6. COMPREHENSIVE PERFORMANCE EVALUATION

6.1 Introduction

Based on individual filter monitoring requirements in the IESWTR, some systems may be required to arrange for a Comprehensive Performance Evaluation (CPE). Specifically, systems must conduct a CPE if any individual filter has a measured turbidity level of greater than 2.0 NTU in two consecutive measurements taken 15 minutes apart in two consecutive months. The system must report the filter number, the turbidity measurement, and the date(s) on which the exceedance occurred. The system shall contact the State or a third party approved by the State to conduct a CPE.

A CPE is the evaluation phase of the Composite Correction Program (CCP). The CCP, including detailed CPE procedures and qualifications for CPE providers, is described in a separate handbook (USEPA, 1998). This chapter's goal is to present a fundamental discussion of CPE concepts and provide a general understanding of what a plant should expect when a CPE is completed. Detailed CPE procedures are not included in this guidance manual. Detailed CPE procedures should be obtained from the CCP Handbook (available by calling the EPA Safe Drinking Water Hotline at 1-800-426-4791).

6.2 Background On The CPE

The CCP is a systematic, comprehensive procedure that identifies and corrects the unique combination of factors, in the areas of design, operation, maintenance and administration, that limit the performance of a filtration plant. It was developed to improve performance at filtration plants using existing facilities thereby minimizing construction alternatives. The capable plant model, presented in Figure 6-1, shows conceptually how the CCP considers the various aspects of the operation, design, maintenance, and administration of a filtration plant. A plant is considered capable when it has treatment processes of sufficient size with adequate mechanical equipment to meet current water demand, adequate administrative support including funding and policies, and a maintenance program that keeps key equipment operational. Once these components are in place, proper operations capabilities are required for the plant to achieve its performance goals, whether for regulatory compliance or treatment optimization.

At the core of the CCP is the assumption that if a filtration plant cannot achieve specific performance, there is a unique combination of interrelated factors with respect to the design, maintenance, administration and/or operations of the filtration plant that are limiting its performance. The purpose of the CPE is to identify these factors and prioritize them with respect to their relative importance in preventing compliance and/or optimized performance. Once the factors are identified and prioritized they can be corrected so that performance can improve and compliance can be achieved. During a CPE, the historic

performance of the plant is assessed with respect to pathogen removal and inactivation. The design, administration, and maintenance of the plant are completely reviewed to determine if they properly support a capable plant. If they are not supporting a capable plant, the root causes are identified as to how they are contributing to the performance problem. Operational practices are also reviewed to assess if operators have the necessary skills to achieve required performance and compliance when provided with a capable plant.

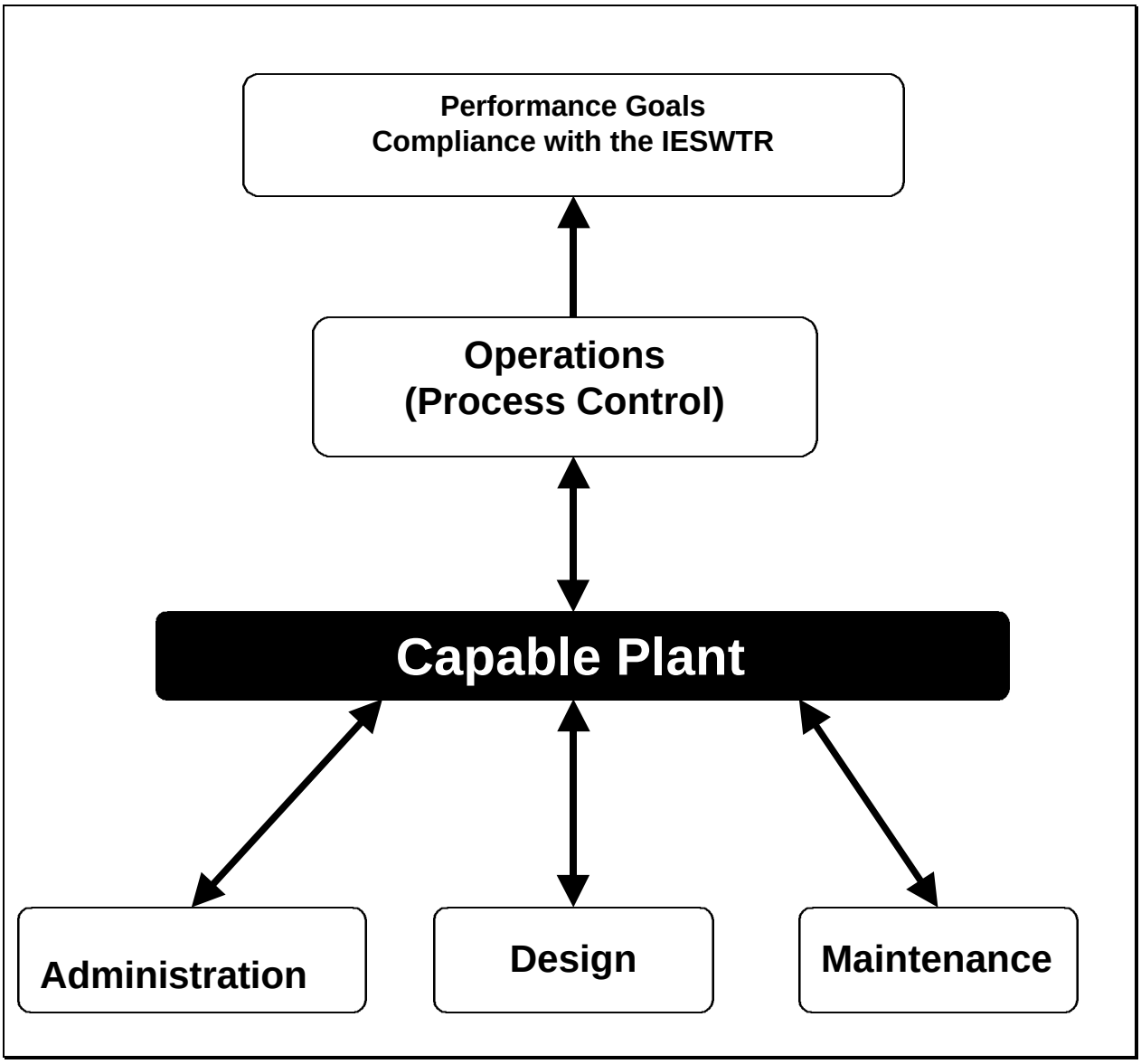


Figure 6-1. Capable Plant Model

In using the CPE/CCP it is important to understand that the approach has applications in addition to achieving regulatory compliance and should be applied as appropriate for meeting desired performance needs. All of the CPE procedures are designed to focus a plant toward meeting the compliance requirements and performance goals described in Table 6-1.

Table 6-1. CPE Treatment Performance Goals

	IESWTR Compliance Requirements	CCP Optimized Performance Goals
Minimum Data Monitoring and/or Reporting Requirements	Continuous individual filter turbidity monitoring with values recorded at 15 minute intervals (conventional and direct filtration systems). Representative filtered/finished water effluent turbidity every 4 hours.	Daily raw water turbidity. 4-hour settled water turbidity from each sedimentation basin. On-line continuous turbidity from each filter.
Individual Sedimentation Basin Performance Criteria	Not applicable.	Settled water turbidity less than 1 NTU 95 percent of the time when raw water turbidity is less than or equal to 10 NTU. Settled water turbidity less 2 NTU 95 percent of the time when raw water turbidity is less than or equal to 20 NTU.
Individual Filter Performance Criteria	Maximum filtered water turbidity of 1 NTU in two consecutive measurements taken 15 minutes apart (conventional and direct filtration systems). Maximum filtered water turbidity 4 hours following backwash of less than 0.5 NTU in two consecutive measurements taken 15 minutes apart (conventional and direct filtration systems).	Filtered water is less than 0.1 NTU 95 percent of the time (excluding 15 minute period following backwashes) based on maximum values recorded during 4-hour increments. Maximum filtered turbidity measurement of 0.5 NTU. Maximum filtered water turbidity following backwash of less than 0.3 NTU. Maximum backwash recovery period of 15 minutes (e.g., return to less than 0.1 NTU). Maximum filtered water measurement of less than 10 total particles per millileter (>3 m) of particle counts are available.
Combined Filtered Water Performance Criteria	Representative filtered/finished water turbidity less than 0.3 NTU 95 percent of the time based on 4-hour measurements (conventional and direct filtration systems). Maximum filtered/finished water turbidity of 1 NTU based on 4-hour measurements (conventional and direct filtration systems).	
Disinfection Performance Criteria	CT values to achieve required log inactivation of *Giardia* and viruses.	CT values to achieve required log inactivation of *Giardia* and viruses.

6.3 Components of a CPE

A CPE consists of the following three components:

- Performance assessment (evaluates historical plant performance);
- Major unit process evaluation (for assessing the physical plant capabilities); and
- Factors limiting performance.

The following subsections discuss each of these components; detailed procedures are provided in the CCP Handbook.

6.3.1 Performance Assessment

The performance assessment component of the CPE determines the status of a facility relative to achieving compliance requirements and performance goals and verifies the extent of any performance problems at the plant. This information also provides the CPE evaluators with some initial insights on possible causes of performance problems. These insights are then used to focus other activities during the CPE to assess the design, operation, maintenance and administration of the plant. Historical turbidity data from plant records is used, supplemented by data collected during the CPE.

To achieve desired performance levels (compliance or optimized), a water treatment plant should demonstrate that it can take a raw water source of variable quality and produce a consistent, high quality finished-water. Further, the performance of each unit process should demonstrate its capability to act as a barrier to the passage of particles at all times. The performance assessment determines if major unit treatment processes consistently perform at optimum levels to provide maximum multiple barrier protection. If performance is not optimized, the assessment also provides valuable insights into possible causes of the performance problems and serves as the basis for other CPE findings.

During the performance assessment, historical turbidity data for the raw, settled, and finished water is collected from the plant records and trends are charted as shown in Figure 6-2. From this example data the CPE evaluator can see that the plant treats a raw water that varies moderately throughout the year. The settled and finished water performance indicates that this plant has a performance problem since turbidity levels produced for treatment processes are significantly above compliance requirements and performance goals described in Table 6-1.

Figure 6-2 also shows how the CPE evaluator can use the performance assessment to gain some insights into the causes of the poor performance. In reviewing this data it is apparent that a spike in raw water turbidity on March 9th carried through the plant resulting in finished water turbidities close to 1 NTU. These pass through variations and spikes provide some insight into the root cause of these performance problems that the CPE evaluators will use to direct the subsequent portions of the CPE. Typically, these types of performance problems are related to the process control skills of the plant staff, but other design and/or administrative issues or raw water events may also make a significant contribution to the problem. During their review of the design, operation and

administration of the plant, the CPE evaluators will use these insights to focus the discussions they have with the plant staff. Information on the possible causes of this spike will be investigated until the evaluators are sure they understand the root cause.

Additional data is collected during the CPE to confirm the historical performance data, further assess the performance of individual treatment processes, and confirm insights on possible causes of poor performance. Typically additional data is collected through special studies including the following:

- Verification of filtered turbidity results by independently comparing a system's measurements with measurements from a continuous turbidimeter brought by the CPE evaluators. If the plant is not already individually measuring turbidity from each filter, the CPE team can select the filter which the operators believe has the most problems and collect individual filter data on that filter.

- Filter inspections for media depth and media condition.

- Filter media expansion during backwash.

- Verification of chemical dosages to be sure plant staff are actually adding the amount of chemicals they are intending to add.

- Verification of the benchtop turbidimeter in the plant laboratory with a unit brought by the CPE evaluators.

Additional data on the performance of individual sedimentation basins may also be collected depending on the needs of the CPE evaluators. Continuous monitoring of individual filters during the CPE allows for an in-depth assessment of the filter performance during critical periods of startup, backwash, and/or changes in plant flow rates. Figure 6-3 shows the performance of a filter during a CPE immediately after start-up following a backwash. Backwash spikes of this magnitude also indicate a possible problem with the plant's process control procedures.

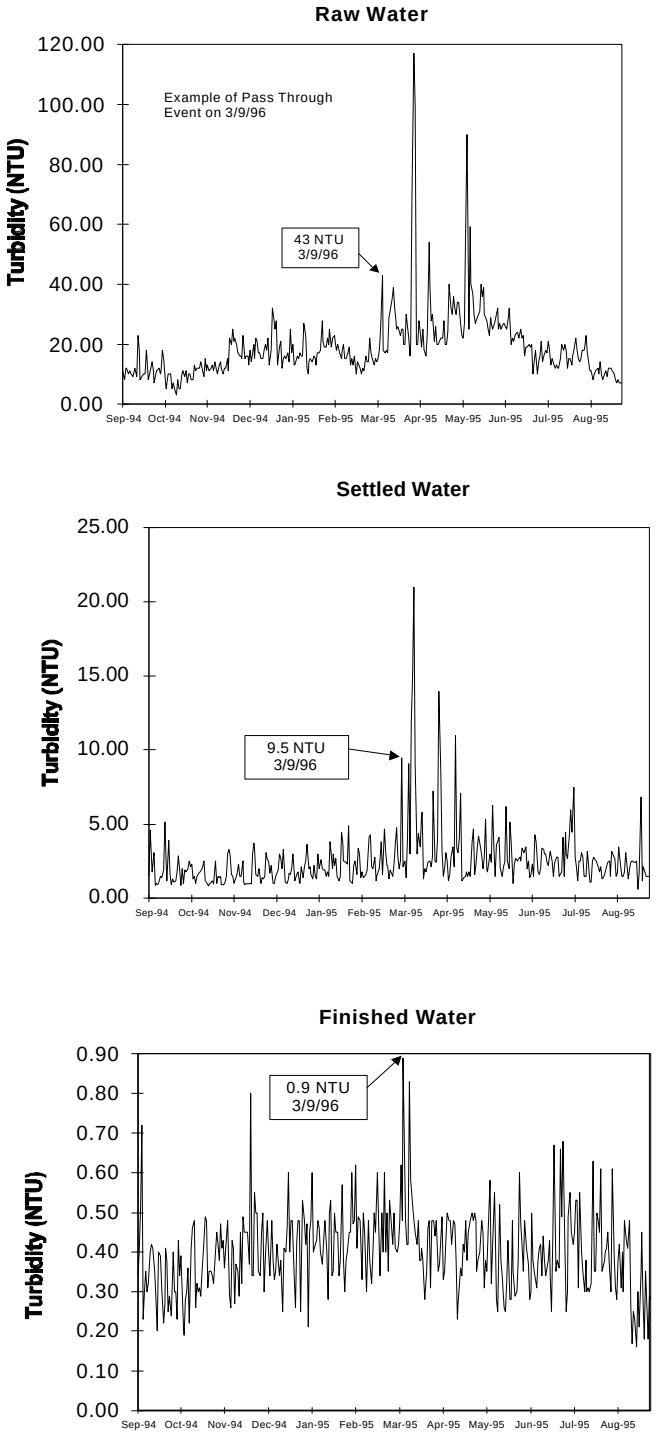


Figure 6-2. An Example of Performance Assessment Using Historical Data

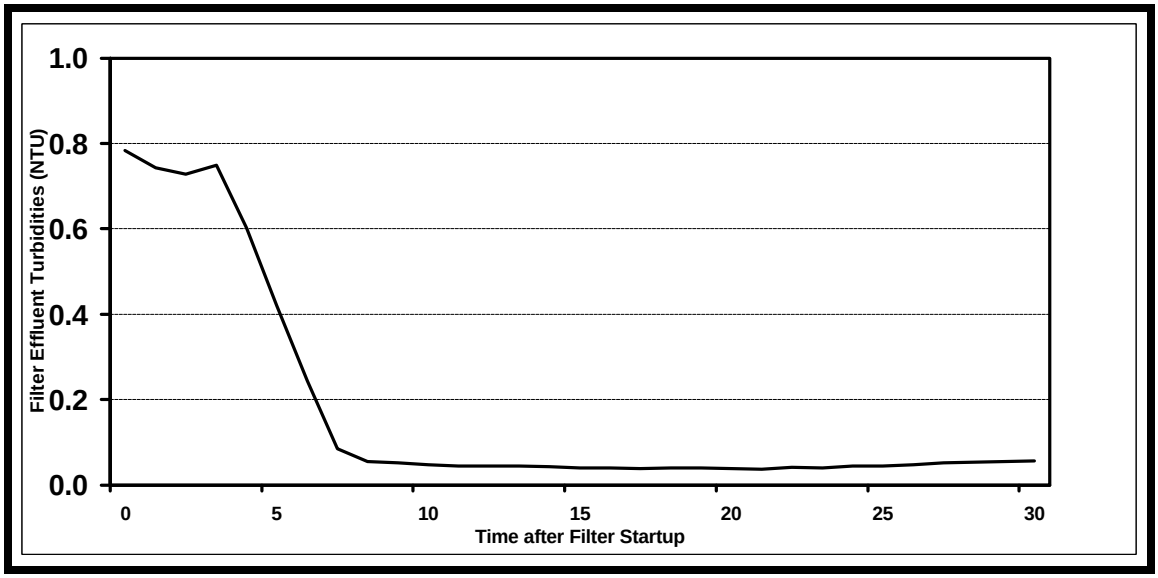
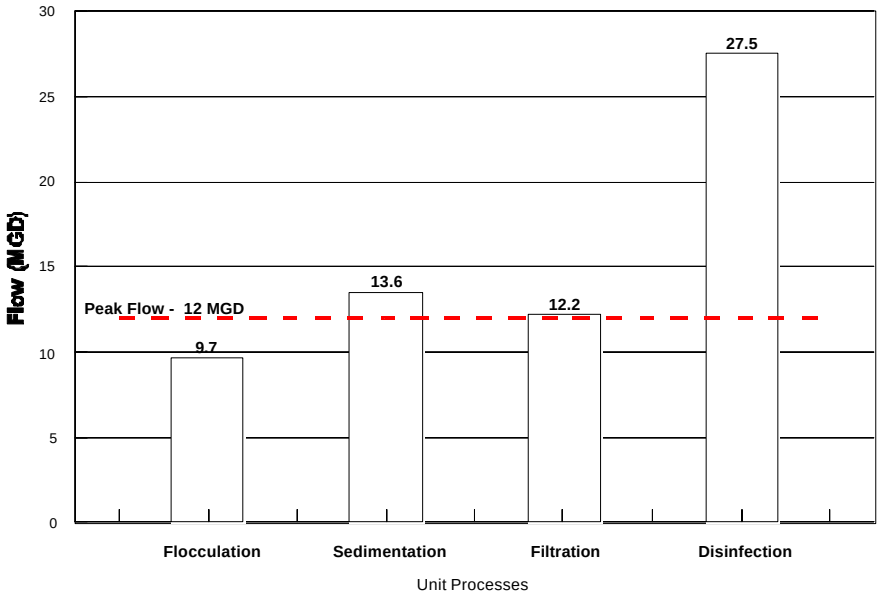


Figure 6-3. An Example of Individual Filter Data Collected During CPE

6.3.2 Major Unit Process Evaluation

After the performance assessment, the CPE begins to focus on the causes of the identified performance problems. The major unit process evaluation determines if the various key existing treatment processes in the plant, if properly operated, are of sufficient size to meet the performance goals at the plant's current peak instantaneous operating flows. If the evaluation indicates that the major unit processes are of adequate size, then the opportunity for the existing facility to achieve compliance by addressing operational, maintenance or administrative limitations is available. If, on the other hand, the evaluation shows that major unit processes are too small, then construction of new or additional processes may be required to obtain compliance or optimize performance.

The major unit process evaluation only considers if the existing treatment processes are of adequate size to treat current peak instantaneous operating flows and to meet the desired performance levels. The intent is to assess whether existing facilities, in terms of concrete and steel, are adequate. This evaluation does not review the adequacy or condition of existing mechanical equipment. The evaluation assumes that if the concrete and steel are not of adequate size then major construction may be warranted, and the pursuit of purely operational approaches to achieve performance may not be prudent. The condition of the mechanical equipment around the treatment processes is an important issue, but in this part of the CPE it is assumed that the potential exists to repair and/or replace this equipment without the disruption of the plant inherent to a major construction project. These types of issues are addressed in the factors limiting performance component of the CPE. It is also presumed in the major unit process evaluation that the necessary process control procedures are in place and practiced to meet performance goals. By assuming that the equipment limitations can be addressed and that operational practices are optimum, the evaluator can project the performance potential or capability of a unit process to achieve performance goals.



Flocculation criteria: Hydraulic detention time = 30 minutes; total volume = 202,500 gal; single stage, tapered flocculation
Sedimentation criteria: Surface loading rate = 0.7 gpm/ft2; total surface area = 13,440 ft2; swd=15 ft
Filtration criteria; Surface loading rate = 4 gpm/ft2; 6 filters in service; 30 inches mixed media
Disinfection criteria; Total Giardia inactivation = 3 log, 0.5 log required by disinfection; available volume = 900,000 gallons @ depth = 10 ft; pH = 7.5; temp = 0.5 C; chlorine residual = 1.5 mg/L; T10/T = 0.7

Figure 6-4. Example Performance Potential Graph

During the CPE, a performance potential graph similar to that shown in Figure 6-4 is developed. The four treatment processes included in this major unit process evaluation are flocculation, sedimentation, filtration and disinfection. The CPE evaluators determine the peak instantaneous operating flow that the plant has seen over the last year and collect data on the sizes of the various basins. To prepare the performance potential graph, the CPE evaluators should select loadings for each process that they consider adequate for the plant to achieve the performance goals. The assumptions and loadings used in this example are shown at the bottom of the graph. Based on these loadings a projected capacity is calculated and shown as a bar on the performance potential graph. Bars above the dashed line in Figure 6-4 represent unit processes that have the capacity to treat the peak instantaneous flow. Bars below the dashed line indicate processes where major or minor changes may be necessary.

6.3.3 Factors Limiting Performance

The last and most significant component of a CPE is the identification of factors that limit the filtration plant's performance. All information collected during the CPE is reviewed and the root causes of any performance problems are identified and prioritized. This step is critical in defining the future activities that the plant will need to focus on to achieve the compliance or optimized performance goals. To assist in factor identification, a list of 50 different factors and definitions that could potentially limit water treatment plant performance is provided in the CCP Handbook. These factors are divided into the four broad categories of administration, design, operation, and maintenance. This list and

definitions are based on the results of more than 70 water treatment plant CPEs. Definitions are provided for the convenience of the user as a reference to promote consistency in the use of factors from plant to plant and to assist others in interpreting the CPE results.

While the definitions for the administrative, operation and maintenance factors adequately explain when these factors are identified, the plant staff may find several of the design factors confusing when reviewing the CPE findings. Design factors are included for each of the treatment processes in the major unit process evaluation. If any of the treatment processes in the major unit process evaluation were classified as marginal or inadequate, they would be identified in the CPE findings as a factor limiting the plant's performance. Treatment processes that were identified as adequate in the major unit process evaluation can also be identified as a factor when there are equipment related problems that are limiting performance. This would occur when key equipment (e.g., filter rate-of-flow control valves) needs to be repaired and/or replaced before desired performance can be achieved.

A CPE is intended to be a performance-based evaluation and therefore factors should be identified only if they impact performance. A proper CPE does not contain factors that are primarily observations that a utility does not meet a particular "industry standard" (e.g., utility does not have a documented preventive maintenance program or does not practice good housekeeping) unless a clear link is made between the practice and the identified performance problem.

The major challenge in identifying a plant's unique list of factors is making sure that the root causes are identified. This is difficult because the actual problems in a plant are often masked. This concept is illustrated in the following example:

Example

A review of plant records revealed that a conventional water treatment plant was periodically producing finished water with a turbidity greater than 0.5 NTU. The utility, assuming that the plant was operating beyond its capability, was beginning to make plans to expand both the sedimentation and filtration unit processes. Field evaluations conducted as part of a CPE revealed that settled water and finished water turbidities averaged about 5 NTU and 0.6 NTU, respectively. Filtered water turbidities peaked at 1.2 NTU for short periods following a filter backwash.

Conceivably, the plant's sedimentation and filtration facilities were inadequately sized. The major unit process evaluation, however, showed that these processes were capable to handle the plant's current peak flows.

A review of the plant's operation procedures revealed that the poor performance was caused by the operator adding coagulants at excessive dosages, leading to formation of a pin floc that was difficult to settle and filter. The operators did not have an adequate process control program or equipment to allow them to identify and set the proper

chemical doses. Additionally, the plant was being operated at its peak capacity for only 8 hours each day, further aggravating the washout of solids from the sedimentation basins.

The CPE evaluators assessed that by implementing proper process control of the plant (e.g., jar testing for coagulant control, calibration and proper adjustment of chemical feed) and operating the plant at a lower flow rate for a longer time period would allow the plant to continuously achieve the desired performance.

When the operator and administration were questioned about the reasons that the plant was not operated for longer periods of time, it was identified that it was an administrative decision to limit the plant staffing to one person. This limitation made additional daily operating time as well as weekend coverage difficult.

It was concluded that three major factors contributed to the poor performance of the plant:

1. Application of Concepts and Testing to Process Control: Inadequate operator knowledge existed to determine proper coagulant doses and to set chemical feed pumps to apply the correct chemical dose.
2. Administrative Policies: A restrictive administrative policy existed that prohibited hiring an additional operator to allow increased plant operating time at a reduced plant flow rate.
3. Process Control Testing: The utility had inadequate test equipment and an inadequate sampling program to provide process control information.

In this example, pursuing the perceived limitation regarding the need for additional sedimentation and filtration capacity would have led to improper corrective actions. Completing a plant expansion without correction of the operation and administrative factors probably would not have solved the performance problems. The limitations in process control would have remained even with a new plant. Administrative policies that led to insufficient staffing of the old plant could have remained with a new plant. The CPE, however, indicated that addressing the identified operational and administrative factors would allow the plant to achieve the desired performance on a continuous basis without major expenditures for construction. The funds that initially were directed towards construction could then be directed towards other factors that truly are limiting the plant's performance.

This example illustrates that a comprehensive analysis of a performance problem is essential to identify the actual performance limiting factors. The CPE emphasis of assessing factors in the broad categories of administration, design, operation, and maintenance helps to ensure the identification of root causes of performance limitations.

6.4 Activities During a CPE

When a plant is required or decides to have a CPE conducted, there are several activities that they should expect to occur. In general, if all of the following activities do not occur,

the plant should question whether the evaluators are following the procedures in the CCP Handbook.

A CPE involves numerous activities conducted within a structured framework. A schematic of CPE activities is shown in Figure 6-5. Initial activities are conducted prior to on-site efforts and involve notifying appropriate plant personnel to ensure that they, as well as other necessary resources, will be available during the CPE. The kick-off meeting, conducted on site, allows the evaluators to describe forthcoming activities, to coordinate schedules, and to assess availability of the materials that will be required.

Following the kick-off meeting, a plant tour is conducted by the superintendent or process control supervisor. During the tour, the evaluators ask questions regarding the plant and observe areas that may require additional attention during data collection activities. For example, an evaluator might make a mental note to investigate more thoroughly the flow splitting arrangement prior to flocculation basins if one basin appeared to receive more flow than the other units (e.g., flooding).

Following the plant tour, data collection activities begin. Depending on team size, the evaluators split into groups to facilitate simultaneous collection of the administrative, design, operations, maintenance, and performance data. Appropriate forms are provided in Appendix F of the CCP Handbook to facilitate the data collection activities. After data are collected, the performance assessment and the major unit process evaluation are conducted. It is noted that often the utility can provide the performance data prior to the site visit. In this case the performance graphs can be completed prior to the on-site activities. However, it is important to verify the sources of the samples and quality of the data during field efforts.

Field evaluations are also conducted to continue to gather additional information regarding actual plant performance and confirm potential factors. This activity may typically include a special study focusing on an individual filter or filters. Once all of this information is collected, a series of interviews are completed with the plant staff and administrators. Initiating these activities prior to the interviews provides the evaluators with an understanding of current plant performance and plant unit process capability, which allows interview questions to be more focused on potential factors.

After all information is collected, the evaluation team meets at a location isolated from the utility personnel to review findings. At this meeting, factors limiting performance of the plant are identified and prioritized. The prioritized list of factors, performance data, field evaluation results, and major unit process evaluation data are then compiled and copied for use as handouts during the exit meeting.

An exit meeting is held with appropriate operations and administration personnel where all evaluation findings are presented and the plant staff are given the opportunity to ask questions. **The evaluation team answers clarifying questions during the exit meeting but does not make recommendations or offer solutions to the factors identified.** A CPE report is then generated off-site by the CPE providers which formalizes the information presented in the exit meeting**. It is intended that all of the CPE findings**

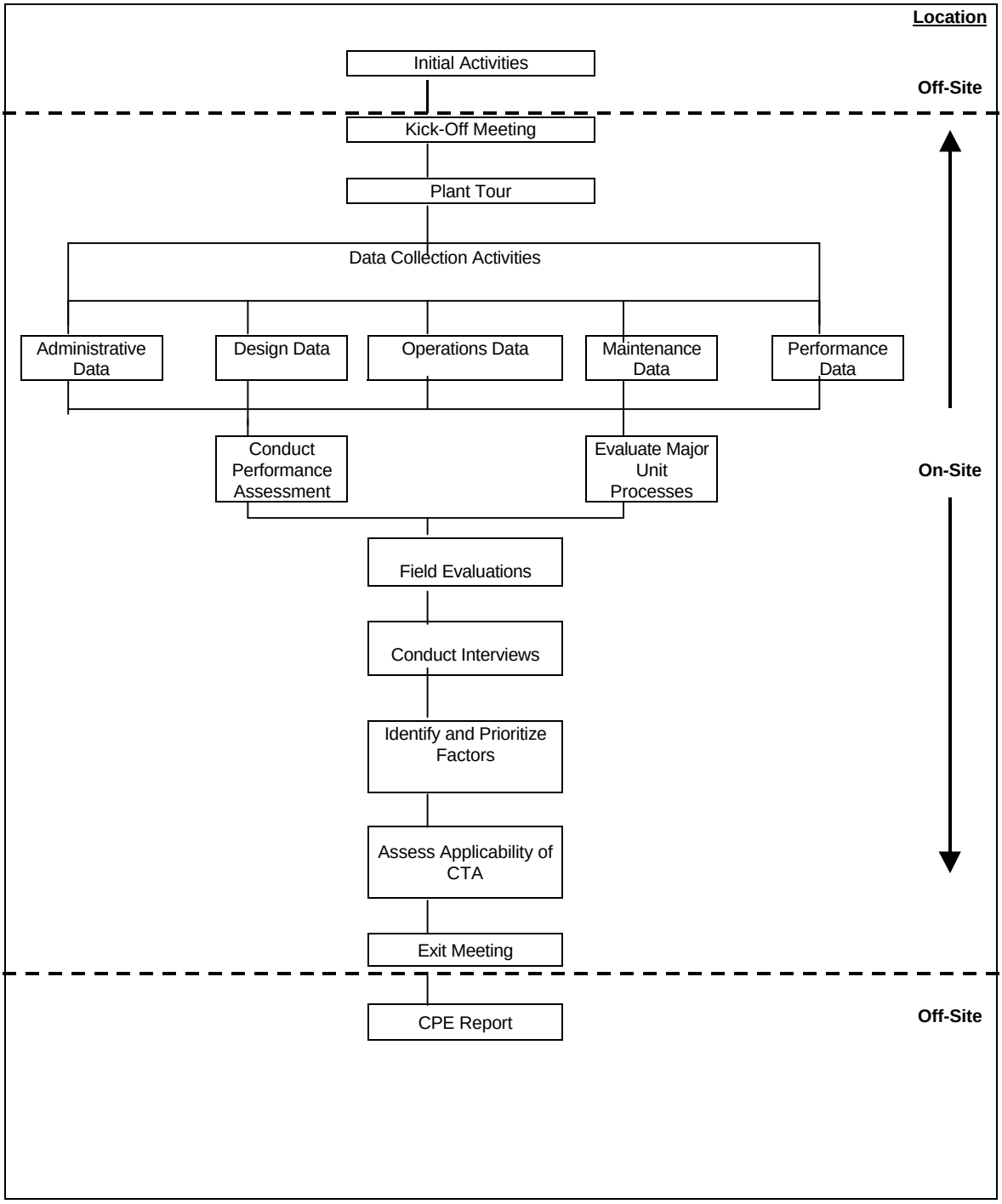


Figure 6-5. Activities During a CPE

are presented in the exit meeting and it is critical that the report not present any additional findings. The CPE provider should not save any controversial findings for the report.

A CPE is typically conducted over a three to five-day period by a team consisting of at least two personnel. A team approach is necessary to allow a facility to be evaluated in a reasonable time frame, and for evaluation personnel to jointly develop findings on topics requiring professional judgment. Professional judgment is critical when evaluating subjective information obtained during the on-site CPE activities. For example, assessing administrative versus operational performance limiting factors often involves the evaluators' interpretation of interview results. The synergistic effect of two people making this determination is a key part of the CPE process.

Because of the wide range of areas that are evaluated during a CPE, the evaluation team needs to have a broad range of available skills. This broad skills range is another reason to use a team approach in conducting CPEs. Specifically, persons should have capability in the areas shown in Table 6-2.

Table 6-2. Evaluation Team Capabilities

Technical Skills/Knowledge	Leadership Skills
• Water treatment plant design	• Communication (presenting, listening, interviewing)
• Water treatment operations and process control	• Organization (scheduling, prioritizing)
• Regulatory requirements	• Motivation (involving people, recognizing staff abilities)
• Maintenance	• Decisiveness (completing CPE within time frame allowed)
• Utility management (rates, budgeting, planning)	• Interpretation (assessing multiple inputs, making judgments)

Regulatory agency personnel with experience in evaluating water treatment facilities, consulting engineers who routinely work with plant evaluation, design and start-up, and utility personnel with design and operations experience represent the types of personnel with appropriate backgrounds to conduct CPEs. Other combinations of personnel can be used if they meet the minimum experience requirements outlined above. Although teams composed of utility management and operations personnel associated with the CPE facility can be established, it is often difficult for an internal team to objectively assess administrative and operational factors. The strength of the CPE is best represented by an objective third party review.

6.5 CPE Quality Control

It is important for CPE providers and recipients of CPEs to be aware of appropriate CCP concepts and expectations of the process. The providers should maintain the integrity of the program and the recipients should make sure they receive the full benefit of the CPE.

This is accomplished by following the protocols described in the CCP Handbook. However, to assure effective and consistent CPE results, quality control considerations have been developed. Table 6-3 presents a checklist for CPE providers and recipients to assess the adequacy of a CPE relative to the guidance provided in the CCP Handbook. The following discusses some of the key areas of concern in more detail.

Table 6-3. Quality Control Checklist for Completed CPEs

Checklist
• Findings demonstrate emphasis on achievement of compliance and/or optimized performance goals (i.e., performance emphasis is evident in the discussion of why prioritized factors were identified).
• Lack of bias associated with the provider's background in the factors identified (e.g., all design factors identified by a provider with a design background or lack of operations or administrative factors identified by the utility personnel conducting a CPE).
• Emphasis in the CPE results to maximize the use of existing facility capability.
• All components of the CPE completed and documented in a report (i.e., performance assessment, major unit process evaluation, identification and prioritization of factors, and assessment of CTA application).
• Fewer than 15 factors limiting performance identified (i.e., excessive factors indicates lack of focus for the utility).
• Specific recommendations are not presented in the CPE report, but rather, clear examples that support the identification of the factors are summarized.
• Identified limitations of operations staff or lack of site-specific guidelines instead of a need for a third party-prepared operation and maintenance manual.
• Findings address administrative, design, operation and maintenance factors (i.e., results demonstrate provider's willingness to identify/present all pertinent factors).

A challenging area for the CPE provider is to maintain the focus of the evaluation on performance and public health protection. Often, a provider will tend to identify limitations in a multitude of areas which may not be related to the performance criteria. Typical areas may include poor plant housekeeping practices, lack of preventive maintenance, or lack of an operation and maintenance manual. Limitations in these areas are easily observed and do not challenge the capability of the operations staff. While they demonstrate a thoroughness by the provider to identify all issues, their identification may cause the utility to focus resources on these areas while ignoring areas more critical to achievement of performance goals. The evaluator should be aware that a utility may take the CPE results and only address those factors that are considered relatively easy to correct without consideration of priority or the inter-relatedness of the factors.

Another significant challenge in conducting an effective CPE is the tendency for providers to identify limitations that are non-controversial rather than real factors that may challenge the plant personnel's roles and responsibilities. For example, it is often easy to identify a

design limitation, since the utility could not be expected to achieve desired performance with inadequate facilities. It is much more difficult to identify "lack of administrative support" or an operator's "inability to apply process control concepts" as the causes of poor performance. This may be especially a problem when the CPE findings tend to criticize the administrators that have hired the CPE providers. Failing to appropriately identify these difficult factors is a disservice to all parties involved. **A common result of this situation is the utility addressing a design limitation without addressing existing administrative or operational issues.** Ultimately, these administrative and operational issues remain and impact the utility's ability to achieve desired performance. Understanding this concept allows the CPE provider to present the true factors, even though they may not be well received at the exit meeting. CPE recipients should be suspicious when a plant has a performance problem and no operations or administrative factors are identified.

A final consideration when implementing a CPE, is to understand the importance that specific recommendations involving plant modifications or day-to-day operational practices should not be made by the CPE provider or accepted without question by the recipient. For example, direction on changing coagulants or chemical dosages is not appropriate during the conduct of a CPE. These types of changes should be evaluated to determine if they are truly appropriate for the specific plant. A coagulant that worked for the CPE provider at one plant may not work for the plant being evaluated; causing unnecessary costs and/or poor performance. There is a strong bias for providers to give specific recommendations and for recipients to want specific checklists to implement. CPE providers should focus their observations during the evaluation on two key areas:

1. Identification of factors limiting the facility from achieving desired performance goals (compliance or optimized); and
2. Providing specific examples to support these factors.

Recipients should, also, not request specific guidance from the providers and, if this guidance is provided, they should make sure that the information provided is truly appropriate to their plant.

6.6 Next Steps

The results of the CPE provide systems and States with a thorough evaluation of processes at a treatment plant. CPE results identify factors which may be limiting performance and subsequently causing compliance problems. The CPE affords systems the opportunity to achieve improvements largely through administrative and operational changes. Most systems can implement any necessary changes through a self-improvement program, but if assistance is necessary facilities should work closely with EPA, the States, and technical assistance programs geared towards improving treatment plant performance.

The second phase of the CCP, the Comprehensive Technical Assistance (CTA), may be used to improve performance in a more formal and structured setting. During the CTA phase, the system, with assistance from the State, identifies and systematically addresses plant-specific factors. The CTA is a combination of utilizing CPE results as a basis for

follow-up, implementing process control priority-setting techniques, and maintaining long-term involvement to systematically train staff and administrators.

6.7 References

1. USEPA. 1998. *Handbook: Optimizing Water Treatment Plant Performance Using the Composite Correction Program*. EPA/625/6-91/027.