

Maintenance

Maintenance is key to the sustainability of every water and wastewater system. A preventive maintenance program, combined with good operational practices, will reduce the need for much corrective or emergency maintenance. A good preventive maintenance program will service not only mechanical and electrical equipment, but also the distribution and collection systems, as well as grounds and buildings.

All maintenance must be performed so that equipment and systems operate efficiently and effectively. Improper maintenance and repairs can lead to unsafe conditions and reduced system performance. It is far better to perform maintenance and repairs right the first time than to risk the consequences of a mediocre approach. Failures caused by a lack of, or improper, maintenance can result in significant risks to public health and safety, as well as potential regulatory action. Failures in the water supply system can cause interruption to service or even delivery of partially-treated water, with potential health risks throughout the service area. Failure within the wastewater management system can cause the discharge of raw or partially-treated sewage at any point in the system, including into residences or businesses or into surface waters. In addition to the public health risks associated with the treatment failures, significant fines and even jail terms could be imposed under federal and local regulatory programs.

Maintenance includes all functions required to keep a facility operating in accordance with its original design capacities and performance. Maintenance includes repairs to broken, damaged, or worn-out equipment (emergency maintenance), and the periodic replacement of equipment and facilities that have reached the end of their design life (corrective or replacement maintenance). Maintenance does not include capital improvements to facilities to increase performance, capacity, or capability.

Maintenance Program Elements

Many of the individual components of a comprehensive preventive maintenance program are listed below, along with brief descriptions.

Equipment and Component Inventory

The backbone of any preventive maintenance program is a comprehensive listing or inventory of all system components and equipment. This listing applies a name and code number to every part of the system. The name should be both unique and descriptive as to the function or nature of the item. The coding system can be used to provide details about the use and type of equipment. The coding system may include fields or descriptors associated with the equipment type, location in the system, original installation date, life expectancy, etc. The equipment and component inventory serves as the basis for the accumulation of all other information on each system component.

In this chapter:

- ◆ Maintenance program elements
- ◆ Spare parts inventory
- ◆ Budgeting
- ◆ Scheduling and monitoring maintenance
- ◆ Reporting and record keeping
- ◆ Life cycle planning



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Manufacturer's Literature

For each piece of equipment or component identified in the inventory, manufacturer's literature should be obtained and compiled. For a new or upgraded facility, it is often the contractor's responsibility to provide manufacturer's information for all installed equipment. When contractors provide this literature, it is best to request multiple copies so that copies can be kept at the facility, elsewhere in a separate permanent file, and perhaps with the system design engineer.

For mechanical and electrical equipment, manufacturer's support literature will generally be quite detailed, including installation instructions, spare parts lists, parts ordering information, preventive maintenance instructions and schedules, and required supplies, such as lubricants. For many minor or less complicated components of the system, the manufacturer's literature may be very limited. When nothing else is available, even a catalog listing for the component can help, by providing contact information for the manufacturer or supplier.

Preventive Maintenance Task List

Once all of the equipment and components have been itemized and the manufacturer's literature has been collected, it is time to develop the comprehensive list of preventive maintenance tasks and to schedule them. Working systematically through each component of the facility, and remembering to address additional areas such as building and grounds maintenance, all preventive maintenance tasks must be identified and a frequency for scheduling should be assigned.

While many of the preventive maintenance tasks can be determined by the review of manufacturer's literature, other tasks can be identified based on the experience of the operations staff and the guidance derived from outside sources.

Records of Maintenance Performed

Records must be kept indicating which maintenance tasks have been performed and when. This is helpful for two reasons. First, it is imperative to verify the completion of each maintenance task. If for some reason a particular maintenance task is not performed at its scheduled time, then that must be documented to ensure that it is rescheduled as soon as possible. Second, to schedule future maintenance activities or to verify the condition of certain equipment, it is always helpful to be able to refer back to the record of past maintenance performed.

Technical Resources

Manufacturer's maintenance specifications do not always provide complete information on all maintenance tasks. Certain general maintenance tasks are not covered in detail in manufacturer's maintenance manuals, and many



Helpful Guidance

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Often the experience of good maintenance personnel can address gaps in manufacturer's information. But even experienced maintenance personnel will have certain limitations in their knowledge of specific areas, or even have incorrect information, or follow erroneous procedures, based on their "experience." Good technical manuals on maintenance topics should be available for reference and continued learning by maintenance personnel.

Tools and Equipment

Every water and wastewater system must have suitable tools and the required specialized equipment available to perform maintenance. These tools and equipment should be of good quality, because they are likely to be used for many years. In addition, tools and equipment must be maintained in good working order, so that they are available for use at any time. This requires organized storage and prompt replacement of lost or broken items.

Spare Parts Inventory

As noted later in this chapter, it is important to maintain an inventory of spare parts required for preventive maintenance, as well as for corrective and emergency maintenance. The initial inventory must be developed based on the requirements of each preventive maintenance task. Procedures also should be implemented to make sure that parts are replaced in the inventory as they are used. Database management of spare parts inventories is usually necessary in larger utilities.

Personnel Training

Even a well-developed maintenance program with a full staff for implementation will not be able to complete the required work unless the staff is trained both in how to carry out the maintenance program and in the precise skills required to perform specific maintenance tasks. If the maintenance program has not been developed internally, the consultant or entity that developed it should be required to provide training in its implementation.

Similarly, on new equipment, manufacturer's representatives are often available to train personnel and may be required to train them as a condition of sales agreements. It may be necessary to make arrangements for new staff to obtain specialized maintenance training on particular equipment. In addition, maintenance personnel should be encouraged to obtain additional training in maintenance and related activities through programs such as those provided by local community colleges, technical schools, professional organizations, state environmental training centers, or in-house training programs.

Importance of Maintaining a Spare Parts Inventory

A spare parts inventory is essential to the timely and efficient operation of any preventive maintenance program. The rapid availability of required parts and materials is also necessary to avoid costly and disruptive downtime during emergency repairs.

The size of the spare parts inventory must be appropriate to the real-world need. Overstocking spare parts and maintenance materials can lead to deterioration during storage, which might reduce the life of the parts or supplies or even make them unusable. Oversupply of potentially hazardous chemicals (lubricants, solvents, paints, etc.) used for plant operations can lead to increased danger associated with their handling, storage, and disposal.

Larger operations with multiple unit processes may find it more efficient to maintain a complete supply of spare parts and maintenance equipment, while smaller utility operations often find it more effective to maintain a spare parts inventory only for certain critical equipment or facilities. Alternatively, these smaller systems may be able to develop a cooperative relationship with other nearby facilities or local suppliers to ensure that spare parts are readily available when emergencies occur.

Proposed Inventory System

To develop an inventory system for spare parts and maintenance equipment or supplies, start with a thorough overview of the facility on a component-by-component basis, including major and minor mechanical equipment, ancillary facilities, controls, structural components, buildings and grounds, and collection and distribution systems.

After an initial spare parts inventory has been developed, it is necessary to have a control system to ensure that inventory is maintained. An inventory control system must include: inventory item description; manufacturer's stock number and internal stock number; storage location; supplier information for reorder; minimum required and maximum desirable on-hand quantities; and actual number on-hand.

Inventory control must also include proper storage facilities for the spare parts, maintenance equipment, and supplies. Storage facilities must be kept neat and secure, to protect materials and guard them against theft.

A good inventory control system will provide for both periodic and as-needed inventory resupply. Periodic inventory resupply consists of a thorough review of current stock levels and procurement to bring the inventory to the original or minimum required on-hand quantity. The frequency of periodic resupply will, of course, depend on the size of the facility and its spare parts needs. Large facilities may need to restock as frequently as weekly, and such facilities should rarely find themselves having to order on an as-needed basis. Periodic resupply at smaller facilities should be less frequent. Regardless of the size of



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Timely Reminder

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the facility, the spare parts inventory should be reviewed and restocked at least annually. The utility's budget makers must consider carefully the budgetary implications of timely and adequate restocking.

Even with periodic restocking, some spare parts or maintenance supplies may fall below the minimum needed stock levels prior to the planned restocking interval. Regardless of the inventory control system used, there must be some way to assure that minimum stocking levels are always maintained and that a triggering mechanism will reorder critical parts *before* they are required for an emergency repair. Inventory control systems can be fairly simple operations using a manual card file or similar system, or can be automated with a computerized system for control and ordering.

Budgeting for Maintenance

Budgeting for maintenance will require that sufficient funding is available for the following:

- ◆ **Preventive Maintenance—Operating budget**
 - Labor (staff time, person hours)
 - Parts and supplies
 - Equipment
- ◆ **Emergency Maintenance—Operations reserve account**
 - Labor (overtime)
 - Materials, parts, supplies
 - Replacement equipment
 - Contractors
- ◆ **Equipment Replacement—Capital reserve account**
 - Evaluation and design
 - Labor
 - Equipment cost
 - Contractors
 - Temporary or by-pass facilities

Estimating Staff Hours for Various Maintenance Functions (Task Analysis)

Sufficient labor must be available, and funded, for preventive maintenance functions. A good preventive maintenance program will document the schedule and work plan for each maintenance function (see Scheduling and Monitoring Maintenance Functions). This schedule serves as the basis for estimating the labor requirements for preventive maintenance.

To determine trade and person-hour requirements for each preventive maintenance function, the function should be broken down into tasks. The tasks can then be analyzed further to determine person-hours required for the specific maintenance function and the specific trades needed. A general summary of the activities associated with each maintenance task follows.

It is important to emphasize the need for using trained and experienced individuals to perform maintenance functions. In larger systems, individuals who are specialized in each trade will in all likelihood be available to service specific maintenance requirements. In smaller systems, however, it may be necessary to contract out for specialty maintenance work, such as electrical control panel repair or generator maintenance.

Task analysis of preventive maintenance functions includes:

- ◆ **Preparation**
 - Assemble required staff, equipment, and materials
 - Complete safety activities: confined space permits, lockout/tagout, etc.
 - Place stand-by (substitute) equipment into service
 - Take equipment to receive maintenance out of service
- ◆ **Service**
 - Access equipment and diagnose condition
 - Complete required service
 - Reassemble and test
- ◆ **Completion**
 - Place equipment back in service
 - Take stand-by equipment out of service
 - Return tools and unused materials
 - Complete maintenance service records
 - Restock parts inventory

Once the task analysis is complete, an estimate of the labor for each activity should be made. A complete task analysis of all maintenance functions will allow plant management to determine the staffing requirements and person-hours needed for annual preventive maintenance.

Staffing requirements can be further refined by grouping similar maintenance functions into maintenance function groups (e.g., electrical). This helps to prevent duplication of efforts in preparing and completing tasks, and in issuing maintenance contracts to specialists, and should be considered when scheduling preventive maintenance functions.

Setting Up Reserve Accounts for Emergency Maintenance and Scheduled Equipment Replacement

Development of an annual budget for maintenance is relatively easy and straightforward, if emergency maintenance and equipment replacement are routinely and sufficiently funded as annual reserve account contributions.

Emergency maintenance is perhaps the most difficult function to address when trying to anticipate the funding requirements for an emergency repair reserve account. A good preventive maintenance program will cut down on emergency maintenance requirements. Unfortunately, unforeseen conditions, defective equipment and materials, and acts of nature make it certain that some emergency maintenance will always be a fact of life.

A sufficiently funded reserve account within the operations budget will ensure that emergency situations can be addressed when required, without putting undue stress on other budgets. The actual level of funding needed for



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emergency maintenance should be determined by the age of equipment, the relative size of the facility, and past experience. One simple formula is to budget the average spent over the last five years for emergency repairs, plus 10 percent, plus 100 percent of the cost of replacing the single most costly capital item, such as a well, main pumping station, elevated storage tank, or filter.

The emergency reserve fund should contain sufficient funds to meet the maximum anticipated annual emergency expenses and should be funded annually. In smaller communities, emergency reserve funds do not need to be held separately for water and sewer facilities, but may be developed for all local government functions that might require emergency expenditures. This can help to balance the emergency reserve account fund level. However, the portion to be dedicated to water and sewer should be funded from revenues, not taxes.

Capital funding for major equipment replacement is a more straightforward process. All equipment has some life span. For water and sewer facilities this span can vary from five years for some mechanical equipment to 100+ years for some structures and physical facilities. A capital equipment replacement reserve account should be developed by annually projecting equipment replacement needs at least five years into the future. Based on this schedule for equipment replacement, a required level of capital reserve funding can be determined.

Scheduling and Monitoring Maintenance Functions

The preventive maintenance program for drinking water and wastewater treatment facilities is an integral part of utility operation. It must be designed to provide all required functions in an efficient and cost-effective manner. In addition to proper design, the preventive maintenance program must be well implemented.

Devising Management Systems to Ensure Timely and Cost-Effective Maintenance

Many operator and management references, such as the Water Environment Federation (WEF) *Manual of Practice 11, Operation of Municipal Wastewater Treatment Plants* and the American Water Works Association (AWWA) *Maintenance Management*, provide a good overview of how to develop a preventive maintenance record system.

Like the spare parts inventory system, basic preventive maintenance and record keeping systems are typically card systems that can be adapted to the complexity of the facility being served. Simple single card systems use one card for each piece of equipment, with the front detailing the equipment and its maintenance requirements and the back used for recording maintenance performed (see the Sample Equipment Maintenance Card). Multiple card

systems are similar, but use separate cards for equipment information, maintenance requirements, and records of maintenance performed.

Sample Equipment Maintenance Card

Front

Equipment Inventory #: _____

Description: _____

Manufacturer: _____ Serial #: _____

Supplier: _____

Address: _____

Phone: _____

<i>Maintenance To Be Performed</i>	<i>Frequency</i>
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Back

<i>Maintenance Performed</i>	<i>Date</i>	<i>Initials</i>
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Many utilities are moving away from card systems, using instead one of the many software programs developed specifically for scheduling and tracking preventive maintenance. These are useful tools for water and wastewater facilities.

Regardless of the type of system used for preventive maintenance management, it is critical that experienced staff provide input in the early stages of development. Also, the initial system must be continuously updated to delete equipment taken out of service and add equipment newly brought on line.

A very important part of the preventive maintenance program development and improvement is appropriate scheduling of maintenance activities. Preventive maintenance schedules must consider variations in plant and equipment utilization. In wastewater systems, this may involve, for example, scheduling to accommodate seasonal wet weather flows or intermittent industrial discharges. In water systems, maintenance should be scheduled to reduce downtime of critical equipment during periods of high water demand. Because equipment must be available when most needed, preventive maintenance must be scheduled for that period when equipment can be taken out of service with the least disruption of utility operations.

Scheduling should consider weather and its effect on maintenance activities and personnel. Whenever possible, outdoor maintenance activities should be scheduled when favorable seasonal weather conditions can be expected. Indoor preventive maintenance should be scheduled when inclement weather is expected. Such considerations will improve both efficiency and safety.

As previously discussed, preventive maintenance scheduling should also consider the most efficient grouping of maintenance activities. Grouping of preventive maintenance activities should assure the performance of similar types of service at the same time for the sake of efficiency such as lubrication, valve exercising, and line cleaning. Additionally, contract services should be grouped to allow, for example, an electrical contractor to do multiple tasks while at the plant.

Maintenance Reporting and Record Keeping

Once maintenance is performed, it must be properly recorded in a timely fashion, usually on the same day as performed. Preventive maintenance tasks are not complete until their accompanying paperwork is done.

Whatever system is used to schedule preventive maintenance, the system must also highlight and reschedule maintenance tasks that remain undone past schedule. Many legitimate factors can cause properly scheduled preventive maintenance activities to be postponed or to go undone, including reduced staffing, emergency maintenance, and changes in priorities. Preventive maintenance schedules must have sufficient flexibility so that all preventive maintenance can be performed in a timely manner given these considerations.

Life Cycle Planning for Major Equipment Replacement

As discussed in the section on the development of reserve accounts for equipment replacement, all equipment has some identifiable life span. For water and sewer facilities this can vary from five years for some mechanical equipment to 100+ years for some structures and physical facilities. Life cycle planning for the replacement of equipment will allow for the development of an equipment replacement capital budget which is based on a five-year projection of equipment replacement needs.

Replacement life for most mechanical equipment is a function of times started and stopped, operating time, and life in years. While some equipment in water and sewer systems is designed to operate continuously, much equipment usage is intermittent. Intermittent service is often a function of production levels. To determine expected life of equipment used intermittently, it is often necessary first to project future growth in hydraulic demand.

An orderly equipment replacement program provides an excellent opportunity to make improvements in the efficiency of performance and/or energy utilization. In both water and wastewater systems, improvements in technology continuously enhance the operational performance of process equipment, particularly pumps, motors, valves, and meters. During routine equipment replacement, a plant's performance or capacity can often be improved by taking advantage of technical improvements.

Increased energy efficiency also can play an important role in choosing replacement equipment. For example, evaluation of the improved energy efficiency of some newer pumping equipment may show that an accelerated replacement schedule can actually save money.

Summary

Clearly, maintenance is necessary. However, only through the development of a proper preventive maintenance program is maintenance likely to be performed in the complete and consistent manner required to realize its greatest benefits. A good preventive maintenance program must include sufficient planning, budgets, record keeping, staffing, and resources to get the job done. A strong preventive maintenance program can help in reducing the frequency of emergency maintenance and helps utility managers be aware of, and plan for, capital equipment replacement. With this in mind, the well-run maintenance system should provide significant benefits in terms of performance, longevity, and operating cost control.