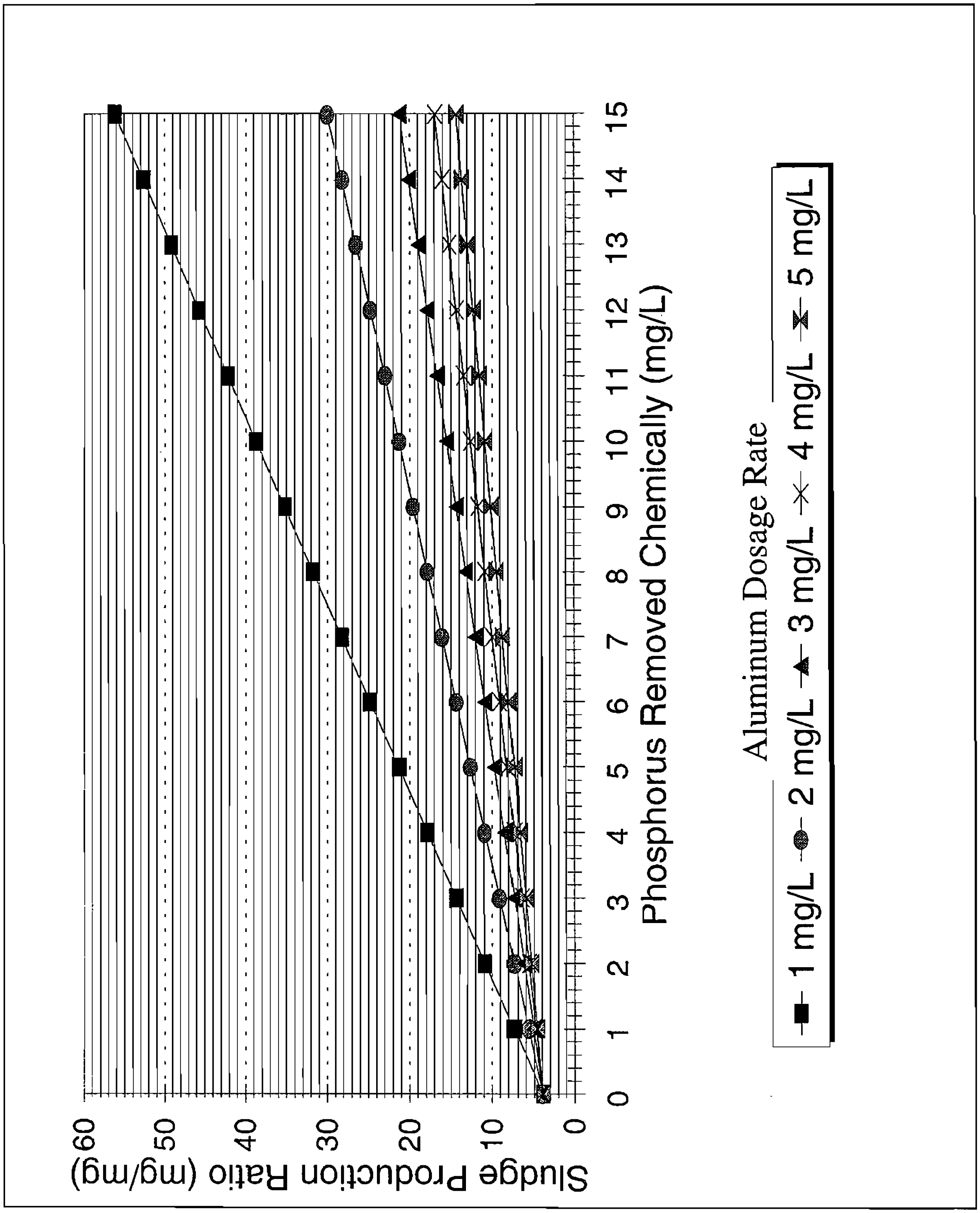


Figure 1. Chemical Sludge Production Ratios for Aluminum Doses Between 1 mg/L and 5 mg/L.

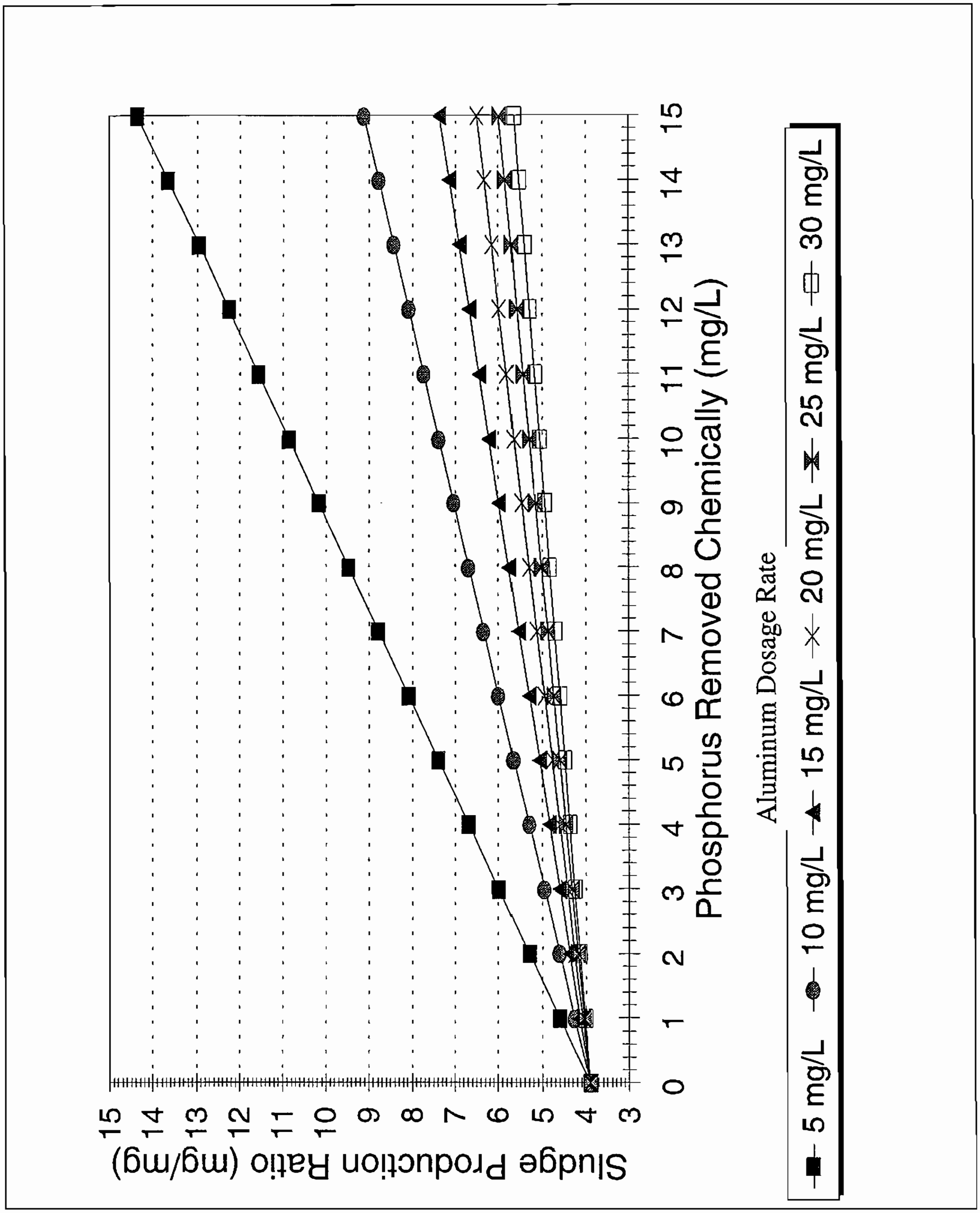


Figure 2. Chemical Sludge Production Ratios for Aluminum doses Between 5 mg/L and 30 mg/L.

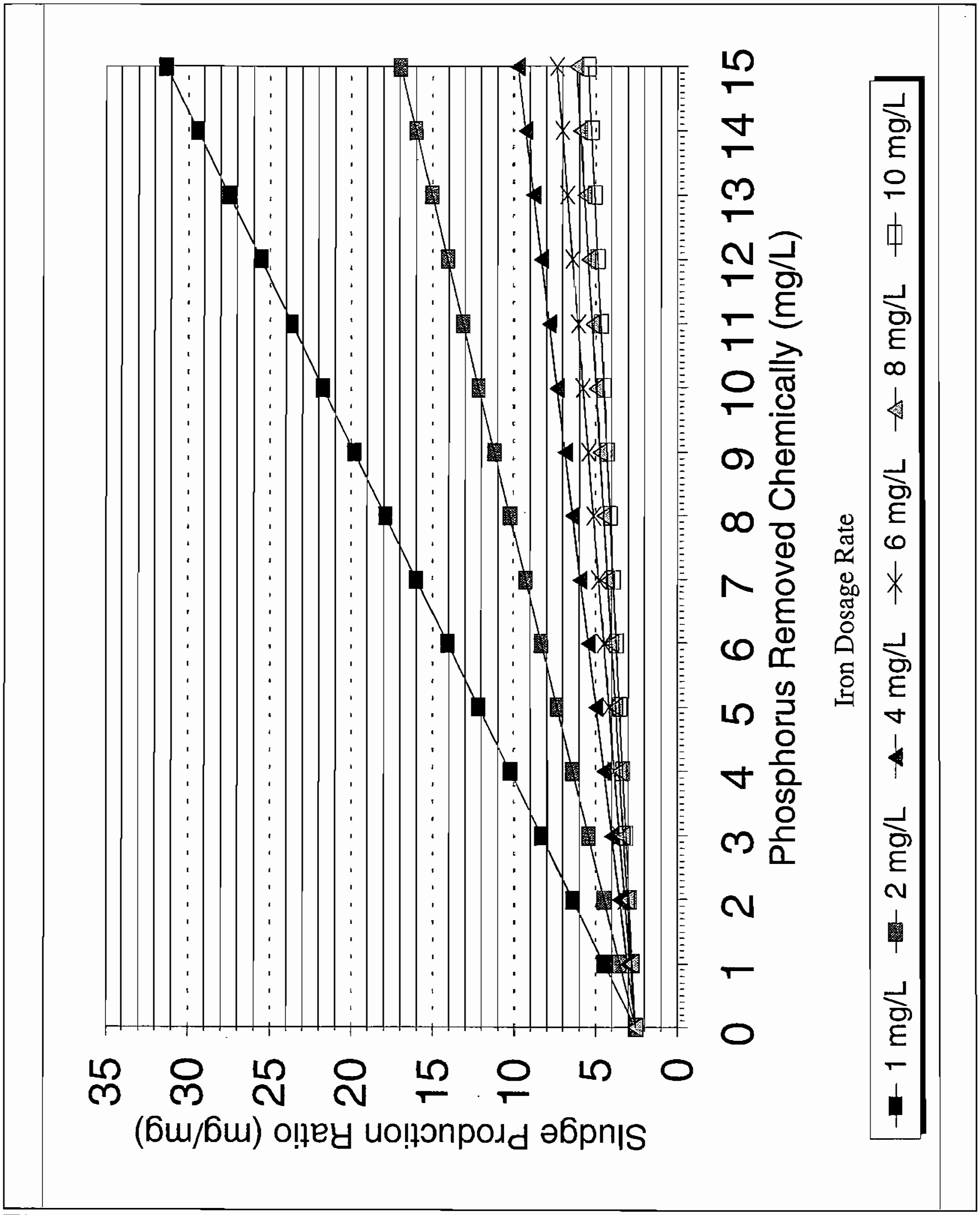


Figure 3. Chemical Sludge Production Ratios for Iron Doses Between 1 mg/L and 10 mg/L.

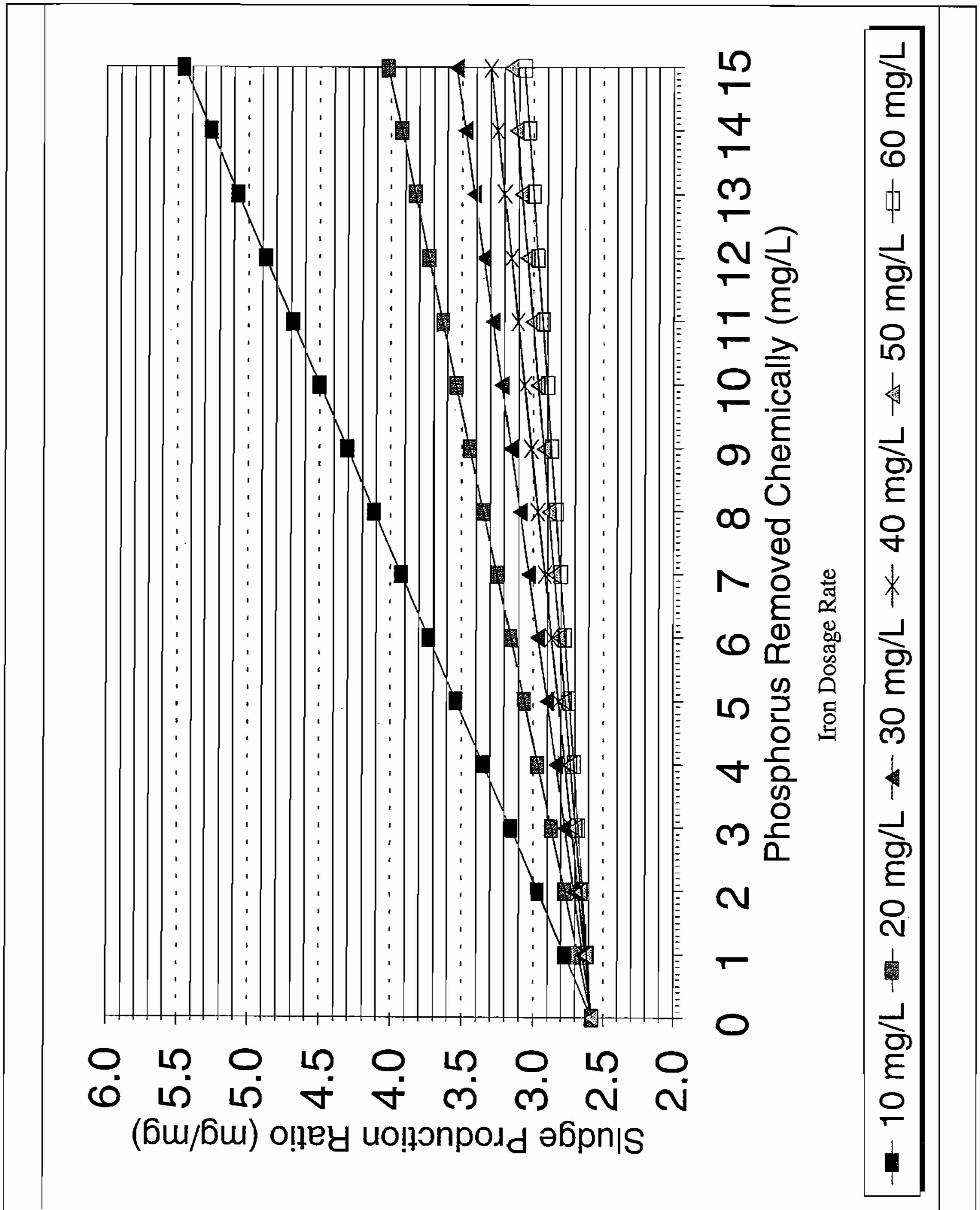


Figure 4. Chemical Sludge Production Ratios for Iron Doses Between 10 mg/L and 60 mg/L.

APPENDIX K
EXAMPLE CTA

RESULTS OF THE
COMPREHENSIVE TECHNICAL ASSISTANCE
AT AN
EXTENDED AERATION STP

July 1994

Prepared by:

Joint MOEE/WTC/OCWA Technical Assistance Team

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1. The Comprehensive Technical Assistance Team members for their continued dedication and commitment to the program.

2. Manager, Ontario Clean Water Agency regional office, Engineering and Technical Services, for providing the support to enable the program to be established, and authorizing funding to enable the step feed demonstration to proceed as a component of the extended aeration STP CTA.

3. Operation Officer, Ontario Clean Water Agency, for providing the support to enable the program to be established.

4. A regional office of the Ontario Clean Water Agency for providing a member of the Comprehensive Technical Assistance Team.

5. extended aeration STP Superintendent and Operations staff.

6. A neighbouring facilities project grouping staff for their support for the program.

7. Staff of MOEE District Abatement Office for their efforts and assistance in obtaining a Section 61 Direction under the Ontario Water Resources Act authorizing the step feed modifications.

8. Mr. B. Hegg, Process Applications Inc., Fort Collins Colorado, U.S.A. for providing the training services and guidance during the CTA.

9. The co-funding agencies Environment Canada, and the Ontario Ministry of the Environment and Energy.

1. INTRODUCTION

1.1 Composite Correction Program Background

The Composite Correction Program (CCP) uses a two step approach to economically improve the performance of STPs. Step one is the Comprehensive Performance Evaluation (CPE). The CPE evaluates a facility to identify the unique combination of operation, design, maintenance, and administration factors contributing to poor performance. When a CPE determines that the major unit processes are capable or nearly capable of treating the existing flow and loadings, and where the performance of the STP is less than that required by the discharge criteria, the second step of the CCP, called Comprehensive Technical Assistance (CTA) is initiated. Typically, the CCP approach focuses on achieving compliance or optimum performance so that major capital expenditure can either be deferred or avoided.

A CPE was conducted from January 12 - 15, 1993 at the extended aeration STP and the factors limiting performance were identified. The facility was evaluated based on its ability to achieve monthly average compliance limits for five day biochemical oxygen demand (BOD_5), and total suspended solids (TSS). The extended aeration Water Pollution Control Plant, located in eastern Ontario, is operated by the Ontario Clean Water Agency (OCWA). The plant has a design average day flow capacity of 955 m^3/d (0.21 MIGD), and is expected to achieve annual average compliance criteria for BOD_5 and TSS of 25 mg/L and 25 mg/L respectively. The extended aeration STP facility is not currently required to meet monthly average criteria for TP.

2. SUMMARY OF CPE FINDINGS

2.1 Performance

Examination of the data during the CPE conducted at the extended aeration STP showed that the plant was in compliance with its annual effluent criteria over the period of January 1 to December 31, 1992. The reported annual average concentration for BOD_5 and TSS was 10 mg/L and 16 mg/L respectively. However, the plant would have had three BOD_5 violations, and four suspended solids violations under the monthly effluent criteria of 15 mg/L BOD_5, and 20 mg/L TSS which were established for the purposes of the optimization study. Throughout the CPE evaluation, monthly average criteria were applied to determine if the treatment facility could achieve the monthly average criteria for BOD_5 and TSS. A sludge accountability analysis showed that the data evaluated probably did not accurately represent true plant performance.

2.2 Major Unit Processes

The evaluation of the major unit processes established that the sludge holding tank capacity may limit the performance of the facility if waste sludge was not hauled on an as required basis.

2.3 Factors Limiting Performance

Excessive Plant Bypassing - (Design)

The treatment facility routinely experienced high flows resulting from storm events or spring melt which necessitated plant bypassing to avoid washing out the biological system. As a result the quality of the combined effluent (secondary effluent and raw sewage) leaving the treatment plant was degraded.

Application of Concepts & Testing to Achieve Process Control - (Operations)

Optimization of the activated sludge process requires attention to key concepts, such as sludge mass control, sludge distribution through return sludge flow adjustment and process sampling. Data and trend development of related parameters is required to determine short-term and long-term effects on process performance. Adequate process sampling and proper sample point selection of process streams are also crucial. These concepts and related parameters were not being utilized or correctly applied by plant staff at the time of the CPE.

Addressing Plant Needs - (Administration)

Although recognizable progress had been achieved over the latter part of 1992 in addressing the needs of the treatment facility, there were additional requirements which remained to be addressed such as reduction of plant bypassing, plant coverage during weekends and holidays, and refocussing plant staff on improved process control versus maintenance and housekeeping.

Performance Monitoring - (Operations)

During the CPE, a sludge accountability analysis was performed in which the actual and projected sludge mass produced were compared. The sludge accountability analysis for extended aeration STP revealed that the facility produced 20 percent less sludge than the projected value; therefore, the monitoring data probably does not accurately reflect true performance of the facility.

Process Controllability - (Design)

During the CPE it was determined that measurement of return activated sludge flow was not possible. Accurate return activated sludge flow is necessary to enable continuous process control adjustments to be made in response to load variations and to changing sludge mass distribution between the aeration tank and the secondary clarifier.

Process Flexibility - (Design)

In the event of high flows resulting from storm water inflow and infiltration, the plant was found not to have the flexibility to change from conventional treatment to step feed. This limits the potential of the facility to successfully and consistently treat higher flows, thereby reducing bypass occurrences and achieving better performance.

Alarm Systems - (Design)

The present alarming system was found to announce high wet well levels, blower failure, and power failure. None of these features monitor continuous high plant flows which could potentially cause biological solids wash-out.

Sludge Storage/Disposal - (Design)

The plant monitoring data indicated that sludge storage over the winter period at a neighbouring wastewater treatment facility was adequate. However inclement weather could extend the required storage time for sludge from both facilities. If sludge storage capacity at the neighbouring facility was not available this would require internal storage of solids at extended aeration STP and thereby threaten plant performance.

Alternate Power Source - (Design)

The absence of a standby power supply could threaten the performance of the facility in the event of an extended power failure.

2.3 Summary

The major factors limiting performance were related to excessive plant bypassing during spring periods, administrative policies regarding plant coverage, and lack of process control focus by the plant staff. By allocating more time for plant operation and redirecting the plant staff activities to a performance-based process control program it was anticipated that the extended aeration STP facility could meet the proposed targeted monthly BOD_5, and suspended solids criteria without major construction. A CTA was therefore recommended.

3. APPROACH TO CTA

The initial efforts of the CTA were directed at addressing the performance limiting factors identified during the CPE, in particular, reduction of spring bypassing, establishing a communication and reporting program to enable the progress of the CTA to be documented, and providing staff training and transfer of skills to achieve and sustain process control.

4. CTA SIGNIFICANT EVENTS

Following the CPE, discussions were held with the OCWA Acting Manager of Utility Operations, and OCWA Operations Officer to identify the items which had to be addressed before the formal start-up of the CTA. The initial on-site CTA activities were initiated in February 1993. Significant project events are summarized below.

4.1 February 1993

CTA Technical Team/MOEE Utility Engineer Meeting (February 1, 1993).

- A commitment was made by the OCWA Regional Area, Acting Manager of Utility Operations, Operations Officer, and a neighbouring facility's project group Superintendent to provide full time (8 hours), and weekend operator coverage at the STP during the assistance program.
- Plant coverage would be achieved during the initial assistance activities by providing a combination of operator and senior operator time to allow two individuals to learn and benefit from technical assistance.
- A commitment for funding the necessary step feed modifications at the STP was made by the Acting Manager of Utility Operations.
- OCWA identified a need for obtaining legal permission to modify the plant in an expedient manner, and recommended that a Direction under Section 61 of the Ontario Water Resources Act (OWRA) be obtained.
- The Joint CTA Technical Team requested that management and staff equip the STP's laboratory for solids analysis.

February 1993

- The CTA Technical Team prepared a Section 61 Direction request and supporting documentation for modification to provide step feed capability at the plant, and forwarded the document to the MOEE's Regional District Abatement Office for processing.
- A CTA process control workshop was prepared by the technical team in February 1993 and presented to the STP staff.
- Daily and monthly process control worksheets were developed to calculate and record daily process control data (Appendix 4.A).
- The waste activated sludge holding tank was calibrated and a calibration table prepared so that accurate daily wasted sludge volumes could be determined.

- The CTA Technical Team prepared drawings, and specifications for the step feed modifications required at the STP for tendering purposes (Appendix 4.B).

4.2 March 1993

On-site CTA activities were initiated in March 1993. The major activities are briefly summarized below.

CTA Technical Team site visit (March 5, 1993)

- Through discussions with operating staff, procedures were developed for sampling and testing. These procedures were written with assistance provided by the team to the operations staff and compiled in a site specific process operations manual (Process Control Manual).

- A sampling and testing schedule was implemented which enabled the total activated sludge mass inventory to be determined and controlled on a daily basis, (see Process Control Manual).

- A special study was initiated to focus the operations staff's attention on the distribution of activated sludge mass between the aeration basin and the secondary clarifier, commonly referred to as the Sludge Distribution Ratio (SDR). The operations staff were informed of the need to maximize the mass of activated sludge in the aeration basin where the biological breakdown of organic matter occurs, and correspondingly to minimize the activated sludge mass in the secondary clarifier. This was accomplished by monitoring and controlling the return activated sludge (RAS) flow (Process Control Manual).

- A second special study was initiated to identify the optimum RAS flow rates for SDR control purposes, i.e. diurnal variations and lower weekend flows.

March 1993

- The plant was found to be experiencing a severe filamentous bulking problem when the daily process control program was implemented.

- On March 11th plant staff identified conditions which were preventing the required volume of sludge to be wasted from the process. Plant staff observed that the filamentous bulking inhibited thickening of the sludge and supernating from the on-site sludge storage tank. The inability to obtain waste activated sludge having a high solids concentration often resulted in a calculated waste sludge volume which exceeded the volume of the on-site storage tank. Sludge storage limitations had also developed at the neighbouring plant thereby restricting acceptance of extended aeration STP's waste sludge on demand.

- During the weekend of March 27th and 28th, the plant flows increased suddenly as a result of spring melting and subsequent inflow into the village's collection system. The recorded average daily flows were 1,160 m^3/d and 1,375 m^3/d respectively. The peak flows on each of the days were 1,818 m^3/d and 4,546 m^3/d respectively. Historically, operations staff maintained a high sludge blanket in the secondary clarifier resulting from the poor settling filamentous bacteria growth. On both days operations staff visited the plant site. On March 27th, the operator found nothing unusual occurring; however, within a period of less than two hours after leaving the site, flows increased sharply and the clarifier sludge blanket quickly washed out. On March 28th, the operator arrived at the plant mid morning and found the clarifier washing out, the operator immediately initiated bypassing to prevent further activated sludge solids loss to the receiving waters and damage to the biological process. The wash outs resulted in a significant loss of activated sludge mass to the final effluent. The final effluent suspended solids for each of the days was 392 mg/L and 803 mg/L respectively.

- On March 30th, sustained high flows were experienced at the treatment plant. The recorded average daily flow treated by the extended aeration plant was 1,408 m^3/d with a peak flow of 2,273 m^3/d. The operations staff achieved control of the clarifier sludge blanket twenty-four hours after the sharp increase in hydraulic loading and subsequent wash-out and had developed an operational plan to handle high flow events and sustained increases in hydraulic loading. The staff determined through monitoring the clarifier sludge blanket and adjusting RAS flow that only 50 percent of the storm flow could be pumped through the plant without increasing the potential of further solids wash-outs. Raw sewage flow to the plant was based on the control of the sludge blanket. No significant loss of activated sludge solids occurred from the plant. The final plant effluent TSS was 15.5 mg/L. A 24 hour composite sampler was not in place at the time to sample combined effluent. Through being informed and prepared, the operations staff were able to minimize the impact of the sustained increase in hydraulic loading on the biological process and reduced the solids loading to the receiving water.

- On March 26th, the CTA Team and the neighbouring facility's Project Grouping Superintendent contacted the MOEE Regional District Abatement Office to discuss the status of the Section 61 Direction, and the sludge storage limitations impacting the extended aeration STP's performance. The CTA Team requested a meeting be held with the District Abatement officials to identify the objectives of the CTA program and the Direction's status. A meeting was scheduled for April 13th, 1993.

- The CTA Team was informed on March 31st by the District Abatement Office that processing of the Section 61 direction had been initiated.

4.3 April to May 1993

- Twenty-four hour composite sampling capability was obtained for sampling the plant's combined effluent (blended final effluent and bypassed raw sewage).

- On April 11th, plant staff handled an extended period of elevated hydraulic loading which produced an average day flow of 1,802 m^3/d, and a peak flow to the headworks of 5,400 m^3/d. The bypass flow for the 24 hour period was 1,430 m^3/d. The plant's final effluent TSS was 2 mg/L, while the TSS in the combined effluent was 46 mg/L. Having developed an operational plan to handle sharp hydraulic loading fluctuations and sustained elevated flows, operations staff continued to maximize raw sewage flow through the treatment plant and minimize raw sewage bypassing to the receiving stream.

- On April 13th, the CTA team, OCWA Area officials, and District Abatement officials met to discuss the CTA, the status of the Section 61 Direction, and the sludge storage situation at the neighbouring project and the effect on the extended aeration STP's performance. The goals and objectives of the CTA, and rationale for the proposed plant modifications were presented by the CTA team. District Abatement officials expressed support for the CTA approach; however, concurrence to proposed solutions for the sludge storage limitations affecting the plant was not obtained. District Abatement officials indicated that approval for winter sludge utilization would not be granted, and obtaining approval for proposed sludge storage in local septage lagoons would be remote. The date identified by the District Abatement Office for completion of the Section 61 Direction was April 19th, 1993.

- A computer spreadsheet was developed by the CTA Team to enable data trending and analysis for process control and plant performance monitoring (Appendix 4.C).

- The CTA Team met with plant management and staff to review the CTA activities to date, review and explain the process control program implemented by the plant staff, and reinforce support for the program. The operations management identified that plant staff were more enthusiastic about their work since the start of the CTA.

- A V-notch weir box was installed on the RAS line enabling improved process controllability, and a V-notch weir plate was installed in the bypass channel to improve bypass flow measurement.

CTA Team/Plant Staff Meeting (April 28, 1993)

- The CTA Team, plant staff and local contractors met at the plant for the purpose of obtaining quotations for modifications to the existing facility to provide step feed capability.

- A discussion was held regarding plant coverage, response to storm events, and sustained increases in hydraulic loading. A decision was made to install an alarm to indicate high hydraulic loading to the plant. A protocol was also established for operator response to the alarm.

- A weir discharge table (flow in inches through the V-notch) was created for the V-notch weir box which had been installed on the RAS line to assist in proper adjustment of the RAS flow.

- A discussion was held regarding the final effluent flow metering installation and flooding of the existing V-notch weir during periods of high flow. The CTA Team suggested relocating the Milltronics ultrasonic measuring device to a more quiescent area of the contact tank, where the unit might be calibrated to a small rectangular weir.

- A discussion was held regarding the plant's ability to achieve nitrification. Plant monitoring data had shown an appreciable reduction of ammonia in the final effluent to date. Plant staff had also reported a sharp increase in oxygen demand in the aeration section which resulted in the operation of an additional blower.

April to May 1993

- Since the plant was nitrifying, the plant staff were encouraged to focus on improving the SDR to reduce the mass of sludge in the secondary clarifier and minimize the potential for denitrification in the secondary clarifier.

- A high flow alarm was installed and linked to a dialler/paging system which alerted the operations staff of a sustained period of elevated hydraulic loading. A strategy was implemented by the superintendent and operations staff for responding to the alarm.

- Minor improvements in sludge settling characteristics were observed. However, a filamentous bulking problem persisted throughout the month of April 1993.

- The plant staff were unable to waste the required mass of activated sludge from the system on a daily basis as a result of the limited sludge storage capacity at the neighbouring facility.

- A review of the process control data for April 1993 (period of sustained elevated hydraulic loading) revealed that the plant staff successfully handled sustained hydraulic loading events resulting from the spring freshet for the entire month of April. The plant's design average daily flow capacity of 955 m^3/d was exceeded 24 of 30 days in April. The average day flow for April was 1,350 m^3/d or 141 percent of the design flow. The average effluent TSS for the same period was 9.8 mg/L.

- On April 27th, the CTA Team contacted the District Abatement Office to obtain an update on the status of the Section 61 Direction. The CTA Team was informed that a first draft of the Direction would be completed by April 30th. MOEE officials also indicated that the contingency plans included in the supporting documentation for the request for Direction may require more detail.

- On May 6th, further enhancements to the Section 61 Direction were requested by the MOEE Regional District Abatement Office.

- On May 12th, land utilization of sludge from the neighbouring facility resumed, allowing waste activated sludge to be hauled from extended aeration STP on demand.

- Refinements were made to the monthly process control worksheet.

- On May 18th, plant operations staff contacted the CTA Team and reported operational difficulties. The plant staff had great difficulty in controlling the sludge blanket level in the secondary clarifier during a storm flow event. The CTA Team discussed the incident with plant staff. It was concluded that the poor performance was caused by the inability to waste appropriate masses of sludge from the system and the subsequent large inventory of activated sludge in the process. This restricted control over the SDR, clarifier sludge retention time (CSRT), and allowed denitrification to occur in the secondary clarifier contributing to excessive solids loss to the effluent. The effluent TSS for the storm event was 319 mg/L.

- On May 26th, the MOEE District Office contacted the CTA Team and explained that more detailed contingency plans were required before a Section 61 Direction could be issued. The CTA Team requested a meeting with District Office officials for the purpose of finalizing all information requirements so that a Section 61 Direction could be secured. This meeting took place on June 7, 1993.

4.4 June to September 1993

- A comparison of raw sewage bypass flow data for 1992 versus 1993 showed that in 1993 the plant staff had achieved a 25 percent reduction in the overall volume of sewage bypassed. This reduction was achieved through improved process control and plant coverage.

- On June 2nd, the MOEE District Office requested the MOEE's Technical Assessment Section's surface water unit to comment on the proposed step feed modifications for the plant with respect to receiving water considerations. A copy of the extended aeration STP's Section 61 Direction supporting documentation was furnished by the CTA Team for the surface water unit's review. After review, the Technical assessment section had no objections to the proposed step feed modifications, concluding that receiving water considerations were not critical based on the existing flows in the Ottawa River.

- On June 7th, the CTA Team met with MOEE District Office officials. MOEE District Office officials identified the need for additional documentation to be supplied by Utility Operations and the CTA Team before a Direction allowing step feed modifications to the plant could be issued. Also requested was an explanation of step feed and contact stabilization, action plans outlining the events expected to take place during installation of the step feed components, and detailed contingency plans. The CTA Team provided the additional documentation, including contingency plans for conditions of activated sludge washout and controlled bypassing on June 9, 1993.

- Trend analysis of the operational and performance data identified that the activated sludge settling characteristics had improved significantly during the period from May 1st to June 15th, 1993 (Appendix 4.C). This improvement was a direct result of the plant staff's ability to adhere to a daily wasting routine as part of the process control program, and ability to haul waste sludge to the neighbouring facility on demand. The CTA Team discussed this improvement with plant staff and the lengthy biological response time required for the change in settling characteristics to occur.

- On June 21st and 22nd a heavy rainfall was received in the extended aeration plant area. Forty-two millimetres (42 mm) of rain were received during the 48 hour period. Improved sludge settling characteristics achieved through good process control combined with the implementation of a strategy to treat high flows allowed the operations staff to successfully handle the storm event without bypassing raw sewage. The average day flows for the two days were 2,191 m^3/d and 1,948 m^3/d respectively. The peak flow on both days was 2,400 m^3/d. The resulting 24 hour composite effluent TSS on each of the days were 18 mg/L and 8 mg/L respectively.

- The CTA Team was notified by the MOEE District Office on July 2, 1993, and was informed by MOEE officials that the extended aeration plant Section 61 Direction had been approved. A copy of the Direction document was received on July 7, 1993.

- The CTA Team reviewed with plant staff the procedure used for wasting sludge. When wasting activated sludge from the system, plant staff would thicken sludge in the secondary clarifier by shutting off the RAS flow for 2 to 3 hours prior to wasting. Staff conducted a special study to compare direct WAS wasting versus sludge thickening and wasting. Staff demonstrated the following during the special study: (1) Direct RAS wasting took 2 - 3 times longer than thickening followed by wasting; (2) On-site WAS storage was limited to 2 - 3 days when wasting RAS, while concentrating prior to wasting provided 4 - 5 days of on-site storage; (3) When wasting RAS directly the WAS suspended solids concentration was found to be highly variable and resulted in poorer control over the solids residence time (SRT). Conversely, thickening sludge prior to wasting produced a WAS of consistent suspended solids concentration, and allowed better control over the SRT.

CTA Team/Plant Management Meeting (July 20, 1993)

- A review of the daily operational data and final effluent quality to date for BOD_5, TSS, SRT, total mass, and SVI was presented by the CTA Team.

- A discussion was held regarding sludge storage contingencies for the extended aeration STP WPCP for the upcoming winter of 1993/94. Plant management presented several sludge storage contingencies for the plant. The contingencies were prioritized by all.

- The CTA Team identified that some reduction in the required daily volume of WAS had been achieved through application of good process control. Since the beginning of the CTA in March 1993 to July 1993, the average daily volume of WAS generated had decreased from 7.5 m^3/d to 5.0 m^3/d. It was recognized that a reduction in the daily volume of WAS would have a considerable impact on alleviating some sludge storage pressures during the winter months.

- A discussion was held regarding the current level of plant staffing. Plant management identified that they did not see a need for two operations staff at extended aeration STP since the period of sustained hydraulic loading had passed, and stable conditions existed at the plant. Subsequently, management requested that the senior operator resume his position at the neighbouring facility. The CTA Team agreed to this request since both operations staff had developed a sound understanding of process control at their facility. It was agreed that the senior operator would maintain involvement with the CTA, and also would be permitted to return to the plant during the spring of 1994 to receive training on the use of step feed.

June to September 1993

- The senior operator for the neighbouring facility returned to his duties at the neighbouring facility leaving one operator to maintain the process control program at extended aeration STP.

- The senior operator applied his knowledge gained from participating in the extended aeration STP CTA and implemented a daily process control program at the neighbouring STP. The senior operator trained another operator within the neighbouring facility in the daily process control program and it was applied to another STP. Noticeable performance improvements were achieved at both plants.

- The contract to fabricate and install the step feed capability at the plant was awarded on July 30th, 1993. The contractor informed the CTA Team that fabrication of the step feed components would not begin until September 1993 and estimated that fabrication components would require approximately 2 months. Installation was estimated to require 3 to 4 days.

- The Operations staff drafted and documented a daily dry weather flow routine for process control which enabled the operator to derive the relevant information to maintain process control (see Process Control Manual).

- The CTA Team recognized the level of skills developed by the operations staff, and reduced the frequency of site visits. Communications with the plant staff were maintained by telephone and fax machine.

- Further refinements were made to the monthly process control worksheet to include a column for reporting clarifier sludge retention time.

- On September 2nd, a storm produced periods of heavy rainfall in the extended aeration STP area. The impact of the storm was evident at the treatment plant for two days following the initial rainfall. On September 2nd and 3rd, plant staff successfully treated average day flows of 1800 m^3/d and 1780 m^3/d respectively. The effluent TSS concentrations in the final effluent for each of the days were 20 mg/L and 17 mg/L respectively. There was no raw sewage bypassed during the storm event.

- On September 9th, the contractor provided plant staff and the CTA team with shop drawings of the step feed components for review and approval.

4.5 October to December 1993

- On October 20th and 21st another storm occurred in the extended aeration STP area. The plant staff successfully treated average day flows of 2166 m^3/d and 2021 m^3/d respectively. The peak flows on each day exceeded 2400 m^3/d. The effluent TSS concentrations were 13 mg/L and 12 mg/L respectively. On October 21st, plant staff had to bypass raw sewage to avoid overflowing the aeration cell. The bypassed flow was 308 m^3/d. The combined effluent BOD_5 and TSS concentrations for this period were 5 mg/L and 11 mg/L respectively.

- The contractor was contacted on October 21st to determine the status of fabrication of the step feed components. The installation was scheduled to take place from November 22-24, 1993 inclusive.

- Installation of the step feed components began on November 22th and was completed on November 24th. A representative from the MOEE District Abatement Office visited the site during the first day of installation. The modifications were completed within 20 hours at a total cost of $ 13,696.00.

- Plant management expressed concern to the CTA Team regarding increased sludge haulage costs for the facility during the CTA. A summary of sludge haulage costs covering the period from March to November 1993 was prepared. The summary indicated that sludge haulage costs were high during the initial period of the CTA, as a result of poor activated sludge characteristics which prevented thickening of WAS, and required larger volumes of activated sludge to be wasted. However, the summary also showed that the actual unit sludge haulage costs had been reduced by 50 percent as the CTA program progressed and good process control was established and maintained.

- On November 28th and 29th, plant staff successfully handled another storm flow event. The average day flows for each day were 2045 m^3/d and 2014 m^3/d respectively. The effluent TSS concentrations on each day were 11 mg/L and 16 mg/L respectively. Plant staff found it necessary to bypass raw sewage on November 29th to prevent washing out biological solids. The bypass flow for the period was 345 m^3/d. The combined effluent BOD_5 and TSS concentrations for the period were 20 mg/L and 9 mg/L respectively. Plant staff were not familiar with the principles and operation of step feed when the storm event occurred, therefore did not utilize the step feed mode of operation.

4.6 January to May 1994

- Plant operating staff identified that historical high flow events were actually greater than reported, and the existing weir arrangement, when flooded, would not provide accurate flow measurement. The plant superintendent agreed to have a new weir plate fabricated to enable measurement of higher flows.

- The CTA team prepared and presented a step feed workshop to the plant staff to provide them with the theory and principles of step feed operation.

- On March 23rd, plant staff identified that the average daily flows at the treatment plant had increased substantially, signalling that the spring freshet had begun, and the plant operation was switched from conventional to step feed mode.

- The monthly process control worksheet was further refined to provide sections for recording pertinent process control data when operating in step feed mode.

- A new 90 degree V-notch weir plate was fabricated and installed in the final effluent contact tank and the measuring device was recalibrated to the new weir.

- During the period April 13th through April 17th inclusive, plant flows peaked at the treatment plant. The design average daily flow for the facility is 955 m^3/d. The recorded average daily flow for the period was 2998 m^3/d, and the average daily peak flow for the period was 3767 m^3/d. The average effluent TSS concentrations for the period was 13 mg/L. Plant staff found it was necessary to bypass on April 14th and 17th; the bypassed flows on each day were 880 m3/d and 521 m3/d respectively. A 24 hour composite sample of combined effluent collected on April 14th had a BOD_5 and TSS concentration of 15 mg/L and 66 mg/L respectively. The OCWA Area Manager, and the plant's Operations Officer were present at the facility on April 13th and witnessed operation of step feed while the plant was subjected to maximum flows during the spring freshet period.

- On April 13th, the plant staff determined that, under the current operating conditions, the treatment plant could handle a sustained flow of 3900 m^3/d. On April 14th, operating staff fabricated and installed a rectangular weir plate into the head of the plant's bypass channel which would allow sustained flows in excess of 3900 m3/d to automatically overflow and bypass.

- The flows to the treatment plant fell below 2000 m^3/d, and the plant was returned to the conventional mode of operation. The period of high flows resulting from the spring freshet subsided by May 4th.

- A comparison of flow data for the spring freshet period for the years 1992, 1993, and 1994 was conducted by the plant operating staff and the CTA team. The comparison of 1992 versus 1994 data showed that, as a result of optimizing plant performance through process control and step feed modifications, a 95 percent reduction in raw sewage bypassing was achieved during the spring freshet period of 1994. This reduction in bypassing coincided with a 49 percent increase in plant effluent flow, while the total flow (plant effluent and raw sewage bypass flows) to the treatment plant for the same period remained consistent. The average plant effluent BOD_5 and TSS concentrations for the 1994 freshet period were 9 mg/L and 13 mg/L respectively.

5. CTA RESULTS

For the duration of the CTA, the technical team, OCWA operations management, plant management, and operations staff adopted monthly average compliance criteria to measure the success of the Comprehensive Technical Assistance program. The targeted criteria was 15 mg/L for BOD_5, and 20 mg/L for TSS. A target criteria for total phosphorus was not set since the extended aeration STP facility is exempt from phosphorus removal requirements under current Ministry of the Environment and Energy policy.

For the period March 1993 to the end of the CTA, final and combined effluent samples were collected using 24 hour refrigerated composite samplers, analyzed daily on-site for TSS and submitted to the MOEE Eastern Regional Laboratory once per week for BOD_5, TSS, NH_3, and TP analysis.

Figure 1 depicts the final effluent TSS quality for the period of January 1992 to the end of the CTA in May 1994. The target of 20 mg/L TSS is depicted by the horizontal line. For the fourteen month period prior to the start of the CTA the plant recorded four instances (Jan 92, May 92, Jun 92, Jul 92) when the TSS concentration exceeded the 20 mg/L target. For the duration of the CTA the plant reported two instances when the final effluent TSS concentration was greater than the targeted 20 mg/L TSS. In March 1993 the plant was impacted by a filamentous bulking problem, limited sludge storage, and a sudden increase in hydraulic loading as a result of the spring freshet. The average TSS concentration for the month was 47 mg/L. In May 1993, limited sludge storage facilities continued to impact the facility. The physical mass of sludge in the system prevented good control over the distribution of activated sludge between the aeration cell and secondary clarifier. As a result, the clarifier sludge retention time was excessive and resulted in denitrification, loss of control over the sludge blanket, and poor effluent quality. The average TSS concentration for the month was 21.5 mg/L. However, as the CTA progressed, sludge storage limitations were resolved, good process control was established and maintained, and the level of operator knowledge and confidence continued to improve, such that the final effluent TSS concentration displayed a downward trend and stabilized below the monthly target of 20 mg/L.

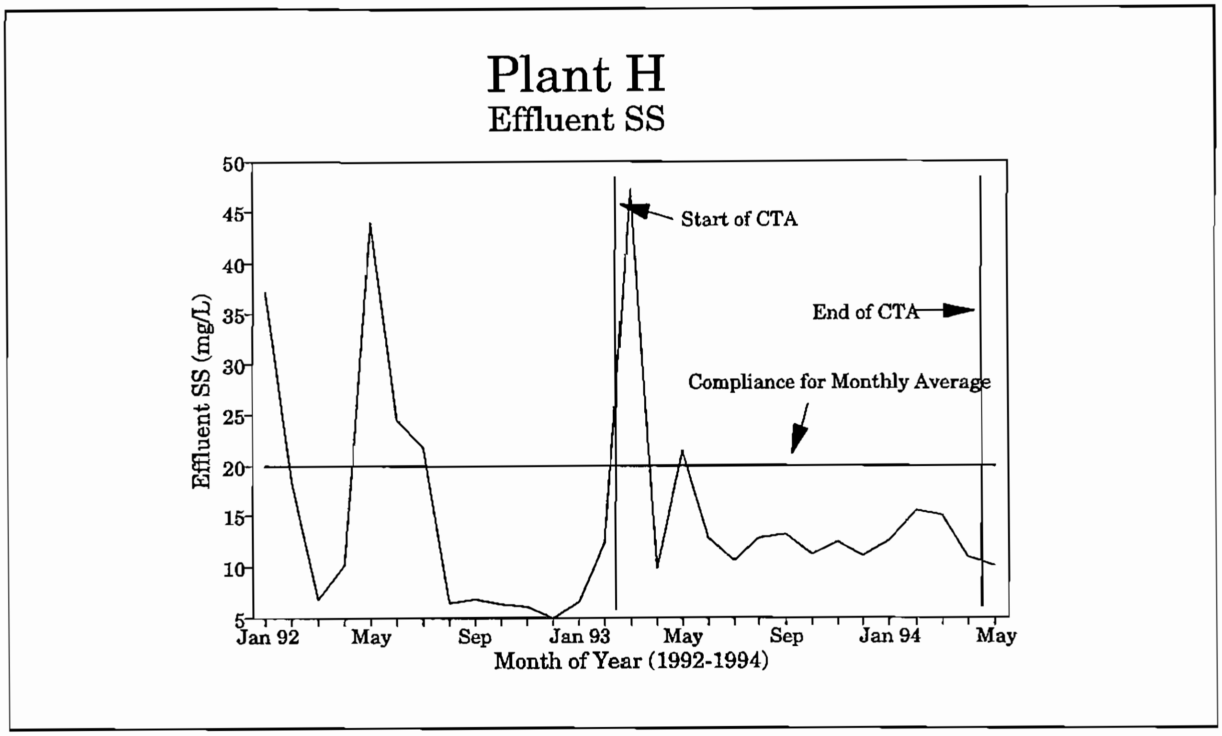

Figure 1 Final Effluent TSS Quality 1992 to 1994

Figure 2 depicts the final effluent BOD_5 quality for the period January 1992 up to the end of the CTA in May 1994. The target concentration of 15 mg/L is depicted by the horizontal line. For the fourteen month period prior to the start of the CTA the plant reported three instances (Jan 92, Apr 92, May 92) when the final effluent BOD_5 exceeded the 15 mg/L target. For the duration of the CTA the plant reported no instances when the BOD_5 concentration exceeded the targeted monthly average of 15 mg/L. Since the beginning of the CTA, the final effluent BOD_5 concentration was consistently maintained below 11 mg/L.

Figure 3 depicts the final effluent total ammonia concentration for the duration of the CTA. The plant was found to be nitrifying at the start of the CTA with the concentration of total ammonia in the final effluent fluctuating between 0.5 and 3.0 mg/L. As the CTA progressed and a routine process control program was established, control over nitrification improved, resulting in effluent ammonia concentrations consistently below 1.0 mg/L from August 1993 to April March 1994. Typically the influent total ammonia concentration averaged approximately 20 mg/L for the duration of the CTA. However, on several occasions spikes of influent total ammonia were identified by composite sampling to be as high as 46 mg/L. In March of 1994, the plant operation was switched from conventional treatment to step feed mode in anticipation of increased hydraulic loading from the spring freshet. This process adjustment increased the final effluent total ammonia concentrations starting in mid March as changes in the activated sludge characteristics occurred, and the hydraulic retention time within the treatment plant was reduced.

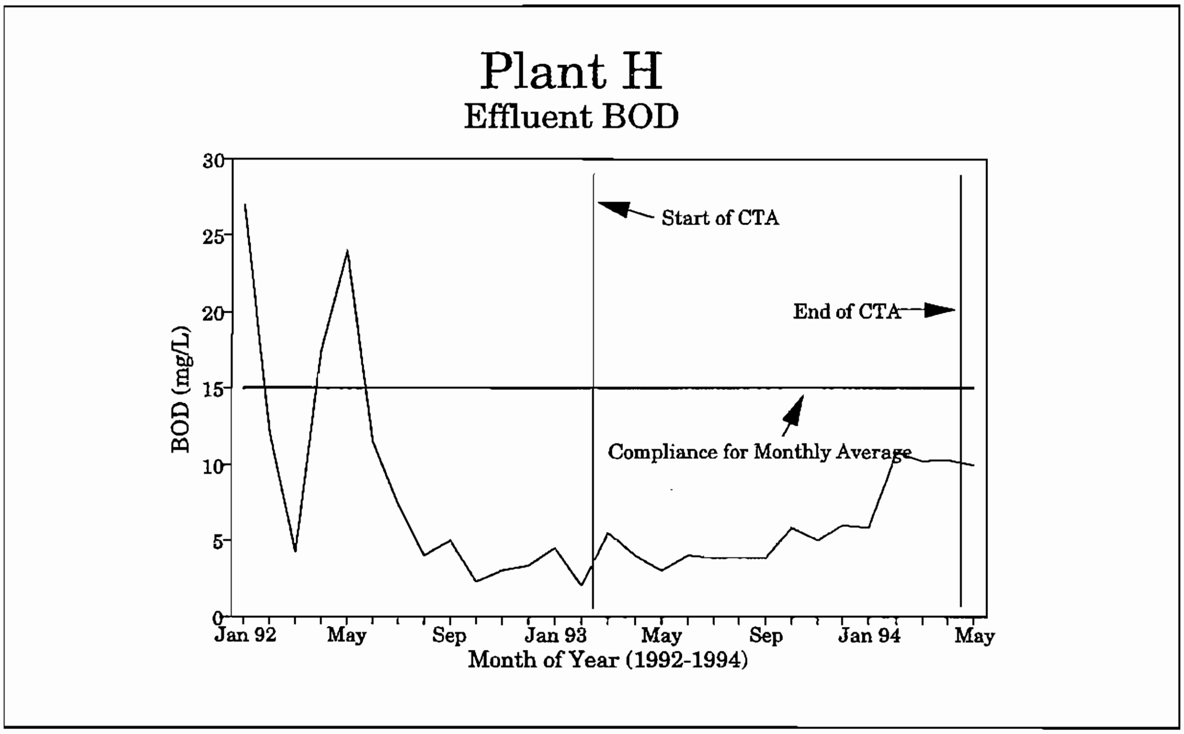

Figure 2 Final Effluent BOD_5 Quality 1992 to 1994

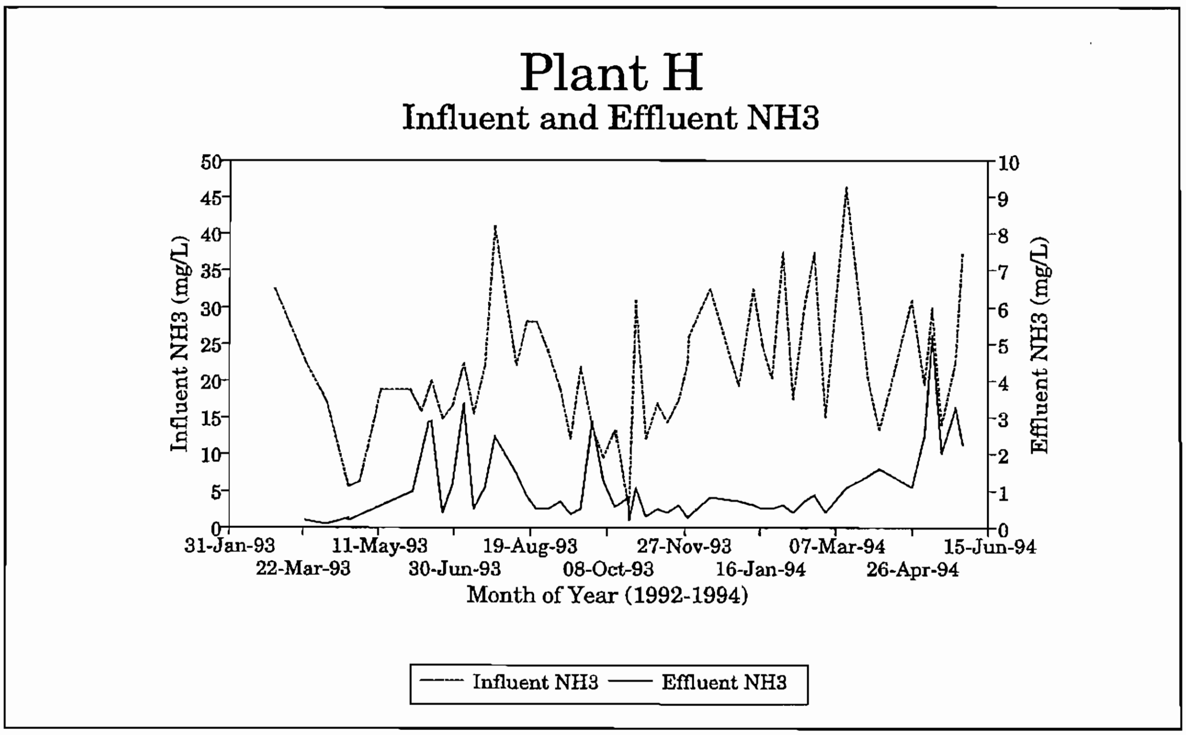

Figure 3 Influent and Effluent NH_3

Figure 4 depicts the benefit which the CTA has had in reducing the impact of storm events and spring flooding, and consequently reducing the solids loading to the river. At the beginning of the CTA two hydraulic shock loading events in March 1993 resulted in 392 kg and 803 kg of solids, respectively, being washed to the river.

However, as the level of operator knowledge and awareness increased, and the required process control steps were implemented, the impact of subsequent hydraulic loading events was significantly reduced. As the CTA progressed the flows successfully treated by the plant during spring freshet and storm events increased while the mass of solids being lost to the river were significantly reduced. In November 1993, step feed capability was added to the treatment plant by means of a simple, low cost retrofit. Use of the step feed capability combined with maintenance of an effective process control program enabled treatment of flows approximately four times the rated design flow of the facility as shown by the high average day flows in April 1994.

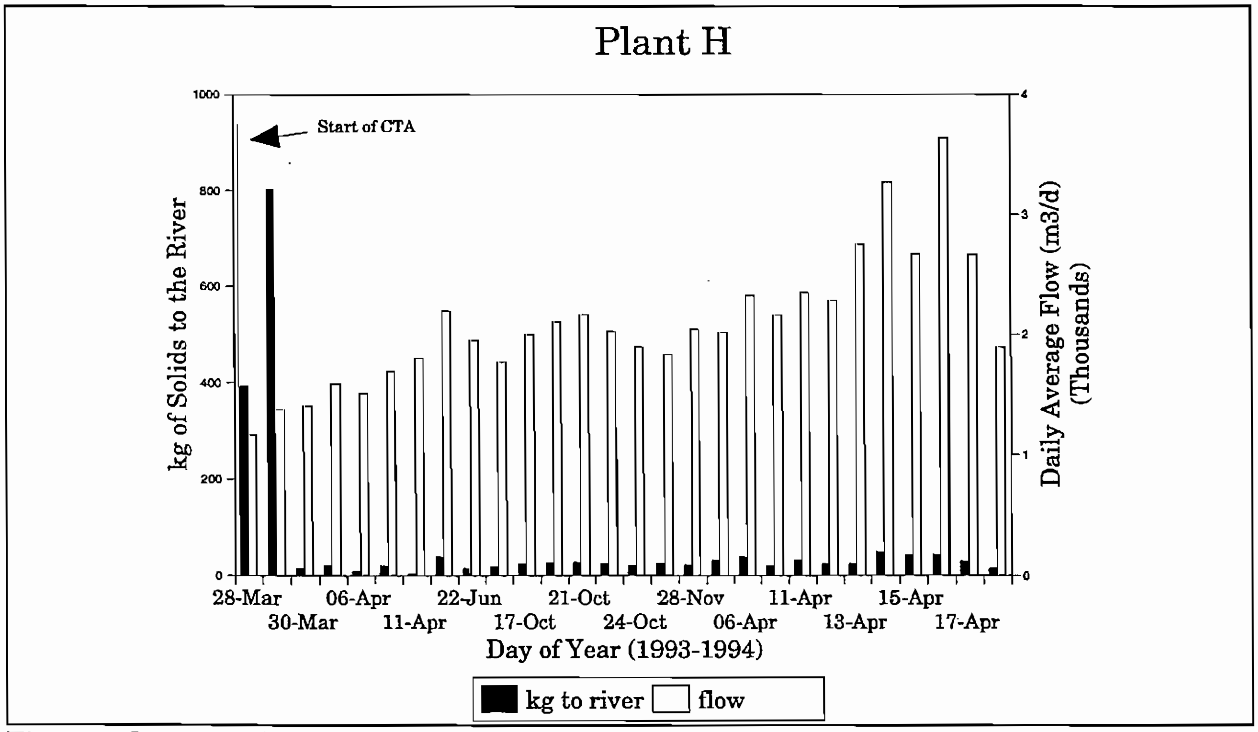

Figure 4 Impact of Storm Events on Solids Loading to River

Figure 5 depicts the benefit which the CTA has had in reducing the volume and duration of raw sewage bypassing during spring months. Prior to the CTA considerable volume and frequency of raw sewage bypassing occurred from the facility during periods of high flow encountered each spring as shown in the data for 1992. However, in 1993 after initiating the CTA, and the level of operator knowledge and preparedness increased and the required process control steps were implemented, the volume and duration of bypassing was reduced by 25 percent and 38 percent, respectively. In November 1993 the plant was retrofitted to provide step feed capability. In the spring of 1994 with the use of the step feed capability in conjunction with good process control and skilled operations staff, the volume and duration of bypassing was reduced by 95 percent and 97 percent, respectively, when compared to the spring prior to the CTA. The total flow to the treatment plant remained consistent for the spring period during the three years examined.

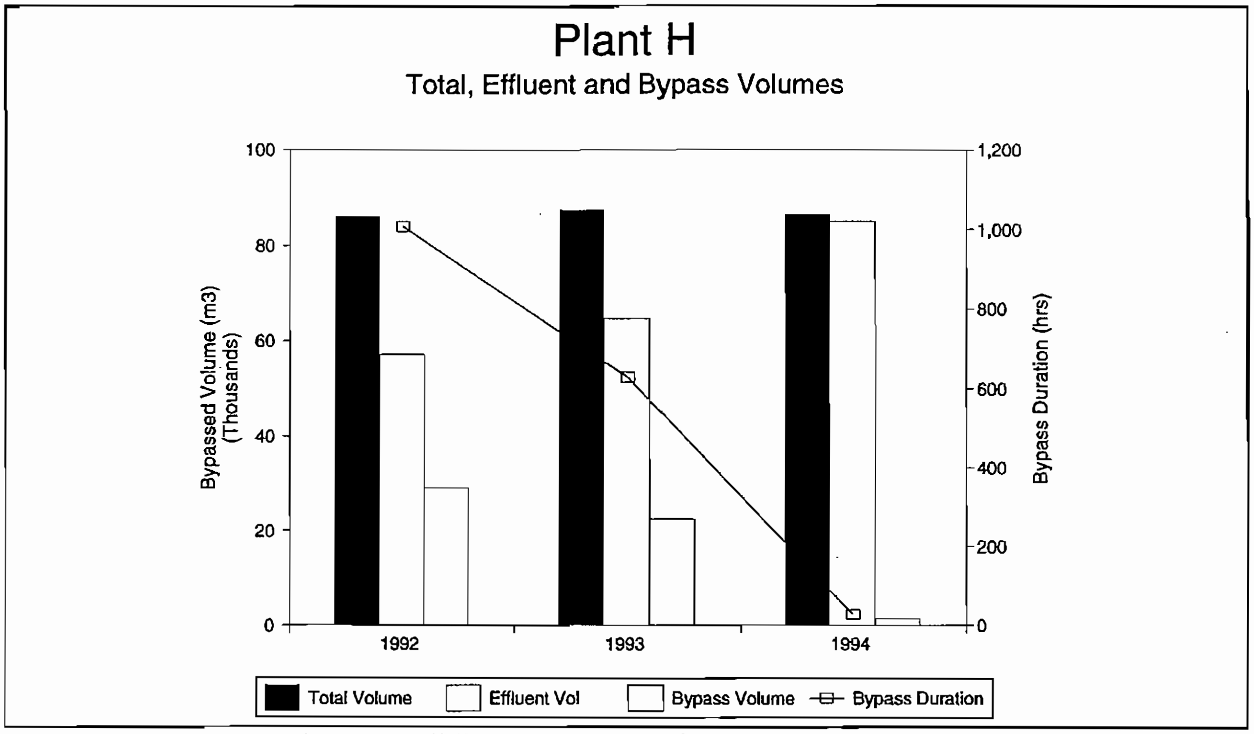

Figure 5 Comparison of Influent, Effluent, Bypass Volume and Duration for Spring of 1992-1994

Figure 6 depicts the reduction in BOD_5 and TSS loading to the receiving stream associated with the reduction in raw sewage bypassing. Prior to the CTA, spring bypassing resulted in considerable BOD_5 and TSS loading to the river as shown in the data for 1992. However, as the level of operator confidence and awareness improved and the required daily process control was put in place, the BOD_5 and TSS loadings contributed from spring bypassing were each reduced by 40 percent as shown in the data for 1993. In the spring of 1994, the use of step feed in combination with good process control and skilled operations staff, enabled a 96 percent and 95 percent reduction in BOD_5 and TSS loadings, respectively, when compared to loadings contributed from bypassing in 1992.

Figure 7 depicts the hauled sludge concentration and unit sludge handling costs per kg hauled for the duration of the CTA. Prior to and during the initial period of the CTA, the plant was affected by a filamentous bulking problem. As a result, the ability to thicken waste activated sludge in the on-site aerated holding tank was compromised as shown by the low hauled sludge total solids concentrations in May through July 1993. As the CTA progressed and the required daily process control program was applied, changes in activated sludge settling characteristics occurred, and the ability to thicken waste activated sludge was consistently improved, as shown from August 1993 to the conclusion of the CTA. By optimizing activated sludge settling characteristics through application of concepts, and consistently improving the ability to thicken waste activated sludge, a 47 percent reduction in the unit sludge haulage costs were achieved during the CTA as represented by the line graph.

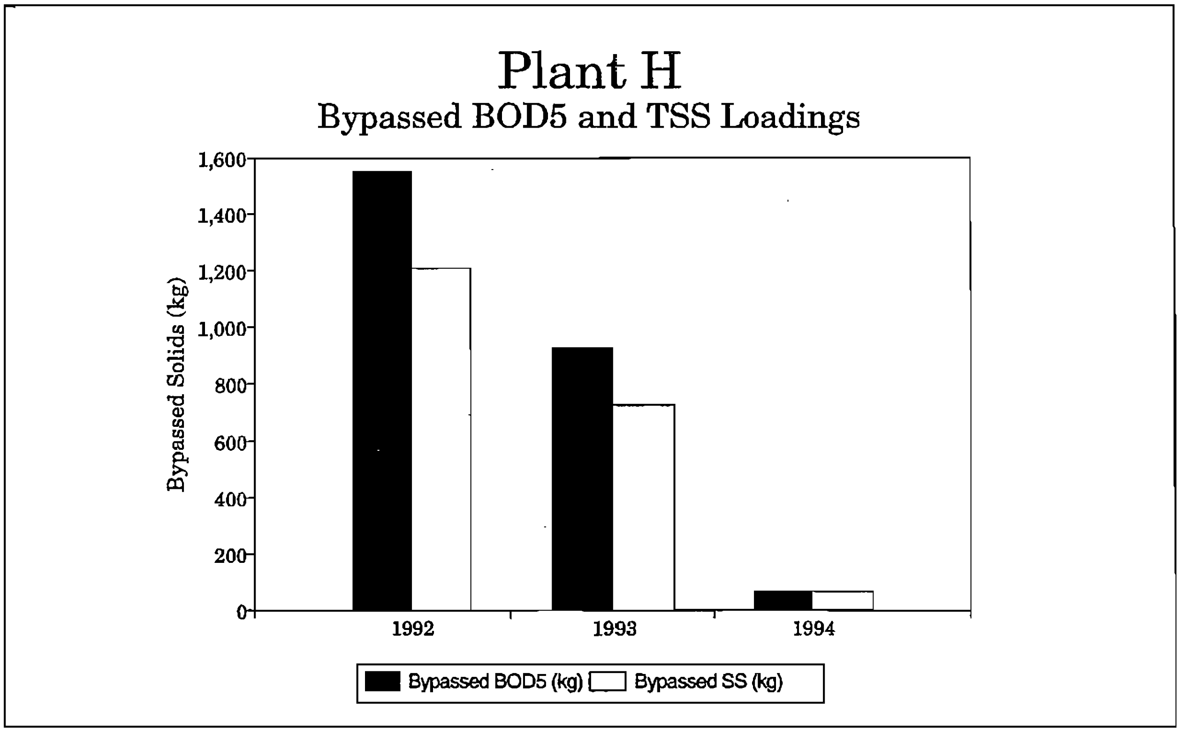

Figure 6 Total Raw Sewage Bypass BOD_5 and TSS Loadings for Spring (March and April) of 1992-1994

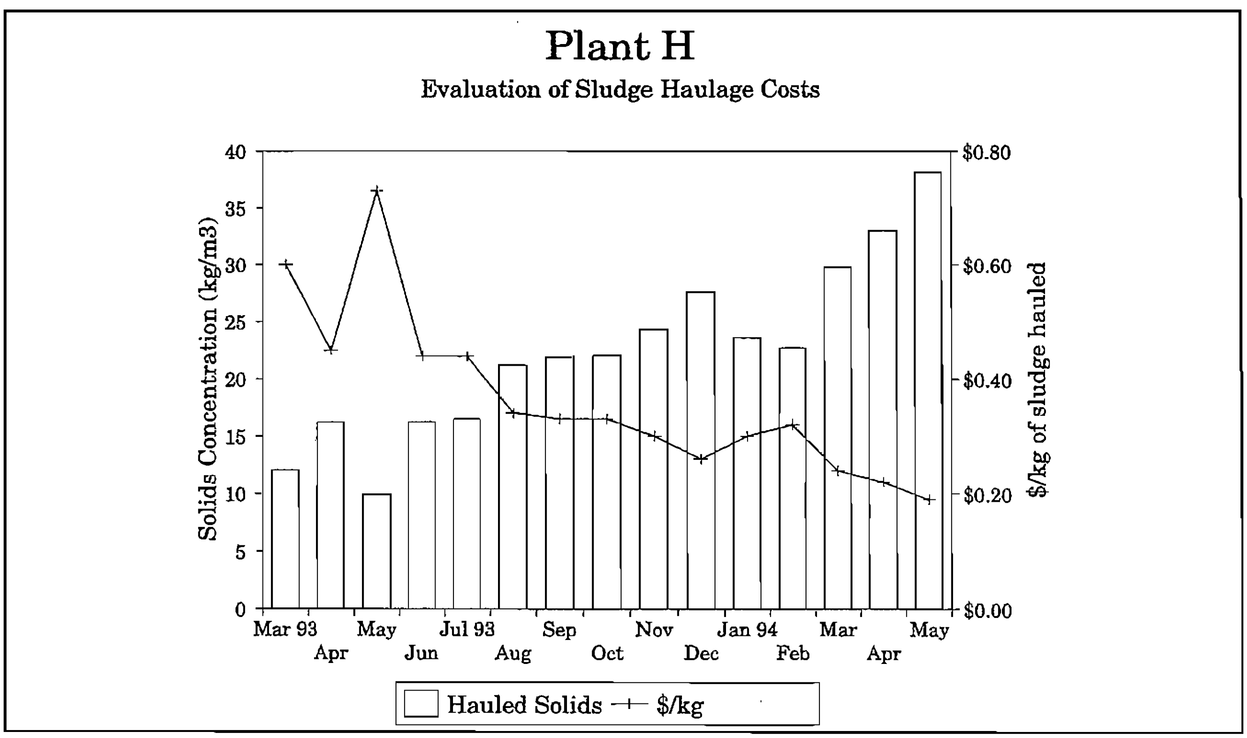

Figure 7 Evaluation of Sludge Haulage Costs 1992-1994

6. SUMMARY AND CONCLUSIONS

Since the beginning of the CTA the plant performance has shown a significant improvement in final effluent quality. Significant reductions in BOD_5 (89%), TSS (83%) and Ammonia (93%) loadings to the river were achieved. The CTA has shown that under current loading the plant can consistently achieve monthly average compliance for BOD_5 and TSS without additional capital expenditure.

The CTA established a focus on demonstrating that the significant volume and frequency of raw sewage bypassing which had occurred historically during spring months could be reduced through establishment and maintenance of process control, improving plant coverage, and performing a low cost retrofit at the facility to provide step feed capability.

Initially, the plant was staffed by two operations staff for eight hours per day. Involvement of two operations staff allowed a senior staff member responsible for other activated sludge plants to benefit from the CTA activities. As the CTA progressed, the level of operator awareness and understanding of the process enabled one staff member to operate the facility effectively while spending four hours on-site during stable dry weather flow conditions.

During the spring of 1993, following the start of the CTA, raw sewage bypass flow and duration was reduced by 25 % and 38 % respectively. The step feed retrofit was performed in late 1993 at a total cost of $ 13,696.00. During the spring of 1994, the use of step feed enabled the raw sewage bypass flow and duration to be reduced by 95 % and 97 % respectively. Flows greater than 4 times the design flow were successfully handled for extended periods without exceeding the desired effluent quality (20 mg/L TSS).

Plant management support in recognizing and addressing the need to respond to storm events, and provide plant coverage during periods of spring freshet is vital to the success of the response strategy.

The operations staff developed a high level of skill required to establish and maintain process control at the extended aeration plant.

The implementation of a routine process control program based on total sludge mass, focused the attention of operations staff on the amount of sludge being produced and wasted from the activated sludge process to the aerated holding tank. The process control activities consistently reduced the volume of sludge being hauled from the process; however, the mass of solids being removed was greater than the historic quantities. To date a 47 % reduction in unit sludge haulage costs has been achieved.

7. RECOMMENDATIONS

- Adequate staffing levels and plant coverage at the extended aeration STP must be maintained to enable the current level of control and performance to be continued.

- Plant and area operations management must continue to identify plant performance as a priority and support the operations staff in maintaining the demonstrated improvements.

- It is recommended that staff continue to utilize the daily process control program which was developed and established during the CTA. Data trending should also be continued.

- It is recommended that use of step feed capability be continued during storm flows and spring freshet.

- To enable totalized flow measurement of bypassed raw sewage it is recommended that the temporarily installed ultrasonic measuring device be permanently installed for future monitoring.

- Modification to the air lift control of RAS flow should be investigated (ie. installation of a timer in conjunction with an electrically activated solenoid valve or installation of an alternate pump arrangement).

- It is recommended that 24 hour composite sampling equipment be made available for monitoring combined effluent quality.

- Long term sludge storage options should be developed for the facility.

REFERENCES

1. Hegg, B.A., L.D. DeMers, and J.B. Barber, Handbook - Retrofitting POTW's, EPA 625/6-89-020, U.S. Environmental Protection Agency, Center for Environmental Research Information, Cincinnati, Ohio, (July 1989).

APPENDIX K.A

Daily Monthly Process Control Worksheets

These process control worksheets are completed each day by the operator. By following the daily routine and by completing the worksheet, the operator identifies the mass of sludge and subsequently the volume which should be wasted each day in order to maintain an effective biological system.

WPCP PROCESS CONTROL WORKSHEET

Data Forward from Last Day, Previous Month

Current Monthly Data   Month: ____________   Year: ____________

Day	Time	Total Flow (m3/d)	Peak Flow (m3/d)	Flow Splitting % Tank #1 %	Flow Splitting % Tank #2 %	MLSS TANK #1 (g/L)	MLSS TANK #2 (g/L)	Average MLSS (g/L)	Aeration Mass (kg)	Clarifier Sludge Conc. (g/L)	Clarifier Mass (g/L)	Total Mass (kg)	AVG. SDR	Effluent TSS (g/L)	Effluent Mass (kg)	RAS Conc. (g/L)	Waste Sludge Concentration (g/L)	Wasted Volume (m3)	Wasted Mass (kg)	SRT (days)	Kg to Waste	m3 to Waste
1																						
2																						
3																						
4																						
5																						
6																						
7																						
8																						
9																						
10																						
11																						
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25																						
26																						
27																						
28																						
29																						
30																						
31																						

ERATION VOLUME: 796 m3

ARIFIER VOLUME: 301 m3

ARGET SRT: ____________ days

COMPLIANCE CRITERIA

Monthly: 15/20/NA BOD/SS/TP

Current: 25/25/NA BOD/SS/TP

SDR = Sludge Distribution Ratio

SRT = Solids Residence Time

Revised April 11, 1994

WPCP PROCESS CONTROL WORKSHEET

Data Forward from Last Day, Previous Month

Day	Tank #1 30 MIN (%)	Tank #2 30 MIN (%)	Average 30 MIN (%)	SVI	AVE SBD (in.)	DO Tank #1 (mg/L)	DO Tank #2 (mg/L)	Temp (deg C)	Precipitation (mm)	Weather Conditions S,R,SN,C	Hauled Volume (m3)	Hauled Sludge Concentration (mg/L)	Supernatant Volume (m3)	Supernatant Concentration (mg/L)	BYPASS FLOW (m3/d)	BYPASS DURATION (hours)	Combined Effluent SS (mg/L)	RETURN RATE (m3/d)	RETURN RATE (%)	CSRT (d)	Sodium Hypochlorite IN (L)	Sodium Hypochlorite OUT (L)	Sodium Hypochlorite USED (L)	Sodium Hypochlorite ADD (L)	Sodium Hypochlorite RES (mg/L)

Current Monthly Data Month: ____________ Year: ____________

Day	Tank #1 30 MIN (%)	Tank #2 30 MIN (%)	Average 30 MIN (%)	SVI	AVE SBD (in.)	DO Tank #1 (mg/L)	DO Tank #2 (mg/L)	Temp (deg C)	Precipitation (mm)	Weather Conditions S,R,SN,C	Hauled Volume (m3)	Hauled Sludge Concentration (mg/L)	Supernatant Volume (m3)	Supernatant Concentration (mg/L)	BYPASS FLOW (m3/d)	BYPASS DURATION (hours)	Combined Effluent SS (mg/L)	RETURN RATE (m3/d)	RETURN RATE (%)	CSRT (d)	Sodium Hypochlorite IN (L)	Sodium Hypochlorite OUT (L)	Sodium Hypochlorite USED (L)	Sodium Hypochlorite ADD (L)	Sodium Hypochlorite RES (mg/L)
1																									
2																									
3																									
4																									
5																									
6																									
7																									
8																									
9																									
10																									
11																									
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14																									
15																									
16																									
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26																									
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28																									
29																									
30																									
31																									

SBD = Sludge Blanket Depth

Weather Conditions: S = Sunny, R = Rain, SN = Snow, C = Cloudy

Revised April 11, 1994

CSRT = Clarifier Sludge Retention Time

WPCP DAILY PROCESS CONTROL WORKSHEET

DATE: ______________________

TIME	FLOW METER	FLOW/hr m3	TREATED FLOW m3	RETURN RATE m3/d	RAS % of PLANT FLOW	BYPASS GATE SETTING	BYPASS FLOW m3	D.O. mg/L	SBD ft	SBD DARK ft	CLARIFIER MLSS g/L	AERATION MLSS g/L	CLARIFIER MASS kg	AERATION MASS kg	SDR
0100															
0200															
0300															
0400															
0500															
0600															
0700															
0800															
0900															
1000															
1100															
1200															
1300															
1400															
1500															
1600															
1700															
1800															
1900															
2000															
2100															
2200															
2300															
2400															
AVG															
TOTAL															

Please do not write in the shaded areas of this form.

COMMENTS/PROBLEMS/OTHER OPERATIONAL CHANGES: This section does not exclude the requirement for bound plant logbook entries.

APPENDIX K.B

Step Feed Retrofit Description and Specifications

Comprehensive Technical Assistance Program

Modification of Treatment Facility to provide for Step Feed Capability

Request for Quotation to Manufacture and Install Equipment

February 26, 1993

Work Description and Specifications

Task 1.0 Comminutor Modification

1.1 Modify existing influent headworks to enable connection to step feed distribution channel.
1.1.1 Install flow control gate in influent trough. (Figure 1)

1.2 Extend height of comminutor swing gate to an equal height with rest of comminutor trough. (Figure 1)

1.3 Fabricate distribution box (if piping is used), complete with control gate to enable regulation of flow to step feed channel. (Figure 1 to 4)
1.3.1 Install 1 inch bar screen at distribution box inlet. (Figure 1)

Task 2.0 Construction and installation of distribution channel.

2.1 Construct and install channel to enable plant flow to be diverted to the latter one-half of the aeration tank. (Figure 2)
2.1.1 Length of channel to be 91 feet 6 inches.
Channel can be constructed to be either open or closed to atmosphere.

2.2 If open channel, width of channel must be 12 inches.
Depth of channel to be 12 inches. Material to be determined by contractor.
If piping is used, diameter must be 12 inch. Materials can be flexible or corrugated piping.

2.3 Channel to be installed clockwise from comminutor.

2.4 Nominal drop in length of channel to be adequate to achieve gravity drainage.

Task 3.0 Construction and installation of flow control baffle in aeration tank. Figure 1 to 3)

3.1 Baffle to be inserted in aeration tank at pre-designated point.

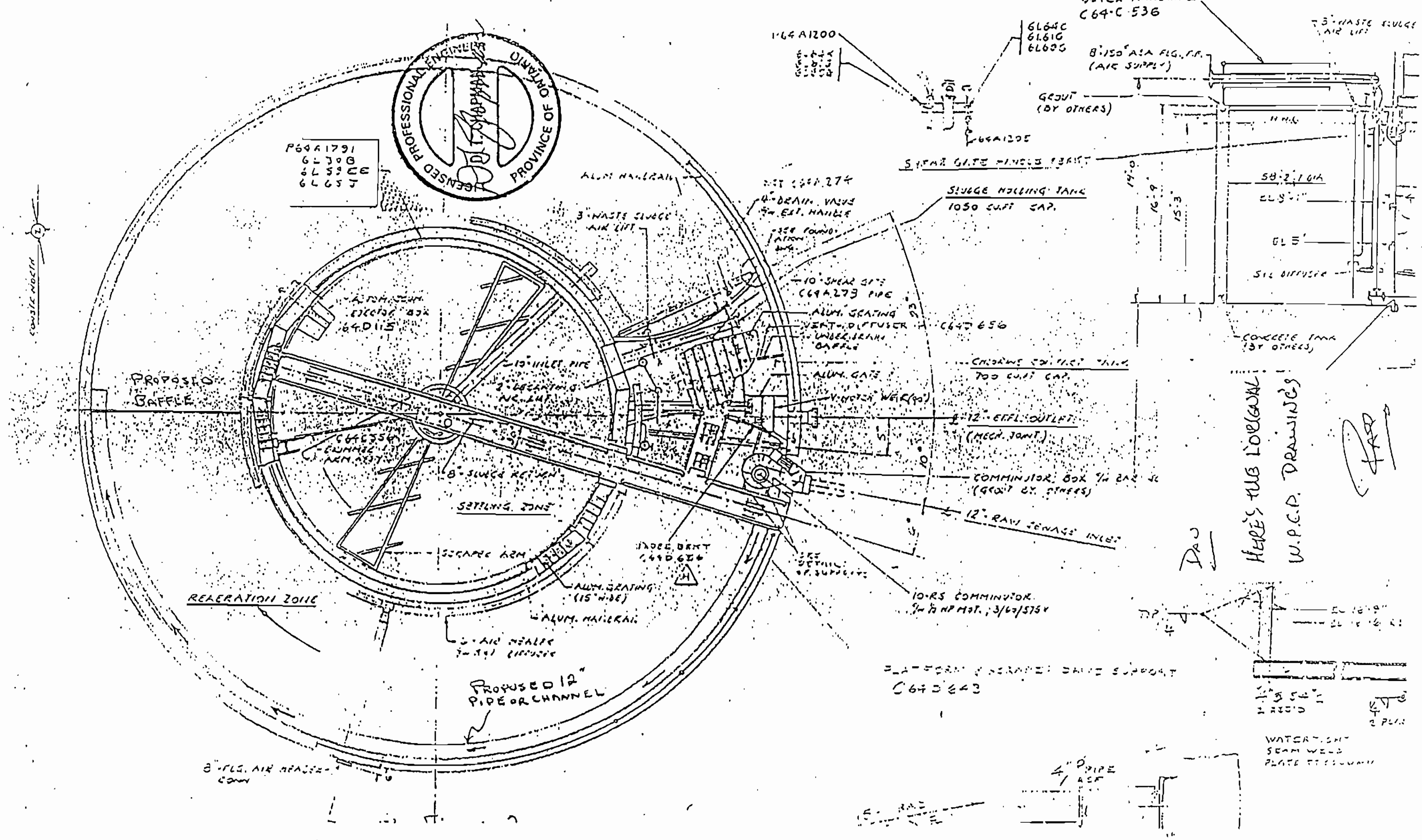
3.2 Baffle to be constructed of steel or wood, width 14 feet, and depth 16 feet 9 inches.

3.3 Baffle opening to be inserted approximately mid depth.(onside closest to outer aeration tank wall). Area of opening to be 10 inches by 12 inches, or similar dimensions to provide 120 square inches of open space. Opening to be fitted with an adjustable sliding gate to enable flow control. Gate to be made of galvanized steel. (Figures 3 to 4) (with [illegible] opening ([illegible] control [illegible], opening [illegible])

3.4 Second opening to be installed at base of baffle to enable controlled drainage of divided tank. Opening to be fitted with gate to enable open and closed function. (Figures 3 to 4) ([illegible])

All measurements are approximate and must be measured and verified on-site by the contractor providing the quotation.

EXISTING FACILITY WITH PROPOSED MODIFICATIONS

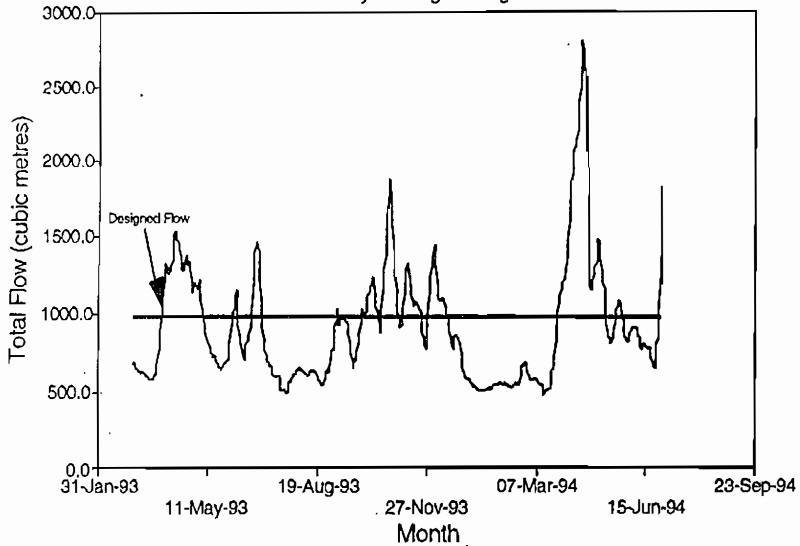


APPENDIX K.C

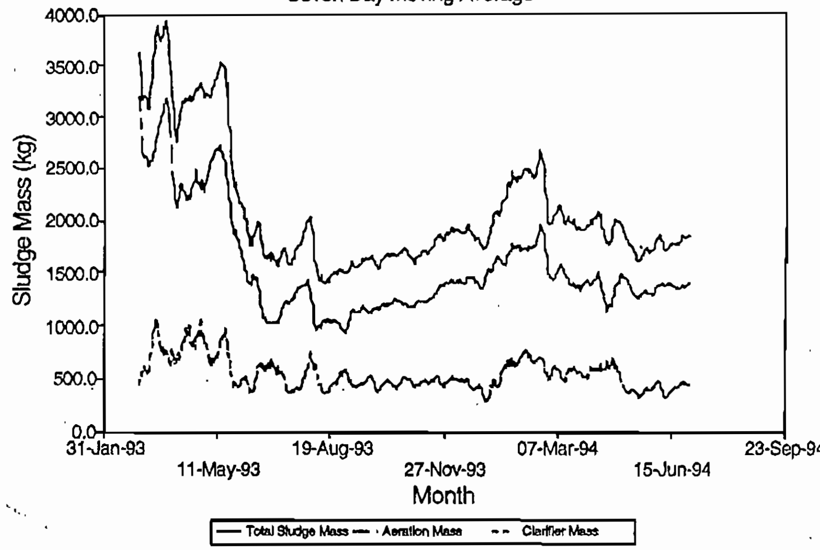
Trend Analysis of Operational and Performance Data

Operational Data Summary for Plant H STP

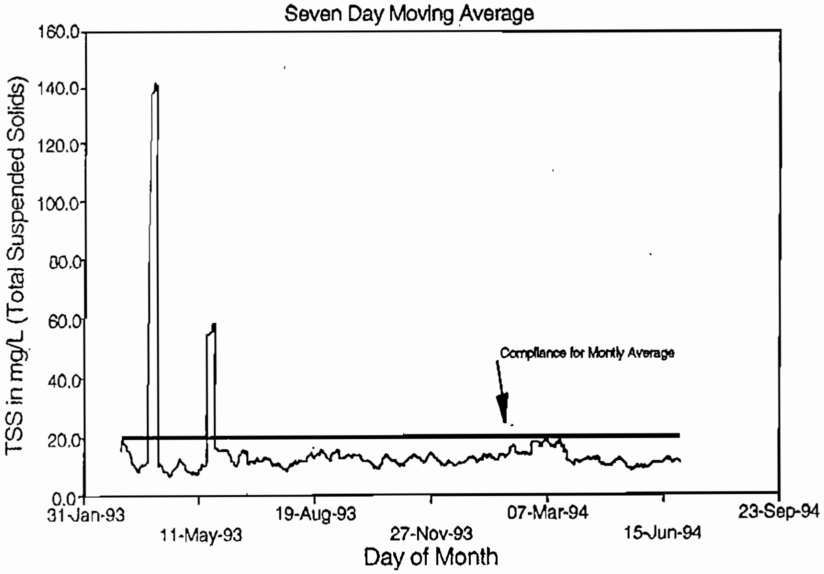
Total Flow vs. Time for Plant H
Municipal Wastewater Treatment Facility
Seven Day Moving Average



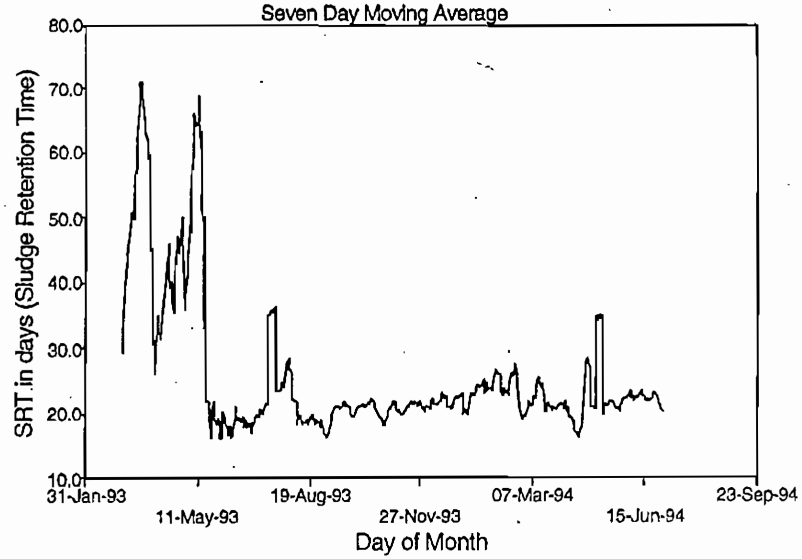
Sludge Mass vs. Time for Plant H
Municipal Wastewater Treatment Facility
Seven Day Moving Average



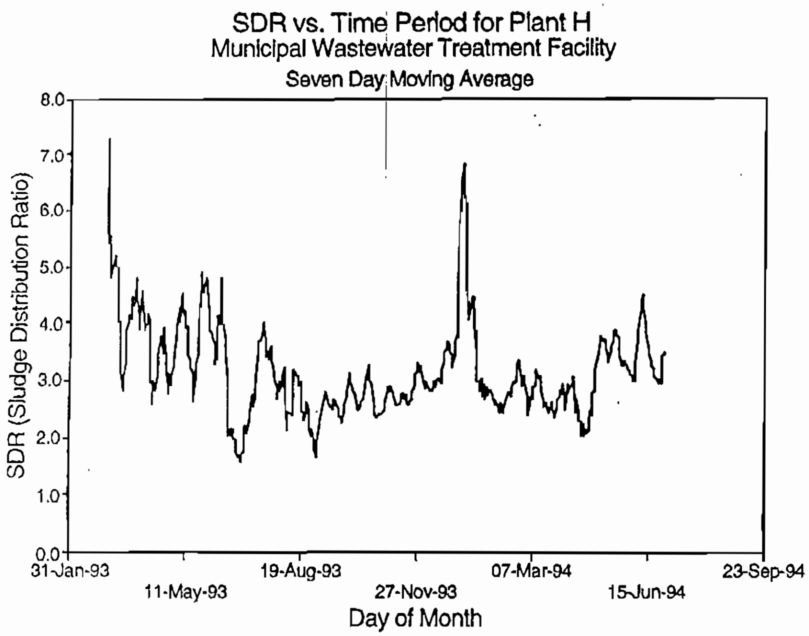
Eff SS vs. Time Period for Plant H
Municipal Wastewater Treatment Facility
Seven Day Moving Average

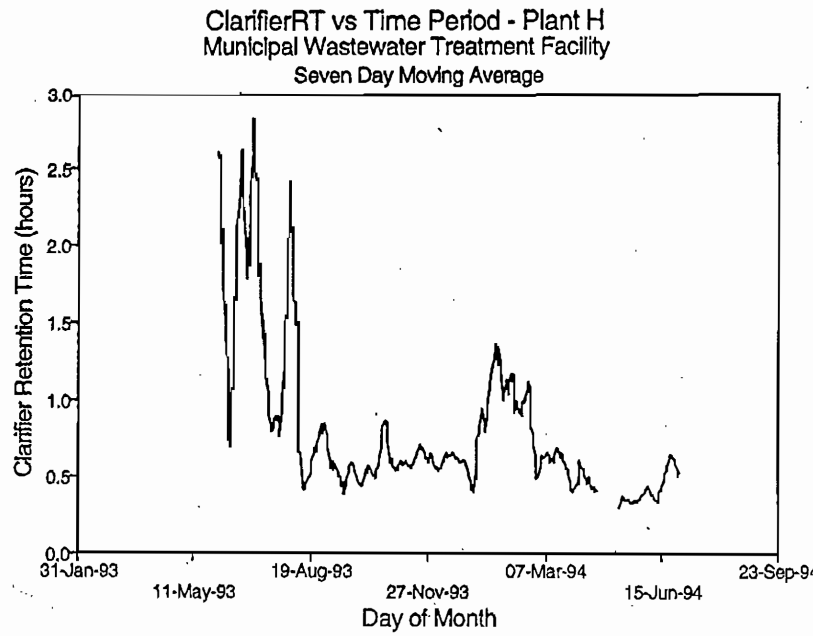


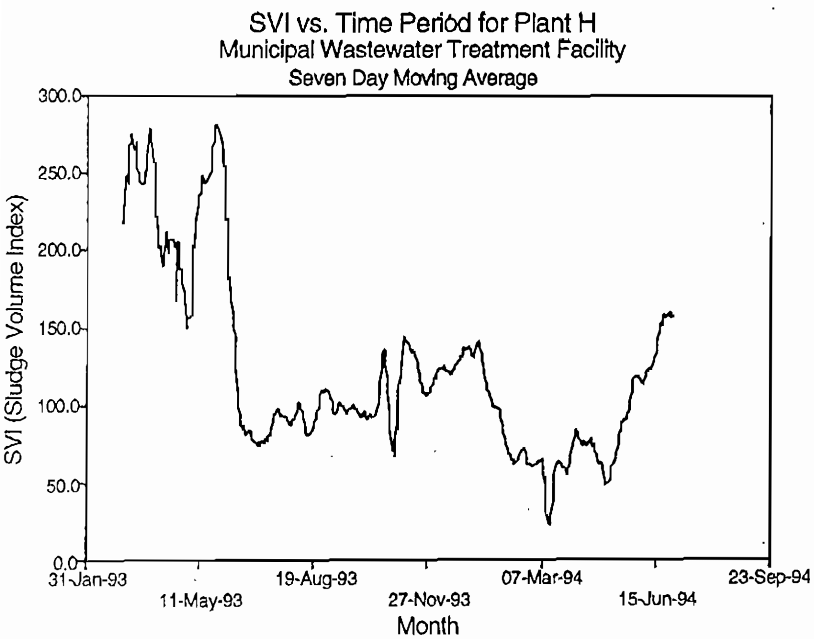
SRT vs. Time Period for Plant H
Municipal Wastewater Treatment Facility
Seven Day Moving Average



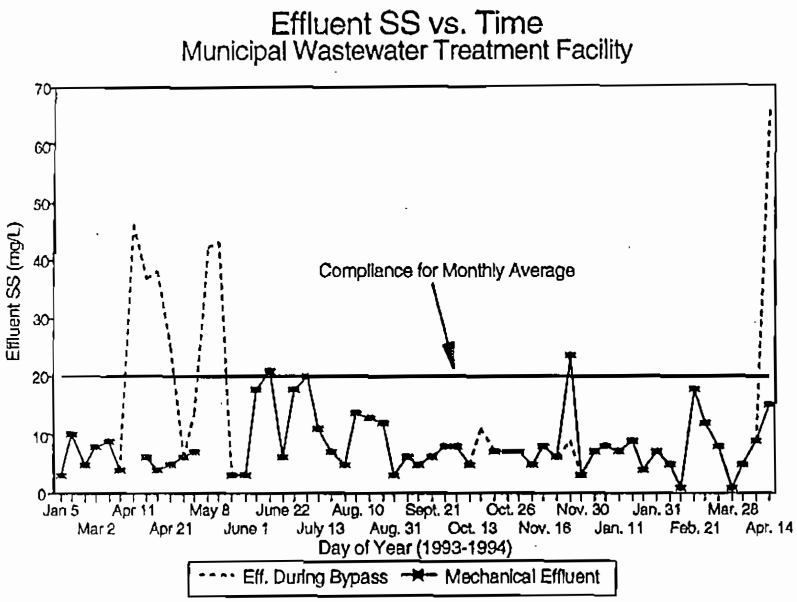
Operational Data Summary for Plant H STP

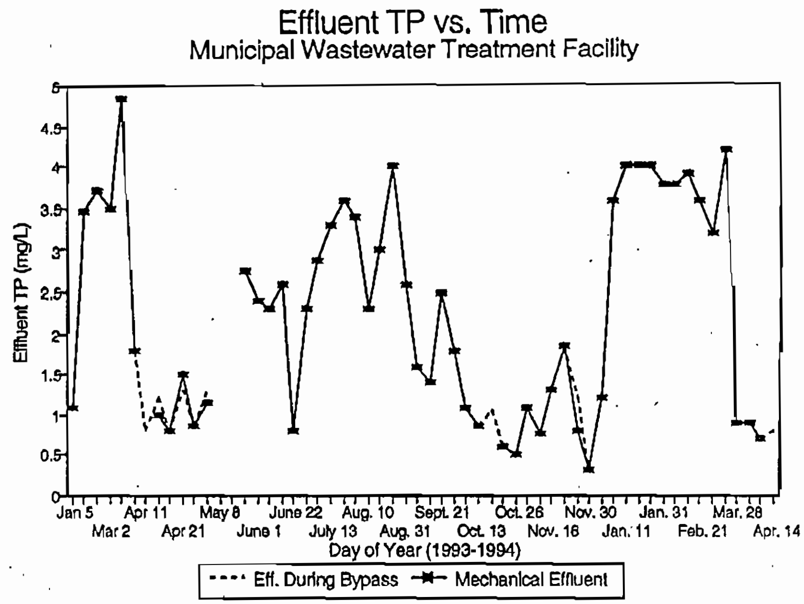


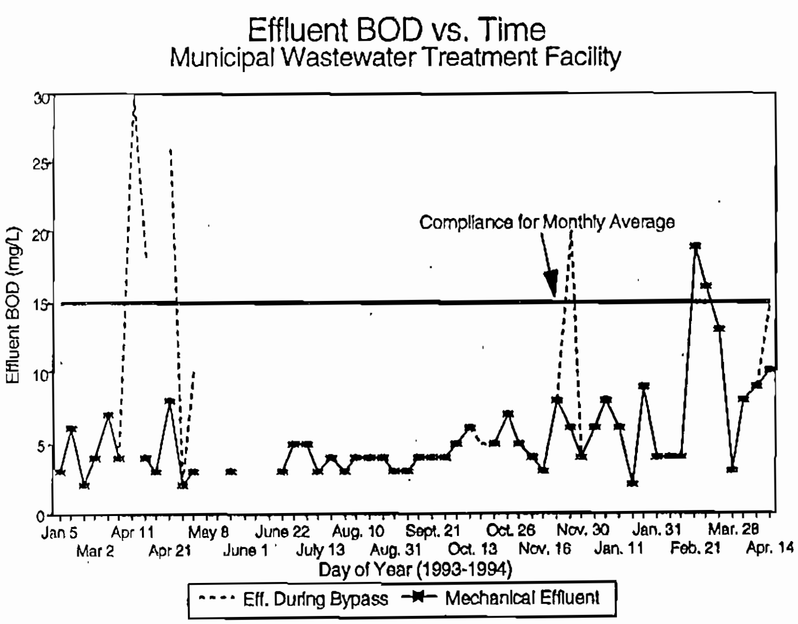


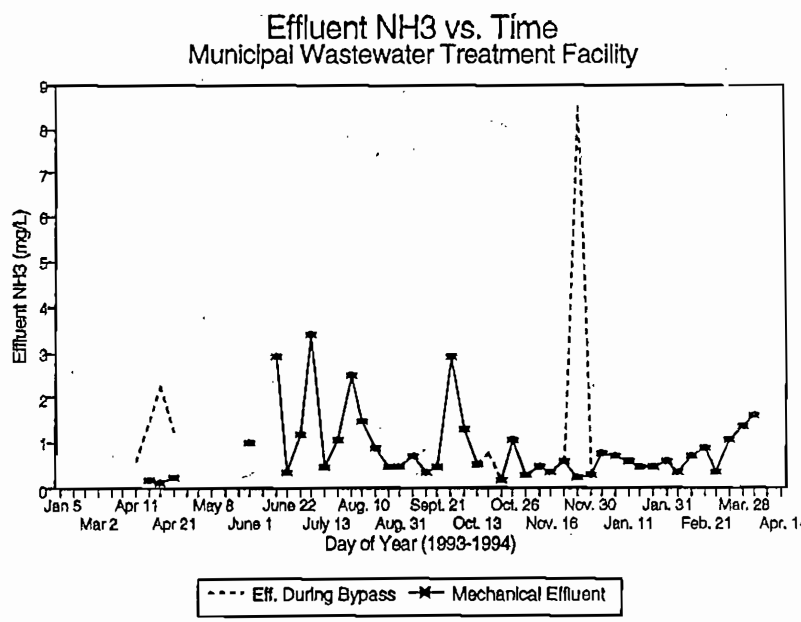


Performance Data Summary for Plant H

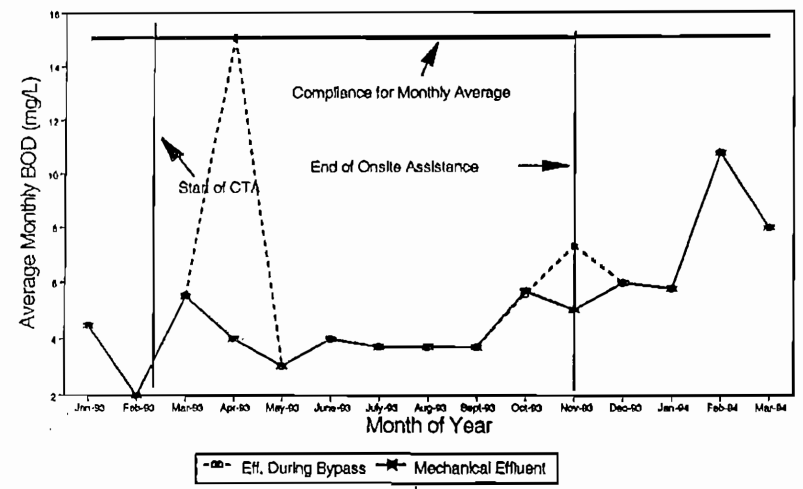


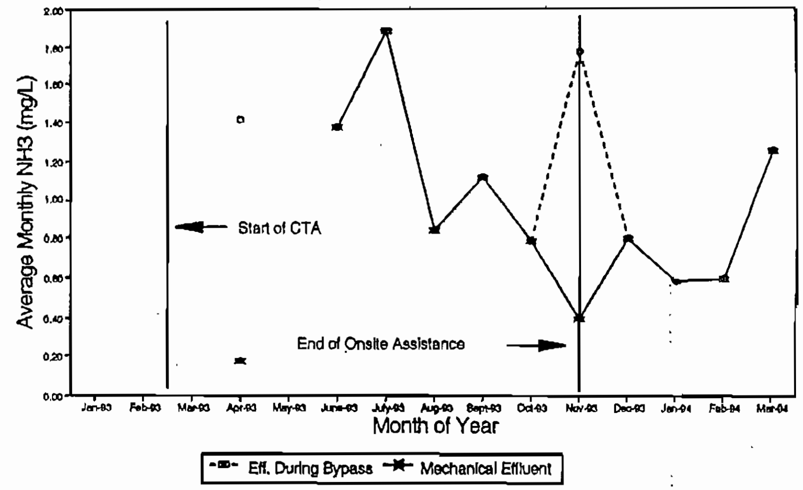


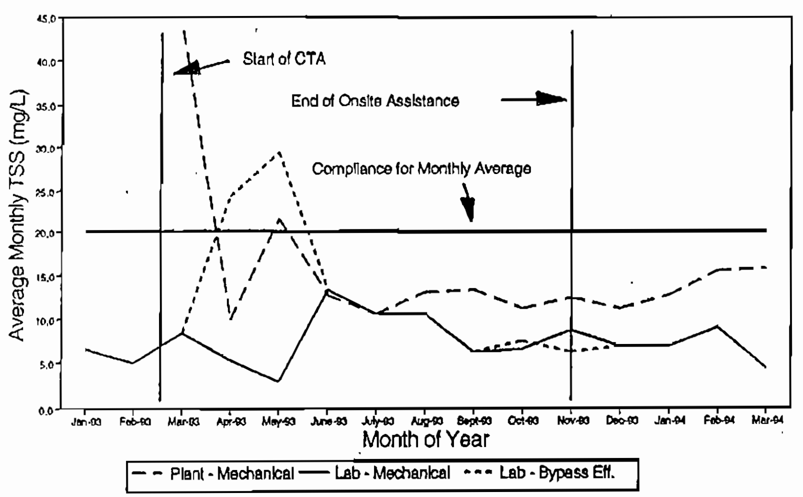




Monthly Average Data Summary for Plant H







Month	TSS (mg/L) Plant Lab Mechanical	Ministry Lab Mechanical	Ministry Lab Combined	BOD Lab Mechanical	BOD Lab Combined	NH3 Lab Mechanical	NH3 Lab Combined
Jan-93		6.5	6.5	4.5	4.5		
Feb-93		5.0	5.0	2.0	2.0		
Mar-93	43.4	8.5	8.5	5.5	5.5		
Apr-93	9.8	5.3	24.3	4.0	15.0	0.2	1.4
May-93	21.5	3.0	29.3	3.0	3.0		
June-93	12.8	13.2	13.2	4.0	4.0	1.4	1.4
July-93	10.6	10.8	10.8	3.8	3.8	1.9	1.9
Aug-93	12.9	10.5	10.5	3.8	3.8	0.9	0.9
Sept-93	13.3	6.3	6.3	3.8	3.8	1.1	1.1
Oct-93	11.2	6.8	7.6	5.8	5.6	0.8	0.8
Nov-93	12.5	8.8	6.3	5.0	7.3	0.4	1.8
Dec-93	11.1	7.0	7.0	6.0	6.0	0.8	0.8
Jan-94	12.6	7.0	7.0	5.8	5.8	0.6	0.6
Feb-94	15.6	9.0	9.0	10.8	10.8	0.6	0.6
Mar-94	15.6	4.5	4.5	8.0	8.0	1.3	1.3
Average	15.6	7.5	10.4	5.0	5.9	0.9	1.1

Appendix L
Example Wastewater Treatment Plant Administration and Management Audit

PLANT: ______________________

DEPARTMENT (circle one)

Administration (off-site)

Administration (on-site)

Operation

Maintenance

Laboratory

IMMEDIATE SUPERVISOR

____

DATE

____

Instructions

Listed below are several questions that will be used to help assess existing conditions. By answering these questions you can provide helpful feedback to the management and adminstration and indicate areas where you feel changes could improve conditions, areas that you feel need enhancement, or areas where you want to support present conditions. Your answers are confidential. Please circle the number you think best describes your opinion. If you want to clarify a point, please do so in the space immediately below each question. If you need more room, reference the question number and use another sheet of paper or the back of the page. Thank you for your cooperation and support.

1. **In your present position, how adequate is your pay (compensation including benefits)?** (1 is very poor, 5 is average, and 10 is excellent)

   1 2 3 4 5 6 7 8 9 10

2. **Relative to your immediate supervisor, please rate the following factors.** (1 is poor, 5 is average, and 10 is high)

A. Technical capability	1	2	3	4	5	6	7	8	9	10
B. Ability to recognize problems and set priorities	1	2	3	4	5	6	7	8	9	10
C. Ability to conduct staff meetings	1	2	3	4	5	6	7	8	9	10
D. Ability to discuss job-related ideas or problems	1	2	3	4	5	6	7	8	9	10
E. Ability to follow through with decisions on tasks	1	2	3	4	5	6	7	8	9	10
F. Use of staff suggestions	1	2	3	4	5	6	7	8	9	10
G. Ability to motivate staff	1	2	3	4	5	6	7	8	9	10
H. Provide recognition for a job well done	1	2	3	4	5	6	7	8	9	10
I. Fairness	1	2	3	4	5	6	7	8	9	10
J. Communication skills	1	2	3	4	5	6	7	8	9	10

3. **What is your potential for continuing employment with the City for more than 3 years?** (1 is definitely no potential, 5 is possible potential, and 10 is definite potential)

	1	2	3	4	5	6	7	8	9	10

4. **What is the adequacy of the number of staff members in your department?** (1 is very inadequate, 5 is adequate, and 10 is more than adequate)

	1	2	3	4	5	6	7	8	9	10

5. **How adequate are the benefits (i.e., sick leave, vacation, insurance, etc.) provided by the City?** (1 is very poor, 5 is average, and 10 is very good)

	1	2	3	4	5	6	7	8	9	10

6. **What is the level of productivity (efficiently getting things done) on the staff?** Please rate each "department" that you are familiar with. (1 is low, 5 is average, and 10 is high)

A. Laboratory	1	2	3	4	5	6	7	8	9	10
B. Maintenance	1	2	3	4	5	6	7	8	9	10
C. Administration (off-site)	1	2	3	4	5	6	7	8	9	10
D. Administration	1	2	3	4	5	6	7	8	9	10
E. Operations	1	2	3	4	5	6	7	8	9	10

7. **Relative to supervisory personnel other than your immediate supervisor, how would you rate the following factors?** (1 is poor, 5 is average, and 10 is high)

A. Technical capability	1	2	3	4	5	6	7	8	9	10
B. Ability to recognize problems and set priorities	1	2	3	4	5	6	7	8	9	10
C. Ability to conduct staff meetings	1	2	3	4	5	6	7	8	9	10
D. Ability to discuss job-related ideas or problems	1	2	3	4	5	6	7	8	9	10
E. Ability to follow through with decisions or tasks	1	2	3	4	5	6	7	8	9	10
F. Use of staff suggestions	1	2	3	4	5	6	7	8	9	10
G. Ability to motivate staff	1	2	3	4	5	6	7	8	9	10
H. Provide recognition for a job well done	1	2	3	4	5	6	7	8	9	10
I. Fairness	1	2	3	4	5	6	7	8	9	10
J. Communications skills	1	2	3	4	5	6	7	8	9	10

8. **Is it clear to you as to what is expected of you in your current position?** (1 is very unclear, 5 is clear, 10 is very clear)

	1	2	3	4	5	6	7	8	9	10

9. **What is the level of staff morale?** Please rate your "department" and any other "departments" that you have an opinion of. (1 is low, 5 is medium, and 10 is high)

A. Laboratory	1	2	3	4	5	6	7	8	9	10

B. Maintenance	1	2	3	4	5	6	7	8	9	10
C. Administration (off-site)	1	2	3	4	5	6	7	8	9	10
D. Administration (on-site)	1	2	3	4	5	6	7	8	9	10
E. Operations	1	2	3	4	5	6	7	8	9	10

10. **How consistently do fellow staff/shift personnel implement daily routines, tasks, or tests (e.g., does previous shift perform all required duties)?** (1 is never consistent, 5 is consistent most of the time, and 10 is always consistent)

    1 2 3 4 5 6 7 8 9 10

11. **How adequate is the equipment (i.e., tools, trucks, typewriters, computers, etc.)?** (1 is very inadequate, 5 is satisfactory, and 10 is very adequate)

    1 2 3 4 5 6 7 8 9 10

12. **What is the qualification level (i.e, education or training) of the staff members you directly work with?** (1 is poorly qualified, 5 is average, and 10 is highly qualified)

    1 2 3 4 5 6 7 8 9 10

13. **To what degree is there a spirit of teamwork or co-operation between staff members in your "department"?** (1 is very poor, 5 is average, and 10 is a high degree of co-operation)

    1 2 3 4 5 6 7 8 9 10

14. **What is the adequacy of the physical environment you work in (i.e., appearance, safety, cleanliness, lighting, etc.)?** (1 is very poor, 5 is average, and 10 is very good)

    1 2 3 4 5 6 7 8 9 10

15. **Do you use a data-based (i.e., use results of analyses, calculations, trend charts, etc.) decision-making process in optimizing treatment plant performance?** (1 is never used, 5 is used for some decisions, and 10 is always used)

    1 2 3 4 5 6 7 8 9 10

16. **How well does the management or City administration keep the staff informed of existing policies, new policies, or other current events that you feel should be disseminated?** (1 is very poor, 5 is average, and 10 is very well)

    1 2 3 4 5 6 7 8 9 10

17. **To what degree is there a spirit of co-operation between different "departments"?** (1 is very poor, 5 is average, and 10 is a high degree of co-operation)

    1 2 3 4 5 6 7 8 9 10

18. **How do you rate the treatment plant staff in terms of being well organized?** (1 is very low, 5 is average, and 10 is very high)

    1 2 3 4 5 6 7 8 9 10

19. **How do you rate the treatment plant staff in terms of communications?** (1 is very low, 5 is average, and 10 is very high)

1 2 3 4 5 6 7 8 9 10

20. Are you challenged in your present position? (1 is not challenged, 5 is average, and 10 is very challenged)

1 2 3 4 5 6 7 8 9 10

List any suggestions that you have that would improve overall performance of the treatment plant. Please be specific.

What are your goals?

APPENDIX M
Example Forms for Establishing a Preventive Maintenance Program

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

Form M-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 __________

Suppliers

Company Name and Address	Contact Person	Telephone No.

Additional Information and Comments

Form M-1 (continued)
Equipment Information Sheet

Recommended Preventive Maintenance | Frequency

Recommended Preventive Maintenance	Frequency

Recommended Lubricants

Part	Lubricant Name/Description	Source

Recommended Spare Parts

Part	Number	Quantity

Form M-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.	________	________
Temperature	p.m.	________	________
#1 Inlet ______ °C Outlet ______ °C			
#2 Inlet ______ °C Outlet ______ °C			
#3 Inlet ______ °C Outlet ______ °C			
• Check auto sampler operation and bottle installation.	a.m.	________	________
	p.m.	________	________

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

Form M-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.	______	______
• **Comminutor:** Check oil level in main gear box (lower).	______	______
• **Comminutor:** 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 daily maintenance.)

Form M-4
Monthly Preventive

	Date	Initials
Inlet Building		
• **Automatic Sampler:** Check pump tubing for signs of failure. Remove from pump housing to inspect.	________	________
Grit Separator #2 Building		
• **Grit 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 daily maintenance.)

Provide similar forms for:

- **Quarterly Preventive Maintenance**
- **Semiannual Preventive Maintenance**
- **Annual Preventive Maintenance**

APPENDIX N
Glossary

activated sludge	a mixture of millions of microorganisms which convert sewage into new cell growth; these microorganisms collide together to form flocs or clumps which are heavy enough to settle and be removed from the liquid
aeration	the process of adding air to water
aeration tank	the tank where raw or settled wastewater is mixed with return sludge and aerated
aerobic digestion	the breaking down of wastes by microorganisms in the presence of oxygen
ADF	average daily flow
ammonia	NH_3
anaerobic digestion	the process by which wastewater solids and water are decomposed by bacteria in the absence of dissolved oxygen
baffle	a flat board or plate, deflector, guide or similar device constructed or placed in flowing water or wastewater systems to cause more uniform flow velocities, to absorb energy, and to divert, guide, or agitate liquids
bar screens	vertical bars used to trap large inert debris entering the treatment facility
biochemical oxygen demand	a measure of the organic strength of a wastewater; untreated, wastewaters containing a high BOD concentration will deplete natural oxygen and produce septic conditions in receiving waters
BOD_5	biochemical oxygen demand (5-day), a measure of the organic strength of a wastewater
BTU	British Thermal Unit
bulking	clouds of billowing sludge that occur throughout secondary clarifiers and sludge thickeners when sludge becomes too light and will not settle properly; caused by excess growth of filamentous organisms or excessive high flows
bypass	flows which are diverted at the sewage treatment plant to the waterbody; bypass flows may receive partial treatment or be directly sent to the receiving water
$CBOD_5$	Carbonaceous BOD_5

CCP	Composite Correction Program was developed by the U.S. Environmental Protection Agency (EPA) to focus on and address noncompliance issues in sewage treatment facilities; the CCP has two major components, the CPE and the follow-up CTA
CEPA	Canadian Environmental Protection Act
clarifier (primary)	a tank or basin in which wastewater is held for a period of time, the purpose of which is to remove readily settleable solids and floating material to reduce suspended solids content
clarifier (secondary)	a tank in which the mixed liquor is held for a period of time, the purpose of which is to separate the activated sludge from the mixed liquor to produce a well clarifier final effluent low in suspended solids and BOD_5
coliform	a type of bacteria typically used as indicator organisms for the presence of pathogenic organisms
combined sewer	a sewer designed to carry both sanitary sewage and storm drainage; in dry weather, the sewage is diverted by a regulator into an interceptor sewer, which conveys the sewage to a sewage treatment plant
combined sewer overflow	the portion of the combined sewage flow that exceeds the capacity of the regulator to intercept, and which is diverted to the waterbody
comminution	a mechanical treatment process which cuts large pieces of wastes into smaller pieces to prevent plugging of pipes and equipment
composite sample	a collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour time span
contact	type of activated sludge process consisting of contact and stabilization tanks; shifting to this configuration decreases solids loading to the secondary clarifiers; this configuration is typically used during storm flow events
contact stabilization	a modification of the conventional activated sludge process in which two aeration tanks are used, one for separate reaeration of the return sludge (for at least four hours) before it is permitted to flow into the other aeration tank to be mixed with the primary effluent requiring treatment

conventional	an activated sludge treatment facility designed with the raw influent and RAS entering at the head of the aeration basin and the air applied uniformly along the aeration basin
CPE	Comprehensive Performance Evaluation, identifies Performance Limiting Factors (PLFs) in four areas: administration, operations, maintenance and design
CTA	Comprehensive Technical Assistance, addresses PLFs with a focus on maintaining or improving effluent quality
d	day
detention time	the time required to fill a tank at a given flow or the theoretical time required for a given flow of wastewater to pass through a tank
digester	the tank in which sludge is placed to allow decomposition by microorganisms to stabilize the sludge; digestion may occur under anaerobic or aerobic conditions
disinfection	the process by which most microorganisms, including essentially all pathogenic bacteria, are killed or inactivated
DO	dissolved oxygen
Eff SS	effluent suspended solids
effluent	wastewater or other liquid flowing from a reservoir, basin, treatment process, or treatment plant
EPA, U.S.	Environmental Protection Agency, U.S.
equalizing basin	a holding basin in which variations in flow and composition of liquid are averaged
extended aeration	an activated sludge treatment facility designed with an aeration basin HRT of 12-18 hours and usually has no primary clarifiers
F/M ratio	food to microorganism ratio, the mass of BOD_5 applied per unit of biomass concentration in the aeration basin per day
facultative	facultative bacteria can use either molecular (dissolved) oxygen or oxygen obtained from food materials such as sulphate or nitrate ions
facultative pond	the upper portion of the (supernatant) is aerobic, while the bottom layer is anaerobic
faecal coliform	bacteria which are indicators of the potential presence of disease-causing organisms

floc	clumps of bacteria and particulate impurities or coagulants and impurities that have come together and formed a cluster; found in aeration tanks and secondary clarifiers
grab sample	a single sample of water collected at a particular time and place which represents the composition of the water only at that time and place
grit	the heavy material present in wastewater, such as sand, coffee grounds, eggshells, gravel and cinders
heavy metals	metals such as nickel, lead, and chromium which are toxic to aquatic organisms at high concentrations; heavy metals are not degraded by secondary treatment plants and either accumulate in the sludge from these plants or are discharged in the effluent
hydraulic loading	plant flow impact on unit processes in a sewage treatment facility
hydraulic retention time (HRT)	the volume of a tank divided by the flow through the tank; represents the time that a unit of wastewater remains in the tank
inflow	water discharged into a sewer system and service connections from sources other than regular connections
influent	wastewater or other liquid flowing into a reservoir, basin, treatment process, or treatment plant
interceptor	a sewer designed to convey sanitary sewage in dry weather to the sewage treatment plant; the interceptor flow is controlled by a regulator which allows only a portion (often 2.5 x dry weather flow) of combined sewage to be diverted to the interceptor in wet weather
kg	kilogram
Kjeldahl nitrogen	nitrogen in the form of organic proteins or their decomposition product ammonia, as measure by the Kjeldahl Method
L	litre
launders	sedimentation tank effluent troughs, consisting of overflow weir plates
LC_{50}	the toxicant concentration killing 50% of the exposed organisms at a specific time of observation (US EPA, 1985)
m^3	cubic meters

MCRT	Mean Cell Residence Time, days

$$MCRT\ days = \frac{Solids\ in\ Activated\ Sludge\ Process,\ kg}{Solids\ Removed\ Process,\ kg/day}$$

mg	milligram
MISA	Municipal/Industrial Strategy for Abatement
mixed liquor	the mixture of raw wastewater and return activated sludge (RAS)
MLSS	mixed liquor suspended solids
MOEE	Ministry of the Environment and Energy
nitrification	the process by which nitrifying bacteria oxidize ammonia to nitrite and subsequently to nitrate
nitrite	NO_2^-
nutrients	nitrogen and phosphorus; discharged to the environment, they can lead to the undesirable growth of algae
pathogens	disease causing organisms including bacteria, viruses and parasites; in the past diseases such as typhoid and cholera have been caused by untreated sewage
PCB	polychlorinated biphenyls
PLF	Performance Limiting Factor
plug flow	a type of flow that occurs in tanks, basins, or reactors when a slug of wastewater moves through a tank without ever dispersing or mixing with the rest of the wastewater flowing through the tank
ponding	a condition occurring on trickling filters when the voids become plugged to the extent that water passage through the filter is inadequate
POTW	publicly owned treatment works
preliminary treatment	the removal of metal, rocks, rags, and similar materials which may hinder the operation of a treatment plant
primary treatment	a wastewater treatment process that takes place in a rectangular or circular tank and allows those substances in wastewater that readily settle or float to be separated from the water being treated
RAP	Great Lakes Remedial Action Plan

RBC	rotating biological contactor
receiving water	a stream, river, lake, ocean, or other surface or groundwaters into which treated or untreated wastewater is discharged
recycle pumps	pumps used to recirculate return activated sludge
regulator	the control structure that diverts flows to the interceptor, designed to cause overflows when the interceptor capacity is exceeded
Residual Chlorine	a measure of the amount of chlorine present in an effluent following chlorination to kill pathogens
return activated sludge (RAS)	settled biological solids which are collected in the secondary clarifier and recirculated back to the aeration basin
sanitary sewer	a sewer designed to carry domestic wastewater from residential, commercial and industrial buildings. Often includes connections to foundation drains in older municipalities.
screen	a device used to retain or remove suspended or floating objects in wastewater
SDR	sludge distribution ratio = aeration sludge mass/clarifier sludge mass
secondary clarifier	a settling basin which separates biological solids from the secondary effluent
secondary effluent	the supernatant resulting from the separation of biological solids in the secondary clarifier
secondary treatment	a wastewater treatment process used to convert dissolved or suspended materials into a form more readily separated from the water being treated
short-circuiting	a condition that occurs in tanks or basins when some of the wastewater or water passes through the unit faster than the desired HRT due to poor design or operating conditions
sludge	biological solids which have been thickened in the secondary clarifier
sludge accountability	comparison of actual reported sludge produced versus estimated sludge produced from similar facilities
sludge wasting	(WAS) biological solids which are removed from the process on a regular basis.
slugs	intermittent releases or discharges of industrial wastes

SRT	solids retention time, the ratio of the mass of cells in the activated sludge system per mass of cells wasted per day
step-feed aeration	raw sewage or primary effluent enters the aeration tank at several points along the length of the tank, rather than all of the raw sewage or primary effluent entering at the beginning or head of the tank
storm drainage	water generated by rainfall or snow melt on urban surfaces; term used interchangeably with stormwater runoff
storm sewer	a sewer designed to convey storm drainage or stormwater runoff from urban areas
STP	Sewage Treatment Plant
supernatant	liquid removed from the settled sludge, commonly the liquid between the sludge on the bottom and the scum on the surface of an anaerobic digester
suspended growth process	wastewater treatment processes in which the microorganisms and bacteria treating the wastes are suspended in the wastewater being treated
suspended solids	a measure of the concentration of particles in a wastewater; untreated, wastewaters containing a high SS concentration may create sludge deposits in receiving waters
SVI	Sludge Volume Index

$$SVI = \frac{\text{Wet Settled Sludge, mL x 1000}}{\text{Dried Sludge Solids, mg}} = \frac{\text{Settleable Solids, \% x 10000}}{\text{Mixed Liquor Suspended Solids, mg/L}}$$

$TBOD_5$	Total Nitrogenous and Carbonaceous Biochemical Oxygen Demand (five day)
TCMP	a chemical used in the $CBOD_5$ test which inhibits nitrifying bacteria
TKN	total Kjeldahl nitrogen test used to determine the combined concentration of ammonia nitrogen and organic nitrogen in wastewater
TN	total nitrogen is the sum of NO_2^--N, NO_3^--N, NH_3-N and organic-N
TOC	total organic carbon

toxic trace organic contaminants	Low concentrations of certain organic compounds which can accumulate in, potentially harm or kill fish and wildlife, and which may be carcinogenic to humans.
TP	total phosphorus
trickling filter	a treatment process in which the wastewater trickles over media that provide the opportunity for the formation of slimes or biomass which contain organisms that feed upon and remove wastes from the water being treated
TSS	total suspended solids
TU	toxic unit is 100 divided by LC_{50} in percent effluent (ie. an effluent with an LC50 of 10% has 10 TUs)
urban drainage	The combination of stormwater runoff and combined sewer overflows. used interchangeably in this review with urban runoff.
UV	ultraviolet; UV disinfection systems can be used in place of conventional chlorine disinfection of STP effluent
VOC	volatile organic compounds are a class of trace organics which readily evolve from water; common sources are solvents which contain VOCs like toluene, chloroform and trichloroethylene
volumetric loading	mass of BOD_5 applied per unit of aeration tank volume
WAS	waste activated sludge, settled biological solids which are removed from the process on a regular basis in order to keep the biological system in balance
Whole-effluent toxicity	A measure of the aggregate effect of an effluent measured by the death of exposed organisms over a specific time.
WTC	Wastewater Technology Centre, a research and development facility operated under contract to Environment Canada
WWTP	wastewater treatment plant
zoogleal film	a complex population of organisms that form a "slime growth" on the trickling filter media and break down the organic matter in wastewater