Maintenance Management for Water Utilities

James K. Jordan

Third Edition

American Water Works Association

The Authoritative Resource on Safe Water®

Advocacy
Communications
Conferences
Education and Training
Science and Technology
Sections

Maintenance Management for Water Utilities

Maintenance Management
for Water Utilities

Third Edition

James K. Jordan

American Water Works Association

The Authoritative Resource on Safe Water®

Maintenance Management for Water Utilities, Third Edition

AWWA Publications Manager: Gay Porter De Nileon
Production Services: PerfecType, Nashville, TN
Cover Design: Cheryl Armstrong
Cover Photos: Bryan Bechtold, AWWA (left); Philadelphia Water Department (right)

Library of Congress Cataloging-in-Publication Data
Jordan, James K.
Maintenance management for water utilities / James K. Jordan. -- 3rd ed.
p. cm.
Includes bibliographical references and index.
ISBN 978-1-58321-783-2
1. Water treatment plants--Equipment and supplies--Maintenance and repair--Management. I. Title.
TD434.J67 2010
628.1068'2--dc22
2010017437

ISBN 978-1-58231-783-2

Printed in the Unites States of America.

American Water Works Association

American Water Works Association
6666 W. Quincy Avenue
Denver, Colorado 80235
www.awwa.org

Contents

List of Figures

Table

Figures

Preface

Success in any project requires careful planning, design, implementation, and monitoring. Establishing an effective maintenance program is no different. Many significant advances have been made in recent years in maintenance management systems, including the introduction of a number of software packages that simplify the task of designing a good maintenance operation and the application of geographic information system and global positioning system (GIS/GPS) technology to facilitate the location of plant equipment and distribution system components. Still, the fundamental requirements for establishing an effective program remain the same. A maintenance manager who initiates a project to establish or improve a program must:

1. Develop a clear statement of the scope of the work with cost estimates.
2. Sell the merits of the project to senior management.
3. Carefully design the program to include all necessary elements, including planning for future expansion.
4. Solicit the cooperation and recommendations of upper management, operations personnel, and field maintenance technicians.
5. Develop an implementation plan and schedule.
6. Plan techniques for monitoring and reviewing the program after implementation.

The establishment or improvement of a maintenance program must be a high priority for any maintenance manager. The benefits to a water utility of an effective maintenance program are well established, and senior managers generally support implementing improved programs for maintenance. The maintenance manager and staff are key members of a utility staff who contribute to the effective operation of a water utility by ensuring that equipment runs smoothly and facilities and grounds are safe and functional workspaces.

This book was prepared to provide guidelines to help water utility maintenance managers develop and analyze their maintenance management programs. The text systematically covers the primary components of effective maintenance management and suggests actions that a maintenance manager can take to improve the operation of the maintenance section.

While this book continues to emphasize the importance of performing preventive maintenance and of carefully planning new and modified maintenance systems, this edition introduces newer concepts involving the use of GPS technology and asset management. In particular, the application of computer technology has expanded from generating and tracking work to integrating maintenance data with the utility's financial and inventory systems. The use of the Internet to provide training for maintenance staff is also introduced as an additional resource for maintenance managers to consider.

The author thanks manuscript reviewers Kenneth C. Morgan, PE, Water Distribution Superintendent, City of Phoenix, Ariz.; and Robert Garcia, City of Peoria, Ariz. The author also wishes to acknowledge the important contribution that maintenance managers and technicians make to the success of their water utility. This acknowledgment extends to those operations staff, particularly in smaller water utilities, who perform many of the maintenance tasks that are essential for the efficient operation of a water utility.

CHAPTER 1

The Need for Maintenance

When a piece of equipment is first placed in service, it generally operates near its maximum efficiency. For example, a new automobile, assembled with new parts, is at its operating peak, with the engine running smoothly and according to the specifications of the designers and manufacturers. The shock absorbers, springs, and tires produce the best ride that the vehicle is capable of delivering.

The same principle applies to a water pumpset and its auxiliary equipment. Assuming proper design, construction, and installation, the volume of water pumped immediately after a system has been commissioned is at or near its design capacity. This principle holds true whether the equipment for transmitting the water is a hand pump located in a village or farm or a 50-mgd centrifugal pumpset providing water to a large community.

Also, of course, all equipment with moving parts eventually wears and must be replaced. The owner of the car, the farm with the hand pump, and the utility using large-capacity pumping equipment all must recognize this fact and develop plans to correct inevitable equipment wear.

A water utility is among the most capital intensive of all utilities. A utility of any size must allocate sufficient resources to perform those maintenance functions needed to protect its investment in equipment. In larger utilities, a separate maintenance group is usually required;

for smaller utilities, staff, for example, plant operators, may perform all duties critical to the operation and maintenance of the system. Only through effective maintenance management can a utility fulfill its responsibility to provide high-quality water to the community it serves.

Role of the Maintenance Department

A water utility's primary function is to provide safe, high-quality water to its customers in sufficient quantities and at a reasonable cost. The performance of the utility's maintenance department plays a key role in the success of this endeavor. In general, the maintenance group provides support services to other departments within the organization. Maintenance is responsible for keeping the equipment, vehicles, and structures of the utility in good operating condition. The services provided by maintenance personnel range from routine tasks such as replacing light bulbs to critical ones such as repairing equipment necessary for production of finished water. Whatever the nature of the work, efficient completion of these tasks requires a planned approach.

Responsibilities

The specific responsibilities of the maintenance group include the following:

- Repairs to equipment, vehicles, distribution system components, and buildings—planning and executing repairs to restore the equipment and structures to acceptable standards
- Preventive maintenance (PM)—developing and implementing a program of regularly scheduled work designed to maintain equipment operation and prevent major problems. In addition, predictive maintenance techniques are now standard procedure in many water utilities
- Communications—developing methods to keep operations personnel, upper management, and other departments aware of maintenance activities
- Budget—preparing realistic budgets detailing labor and material needs

- Inventory—ensuring that the parts and material necessary to perform maintenance tasks are available and can be accounted for
- Supervision—developing techniques for monitoring the activities of maintenance personnel
- Training—providing opportunities for both supervisory and field personnel to improve their skills and performance
- Safety—developing safety education programs for maintenance personnel and implementing techniques to improve the safety of the workplace
- Contract management—preparing contract specifications and inspecting the work of independent contractors to ensure compliance with requirements
- Construction—reviewing plans for new facilities and installation of new equipment
- Record keeping—maintaining up-to-date information on equipment and plant services, including files containing operations and maintenance (O&M) manuals and water system plans

The facilities maintenance department of a water utility bears major responsibility for ensuring the efficient and reliable delivery of water. To fulfill this responsibility, the maintenance department must develop and implement a maintenance management program consistent with the needs of the utility.

Maintenance Department Management

The prevailing image of “seat-of-the-pants” management in the maintenance department is changing. The rising cost of equipment, spare parts, and supplies along with the increasing complexity of contemporary water treatment processes have drawn the attention of upper management to the operation of the maintenance department. Consistent equipment reliability and cost control require a maintenance manager who combines professional skills in both technical and financial fields with people management abilities. Increasingly, water utility managers are learning that the head of maintenance must possess both technical and managerial skills.

Advances in Maintenance Management

A number of significant advances have been made in maintenance management in the last thirty years. The most important of these is the use of personal computers to schedule and track maintenance work. The new tools have made the manager's job easier by gathering information that has never been so readily accessible. At the same time, the availability of a large number of techniques requires careful selection to find the proper alternatives for the facility over both the short and long terms.

The role of maintenance technician is also changing. The task of maintaining large, complex equipment requires extensive knowledge of troubleshooting and repair methods. There is increasing emphasis on the importance of the first-line maintenance supervisor, who must be able to effectively use the skills of the technicians.

Recently, maintenance departments have added new members to their teams: the professionals responsible for the development, implementation, and maintenance of information systems. The advent of packaged information systems coupled with increasing demands by upper management for timely, accurate data on maintenance activities have resulted in the need for staff who can troubleshoot basic software problems, develop reports from computer-generated data, and communicate effectively with companies offering MMS-related software and hardware.

A key responsibility of the maintenance manager is to determine what data to gather and how to accomplish this task.

Maintenance Management Information Systems

The term *maintenance management information system* (MMIS) is generally used to describe a program designed to schedule, assign, and track maintenance tasks. The program can also be structured to provide information on other aspects of maintenance activities, such as inventory and budget control. An MMIS may use either manual methods or computers, making it a computerized maintenance management system (CMMS). In fact, a maintenance department may use several different information systems to control its operations. Some water utility programs process information entirely manually, while others involve visual aids such as schedule boards. CMMSs can be programmed for use in mainframe or personal computers.

The development of numerous packaged programs has brought computer-assisted information systems within the reach of almost any water utility in North America. The significant developments in information gathering, processing, and reporting justify a full chapter, chapter 4, on this component of maintenance operations.

Relationship Between Operations and Maintenance

Although the maintenance department interacts with virtually all other personnel in the water utility, the relationship between operations staff and maintenance staff is a particularly close one. Operations and maintenance are frequently considered a single function (O&M), and operations personnel frequently perform minor maintenance tasks as part of their regular duties. The two staff groups are strongly dependent on each other, but they differ substantially in their objectives.

In general, *operations* is defined as a series of actions by operators to make equipment and systems do the work they are intended to do. This process includes, for example, operating water pumps, opening valves, and backwashing filters. In a water utility, operations is usually associated with activities related to the processing and delivery of water.

Maintenance is defined as a series of activities intended to ensure that equipment, systems, and facilities are able to perform as intended or to provide an environment conducive to effective work. Examples are troubleshooting electrical gear, repairing and replacing components of a water pump, repairing a water main break, and repainting a room.

General Maintenance Functions

The maintenance department takes care of all equipment and facilities necessary to effectively serve the water utility's customers. However, system components require specialized maintenance activities that balance the use of available resources for reacting to problems after they occur with those for preventive measures. Maintenance managers must be aware of varying approaches to maintenance and how they affect the strategy for maintaining the water utility's components.

The activities carried out by the maintenance department are divided into three categories: preventive (including predictive), corrective, and breakdown maintenance.

- *Preventive maintenance* (PM) actions are performed on a regular schedule to keep equipment or structures operating effectively and to minimize unforeseen failures. These actions consist of inspections and/or maintenance tasks.
- *Corrective maintenance* (CM) actions are taken to either repair or restore malfunctioning equipment or structures to effective operating condition through either scheduled or unscheduled work. These actions may result from problems discovered during PM or as a result of failures during operation. CM actions are scheduled if they can be carried out as part of the normal work plan. They are unscheduled if immediate intervention is needed to correct a fault, a process often called emergency maintenance.
- *Breakdown maintenance* actions differ from CM in that preventive measures are minimized or entirely omitted. Actions are taken to repair or restore equipment or structures to effective operating condition only after they fail to operate. Any maintenance manager who recognizes this type of maintenance as a normal mode of operation needs to consider the methods of maintenance management detailed in this book.

These three maintenance methods differ with respect to handling maintenance of equipment, pipelines, and facilities, depending on cost factors; availability of practical methods to assess maintenance needs; and the importance of the equipment or structure needing maintenance.

Balancing Maintenance Requirements

A large utility's maintenance department is frequently organized into four sections to accommodate different O&M requirements:

- Electrical and mechanical (E/M) equipment maintenance
- Distribution system maintenance

- Building and grounds (B&G) maintenance
- Vehicle maintenance

A particular water utility's maintenance function may, of course, be structured in another manner, but all utilities need to recognize that physical structures and equipment do have different maintenance characteristics and requirements.

Electrical and Mechanical Equipment

E/M equipment consists of all of equipment operated electrically, mechanically, or pneumatically to draw water from the utility's source and deliver it from the discharge point(s) of the utility's treatment works. Also included are similar components at booster pumping stations and water storage facilities. Depending on the size and complexity of the operation, maintenance may be required, for example, on pumps for source water and finished water; chemical-feed equipment; flocculation, sedimentation, and filtration units; process instrumentation devices (such as flowmeters and other telemetry components); and transformers, motor control centers, and protective relays.

Since E/M equipment incorporates a multitude of moving parts (e.g., bearings and contacts) subject to wear, it requires effective PM for reliable and economical operation of treatment plants and pumping stations. However, PM is not cost-effective for all E/M equipment—some equipment is generally operated until it fails. For example, unless a fractional horsepower motor is driving a critical piece of equipment, PM for it is probably not cost-effective. The motor will be replaced when it fails. Even under a good PM program, other equipment will fail on occasion simply because of faulty components. Thus, provision for CM must be made in the work schedule. An effective PM program will cover 70–80 percent of maintenance for E/M equipment.

Distribution Network

Transmission and distribution mains together with lateral connections to individual customer facilities constitute the distribution network. The pipelines that transmit water from the treatment works to the consumer are included in this category. Also included are the valves that control the flow of water in the pipeline, such as those used to reduce system pressure or to isolate sections of the network for repair. Consumer water meters and fire hydrants are also distribution components.

Increasingly, sensing and transmitting devices are being installed in pipelines to monitor water quality, to detect breaks, and for other purposes. This places additional responsibilities on the instrumentation maintenance group. For example, the city of Ann Arbor, Mich., installed and tested an online monitoring system that involved several types of devices that would effectively detect the release of chemical contaminants or biological agents into the distribution system. The utility's maintenance department would likely be charged with the responsibility for maintaining this new equipment (Skadsen et al. 2008).

Nevertheless, the maintenance of pipelines is primarily a reactive process. Maintenance crews must be available to respond to water line breaks, valve leaks, and reports from customers of nonavailability of water. These same crews are also responsible for flushing fire hydrants in the case of cloudy or other water quality issues. These types of tasks constitute the bulk of distribution network maintenance, approximately 75 percent of them handled as corrective maintenance. This section of the department can, however, carry out some regular, scheduled maintenance work, including exercising valves, testing fire hydrants, and controlling leaks in the system. Programs for cleaning and relining pipelines may also be the responsibility of this group.

Building and Grounds

Maintenance activities involving the utility's B&G include renovations requiring carpentry, painting, and masonry work, planning and execution of building modifications, as well as groundskeeping and general housekeeping.

Very little of the work carried out by this section is unscheduled CM. Generally, only responses to problems related to safety or security issues fall outside of planned work. Responding to conditions caused by weather may also be the responsibility of this group. Maintenance of the utility's grounds is a regularly scheduled activity, depending on seasonal conditions; it can be described (loosely) as PM. Facility housekeeping is handled in a similar manner.

Aesthetic upgrades to buildings (e.g., painting and flooring replacement) are also scheduled work, though the intervals between such activities are measured in years rather than weeks or months.

The B&G group may also be responsible for relocating personnel within the utility when work assignments change and when the facility is modified because of reorganization, expansion, or other reasons. This type of work should be planned, but its occurrence can usually be predicted only a few weeks, or possibly months, in advance. Many utilities contract with outside firms to handle this type of work.

Vehicle Maintenance

Servicing automobiles, trucks, and specialized mobile equipment (e.g., cranes and backhoes) is the responsibility of the vehicle maintenance section. Vehicle maintenance is a vital component of effective utility O&M activities, but it requires a separate publication. Therefore, this subject will not be covered in this book.

Summary

Maintenance managers and personnel must recognize that structures and equipment require different approaches for well-organized maintenance. Staffing, record keeping, budgeting, work monitoring, and other functions are affected by differences in maintenance requirements among the electrical/mechanical, distribution, buildings and grounds, and vehicle maintenance sections. Analysis of the organizational requirements for a water utility's maintenance department is the first step in establishing an effective maintenance management system.

Reference

Skadsen, J., R. Janke, W. Grayman, W. Samuels, M. Tenbroek, B. Steglitz, and S. Bahl. 2008. Distribution system on-line monitoring for detecting contamination and water quality changes. *Journal AWWA,* 100(7):81–94.

CHAPTER 2

Organization of the Utility

Before investigating the organization of the maintenance group, it is important to understand that this group does not stand alone in a water utility. To make maintenance programs a success, maintenance personnel must interact with personnel from all other departments within the utility.

Organization-Wide Involvement in a Maintenance Program

To appreciate the importance of this concept, it is instructive to review the key elements of an effective maintenance program and note the participation of other groups within the utility.

Institutional Support

Senior management's active support is an essential element of an effective maintenance management program. The *Journal AWWA* has been carrying, for several years, articles in which this important point is highlighted (see, e.g., Jordan 1987). This support extends beyond allocation of adequate funds for maintenance. Participation often includes reading and reacting to management reports on maintenance activities. Visits to maintenance sites by senior managers can also signal the value given to this function. Such support must come from all levels of management, including the utility's top managers. Failure to provide such support will almost certainly result in an ineffective maintenance management system.

Maintenance Organization and Management

Skilled maintenance personnel are a must for the effective maintenance of equipment and structures. Well-defined staff responsibilities and access to maintenance tools are other requirements.

Spare Parts and Supplies

An effective inventory control system is essential for efficient maintenance. Because another department usually handles inventory, efficient purchasing and inventory management requires close coordination between the departments concerned.

Logistics

Staff members must ensure that vehicles and structures required by the maintenance department are available. Coordinated activities can guarantee provision of vehicles selected to carry out particular maintenance functions and workshops equipped for preventive maintenance (PM) and corrective maintenance (CM) work.

Finance

The funds needed to support the maintenance program, particularly PM, are frequently the first targets of a utility anxious to reduce costs. While maintenance management must be a cost-conscious function, significant cuts in funding for maintenance usually result in increased equipment downtime, and in the long term, more costly maintenance and utility operations.

Records

Up-to-date and accurate records must be kept for all water utility maintenance operations. The type of system determines the types and number of records that are kept and reports that are developed.

Human Resources and Training

The continuing development of skills through training is an essential element for a successful maintenance program. Management and technical training are provided through close coordination with the utility's training group.

Comprehensive Organization for Maintenance

A review of these key elements reveals the extent to which the maintenance department must rely on other groups within the utility. Departments responsible for purchasing, budgeting, information management, transportation, and other functions play key roles in a well-run maintenance department. Some are more closely allied with maintenance than others, and varying relationships require that maintenance personnel make special efforts to ensure that mutual goals are achieved.

Effective Organization Models

Clearly, the maintenance department requires numerous resources to carry out its function effectively, including spare parts, transportation, and tools. However, the most important resource of the department is its personnel, who have the responsibility to maintain the utility's equipment and structures. If maintenance personnel lack the knowledge and skills needed to plan and execute their duties, the other resources available to them will be poorly used at best; at worst, improper use of resources can result in serious interruptions in water processing and delivery. Equally important, a utility must organize and locate maintenance department personnel in a manner that reflects their function. For example, some electrical/mechanical (E/M) maintenance personnel should be stationed at plant sites, while the group responsible for pipeline and valve maintenance should be located nearer to the central point of the distribution system.

Decisions on two other important issues must precede planning for the size and type of organization and the locations of maintenance personnel:

1. The role of operations personnel in the maintenance function
2. The amount and type of work assigned to private contractors

These issues will be addressed later in this chapter.

Organization of Large Water Utilities

A water utility may be considered large because it either operates in a large service area or operates a large facility (e.g., 70 mgd), or both.

Generally, separate divisions or departments are organized to handle the maintenance of the distribution system—systems maintenance—and the maintenance of plant and office structures—electrical and mechanical maintenance. These divisions are shown in the organization chart in Figure 2-1. This structure is necessary because the types of maintenance skills required by the field staff are quite different. Systems maintenance staff is, for example, frequently required to excavate and repair damaged pipelines and valves, whereas E/M staff is called upon to repair equipment and monitoring/recording/transmitting devices. In addition, some organizations combine their E/M groups into a single division, with the field staff performing both functions.

Building and grounds staff also report to the maintenance department. Maintenance departments require the services of one additional division not shown in the chart: purchasing and receiving. This group has the responsibility for purchasing, receiving, inventory control, and warehousing, all of which are vital components of a successful maintenance management program.

Division/Section Level. The systems maintenance division, particularly in utilities with large service areas, needs to be decentralized to reduce the travel time to job sites because most of its work is performed in response to emergency situations, for example, broken water mains. Generally, this division establishes a separate group within its organization to receive, process, and track requests for work. The term *maintenance management* is often applied to this group. This effort is an essential step in the development and implementation of a maintenance management information system for automated monitoring of tasks carried out by the division.

The electrical, mechanical, and instrumentation sections provide services to filtration plants, pumping stations, and other sites. As seen in chapter 1, on-site monitoring of distribution systems will require the instrumentation staff to maintain various telemetry devices. As shown in Figure 2-2, the electrical maintenance division consists of three sections: instrumentation, plant electrical, and off-site electrical.

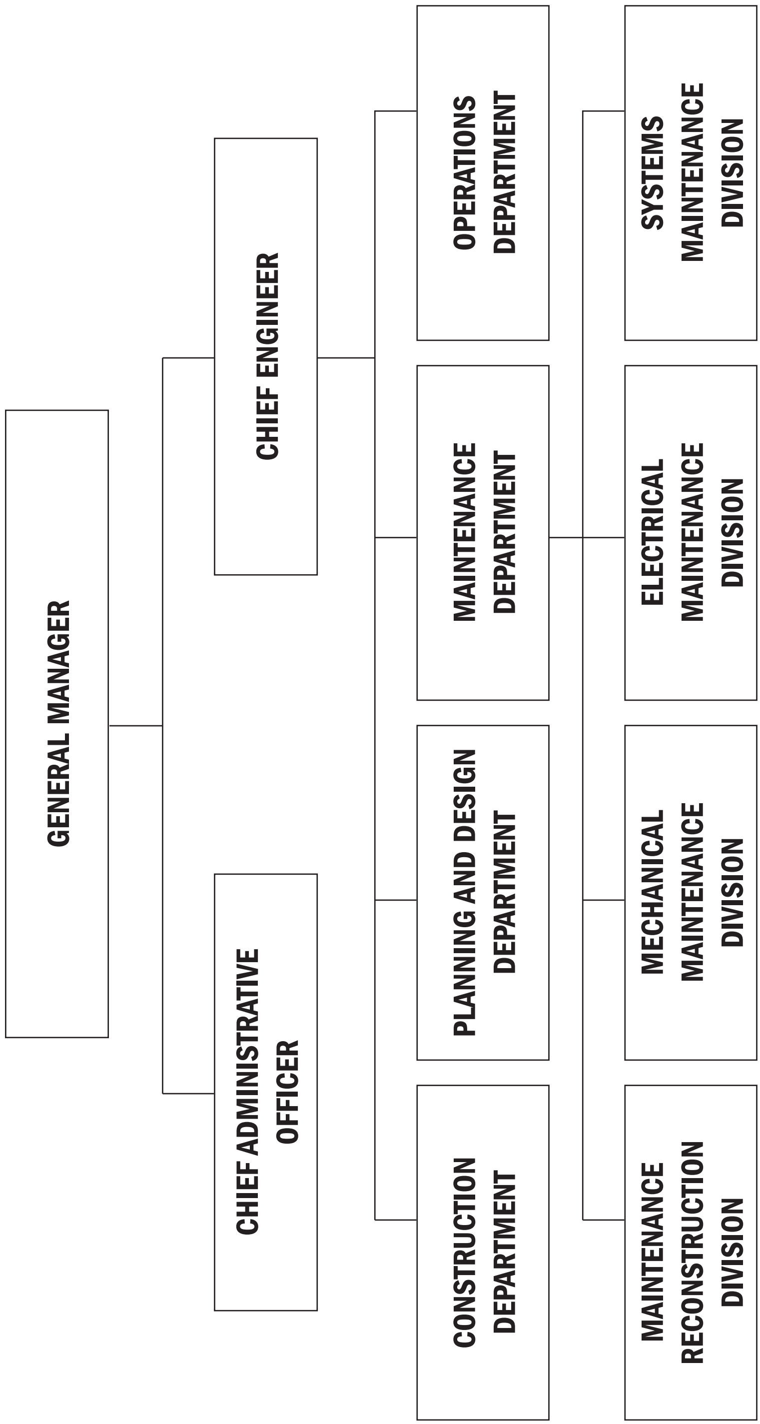


Figure 2-1 Sample large water utility—general manager/chief engineer's office/ technical departments

Field personnel likely to be stationed at either a plant or an off-site office include the following:

- Supervisor
- Electrician
- Mechanic
- Electrical and mechanical helpers
- Instrument technician
- Inventory clerk
- Planner/scheduler

Other Maintenance Organizations

Other water utilities have organized their maintenance groups in different but equally successful ways. Two perspectives seem to determine how a maintenance organization is structured.

1. Management may believe that the maintenance group, particularly personnel responsible for equipment maintenance, should be directly controlled by the plant superintendent of the water treatment facility. In this case, responsibility for plant operations, including maintenance, will be decentralized to the lowest practical management level.
2. The size of the utility is an important consideration. A utility with a relatively small service area, operating a single treatment plant, usually finds that the most cost-effective and manageable structure is to align all maintenance functions under the authority of the plant manager. This arrangement includes building and distribution system maintenance as well as that for E/M equipment. As noted earlier, larger utilities may find it more efficient to have a separate distribution system maintenance group.

Maintenance Personnel

A water utility's maintenance department needs personnel with a variety of skills. Among the maintenance manager's most important responsibilities is to properly identify the department's personnel needs and to create an environment in which competent people are selected

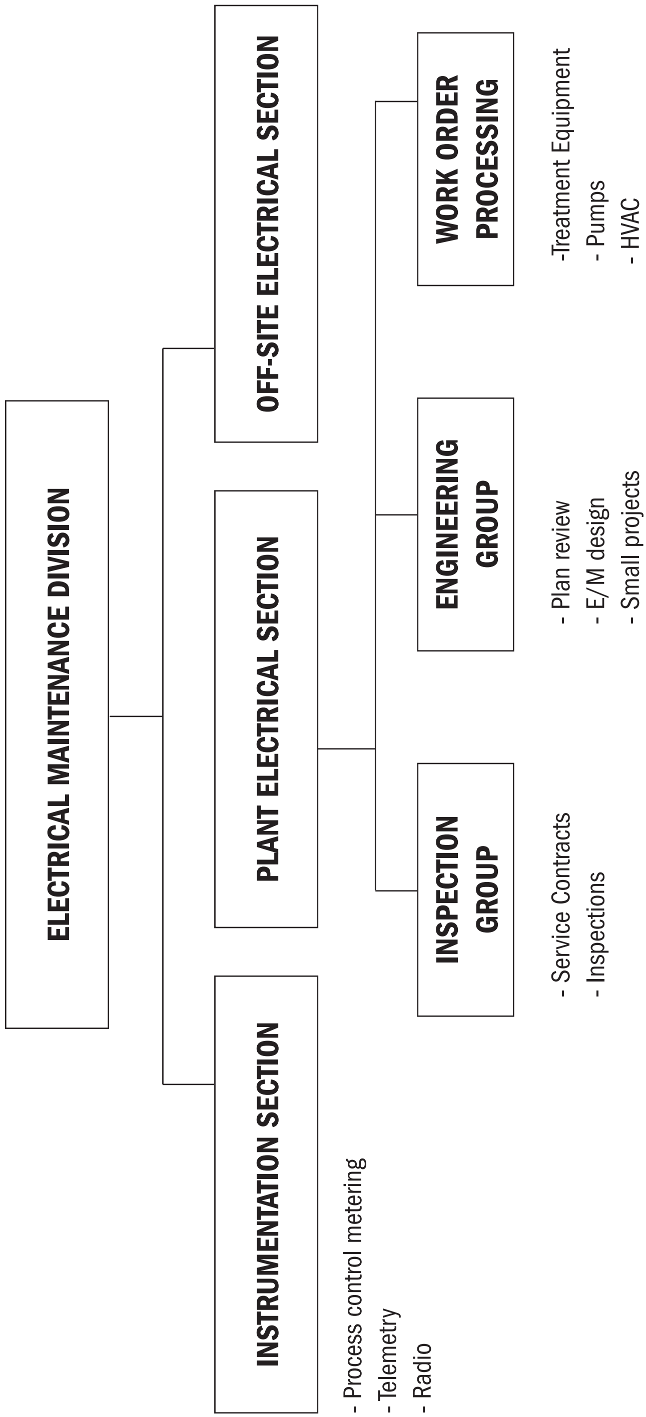


Figure 2-2 Sample maintenance organization–division/section levels

for all maintenance positions and then adequately rewarded for good performance. The *Journal AWWA* devoted a significant portion of its August 2008 edition to presenting various aspects of the importance of employing, training, and retaining good staff in the years ahead. The issues raised by these articles apply particularly well to the utility's operations and maintenance (O&M) staff (Isbell et al. 2008, Blankenship and Brueck 2008, Roy 2008). The general theme of these articles is that water utility workforces are aging and what steps can be taken to cope with this issue. Specific topics and advice included:

- Recruiting great employees
- Retaining employees
- Alternatives to employee retirement, e.g. reduction in hours worked
- Planning for knowledge retention
- Learning and training about the organization's best practices

Supervisory Staff

The maintenance department of a typical water utility with multiple plants will require several levels of management for effective operation. These levels will range from the maintenance managers responsible for the different types of activities described earlier in the handbook to regional maintenance supervisors and crew leaders. In the example given earlier, the highest level of management overseeing all maintenance work is in the maintenance department.

Functional Maintenance Manager. The responsibilities of the functional maintenance manager (e.g., the head of the electrical section in Figure 2-2) include:

- Establishing effective PM, predictive maintenance (PDM), and CM programs
- Supervising regional maintenance supervisors
- Preparing and monitoring budgets
- Determining proper staffing levels for regional sites
- Monitoring personnel and program effectiveness
- Developing and implementing new programs
- Developing effective maintenance information systems
- Applying and monitoring personnel policies and procedures
- Informing senior management of group progress and problems

In general, managers at this level must maximize the effective utilization of personnel and physical resources.

Regional Manager. The regional managers, on the other hand, are generally not involved in specific maintenance tasks. Instead, they provide hands-on direction to the field crews assigned to the regional office. This role involves implementing maintenance programs by

- preparing work schedules;
- assessing the effectiveness of crews;
- ensuring that spare parts, materials, and transport are available;
- interacting with other utility organizations, particularly with operations personnel; and
- ensuring compliance with safety programs.

Crew Leaders. The crew leader plans the work of other crew members. Depending on the number of subordinate personnel and the work procedures of the organization, the crew leader may participate in the work of the crew. The leader is likely to be a working member if the crew has only two or three members. For larger crews, the primary responsibility of the crew leader is to organize work to achieve maximum productivity. This leaves little time for physical work.

Field Staff

The field staff required to maintain water utility resources range from equipment operators (e.g., backhoe operators) to painters and electricians. The amount of experience and training needed by a maintenance person may vary from minimal experience with common tools to an extensive background in the field. The primary responsibilities of field staff include:

- Carrying out assigned duties in a professional manner
- Completing all required paperwork
- Reporting any operational problems, including any that do not directly affect their units
- Communicating regularly with their immediate supervisors
- Following work rules

Technical Support Staff

A large utility typically employs an engineering staff attached to the maintenance group, particularly for functions involving design and construction activities. Engineers who work in equipment maintenance need expertise in troubleshooting operational problems. They also must review design drawings for new construction with a view to ease of maintenance after the equipment is placed in service. In some cases, they assume responsibility for executing small projects as construction managers. Using information on the history, location, and type of water main breaks and their own experience, the engineers working on distribution system maintenance can provide valuable insight on the need for replacement or relining in analyzing stretches of pipeline.

In any case, the maintenance manager must justify the level of engineering support that the maintenance group needs and determine whether the work warrants full-time engineer positions or reliance on other sources. For example, a consulting firm may complete the engineering required for a particular job more cost-effectively than a technical staff could do it. This situation is likely to arise in small utilities and for work requiring specialized technical skills.

Nontechnical Support Staff

Maintenance departments have only recently added some of the personnel in this category. While maintenance organizations frequently include stockroom clerks, and possibly, work order clerks, the data entry clerk has become a regular member of staff. The introduction of automated information systems has placed new demands on maintenance managers, who must now balance the advantages of access to previously unavailable information with the cost of the equipment (e.g., computers) and particularly the personnel to operate this equipment.

This issue will arise again later in this book, but it clearly indicates the need for new skills on the part of the manager. These duties may involve investigating and possibly communicating the need for new support staff.

Maintenance Personnel Policies

The multitude of personnel needed to staff the maintenance department points to the need for clearly stated rules and regulations with respect to personnel.

General Principles

Since staff members play such an essential role in carrying out a successful maintenance management program, a maintenance manager should view the utility's human resources department as a valuable contact within the organization. Clear and comprehensive rules and regulations are essential for effective management of staff. In general, employees need to understand

- their specific job responsibilities,
- how their performance will be judged,
- what opportunities are available for advancement,
- rules of conduct, and
- the overall goals and objectives of their system.

Job Descriptions

Job descriptions must be prepared for all members of the maintenance team. These documents inform personnel about their particular duties and provide a basis for annual performance evaluations.

Job descriptions, such as the one shown in Figure 2-3 for an electrical mechanic, also denote the skills and experience needed by an employee in order to be eligible for promotion or lateral transfer to the position.

Promotion Policies

Water utilities, along with most other organizations, accept the value of filling higher-level positions from within their organizations. However, in some cases, the type of individual needed to fill a particular position is not available within the utility, creating a need for recruitment from outside. These situations underscore the value of a well-written promotion policy. The maintenance manager will gain substantial benefits by working with counterparts in the human resources office to verify the terms of a promotion policy that satisfies the needs of the maintenance department. Maintenance staff must receive copies of the policy.

Electrical/Mechanic Journeyman

GENERAL STATEMENT OF DUTIES: Performs journeyman-level electrical/mechanical (E/M) tasks in a wide variety of maintenance activities, does related work as required. DISTINGUISHING FEATURES OF THE CLASS: An electrical mechanic is responsible for performing assigned tasks in accordance with standard practices of the electrical/mechanical trade at a journeyman level, but is not as well versed in electrical theory and practices as the electrical/mechanical technician. Working conditions include inside and outside work in inclement weather, climbing ladders and scaffolding, and descending underground, as well as exposure to the hazards of high-voltage electrical shock. Work is performed independently, or for more difficult work, under the general supervision of a lead electrical mechanic or electrical/mechanical technician with inspection upon completion for quality of work.

EXAMPLES OF WORK: (illustrative only) Diagnoses and makes repairs on electric motors and other electrical equipment; inspects and tests various electrical/mechanical units; maintains various electrical and mechanical equipment in the buildings, plants, dam sites, and pumping stations; disassembles and repairs a wide variety of pumps, generators, heating and air conditioning units, telemetering devices, and other equipment; assists an electrical/mechanical technician in installing and repairing high-voltage electrical power supplies, transformers, motor controls, and related repair operations.

REQUIRED KNOWLEDGE, SKILLS, AND ABILITIES: Good knowledge of the practices, methods, tools, materials, and equipment of the electrical mechanic's trade; good knowledge of the occupational hazards of the trade and of necessary safety precautions; some knowledge of electronic and mechanical theory; ability to locate and correct defects in electrical and mechanical systems and equipment; ability to acquire a working knowledge of blueprints and schematics; ability to understand and follow oral and written instructions; good physical condition.

ACCEPTABLE EXPERIENCE AND TRAINING: Considerable experience in electrical/mechanical maintenance work at the level of electrical mechanic apprentice, or its equivalent, with completion of technical courses in basic electricity and blueprints and schematics or any equivalent combination of skills and training that provides the required knowledge, skills, and abilities.

ADDITIONAL REQUIREMENTS: Possession of a valid state driver's license

Figure 2-3 Example job description: Electrical/mechanical journeyman

Disciplinary Policies and Safety Rules

Similarly, a utility must prepare a written policy detailing actions to be taken if an employee violates its rules and regulations with respect to conduct on the job, safety, and attendance. Again, a maintenance manager will be in a better position to resolve conflicts related to these areas if the utility's policies are clearly stated in writing. Because of the inherent danger associated with some maintenance tasks (e.g., electrical work), the manager may need to formulate additional safety rules for maintenance personnel. Certainly, all safety rules must be logical, and they must be strictly enforced.

Employee Evaluations

Most water utilities require that each employee undergo an annual evaluation of job performance. A conscientiously implemented evaluation program can be a valuable tool for informing an employee of supervisors' impressions of performance.

However, the annual evaluation is not an end in itself. The practice can even lead to problems if not properly applied. For instance, field personnel promoted to supervisory roles must be trained to work with and evaluate subordinates. Poorly conceived evaluations can cause serious morale problems and hamper the effectiveness of the entire maintenance system. Additionally, annual evaluations should not substitute for routine monitoring of an employee's performance. In this way, the maintenance manager can avoid confrontations with employees who are frustrated and unhappy with annual evaluations, because they were not told earlier about perceptions of unsatisfactory work. One approach to counteract this problem is to schedule quarterly or semiannual meetings with each employee to review strengths and problems. These informal meetings should address any problems and acknowledge any significant contributions the employee has made to the maintenance effort.

Maintenance by Operations Personnel

The role of each person on the maintenance staff must be clearly defined to avoid duplication of effort, and more importantly, to avoid overlooking necessary tasks. For similar reasons, the operations staff must understand its role with respect to the maintenance function.

Role of the Water Plant Operator

The maintenance function of the equipment operator can range from very little work—strictly starting and stopping pumps and motors and recording operating data—to high levels of equipment maintenance. The water plant operator is always in the best position to inspect equipment on a daily basis. Because the operator sees the equipment often, changes become apparent through familiarity. For example, variations in pump performance may not be apparent to an electrical technician who performs monthly PM on a pumpset motor, but the operator may note the change. The operator can, by touch, note excess vibration or higher than normal temperatures in motors. A familiar ear listening for unexpected noises might detect problems in operating equipment. Daily presence helps one to see problems related to, for example, leaking fluids. The maintenance manager should work with the water plant superintendent to develop a checklist to guide plant operators in inspecting plant and pumping station equipment.

The role of the water plant operator in carrying out minor maintenance tasks must be determined at the senior management level in order to ensure consistent application of the decision to all sites. While some utilities do require operators to perform minor maintenance tasks such as changing the packing on water pumps or fan belts on compressor equipment, others limit the operators' functions to inspection activities. If the workload permits, the preference should be for operators to carry out some minor maintenance activities.

In summary, the role of water plant operators involves

- inspecting equipment daily,
- reporting malfunctions to the maintenance department,
- performing minor maintenance tasks (if directed by management), and
- understanding the criticality of the equipment they are handling.

Plant operators play an important role in maintaining reliable equipment performance. Therefore, facility operation managers should meet regularly with maintenance staff, particularly plant equipment maintenance personnel, to discuss issues and work together to resolve any problems. Regular meetings are one method of establishing good communications between operations and maintenance.

Maintenance by Outside Contractors

Virtually all water utilities hire outside contractors to carry out some maintenance work. For example, a maintenance manager may contract with outside services to carry out building renovations or grounds maintenance. A pipeline maintenance group is likely to use contractors to reline water distribution lines. Equipment maintenance personnel may hire outside contractors for numerous specialized tasks such as performing work on high-voltage electrical equipment. Therefore, maintenance managers must prepare carefully considered rules and regulations for working with contractors. For example, the manager should require that multiple (at least three) bids are solicited, that a Request for Bids is advertised in local newspapers and, if the job is large enough, in national publications, that the contractors identify the firm's experience and that of the staff who will work on the project, that appropriate references are provided and, of course, that each contractor detail the cost to do the work. In addition, utility staff—particularly those from contracting and maintenance—must be available to ensure that the contractor follows the regulations during the bid process and as the work is being executed.

While contractors provide cost-effective service under the proper circumstances, failure to adequately prepare for dealing with contractors could result in incomplete work, unexpected costs, poor quality, and legal entanglements.

Advantages and Disadvantages of Working With Contractors

Maintenance managers can gain important advantages by using contractors. Some of the advantages in hiring contractors include:

- Contractors can help smooth out the peaks and valleys in the workload and enable the maintenance department to keep a constant workforce.
- Contractors can bring specialized skills or equipment to a job, particularly jobs that occur infrequently.
- Contractors may be able to perform the work at lower cost than utility personnel can. This situation is likely only if a number of qualified contractors are available to bid on the work and if the utility's workers lack skills in the particular type of work required.

- Contractors are usually easier to terminate than full-time employees once they are no longer needed. (The contract document must take this possibility into account.)

Managers also need to understand the disadvantages of engaging contractors:

- Dedicated employees are more likely to show greater pride in work for their utility than are contract employees.
- The utility will need specialists to prepare effective documents for contract bidding and enforcement.
- The maintenance department will need to employ inspectors to monitor a contractor's work. Because experienced personnel are needed to perform this work, senior field people should be assigned this responsibility, which means these staff members may not be available to carry out the complex maintenance tasks they routinely handle.
- Costs may be higher than expected if few contractors are available to bid on the work.
- The utility will have less control of the schedule and worksite than it would have if maintenance department personnel were to perform the work, and the quality of the finished work may be lower than expected.

The maintenance manager must take time to assess these factors to determine if outside contractors offer the most efficient way to complete certain maintenance tasks. Of course, rational arguments must justify this decision.

Methods of Employing Contractors

Once it is decided that outside contractors would be appropriate for completing certain maintenance tasks, the next step is to structure the deal for the contractor's services. Three types of contracts are used.

Service contracts are generally negotiated for work involving preventive and corrective maintenance. The contractor agrees to perform scheduled PM tasks in exchange for a fixed price covering both labor and materials. If any problems are uncovered during PM, the contract requires the contractor to either submit a fixed price for completing the repair or carry out the work at a contractually fixed rate for labor and materials. The latter method, although more difficult to control, permits a faster response by the contractor to carry out the repair.

The second type of contract covers a period of time, typically one year, during which the contractor executes specific work orders for the utility at specified rates for labor and material. The work is nonrepetitive maintenance (not PM), and a price is submitted for each job. The utility has the option of accepting or rejecting the price. The utility can get work done fairly quickly without formal bidding procedures in this way, while retaining the option of using another contractor if competitive bidding might produce a better price. The contractor effectively becomes an extension of the maintenance workforce.

The third type of contract requires development of specifications and requests for proposals for a particular job. Contractors submit bids to complete the work for stated prices, and the technically qualified bidder that agrees to the lowest price is generally awarded the contract. This type of contract is often limited to large-scale repair or rehabilitation work.

To be successful, each type of contract must be developed under certain conditions:

- Competitive bidding
- Close coordination between the maintenance and purchasing departments
- Effective contract documents
- Close monitoring of performance by maintenance inspectors

A maintenance manager can often increase department efficiency by working with outside contractors. Time spent learning how to select and work with contractors will help to yield the maximum benefit from the relationship.

References

Blankenship, L. and T. Brueck. 2008. Planning for Knowledge Retention Now Saves Valuable Organizational Resources Later. *Journal AWWA*, 100(8): 57–61.

Isbell, M., K. McCain, D. Meadors, A. Post, and S. Schneider. 2008. Recruit and retain great employees: Proven approaches you can implement now to address the workforce gap. *Journal AWWA*, 100(8): 52–56.

Jordan, J.K. 1987. Establishing a maintenance program. *Journal AWWA*, 79(8): 32–36.

Roy, J.G. 2008. Keeping the experienced generation. *Journal AWWA*, 100(8): 38–39.

Runge, J. and Mann, J. 2008. State of the industry report 2008: Charting the course ahead. *Journal AWWA*, 100(10): 61–64, 66–68, 70–74.

CHAPTER 3

Planning a Maintenance Management System

A maintenance management system (MMS) is primarily a technique for organizing the operations of the maintenance department(s) within a utility to enable personnel to execute their responsibilities in a consistent, timely manner while maintaining high performance standards at minimum cost. To establish a system that fully realizes this definition, the maintenance manager must first develop a strategy for planning and implementing the MMS. The strategy should include

- Organizing a team to develop and install the system
- Carrying out a needs assessment
- Identifying the costs and benefits of implementing the system
- Establishing a timetable for implementing the components of the system

The process of developing an effective strategy requires an understanding of the elements that constitute an MMS.

Elements of an Effective MMS

Development of a new MMS or an extensive upgrade of an existing system is a major project. Careful planning is a key condition for success.

Functional Responsibilities and Maintenance Management

Rather than develop the MMS from scratch, a maintenance manager usually begins with an existing maintenance program, modifying features and adding enhancements as needed. In addition, as seen in chapter 1, the particular structures and equipment found in a specific utility have substantially different maintenance requirements. Therefore, individual water utilities organize maintenance work in different ways. In particular, organization schemes vary for utilities of different sizes. For example, some rely heavily on outside contractors, while others tend to do more work by their own personnel.

Also, the functions of different groups within a maintenance department require different management techniques. Pipeline maintenance crews generally perform a lot of corrective maintenance (CM), whereas electrical/mechanical (E/M) crews should devote more time to preventive maintenance (PM). In addition, the work performed by pipeline maintenance crews is generally better suited for the development of time standards. Grounds maintenance crews often carry out seasonal work, so the manager of that group must plan off-season work with care to maximize staff utilization.

Development of an MMS should allow for different teams to carry out needs assessments for different maintenance sections. Equally important, different maintenance groups may be assessed at different times. Management can evaluate where the need for reviewing the maintenance system is most urgent and concentrate efforts on that basis. However, planning for any successful maintenance system must account for certain key elements.

Key Elements of a Maintenance System

Identification of the key elements of a particular maintenance system is a subjective decision, but a review of successful programs (including both manual and automated systems) does suggest a number of elements required for a successful system.

Equipment/Structure Inventory. All equipment and structures that may require maintenance work, either preventive or corrective, must be included in an exhaustive inventory. Even a small water system will encounter problems in setting up maintenance records if all equipment and structures have not been specifically identified as part of an inventory of water system components. In most cases, this evaluation includes assignment of identification numbers.

To facilitate distribution system maintenance work, all valves and fire hydrants should be identified with a suitable numbering system. Information on buried piping is necessary in order to facilitate repairs to broken water lines. The implementation of GIS/GPS programs to assist with identifying the location of distribution system components will help the utility automate the tracking of these components, making maintenance scheduling easier and simplifying system updating.

Equipment maintenance tasks rely on a numbering system to maintain equipment histories. An automated MMS manipulates these numbers to generate PM schedules and track work orders.

For building and grounds maintenance, a facility identification system guides maintenance personnel to the correct job locations and helps them to schedule building and room renovations such as periodic painting.

Work Orders. Work orders are essential requirements for any MMS. Layouts vary, but any work order must include space for the following:

- Equipment or structure affected and/or the location of the problem
- Work to be done (if known) or the nature of the problem
- Equipment specifications
- Special tools needed
- Work done
- Pertinent dates
- Labor hours and crew identification

If the person who initially reports the problem cannot immediately see the results of the maintenance action, the work order system should also include a means of reporting the status of the work to the originator. Equipment maintenance work often falls into this category, whereas the results of work done by pipeline maintenance crews (e.g., repair of a burst main) are frequently quite apparent. Manual and automated work order systems will be discussed further in the next chapter.

Preventive Maintenance. A consistent PM program is a key requirement for ensuring reliable equipment operation. The PM program should include building services equipment such as HVAC units, water pumping equipment, and valves for controlling the flow of water. Thus, the utility cannot limit the PM program to any single maintenance function. This important element of the maintenance system is considered in detail later in this chapter.

Work Planning and Scheduling. Maintenance managers need to be able to estimate the level of effort (LOE) required to complete both PM and corrective maintenance tasks during the planning period, for example, the next month or quarter. The LOE required to complete PM tasks for most equipment is relatively easy to calculate. The difficult task is to estimate the LOE to complete CM and emergency work. Past experience is one guide, particularly for scheduled CM work where the specific requirements in labor and material can be reasonably estimated. For the type of emergency work encountered most often in pipeline maintenance, the best approach is to have sufficient material on hand to accomplish virtually any repair and to have sufficient crews on duty and on standby to make at least essential repairs as quickly as possible.

Feedback and Control. This information loop is a frequently overlooked aspect of any maintenance program. The maintenance manager must be able to determine the status of all PM and CM work to ensure that PM is being completed as scheduled and that CM (particularly high-priority work) is done in a timely manner. It is futile to issue work orders if no mechanism for tracking them is built into either a manual or an automated system.

Accountability for Resources Expended. The importance of readily available, up-to-date information on resource usage is increasing. Data on utilization of labor and material help to justify additional personnel, increased supplies of spare parts or material, or labor-saving tools and equipment.

Maintenance History. A method for tracking the maintenance history of equipment and structures is a fundamental part of an effective maintenance program. This function keeps a record of all corrective maintenance tasks completed, and PM tasks are tracked for a period of one to three years, depending on the utility's PM cycle.

The need for a history of equipment and structures such as pipelines may be obvious, because it will provide vital information in such areas as equipment reliability and replacement. However, accurate records are also important, particularly for cost control, to track the work of building maintenance personnel such as painters and carpenters. The manager of the building group will find such data very useful during the preparation of the department's annual budget.

The elements listed in this section form the basis for a system that will provide efficient, reliable control of maintenance activities. The most important of these elements, with a critical role in consistent water processing and extensive links to other elements, is a consistent PM program.

Preventive Maintenance

For a water utility, the foundation of a successful maintenance program is preventive maintenance. Effective PM enables field technicians to limit time spent on corrective maintenance, resulting in a significant increase in productivity through effective planning. While this relationship is most easily verified for equipment maintenance activities, it is also true for pipeline maintenance work. For example, an article in AWWA's *Opflow* magazine related the positive experience of one utility when it embarked on a valve exercising program (Nayer et al. 2008). Regular maintenance of distribution system valves simplifies the work of pipeline repair crews, as does periodic updating of system maps. Certainly, quick identification of the location of valves during an emergency, for example, a water main break, will likely reduce the number of customers negatively affected as well as the amount of water lost.

For equipment maintenance, equipment reliability is substantially improved by the introduction of a PM program for treatment plant and pumping equipment. PM is characterized by consistent, timely completion of regular maintenance tasks, according to guidelines composed of three primary components: documented procedures, a clear schedule, and regular follow-up. Brady (2010) explained why regular maintenance is important in an *Opflow* article: "If properly operated and maintained, pumps can provide decades of efficient and reliable service." He also noted that pumps represent a significant portion of a utility's equipment investment and discussed major elements of an effective pump maintenance program.

Maintenance Procedures. The first activity in planning PM is to establish the tasks that must be performed on each piece of equipment. The usual sources of information include

- equipment operations and maintenance manuals,
- other product information from equipment manufacturers, and
- experience of plant maintenance personnel.

Task specification must include the PM cycle. Normally, tasks are categorized as daily, weekly, monthly, quarterly, semiannual, or annual activities. Each PM task must be described in a detailed maintenance procedure (MP).

Documentation of procedures aids in training new employees, helping them to follow correct sequences and complete all required tasks, and ensures uniformity in the performance of PM tasks. Figures 3-1, 3-2, and 3-3 are checklists of typical maintenance procedures. These checklists identify specific PM tasks to be performed on the flexible coupling of a filtrate pump, on a motor control center, and on a slip-ring motor.

Note that the first of these procedures was developed for an automated system, whereas the other two are used within a manually operated system. The MP sheet for the automated system includes:

- A description of the maintenance task, the name of the equipment or structure, and its location
- The PM cycle and its estimated completion time
- All skills or trades needed, as well as tools and safety precautions
- Complete work instructions

The maintenance procedure sheet for a manual system can be simplified by excluding data on completion time, skills, and tools needed.

PM Schedule. Information from the procedure descriptions allows preparation of the PM schedule. Typically, the schedule is developed annually, guided by several considerations:

- The workload should be balanced.
- For especially expensive or critical equipment, running time, not lapsed time, should be used to schedule PM.
- Since labor may be limited, critical tasks and components are identified and fitted into the schedule first.
- The schedule should be monitored and revised if necessary, at least on an annual basis. Figure 3-4 gives an example of an annual PM schedule developed for a water filtration plant as part of a manually operated PM program.

Preventive Maintenance Procedure

EQUIPMENT NAME AVERAGE TIME _______ MINUTES

Flexible Coupling, Motor Filtrate Pump

PLANT AREA	LEVEL	LOCATION
Secondary	Ground	Dewatering

MAINTENANCE DESCRIPTION

Inspect coupling

SAFETY PRECAUTIONS

Observe standard safety precautions
De-energize unit, lock and tag "out of service"

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Rags
Safety tag
Adjustable wrench
Screwdriver
Hammer

PROCEDURE

Preliminary—De-energize unit, log and tag "out of service"
To inspect coupling:

1. Remove cover on coupling.
2. Slide coupling apart.
3. Remove rubber spider and inspect for wear, deterioration, and breaks.
4. Check both halves of coupling for wear and damage.
5. Replace rubber spider and slide coupling together.
6. Put cover back and bolt down.
7. Remove lock and safety tag and return to service.

Figure 3-1 Maintenance procedure for flexible coupling of a motor filtrate pump

Preventive Maintenance Checklist

Work Request No. | Interval: Annual

Equipment Name: Motor control centers | Equipment Type: 51

Facility: | Bldg/Room. | Motor No.

OK	Not OK	
		1. De-energize all circuits before working in equipment.
		2. Clean interior by vacuuming.
		3. Replace badly worn contacts as quickly as possible.
		4. Do not sand silver cadmium contact points of line starters. In the event of wear, replace all contacts to avoid misalignment problems.
		5. Inspect all bolts, nuts, and screws for tightness.
		6. Inspect all wiring for signs of damage.
		7. Examine the insulation system for evidence of heating.
		8. Open all hinged panels; remove all bolted panels to thoroughly inspect all internal devices, and clean.
		9. Check instantaneous trip on breakers to verify that settings agree with specifications.
		10. Never lubricate any part of an electrical device.
		11. Change all indicating light bulbs.

DO NOT USE emery paper, sandpaper, or a file cloth to clean or dress up any portion of the electrical equipment.

Completed by: | Date:

Crew No.: | No. of Workers: | No. of Hours:

Figure 3-2 Preventive maintenance checklist—motor control centers

Preventive Maintenance Checklist		
Work Request No.	Interval: Semiannually	
Equipment Name: Motor with slip-rings	Equipment Type: 12	
Facility:	Bldg/Room.	Motor No.

OK	**Not OK**	
		1. Clean motor thoroughly, blowing out dirt from windings.
		2. Inspect and tighten connections on motor and controls.
		3. Run motor and examine drive critically for smooth running.
		4. See that all covers and guards are in good order.
		5. Inspect brushes to confirm the following: a. Pig-tail shunts are properly attached to brushes and holders. b. Correct tension is maintained as brushes wear. c. Worn-out brushes are replaced before they reach their limit of travel and break contact with the slip-rings or cut out due to contact with the metal brush shunt clip. d. Newly installed brushes are fully seated and free in the brush holder. e. "Sanding-in" allows full contact with the slip-ring.
		6. Check for excessive brush movement, brush chattering, and brush chipping.

DO NOT USE emery cloth or emery paper to seat brushes.		
Completed by:		Date:
Crew No.:	No. of Workers:	No. of Hours:

Figure 3-3 Preventive maintenance checklist—motor with slip-rings

Preventive Maintenance Schedule

175-mgd Water Filtration Plant

MONTH/TASK	INTERVAL
JANUARY	
Alkaline Batteries	Monthly
Lead Acid Batteries	Monthly
Emergency Lighting	Monthly
Indicating Lights	Monthly
Brushless Motors, Group B & C	Quarterly/Monthly
Slip-Ring Motors	Quarterly/Monthly
Rectifiers	Quarterly/Monthly
Kingsbury Bearing Cooling Water System	Quarterly
Transfer Switches MCC-1	Quarterly
Motor Control Center A	Semiannual
FEBRUARY	
Switchgear	Semiannual
Alkaline Batteries	Monthly
Lead Acid Batteries	Monthly
Emergency Lighting	Monthly
Indicating Lights	Monthly
Slip-Ring Motors	Monthly
Rectifiers	Monthly
Brushless Motors, Group B & D	Semiannual/Monthly
Motor Control Center B	Semiannual
5 kV Switchgear	Semiannual
MARCH	
Alkaline Batteries	Monthly
Lead Acid Batteries	Monthly
Brushless Motors, Group B	Monthly
Emergency Lighting	Monthly
Indicating Lights	Monthly
Slip-Ring Motors	Monthly
Rectifiers	Quarterly/Monthly
Traveling Screens	Semiannual
APRIL	
Alkaline Batteries	Monthly
Lead Acid Batteries	Monthly
Emergency Lighting	Monthly
Indicating Lights	Monthly
Brushless Motors, Group B & C	Quarterly/Monthly
Slip-Ring Motors	Quarterly/Monthly
Rectifiers	Quarterly/Monthly
Kingsbury Bearing Cooling Water System	Quarterly
Transfer Switches MCC-1	Quarterly

Figure 3-4 Preventive maintenance schedule—175-mgd Water Filtration Plant

Follow-up Techniques. PM tends to be a routine activity that is easy to overlook. An effective PM program requires methods (1) to ensure that PM tasks are completed as required and (2) to measure program effectiveness. Utilities implement several techniques for monitoring the PM components of their maintenance programs. Methods for tracking both PM and CM work are given in chapter 4.

Maintenance System Enhancements

The program for managing the maintenance function can be designed to include a number of features in addition to those described so far. The long list of potential enhancements can be summarized in the following categories.

Inventory Control Systems. A basic maintenance system need not include a system for controlling parts and materials inventory. For example, PM and CM tasks can be performed on a motor control without detailed data on its components, but a parts warehouse cannot be set up without knowledge of the breakers, relays, and protective devices that make up the unit. If the maintenance group maintains its own inventory of spare parts and materials, the data collection effort needed to prepare the equipment history files must be extended to include all significant parts. This investigation will require an extensive effort, and it may delay the implementation of the maintenance system. Inventory management will be considered further in chapter 5.

Purchasing. A maintenance system can be designed to interface with inventory and work order systems to generate purchase orders. If the utility does not have a centralized purchasing function, purchasing procedures must be considered in the development of the maintenance program. A large utility likely operates a separate purchasing department, so primary responsibility of the maintenance manager for this function is limited to communicating the needs of the maintenance section to the appropriate personnel in the purchasing group.

Planning is equally important to anticipate the needs of the department early enough for purchasing staff to fill orders. Maintenance department personnel cannot expect purchasing agents to know which parts are in high demand and which are hard to obtain. Proper communication is usually the way to make the right parts available at the right time.

Predictive Maintenance. The predictive maintenance (PDM) approach emphasizes continuous monitoring of equipment condition. The information learned from PDM monitoring allows evaluation of trends to determine a machine's current status. PDM differs from the focus on regular intervals in preventive maintenance; PM tasks are completed at predetermined intervals recommended by manufacturers or in-house maintenance staff, even for normally operating equipment, whereas PDM tasks result in additional maintenance work only if an unusual condition is detected in the equipment.

The primary function of PDM (also called condition monitoring) is to obtain information representing the condition of a machine without interrupting its operation. Without PDM, virtually the only method of determining a machine's condition is disassembly. A comprehensive PDM program might include a number of monitoring methods:

- Oil analysis—Laboratory analysis of samples from the machine's lubricating oil looks for the presence of components indicating wear (such as chrome, lead, tin, etc.) and for contamination such as water.
- Vibration monitoring—This procedure is implemented by comparing current vibration measurements against the machine's "as new" vibration signature, obtained when the equipment is first started up or through standards of ASTM International or a combination of both. Vibration monitors can be installed to gather data continuously, leading to automatic generation of work orders if vibration readings range outside acceptable limits.
- Thermographic imaging—This technique plots measurements of the heat emitted by objects to compose a visible picture that the operator of the imaging equipment can interpret to identify problem areas. This technique may evaluate motors, gear reducers, pumps, and other equipment in which a problem bearing, for example, would heat up more than a similar bearing without a problem. Similarly, a three-phase motor with one phase stressed would display uneven heating. Thermographic imaging is also very useful in scanning electrical motor control centers and distribution panels for poor connections and other problems that cause hot spots. Identified problem areas can be investigated and corrected

prior to failure or interruption of electrical service.

- Electrical testing—This process involves two general methods. Traditional high-potential testing can identify poor insulation conditions in both the wiring between a motor control center and the motor itself. New, proprietary diagnostic testers for motors can perform these tests plus identify other problems that can occur within a motor, such as loose or broken rotor bars or winding faults.
- Ultrasound testing—Another useful monitoring technique, ultrasound testing, can evaluate equipment condition in a number of different ways. Essentially, an ultrasonic tester can be described as an electronic stethoscope. Bearing sounds are evaluated in order to determine if the races are dry or wear has begun but has not yet caused a vibration problem. Piping joints and valves can be scanned for leaks, and electrical equipment can also be scanned for faults and leaks.

Some organizations have begun to modify their preventive maintenance program to directly include PDM methods in their PM job plans. For example, a PM task that initially called for the oil to be changed at a specified interval, say six months, or at a specified number of running hours, will be modified to require testing of the oil first to determine its condition before a change is performed. This strategy is particularly cost-effective for equipment with large reservoirs. Similar principles might be used when motors are to be checked as part of a PM task. The procedure described in Figure 3-3 includes tightening connections on the motor and its controls. A more prudent approach may be to perform an infrared scan before actually working directly on the equipment.

Performance and Productivity Reporting. A number of organizations have incorporated performance and productivity information into their maintenance management programs.

Obtaining this information does require the establishment of work standards, which can be a costly and time-consuming process, particularly for electrical/mechanical work, and thus equipment maintenance work in general. In addition, processing of such data will almost certainly require use of a computer. It is advisable to consider adding utilization reporting only in the later phases of the maintenance program, and then only after a careful cost–benefit analysis.

Management Reports. Management reports allow for system control, making them essential components of a successful maintenance program. Once a database is established, additional reports can be prepared by and for the maintenance manager, particularly if the record keeping uses an automated system. These reports are useful not only to the maintenance department manager but also to operations and senior utility managers. Managers at all levels will almost certainly request supplementary reports as experience with the system grows.

Integration with Business Applications. Maintenance management systems, for example, IBM's Maximo,® can be integrated with business applications like Oracle E-Business Suite® or SAP using prebuilt adapters. The integration provides real-time information exchange between the MMS and modules in the business application such as General Ledger, Purchasing, Inventory, Human Resources, and Projects. The business benefits of this bidirectional connectivity are automation of business processes across the organization, improved efficiency because data collection is minimized, and increased accuracy due to the utilization of current data. The implementation of this level of technical sophistication is likely limited to large organizations, and then only when the key elements of the MMS are firmly established.

Planning the System

Once the manager of a maintenance group identifies a need for changes within the organization to improve its effectiveness, the next step is to convince senior management that the project, and the funds needed to implement the modifications, are justified.

Gaining Management Approval

One of the primary responsibilities of the maintenance manager is to provide for reliable equipment operation, a goal that cannot be achieved without a well-planned maintenance program. As part of this planning, the maintenance manager must be prepared to present solid evidence that improved equipment and process reliability provides monetary benefits to the utility. Upper management may well acknowledge the importance of dependable equipment operations, but this belief alone may be inadequate to justify the expenditures necessary to establish or modify a maintenance program. Valuable clarification may come from considering some of the ways effective maintenance management contributes to smoother operation of the water utility.

Fortunately, a number of valid reasons support implementing a program of improved maintenance. Some are subjective in nature; while they are accepted benefits of improved maintenance practices, they cannot easily be assigned a value in terms of cost savings. Other results of planned maintenance allow quantitative evaluation.

Subjective Benefits. Two of the most important subjective justifications for system improvements affect the mechanics doing the field maintenance work. The first of these is safety. If breakdown maintenance is the normal mode of caring for equipment, field crews are frequently working under pressure to return equipment to service as quickly as possible. Clearly, employee safety may be compromised in this situation, with an increase in the accident rate as a result. While an effective maintenance program will not (and should not) completely eliminate emergency equipment repairs, it will reduce their frequency, and a safer environment will result.

This same principle holds true for pipeline maintenance crews, despite their frequent involvement in emergency repairs. The work of these crews is difficult in any case, but if valves are inoperable or impossible to locate, their work becomes substantially more time-consuming, and because of pressures to complete repairs quickly, more hazardous.

The morale of maintenance personnel will deteriorate if they are constantly rushing to "put out fires" rather than completing their work in an orderly manner. Any maintenance supervisor knows how frustrated an equipment crew feels when they arrive at a job, lay out the tools and spare parts needed, and begin work, only to be called to an emergency elsewhere. The group manager may eventually lose the respect of the field mechanics if steps are not taken to limit the number of emergency jobs.

Other subjective reasons for improving maintenance management involve the operation of the plant and its equipment. Large maintenance organizations find few sources of information necessary to control operations if it is not generated by the MMS. Senior management recognizes the need for and insists upon accurate data, and only a good MMS will enable this information to be gathered.

Objective Benefits. Planned maintenance results in a number of quantifiable gains:

- Reduced breakdowns
- Decreased equipment downtime
- Increased equipment life
- Reduced personnel needs (over time)

An effective maintenance system may generate measurable gains of these kinds only over several years. In fact, the maintenance costs often rise as an MMS is being established, until the quantifiable benefits begin to reflect program effectiveness. However, their inherent value is clear, and they form an important part of the argument for taking a fresh look at the maintenance operation.

Justifications for such a program may cite estimates of savings in labor costs through increased productivity that will result from the new maintenance program. Implementation of PM and increased control of maintenance activities are the primary methods for improving productivity. A conservative estimate of a typical increase is 5 percent. In one example, reductions in staff of 6–8 percent were realized despite the addition of approximately 5,000 PM work orders per year within three years of the start of the maintenance management program.

The experience of other organizations has been similar. Savings can also be expected in costs for overtime, material usage, and outside contractors.

Finally, computerized maintenance management software packages have resulted in a dramatic reduction in the cost of implementing an effective program. The cost of installing an automated system to support the maintenance group is no longer prohibitively high, as it once was. An effective maintenance program is within the reach of virtually every maintenance group. Equally important, the maintenance manager can present sound reasons for undertaking the effort.

After approval is given to fund the project, the next step is to determine what action steps need to be taken to plan and implement the program.

Planning Team

Once senior management approves a maintenance manager's proposal for an evaluation of the maintenance program, the next step is to form the planning team. This group develops specific information on proposed modifications to the maintenance department.

The team needs technical and financial capabilities with inputs from other departments, including purchasing, personnel, and information technology. In addition, the makeup of the team depends on the particular maintenance activities to be addressed. For example, if a team is studying the maintenance needs of filtration plants and pumping stations, it should include an equipment maintenance specialist. A civil engineer with experience with distribution system valves is a good candidate for investigating the requirements for pipeline maintenance.

A team to evaluate an equipment maintenance system may require the following members:

- Financial analyst—This position could be filled by either someone from the utility's financial department, someone from the maintenance department itself, or an independent consultant. This individual would be responsible for investigating implementation costs and carrying out cost–benefit analysis if required.
- Maintenance engineer—This individual should be a member of the maintenance department who understands its operations. Responsibilities include developing the technical needs of the department with respect to maintenance activities and coordinating activities with those of other departments. This person is a good candidate for team leader.
- Senior maintenance technician—An experienced field person, either a line supervisor or a crew leader, should be part of the team in order to provide guidance with respect to the practicality of implementing any proposed change. Any additional paperwork requirement, for example, inevitably causes negative reactions from technicians unless the need is explained and justified.
- Operations representative—For a team developing distribution and plant equipment maintenance systems, a representative from the operations group is very important, because operations personnel may carry out minor maintenance tasks and report on problems. This member helps the team resolve any disagreement on responsibility prior to system installation.

This proposed team composition represents one scenario for planning the maintenance system. Such a team may, however, be unnecessary for a small water utility or if only modest changes in the operation are being considered. The important point is that modifications to the functions of the maintenance department must be carefully planned.

Implementation Steps

The first task of the planning team is to agree on the steps that need to be taken to implement the new maintenance system. The following steps should be part of any program, whatever its magnitude:

- Determine what should be done, that is, complete a needs assessment.
- Design the maintenance system, integrating current procedures with proposed changes.
- Establish an implementation schedule.
- Determine training needs.
- If necessary, test proposed changes on a small scale.
- Implement the system.
- Evaluate the effectiveness of the new system.

These steps will help to establish an orderly process for the team and set a standard by which they can measure their progress.

Needs Assessment

The team should begin the assessment by agreeing on a description of the present program, its strengths and weaknesses, and the kind of system needed to satisfy the needs of the maintenance function. For example, is the work order system adequate? Does it allow collection of the right information? Does it permit easy follow-up for monitoring purposes?

One of the first steps that should be taken is to identify several characteristics of the organization:

- Plant size
- Staffing and skill levels available
- Complexity of plant operation
- Size of distribution network
- Variety and number of pieces of equipment

- Available budget for development and implementation
- Number of sites

The planning team also should evaluate the maintenance system's needs for each of the following factors:

- Institutional support—How will senior management be involved in the program?
- System maintenance—Are responsibilities for maintenance tasks well defined?
- Spare parts/material—Is the supply of spare parts adequate? Is coordination between maintenance, purchasing, and warehousing satisfactory?
- Logistics—Are the number and type of vehicles available for maintenance sufficient to support any program changes?
- Finance—What level of funding is available to support changes in maintenance operations?
- Records—What records are needed, and can they be obtained through current data-collection techniques?
- Human resources and training—Are existing training programs adequate? Is staffing available to support modifications in current operations?

One approach is to prepare a list of issues that need to be resolved for each factor. The planning team may need to consider additional issues.

After reaching consensus on potential solutions to problems identified as a result of this exercise, the team may see a need to prioritize proposed modifications to the maintenance system. In any case, funding limitations may force the team to consider a phased implementation schedule spread out over several years.

Certainly one major issue facing the team will be the question of using computers, or at least, where the use of computers is justified to facilitate operations.

Automated and Manual Maintenance Information Systems

A small- to medium-sized water utility operating a single treatment facility can realistically expect to achieve satisfactory maintenance with a manual information system. However, a maintenance group responsible for a large utility or multiple facilities will require an automated system to gather and report the information necessary to control the maintenance effort. For example, substantial clerical effort would be needed to manually gather data on labor hours devoted to preventive versus corrective maintenance or on the cost of maintenance. Yet, today's maintenance managers cannot do their jobs without this type of data. A computer system enables the manager to receive frequent updates on the operation, allowing early identification of potential problems, so they can be corrected before they become more serious.

The choice between automated or manual maintenance systems comes up quite frequently. As noted in chapter 1, relatively inexpensive desktop computers and off-the-shelf software have made automation a reasonable alternative for water utilities regardless of size. Low-cost software may not be able to perform all desirable functions; a module that includes inventory control may be purchased for several thousand dollars.

After making an initial determination of where computers could fit into the maintenance operation, the planning team should conduct a search of available software to determine if a package exists that will satisfy their requirements. Example applications of automation appear throughout this book, particularly in the chapters dealing with information processing. The book's discussion of automated maintenance management systems proposes alternatives for the planning team to consider in view of their particular circumstances.

References

Brady, J.M. 2010. Pump maintenance ensures reliable, efficient operation. *Opflow*. 36(2):14–18.

Nayer, S.B., L.R. Carson, and P. Olson Sr. 2008. Exercising valves boosts system performance. *Opflow*. 34(8):14–16.

CHAPTER 4

Information Management and System Monitoring

Accurate, timely information is essential for effective maintenance management. Consequently, one of the first steps for a team planning a new system is to assess the completeness and correctness of data currently on file for the utility's equipment, pipelines, and buildings.

Equipment and Structure Records

Important information needs relate to equipment used to process and treat water and to pipelines and valves that make up the distribution network. Recording this information serves two purposes: retaining data on hardware (equipment and structures) specifications and keeping a written record of maintenance activities. If the planning team determines that data about equipment specifications are not available or are incomplete, then gathering this data is the first task when implementing a maintenance program. This component of a maintenance management system (MMS) is usually described under the general topic of asset management.

Water System Inventory

A maintenance department cannot operate without information on the hardware that it is required to maintain. Therefore, the maintenance manager should begin to gather the necessary data (if they are not available) even before senior management have approved modifications to the maintenance program or the formation of a planning team.

In fact, because gathering this data may be a lengthy process, it is wise to begin this task early. In-house staff can gather the necessary information if enough time is provided. They can record data as they carry out their normal activities or during slack periods. This process could save funds and take advantage of the knowledge and experience of field personnel. Before beginning this task, however, the manager needs to decide what hardware to inventory first, what data to record, and finally, how to file this information.

Equipment Inventory. The first priority for the inventory is equipment critical to the water treatment and delivery process. Special consideration should be given to such equipment that is not supported by standby capability. The data collected include the following:

- Manufacturer and local supplier
- Dates of purchase and installation
- Model name, number, and serial number
- Physical location and GIS coordinates
- Specifications

This information is recorded on an appropriate data sheet, such as the one shown in Figure 4-1 for electric motors. The data sheet then becomes the first entry into the equipment data file as well as the source for the basic information needed to implement an automated maintenance information system. This information can also be entered directly into a portable computer for eventual downloading into the equipment data file.

Distribution System Inventory. Many water utilities use maps to record inventory data on their distribution systems. These maps show the locations of pipelines and water valves on the basis of grid systems. A map book shows distribution network features, and detailed maps for sections of the system show pipeline sizes and the locations of valves and hydrants with respect to nearby landmarks. Field crews can use

Equipment Data Sheet
Electric Motors

Identification	**Location**
Name: ______	Zone: ______
ID #: ______	Site: ______
Model Name: ______	Process: ______
Model No.: ______	______
Serial No.: ______	Installation date: ______
Specifications	**Acquisition**
Motor Type: ______	Date Purchased: ______
Horsepower: ______	P.O./Contract No.: ______
Volts: ______ Amps: ______	Manufacturer: ______
Phases: ______ RPM: ______	______
Power Source: ______	______
Utility: ______	Local Suppliers:
Feeder No: ______	______
Driven Unit: ______	______
ID No.: ______	______

Other Information

______

______

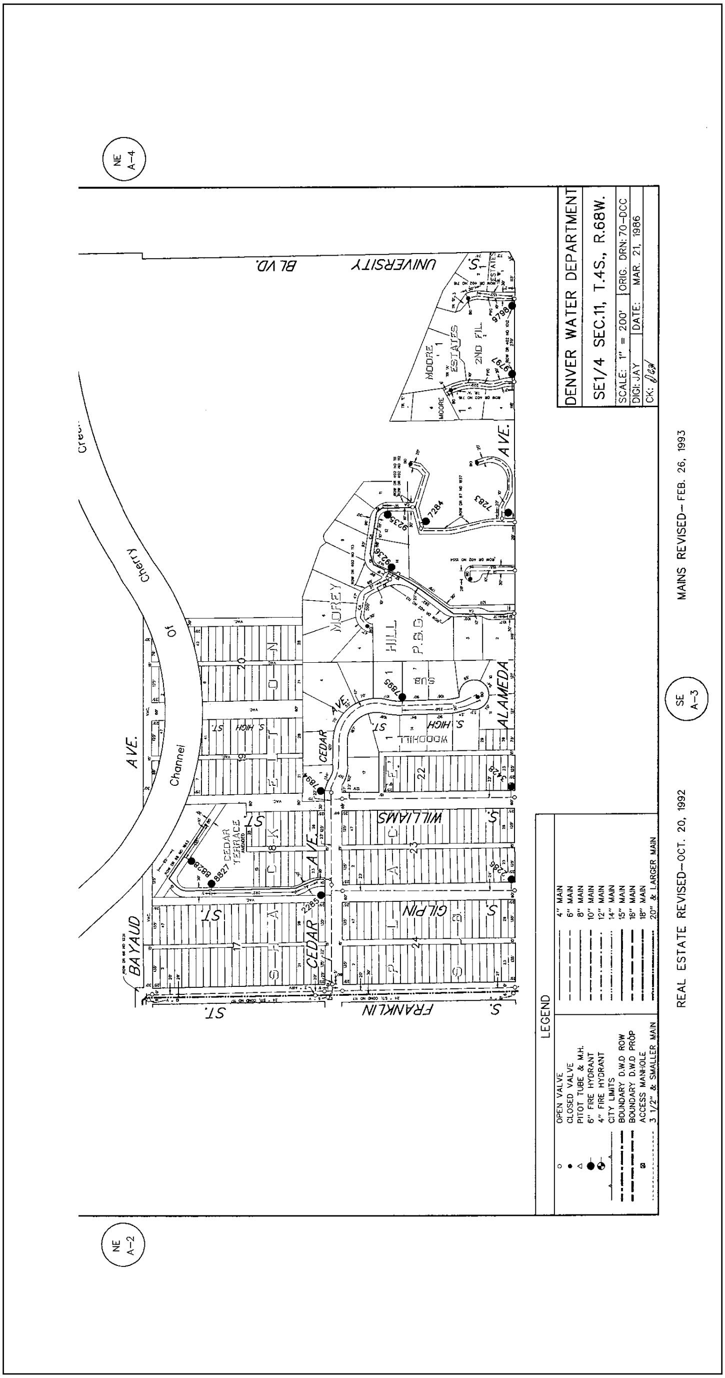
______

______

Figure 4-1 Equipment data sheet—electric motors

these books to locate valves when they need to isolate sections of the distribution system, for example, to allow repairs to a water main. An example from a distribution system map book is shown in Figure 4-2.

Many utilities are now computerizing these records to develop databases incorporating their mapping systems. Geographic information systems (GIS) are being used by many larger utilities to track their distribution networks. Converting paper records to a GIS is a major



Source: Courtesy of Denver Water.

Figure 4-2 System map with maintenance information undertaking (Singer 2008); however, once complete, GIS makes maintaining distribution system information significantly easier. Field crews can access GIS files from their service vehicles via a laptop or other mobile device—a particular advantage when it comes to emergency response. In addition, after automating the mapping system, minimal effort is required to update the master file to reflect system changes. An additional advantage of GIS is its ability to accurately locate distribution system components during natural disasters such as flooding, hurricanes, and tornadoes that may have destroyed or misplaced landmarks. GIS technology can also be used to track plant equipment. For example, staff can use GIS to assist in an asset management program by identifying important pieces of plant equipment and linking them with inventory information, including CAD drawings and photos (Simmons et al. 2009).

Water Meters. Water meters are a special case, because they are important to the revenue of the utility and their preventive maintenance (PM) cycles are measured in years rather than in weeks or months. Maintenance of water meters is frequently handled by a separate group, particularly for a larger utility. Still, the system for carrying out their maintenance is similar to that for other water utility equipment.

Fire Hydrants. Clearly, fire hydrants are an integral part of the service provided by a water utility, and they must be included as part of the inventory. Data to be collected include location, manufacturer, size, and date placed in service. Locations can best be identified using the mapping system described earlier or, because hydrants stand aboveground, by citing intersecting roads to give approximate locations.

Equipment Files

Collected system inventory data are filed in equipment history files along with the following:

- Operations and maintenance manuals
- History of corrective maintenance (CM) activities
- Records of preventive maintenance (PM) requirements

Equipment Identification Number

The identification (ID) number for a piece of equipment ties together the information contained in its record file. Utilities use a variety of numbering schemes to identify electrical and mechanical equipment. Some number equipment sequentially as each piece is inventoried, while others develop more complex methods in which, for example, the location, process type, and particular unit can be categorized.

Because the ID number has a significant effect on the development of management reports and the availability of data for other purposes (e.g., parts inventory), the planning team should take the time initially to establish a suitable numbering scheme for their utility. The sequential numbering technique, though easy to implement, is not likely to satisfy the needs of maintenance management, particularly for an automated information system, because the ability to sort data by equipment type or location or process would not be possible.

For example, a utility with a number of plant and pumping station sites might define a scheme in which

- the first three digits specify the site of the equipment
- the second two digits specify the equipment type
- the third two digits specify the process type
- the last digit specifies the particular piece of equipment

In such a scheme, the ID number for the electric motor driving finished water pump no. 2 might be 001–13–03–2. This method is as detailed as any water utility is likely to need.

The number of digits used for each category could be expanded or contracted depending on the size of the utility's operations. A small utility with one plant site, for example, could use fewer digits.

Other utilities, whatever their size, should consider their data needs and adopt ID systems suitable for their purposes. In any case, the planning team should begin with a system that accommodates an automated maintenance information system and allows possibilities for future system expansion, even if initial plans call for a manual MMS.

Distribution System Files

Similar records must be kept for valves, meters, and fire hydrants. These records are managed in the same manner as are those for plant equipment. Conversely, records for the distribution system focus on a history of CM work. This information helps to identify sections of the distribution system that are particularly prone to breaks and should be considered for replacement. As noted, GIS technology can facilitate the tracking of corrective and preventive maintenance activities related to the distribution system.

Work Order Systems

One of the prime requisites for an effective information system for maintenance management is a work order system covering all work done by maintenance department personnel. For example, tracking PM work is virtually impossible without work orders. In addition, work orders provide the data required to build the history segment of an equipment file.

Each of the maintenance functions described in chapter 1 has different requirements for a work order system. For example, most requests for maintenance of the distribution system originate from customers or the general public via the telephone. In addition, action taken to respond to the call is generally apparent, for example, repairs to a leaking valve or flushing a fire hydrant to resolve a cloudy water situation.

On the other hand, reports of problems to the equipment maintenance group generally originate within the utility itself. Equipment repair activities often are not readily apparent, so the work order system should incorporate a means of reporting back to the department or individual that reported the problem.

Work order systems are also needed for buildings and grounds (B&G) maintenance activities. Since requests for these services usually originate within the utility, information requirements are similar to those for equipment maintenance. Note, however, that this group is normally responsible for the grounds maintenance, and if this work is not carried out in a timely manner, complaints will come from the public. The work order system should, therefore, be designed to handle this type of situation.

All work order systems must be tailored in order to effectively support particular maintenance activities. Priorities vary for manual and automated work order systems.

Manual Work Order Systems

Manual work order systems can be implemented for all types of water utilities irrespective of size. Manual systems have several advantages compared to automated systems.

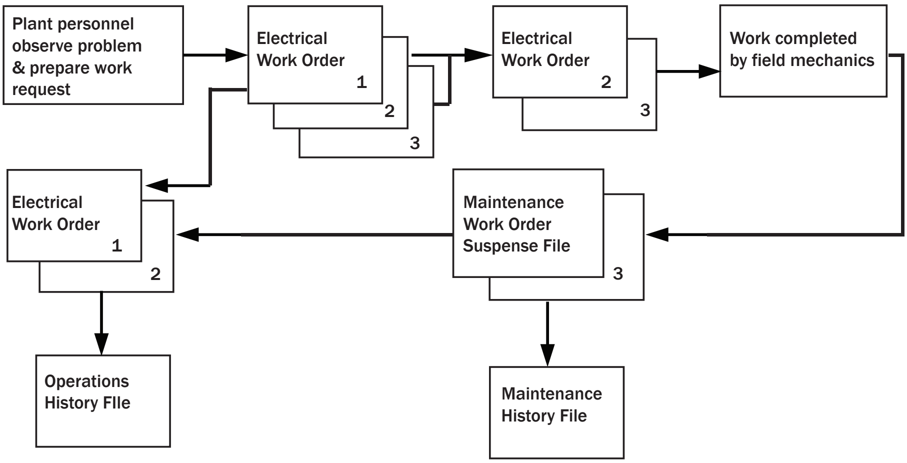
- They can be developed in-house.
- They can be implemented quickly.
- They are relatively inexpensive to develop.
- They can be designed for conversion to automated systems when appropriate.

The disadvantages of manual systems are particularly serious for large systems.

- A manual system is impractical for covering all equipment in a PM program.
- Logistics limits the number of management reports that can be prepared from data generated by a manual system.
- Information in the history segment of the equipment file is difficult to use.

The first step in the development of a manual work order system is to determine how information will flow from the time a problem is reported or a need for work is identified until all work related to the work order is completed. For example, how will operations personnel complete equipment maintenance work? Can PM and CM work be covered by the same form? Will the work order system facilitate tracking work?

Figure 4-3 shows a flowchart of the manual work order system used by one water utility for its equipment maintenance activities. This system is focused on nonemergency CM, but with some modifications to handle different information flows and originators of work, the same work order can be used to handle emergency and PM work. The work order form shown in Figures 4-4 and 4-5 can accommodate PM work by discarding copy 1 of the three-part form; the system can accommodate emergency work by issuing field mechanics a field work order with the same work request number shown in the upper right-hand corner of the work order in Figure 4-4. Information from the field work order is entered on the main work order form when it is received from operations personnel. This approach enables operations to receive the same information feedback as they would for nonemergency work.



Electrical Work Order Log

Work Order Number	Date Received	Priority	Work Request Number	Work Description	Location	Labor Hours	Date Finished
12006	6/16	1	32440 26182	Inspect noisy bearing No. 1 pump motor	Mont Alto WPS	8	6/17
12007	7/17	3	26182	Replace No. 2 compressor fan belt	Finished water building	2	7/23

Note: Operations can discard copy 1 because copy 2 shows work done plus the data of the top part of copy 1.

Figure 4-3 Corrective maintenance work order flow and work order logbook

To enable tracking of work orders, each work request is assigned a work order number, which is entered into a work order logbook. An excerpt from the logbook is given in Figure 4-3. When work is completed, the work order is closed out in the logbook. Regular reviews of the logbook enable management to pinpoint maintenance tasks, both CM and PM, that are not being completed in a timely manner.

<table>
<tr><th colspan="5">Equipment Maintenance Work Order</th></tr>
<tr><td colspan="5">INSTRUCTIONS: Keep first copy. For emergency work, give copies 2&3 directly to electrical field supervisor. For lower priorities, send copies 2&3 to office.</td></tr>
<tr><td>Equipment Name</td><td colspan="3">Location (facility name and building)</td><td>Work Request No. 32440</td></tr>
<tr><td>Equipment I.D. Code</td><td colspan="3">Work Required</td><td>Priority</td></tr>
<tr><td colspan="3">Indication of Trouble</td><td colspan="2">When Problem was Discovered
Starting ____ During Oper.
Stopping ____ During PM __</td></tr>
<tr><td colspan="3">Special Instructions</td><td colspan="2">Time Problem Observed</td></tr>
<tr><td>Reported By</td><td>Phone No.</td><td>Date of Report</td><td colspan="2"></td></tr>
<tr><td colspan="5">ELECTRICAL WORK REQUEST</td></tr>
</table>

Figure 4-4 Equipment maintenance work order—copy 1

However, in a large water utility, such an effort will consume a large amount of clerical time. Thus, the feasibility of using computers to manage the work order system must always be considered.

Automated Work Order Systems

Numerous computer-based systems have been developed to replace manual work order systems. For example, the *AWWA Source Book* provides information on a number of automated systems including those with maintenance applications under the Computer Hardware & Software category. *Maintenance Technology* magazine has provided similar information (Dahlberg 1999). A further source of this information is the Internet. A Google search identifies several sources for MMSs.

While not all of these systems are suited for use by a water utility, many can be adapted. Certainly, among the most important functions

<table>
<tr><th colspan="7">Equipment Maintenance Work Order</th></tr>
<tr><td>Reported By</td><td>Phone No.</td><td>Date of Report</td><td>Source Code</td><td>Account No.</td><td>Issued To:</td><td>Total Hours Used</td></tr>
<tr><td colspan="7">
<table>
<tr><td rowspan="2">Date Work Request Received</td><td colspan="2">Is Additional Work Required?</td><td colspan="2">Has Work Been Delayed?</td><td rowspan="2">Estimated Start Date</td></tr>
<tr><td>Yes___
No___</td><td>If yes, see work order</td><td>Yes___
No___</td><td>If yes, why?</td></tr>
</table>
</td></tr>
<tr><td colspan="7">Cause of Problem</td></tr>
<tr><td colspan="7">Work Performed

Date Repair Was Completed</td></tr>
<tr><td colspan="5">ELECTRICAL WORK REQUEST</td><td colspan="2">copy 2 – SUSPENSE</td></tr>
</table>

<table>
<tr><td>Reported By</td><td>Phone No.</td><td>Date of Report</td><td>Source Code</td><td>Account No.</td><td>Issued To:</td><td>Total Hours Used</td></tr>
</table>

<table>
<tr><th>Date</th><th>Crew No.</th><th>Work Done</th><th>No. of Workers</th><th>No. of Hours</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Completed by</td><td>Date Comp.</td><td colspan="2">Additional Work Required</td></tr>
<tr><td colspan="3">Note: List all parts or materials ordered on the back of this form.</td><td colspan="2">copy 3 – MECHANIC</td></tr>
</table>

Figure 4-5 Equipment maintenance work order—copies 2 and 3 (bottom section)

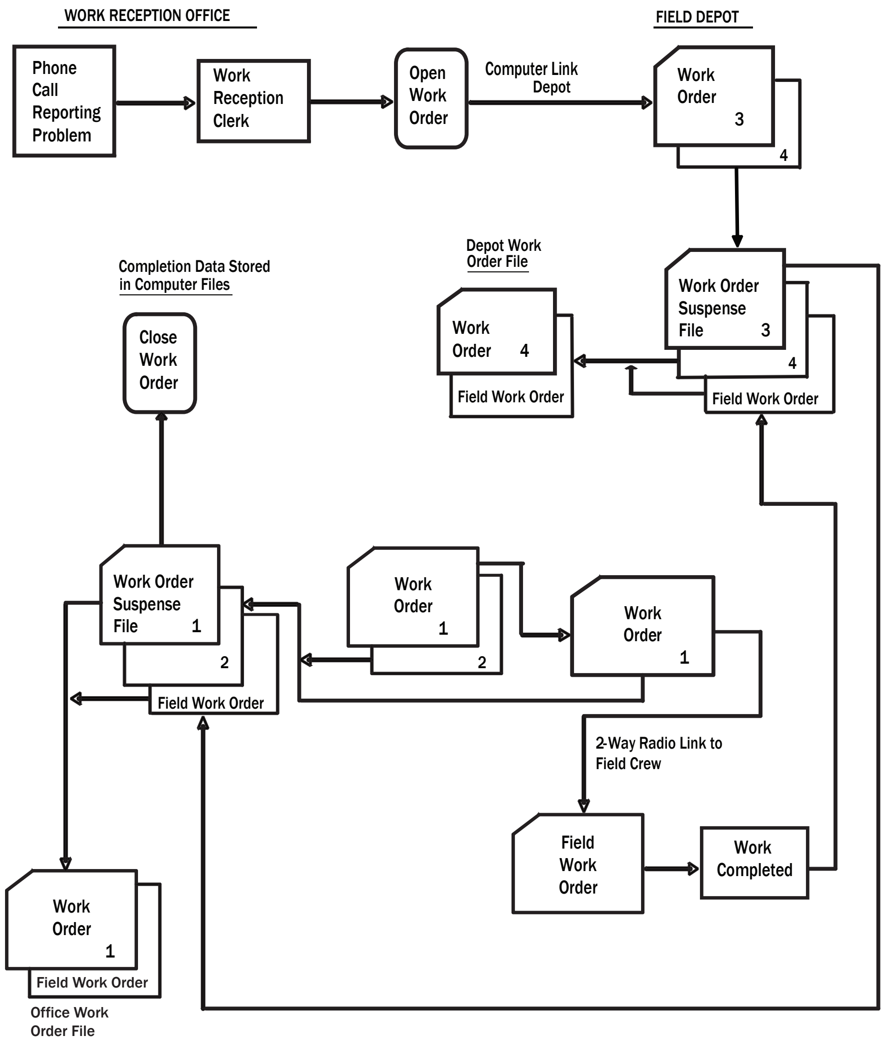
of the planning team are to decide if an automated system is justified and to determine what part of the maintenance information system should be automated.

As mentioned earlier, different maintenance functions require different approaches to carrying out their responsibilities, so different types of work orders may be needed to satisfy the particular requirements of a maintenance group. Figure 4-6 shows the flow of work orders in a maintenance section responsible for work on a distribution system. This system evolved over a period of time. It originally used the computer only to record data on work order activity. The next step toward automation was to print work orders at the central office. The current system prints work orders at the appropriate depots based on information entered by the work reception staff. The next step for this system may be to establish the capability to enter data to the work order file and to close out the work order from the depots.

The utility decided to maintain all customer files in one central area, so the field work order is delivered by internal mail to the work reception office. One reason for this decision is the need to ensure the utility's legal department easy access to customer files containing maintenance information. Also, work orders prepared and signed by field personnel must be retained in case of a need to defend against lawsuits involving, for example, alleged negligence by the utility.

Figure 4-7 shows the work order printed after the work order clerk enters the required information into a form displayed on a workstation monitor. The work order form is menu driven for ease of use by the clerk and to ensure that all entries are made, particularly if a telephone call from outside the utility is the source of a problem report. Various codes are used to identify the nature of the problem, its location, and the type of crew needed to respond to the problem.

All the information needed to produce the work order in this automated system could have been generated manually. The utility chose this system, however, because it allowed current staff to handle an increasing number of work orders. Also, automation met the need to manage a large amount of data.



Notes: 1. Copy 2 is not needed after Copy 1 returns from Radio Center and is discarded. 2. Field work order is used for emergency work only. Copy 4 replaces it for nonemergency work.

Figure 4-6 Work order flow—distribution system maintenance (emergency work)

8837008	204	INSPECT FOR POSSIBLE LEAK	P 09 C03	2/15/09	01	53	S	.4	01
work order #	wdc	work description	cty page grid	date rec'd	cr sz	cr tp	s/e	elapsed hrs	priority

711 WILLOWSHIRE RD		208NE01	15/108	60 237721 00 0	
Service address/location	c-code	200' sheet	lot/block	cust acct/comp id	resp co

Chambersburg	42	07	05	N	10601P		2/15/09
Locality	section	depot	subzone	billed work	account #	charge #	req'd start

J. Flacco	555-3521	1:25 pm	DAS			Insp. R. Jones
Initiator	phone	time rec'd	rec'd by	sc	miss utility	assignee

TIES	PKG 7 R OF R WALL	
ADD'L INFO	CALLED IN BY CHAMBERSBURG PUBLIC WORKS	
DATE	CREW #	WORK DONE

Completed by:	Date:

Copy 2 sent to office on: When Copy 2 or Field Ticket indicating job completed is sent to the office, no additional work may be done on this work order number.

Dispatch Copy: Work reception work order (perforation) Copy 1 schedule board

711 WILLOWSHIRE RD	8837008	10601P	INSPECT FOR POSSIBLE LEAK
Service address/location	work order #	account #	work description

Chambersburg	P 09 C03				
Locality	cty page grid	charge #	issue to	i.d. #	truck #

STOCK NO.	MATERIAL REQUISITION	STANDARD ISSUE	QUANTITY REQUESTED	QUANTITY ISSUED	QUANTITY USED

Crew chief signature	Crew chief i.d.	Date	Supervisor signature	Super i.d.	Date:

MATERIAL LIST	Warehouse retains yellow copy – white copy to maint. mgmt. div. when complete

Figure 4-7 Computer-generated work order—distribution system maintenance

Maintenance Work History

Criteria for Retaining/Discarding Work Orders

Since the number of work orders generated by any maintenance group is quite large, the planning team needs to consider carefully what information to retain in the maintenance history file. While the simplest method is to keep all work orders, this is not a good strategy in the long run. Sooner or later, the files will have to be purged of information that is no longer useful. In the interim, individual files will be difficult to use because of their bulk.

A better strategy is to establish criteria for retaining or disposing of completed work orders. Since the types of work carried out by the three maintenance sections covered in this handbook differ significantly, their needs for work order records will be reviewed separately.

Distribution System Maintenance Records. This group's work falls into three categories:

- Responses to customer complaints (e.g., cloudy water)
- PM on distribution equipment (e.g., valves, fire hydrants)
- CM unrelated to a specific customer facility (e.g., broken mainline pipes)
- The results of system evaluations and/or modeling projects

As a general rule, work orders related to customer complaints should be kept indefinitely, while those generated for PM work may be discarded after two to three cycles of the PM schedule are completed. For example, if the mainline valves are scheduled to be exercised yearly, then PM work orders covering this work may be discarded after, say, two years.

For work relating to particular customer facilities, the hard copies of work orders could be retained in the active history file for several years or until a particular problem is resolved. Renewing water service in response to a complaint concerning a water leak is an example. Work orders should then be transferred to the utility's archives for storage. In addition, if the utility's record system is automated, data on maintenance activities relating to a particular customer can be stored on a computer file for easy reference by service representatives. Figure 4-8 shows the output from a maintenance service history file.

12/20/07			CUSTOMER WORK ORDER HISTORY	
		ACC'T 60	237721 00 0	
WO NO	WORK DESCRIPTION	STATUS	REC'ED DATE	COMPLETED
9946629	REPAIR BROKEN MAIN	F	01/16/05	1/17/05
8807292	REPLACE METER—NR	F	06/15/01	6/15/01
6676126	SOD R/W	F	10/27/95	10/30/95
5577051	REPLACE METER—NR	F	08/26/95	10/26/95
3839289	REPLACE METER—NR INSIDE	F	06/13/91	06/15/91
3808516	REPLACE METER—NR INSIDE	F	09/01/83	09/05/83
3253812	CLR SEWER MAIN—SERV IN MANHOLE	F	04/21/83	04/21/83
2482107	INSPECT LEAKING HYDRANT	F	10/05/82	10/06/82
8678351	INSTALL METER NEW	F	12/19/78	12/23/78
8339474	INSTALL CURB BOX	F	09/20/78	09/27/78

Figure 4-8 Data printout from a maintenance service history file

For CM work on the distribution network, work orders should probably be retained for at least five to seven years after incidents occur or until the section of pipeline is replaced. Since this decision may have legal ramifications, the utility's legal advisors should be consulted before the criteria for disposal are established.

Evaluations, for example by outside consultants to assess the feasibility and cost of distribution system rehabilitation or replacement programs, need to be retained as reference guides for future system assessments.

Fire hydrants are a special case. Regular maintenance of fire hydrants is an essential task, and the utility must be able to demonstrate through its records that it has properly maintained its hydrants. The utility could be held liable if a hydrant does not operate resulting in serious damage or loss of life during a fire. Note also that fire hydrant maintenance programs have a direct impact on the fire protection rating of the communities and service areas they are in.

Equipment Maintenance Records. Most work done by the equipment group will be PM, if the maintenance system is operating effectively. Therefore, history files will need regular purging of older work orders to keep the size of the equipment file at a reasonable level. The same rules should apply for plant and pumping station equipment as for distribution system equipment. A summary report of the maintenance history of a particular piece of equipment can help supervisors to promptly answer questions regarding the work performed on that equipment. Figure 4-9 shows an example of this type of report.

For CM work orders, the best approach is to retain work orders resulting from normal wear for a period of two to three years. Those relating to unexpected wear should be held for an indefinite period. For example, if a defect in manufacturing is suspected, work orders relating to the equipment must be kept until the issue is resolved.

Once a piece of equipment is replaced, work orders relating to it can be discarded unless legal questions remain. Management may, however, want to retain the equipment file with a summary of the performance of the equipment noted for future reference.

Building and Grounds Maintenance Records. Records pertaining to the maintenance of building and grounds are primarily kept in order to schedule proper maintenance of the integrity and aesthetics of the utility's

CMMS REPORT RUN DATE 8/31/08

OVERVIEW OF PREVENTIVE MAINTENANCE WORK ORDERS

PRIMARY PROCESS—CLARIFIER 12

WO NO	WORK ORDER DESCRIPTION	TARGET COMP. MONTH	ACTUAL COMP DATE	PRIORITY
36876	PM PUMP NO. 4—PRIMARY CLARIFIER 12	7/08	7/5/08	3
38913	PM PUMP MOTOR NO 4—PRIMARY CLARIFIER 12	7/08	7/5/08	3
39383	PM PUMP NO. 4—PRIMARY CLARIFIER 12	10/08	10/14/08	3
39368	PM PUMP MOTOR NO 4—PRIMARY CLARIFIER 12	10/08	10/14/08	3
39405	PM PUMP NO. 4—PRIMARY CLARIFIER 12	01/09	1/10/09	3
39422	PM PUMP MOTOR NO 4—PRIMARY CLARIFIER 12	01/09	1/10/09	3
40166	PM PUMP NO. 4—PRIMARY CLARIFIER 12	04/09	cancel	3
40186	PM PUMP MOTOR NO 4—PRIMARY CLARIFIER 12	04/09	cancel	3
40266	PM PUMP NO. 4—PRIMARY CLARIFIER 12	07/09	7/20/09	3
40281	PM PUMP MOTOR NO 4—PRIMARY CLARIFIER 12	07/09	7/20/09	3
40299	PM PUMP NO. 4—PRIMARY CLARIFIER 12	10/09	PEND	3
41332	PM PUMP MOTOR NO 4—PRIMARY CLARIFIER 12	10/09	PEND	3

Figure 4-9 Equipment history for a process unit

properties. Such records also may help to support or deny requests for renovations from other departments. The section manager may consult these records to prepare contracts for grounds maintenance by establishing schedules for services like grass cutting and fertilizing.

CM work orders can be kept for several years unless legal questions arise, as mentioned earlier. For example, if injuries result from a hazard in a building, the time required for the maintenance group to respond to the problem is likely to be an important fact.

The planning team should review the criteria they establish with the utility's legal staff to ensure that the records retention rules are consistent with the utility's procedures as well as the requirements of local, state, and federal regulatory agencies. Ultimately, rules must satisfy the needs of the maintenance group as well as other departments.

Management Reporting

Management at all levels of the utility must be kept informed of maintenance activities. Regular reports to management serve several purposes. The first, and most important, is to ensure that maintenance work is carried out as required. A second purpose is to keep management informed of particular problems, while a third is to keep maintenance high on the list of management priorities. A fourth reason is to encourage senior management to demonstrate their interest in maintenance activities by intervening in selected maintenance actions. Finally, management reports help track the cost of a maintenance function.

Types of Management Reports

The types of reports that are prepared depend on the maintenance function involved, on the level of management that will receive the report, and on the type of maintenance information system. Clearly, an automated system will provide greater opportunities than a manual system for gathering and analyzing data. Typical reports include the following:

- Number of CM actions taken for the month
- Number of CM work orders originated during the month
- Number of PM actions initiated and completed for the month
- Backlog of PM and CM work orders
- Work orders started but not completed, in order by priority

- Maintenance costs for various categories
- Labor utilization
- Labor hours used for the month
- Various types of exception reports
- Spare parts availability

Figure 4-10, for example, shows a (partial) backlog report listing the completion status of all PM and CM work orders. Note: The category labeled "Maint Improvement" is defined by the electrical group for jobs that are planned to improve the operation of a piece of equipment or process, so they are not considered either PM or CM work. The scheduled completion date is given along with the priority of the job and the estimated hours to complete. Figure 4-11 displays two reports used by management to track PM work orders scheduled and completed over several months. The reports cover both number of actions and estimated hours, helping managers not only to determine whether the crews complete their PM tasks but also whether planners assign accurate estimated times. For example, crew chief Ripken completed 82 percent of the 95 preventive maintenance tasks assigned in January, utilizing 101 percent of the estimated hours. If this pattern continues, management needs to investigate and determine the reasons for the discrepancy.

These reports and a number of others may all contribute to the effective management of the maintenance section. However, each report costs money to produce, and the planning team and the maintenance manager should review each carefully to ensure that the expense is justified.

One role of the planning team is to determine the information needs of the different levels of management. The maintenance section itself will need a list of all work orders generated and completed during the month plus cost and monitoring data. Senior management may need only a listing of the total number of work orders started plus the backlog of CM and PM work, and, of course, information on expenditures. Upper management will also be interested in employee productivity and utilization, if the MMS is designed to provide such data. Generally, managers at all levels are interested in trends and changes from the status quo. The information system should address at least these basic questions:

Backlog Report—Fayetteville Filtration Plant Electrical Shop

CORRECTIVE MAINTENANCE	WO NUMBER	REQ COMP DATE	PRIORITY	EQUIP DESCRIPTION	WORK DESCRIPTION	EST HOURS
	604867	7/10/09	03	PRIMARY PUMP 1	REPLACE CHK VALVE	10
	618774	7/18/09	03	CHEMICAL FEED PUMP 3	RECALIBRATE	2
	738093	7/18/09	03	PUMP MOTOR 2	RUNNING HOT	3
	745782	6/15/09	03	BACKWASH PUMP 4	CHK LIMIT SWITCH SETTING	2
MAINTENANCE IMPROVMENT	**WO NUMBER**	**REQ COMP DATE**	**PRIORITY**	**EQUIP DESCRIPTION**	**WORK DESCRIPTION**	**EST HRS**
	548879	9/01/09	05	CHEMICAL FEED PUMP 4	REPLACE SEALS/ RECALIBRATE	5
	556734	9/01/09	05	FILTRATION BASIN 3	RECALIBRATE LEVEL CONTROLS	2
	565710	9/15/09	07	RWP 3 DIST VALVE	REPAIR LEAK	8

Figure 4-10 Sample management report (partial listing) on work order backlog

Monthly PM Work Order Performance

NUMBER OF PM TASKS ASSIGNED AND COMPLETED													
		JANUARY			FEBRUARY			MARCH			APRIL		
Area Manager	Supervisor	1	2	3	1	2	3	1	2	3	1	2	3
Jordan	Ripken	95	78	82%	106	103	97%	97	95	98%	108	99	92%
	Bauer	94	94	100%	126	122	97%	117	98	84%	116	112	97%
Unitas	Moore	103	96	93%	71	65	92%	87	80	92%	89	87	98%
	Ameche	4	4	100%	5	5	100%	4	3	75%	7	7	100%
	Brown	17	15	88%	20	17	85%	25	25	100%	28	24	86%
	Totals	313	287	92%	328	312	95%	330	301	91%	348	329	95%
ESTIMATED AND ACTUAL TIMES USED FOR PM TASKS													
		1	2	3	1	2	3	1	2	3	1	2	3
Jordan	Ripken	192	194	101%	212	209	99%	200	205	103%	196	199	102%
	Bauer	450	420	93%	438	419	96%	357	376	105%	402	397	99%
Unitas	Moore	78	64	82%	65	50	77%	68	53	78%	72	62	86%
	Ameche	12	12	100%	20	19	95%	18	18	100%	12	14	117%
	Brown	68	59	87%	75	80	107%	77	80	104%	68	60	88%
	Totals	800	749	94%	810	777	96%	720	732	102%	750	732	98%

Figure 4-11 Monthly PM tracking report (Report format adapted from PSDI MAXIMO CMMS software)

- Is the total number of PM and CM work orders carried out increasing or decreasing?
- Is the backlog of work remaining constant?
- Is the ratio of PM to CM work changing?
- Are costs related to maintenance rising? If so, why?
- Are high-priority jobs completed in a timely manner?
- Are customer complaints increasing? If so, in what areas?

Of course, information does not flow in only one direction. Feedback from management is vital for the success of the maintenance program. Since lack of time to review reports is a frequent complaint of senior management, one reporting strategy is to develop a series of exception reports. Information is forwarded to upper management only about deviations from normal performance along with descriptions of the reasons for the changes. For example, detailed data on CM work orders is inappropriate for upper management, but decision makers do want to know, for example, if the number of CM jobs is steadily increasing and why. This reporting helps to target management feedback on specific issues without devoting excessive amounts of time to reading detailed reports.

The system should always serve the underlying purpose for developing management reports: to monitor and control the maintenance function.

Maintenance System Monitoring Techniques

Monitoring MMS performance serves four functions. The first is to ensure that work is carried out in a timely manner, and the second, related purpose is to ensure that no work slips between the cracks. The third purpose is to provide the data needed to keep track of the costs of performing maintenance, while the fourth is to provide a means to assess the performance of the maintenance group.

Monitoring reports and related tools fall into two categories. Most reports are designed to track the work itself, while some, particularly those in automated MMSs, are used to check the entry and processing of data by the information system. As noted before, manual systems offer limited resources for monitoring because of the time needed to process data. However, system control is still needed, and techniques have been developed to monitor such systems.

Work Order Priority

All jobs performed by the maintenance sections are not, of course, of equal importance. Some work must be done immediately, while less urgent work can be delayed for weeks or even months. Between these extremes are jobs that are not emergencies but also cannot be delayed for extended periods of time. Since the monitoring system must differentiate among these jobs to track response time by the maintenance crew, a priority system for work needs to be established. The priority numbering scheme will enable maintenance management to track work with the highest priority to ensure expeditious responses. One example of a priority system is shown in Table 4-1.

Table 4-1 System of classifying priorities for maintenance work

Priority	Description
1	Work must be done within 3 days. (All emergency work is in this category.)
3	Work must be done within 7 days.
4	Work must be done within 30 days.
5	Handle as available labor permits.
7	Can't start.

This numbering scheme was developed for a manual tracking system, kept simple because additional categories could not easily be analyzed with a manual MMS. However, gaps were left in the priority numbers to allow for greater differentiation when the MMS was automated. The Priority 1 category may be misleading, because emergency work is always started as soon as possible.

Priority numbering schemes will vary depending on the utility and the department within the utility. However, some system must be established by the maintenance group. Tracking all levels of work is important. While the highest-priority jobs are most critical, a large backlog in the other categories will also cause significant problems for maintenance management. Work with a low priority today may become emergency work later, and the reason for any increase in the backlog needs quick attention.

Maintenance Management System Control

Both manual and automated maintenance management systems need mechanisms or controls to maintain the integrity of system data. Since automated systems ease data processing, they normally implement more comprehensive control techniques, permitting greater control over maintenance work than is feasible with manual data control techniques.

Manual Control Systems

The primary tools for monitoring activity in a manual system are the work order and the logbook. Each maintenance manager needs to establish requirements for monitoring reports, while recognizing clerical limitations. This section reviews several examples of typical monitoring reports designed to satisfy the four purposes of a monitoring system as described in the last section. The most important of these reports are likely to be those that ensure appropriate responses to all work.

Figure 4-12 shows a form combining raw data on work orders started and completed during the month, as well as a listing of all Priority 1 jobs that were started but not completed in the period, and all Priority 3 work that remains undone from previous periods. The work order summary report is a listing of work accomplished during the period with emphasis on the highest-priority CM work orders. If time and staff support permit, similar reports can be prepared for other CM work.

The section of the work order summary report dealing with specific uncompleted jobs is an example of an exception report. This type of report is particularly valuable in a manual MMS, because it can be prepared relatively easily by scanning the work order logbook. Detail like data for the work orders shown earlier in Figure 4-3 would be omitted from the summary report.

Since PM is such a critical component of a successful maintenance program, special reports should be developed as tools to monitor this type of activity. Figure 4-13 is an example of such a report (Jordan 1981). The main purpose of this exception report is to alert the maintenance manager of any PM work orders that are not completed in a timely manner. As will be discussed later, only the smaller systems are

Work Order Summary

Maintenance Depot ______________________ Month ______________

	PM	CM
Number of work orders outstanding from last month.	______	______
Number of work orders started this month.	______	______
From Maintenance	______	______
From Operations.	______	______
Number of work orders originating this month but not completed.	______	______

Incomplete Work Orders

Work-Order Summary	Date Opened	Reason for Delay	Expected Completion Date
Number 1 priority work orders not completed this month			
Number 3 priority work orders not completed from previous months			

Figure 4-12 Work order summary

likely to use manual reports such as this one. The important point is that tracking and accounting for work orders is essential.

Cost reports are difficult to develop and prepare within manual systems. Even for a small system, an extensive effort may be needed to assemble and analyze data for an accurate picture of maintenance costs. One such report is shown in Figure 4-14. This report does not attempt to analyze individual jobs, but it does provide a basis for measuring the cost of maintenance from month to month. Another alternative, or one that may function as a supplementary report, details costs only for top-priority jobs, because these are the ones for which costs are likely to be under the least control. The report format shown in Figure 4-13 could be expanded to incorporate this additional data.

Assessing the productivity of field staff is another area that is difficult with a manual MMS tracking system. As with cost reports, unless the number of work orders is quite small, the clerical time needed to gather the necessary information will be excessive. One method that the maintenance manager can use to evaluate productivity is to take a

Preventive Maintenance Work-Order Summary

ZONE: ______________________ MONTH: ______________

Number of preventive maintenance work orders outstanding from last month. ______

Number of preventive maintenance work orders originated this month. ______

Number of preventive maintenance work orders originated this month but not completed.

____

Equipment types for which preventive maintenance was scheduled but not completed.

1. ____

2. ____

3. ____

4. ____

5. ____

Figure 4-13 Preventive maintenance work order summary

Monthly Cost Summary			
Maintenance Office:			Month:
	PM	**CM**	**Total**
Total labor cost:			
Total materials cost:			
Total other cost:			
Other comments:			

Figure 4-14 Monthly cost summary

random sample of PM and CM work orders and rely on experience to assess whether the time spent carrying out the work seems reasonable. If not, the manager may ask the crew if they experienced any particular problems with the work.

One practical quantitative approach is to determine the ratio of labor hours spent on work orders to total labor hours available for the time period. The work order labor hours can be obtained from work orders and total labor hours from time sheets. This ratio can be compared on a month-to-month basis.

Graphical techniques are quite useful for displaying and reviewing this type of data. Figures 4-15 and 4-16 give two examples of this method. The first graph shows incomplete PM work orders over time. Note that the number of open work orders is important only if it increases with time.

Graphical techniques can also be used to monitor the effectiveness of PM by tracking hours spent on CM activities over time, as is shown in Figure 4-16. A ratio of 3 to 1 CM to PM is likely for equipment

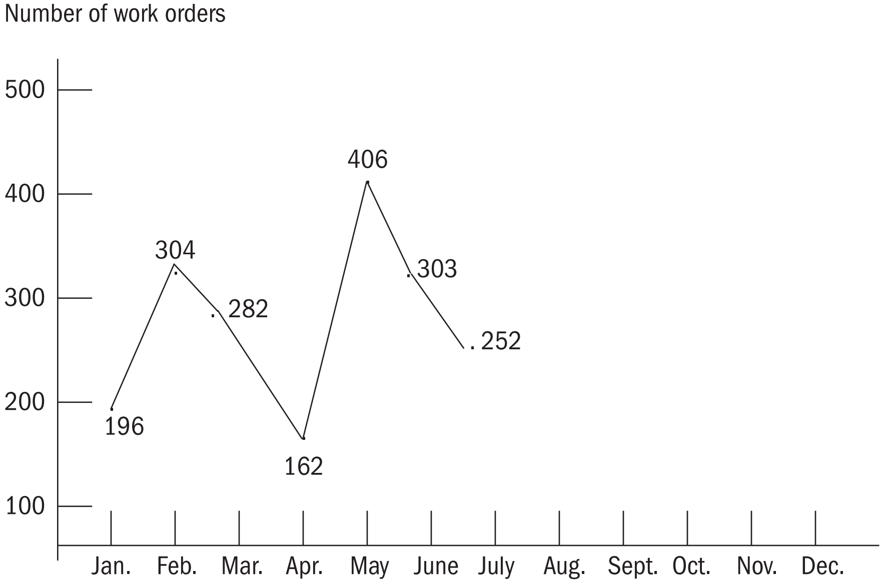


Figure 4-15 Graph—number of incomplete preventive maintenance actions vs. time

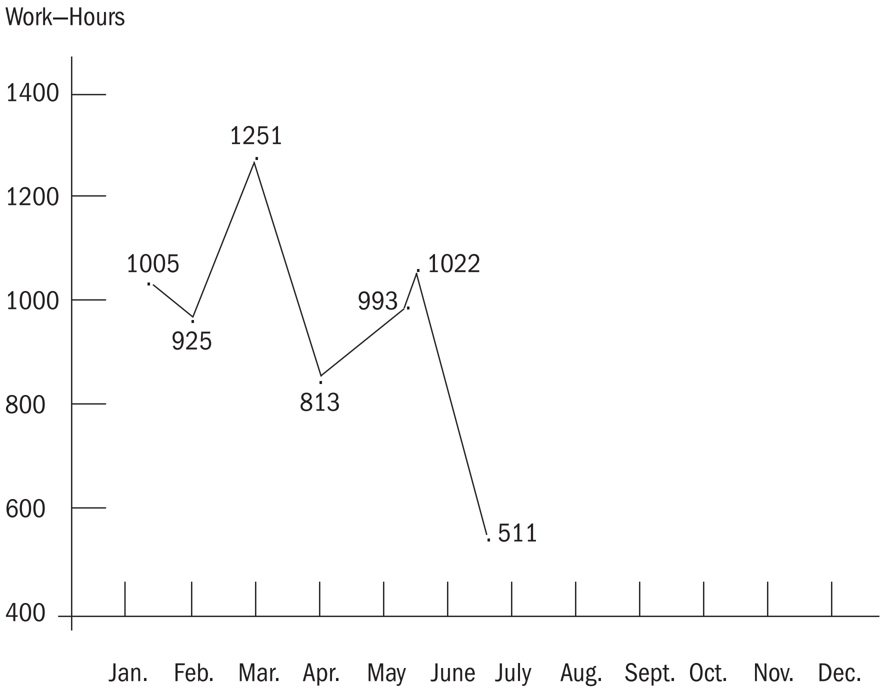


Figure 4-16 Graph—corrective maintenance work hours

maintenance in an organization without a good program for managing this work, while the reverse of this ratio is a reasonable expectation as the maintenance management program matures. If the CM labor hour graph is updated from the beginning of the PM effort, a continuing record of progress can be charted.

The ratios cited for equipment maintenance do not apply for distribution system or building and grounds maintenance. The most reliable graphic indicator for these functions is probably the ratio of labor hours spent on work orders to total available labor hours. In addition, because distribution system activities often must be carried out on overtime, the ratio of overtime hours to total labor hours spent on work orders is a useful barometer to assess whether the number of field crews is adequate to carry the work load.

An important task for the maintenance manager is to determine how much staff time is available for gathering and analyzing data. The manager should then select monitoring techniques that will give the best return in terms of system control for the time investment. This review of the information component of maintenance management also points to another task for the maintenance manager. If the maintenance section is currently operating with a manual MMS, staff probably should begin reviewing the possibilities for automating the information system.

Automated Control Systems

The introduction of computers to manage information for utility maintenance has opened up numerous opportunities for the maintenance manager to gather and manipulate data in order to review activities in ways never before possible. For this reason, every manager should consider the practicality of an automated MMS. However, implementing an automated system is not a simple or inexpensive task, despite the availability of easy-to-use hardware and software.

Once the planning team has determined which components of the maintenance program to handle by computer, the next step is to survey available software packages to identify those that can fulfill the section's requirements. Part of this planning process includes analysis of the capabilities of the various packages to deliver management reports, particularly those that address the need for system control. In particular, the planning team should select a package capable of delivering the two types of monitoring reports already described in this chapter: reports that track actual maintenance work done as well as those that check the entry and processing of data to ensure that the system gathers and stores quality data.

Data Maintenance. Because the output of any information system is only as good as the data entered, ongoing data maintenance is the key to the success of any automated MMS. The integrity of the information in the computer file is contingent upon control of the work order from the time it is generated, through field processing, to the processing of the completed work order. System control is mandatory at each of these stages.

For example, if the maintenance group processes 10,000 work orders per year, and the error rate is 10 percent of total labor hours reported, the accuracy of the management reports generated by the MMS is seriously in doubt. One water utility established a straightforward flow of data for the distribution system MMS but still experienced an unacceptably high error rate. A review of the steps this utility took to address the problems with data integrity may guide other maintenance managers in resolving difficulties they may face when considering automation for their maintenance operation.

Since the primary problem concerned work orders generated by reports received from outside the utility, the team analyzing the flow of data first looked at work order generation. Typically, a work order is generated when a customer service representative gathers information from a caller. Several problems can occur at this stage. The representative may not receive enough information or may incorrectly identify the work required. Either of these problems can result in dispatching the wrong type of work crew to the job. One result of this type of error is a distortion of data on crew productivity. For example, a three- or four-person crew may be dispatched to respond to the problem only to learn that the problem could have been readily handled by a single individual. It is important that the person receiving the call reporting the problem be prepared to ask the right questions of the caller to establish to the extent possible the actual problem.

It is also important that each of the staff receiving these calls ask questions in much the same way. Developing a uniform series of questions to be asked promotes effective system control in several ways. A systemic approach helps to organize information obtained from the caller, helping to ensure that the right crew is dispatched to the job with a better understanding of the reported problem. The use of the same descriptive format can lead to the development of standardized work descriptions with numeric codes, allowing direct entry of information into the computer. For example, upon receiving a phone call reporting a water leak, the utility representative will want to establish the following:

- The location of leak, that is, inside a building or outside
- What is the address or nearest intersection
- If outside, on or off property
- Is the leak from the water meter
- Is the leak in the street
- Is the flow of water substantial or minimal
- Is the water flowing from a fire hydrant
- Are other agencies on the scene, for example, fire department, police

The answers to these inquiries as well as the questions themselves should be structured so that a specific type of work order with an appropriately sized crew is dispatched to investigate the problem.

The next step in the initial information flow was the entry of the work order information, with a seven-digit work order number, into the computer. The number was designed to allow a computer check to determine if the number was valid. The data was entered from the second copy of the work order into the computer. However, in many cases, the data did not subsequently appear in the maintenance master file, often because of simple clerical error. The maintenance clerks either wrote the wrong numbers on the work orders, or data entry personnel made a mistake. Either of these errors caused the computer to reject the incorrect number. Even though a computer report had been developed to list errors, backtracking was a problem when the correct number for the rejected work order was unknown.

The solution to this problem was a change to online data entry. A clerk would enter the work order information directly into a computer terminal, and the software would immediately check the work order number. If it was incorrect, the terminal would transmit an error message to the clerk. This process also eliminated the problem of data entry error.

After the work order was prepared, it was dispatched by radio or to onboard computer terminals to a crew for an emergency job or sent to the appropriate depot for a routine one. This referral began the field processing stage of the system. A number of problems were associated with this stage:

1. The work order document may be lost in the depot.
2. The crew chief may either fail to submit a field work order to close the work or may enter incorrect data on the work order, causing it to be rejected by the computer.
3. The crew chief may fail to submit a correctly completed activity report listing labor hours, crew numbers, and work order numbers.

Field processing errors resulted in loss of productive time, work orders remaining indefinitely on the open file, and incorrect management reports. The solution to these problems was a combination of computer checks via the terminal, and system control reports.

An article in the *Journal AWWA* (Jordan and McLeod 1979) includes information on three reports introduced by maintenance managers specifically designed to address the problem of system error.

The first of these, called the "Golden Oldie" report, was created to identify errors by listing the oldest three work orders by crew type for each depot. To update the file of routine work orders, the depot scheduler needed only a list of about 30 jobs instead of an entire file of several thousand open work orders. A column in the Golden Oldie report indicated the number of times a work order had appeared in the report. A sample of this report is shown in Figure 4-17.

Also displayed in Figure 4-17 is an excerpt from the second of the control reports, the 01 Priority report. This report was designed to pinpoint work orders for emergency jobs that had been started but, according to the computer file, not yet completed. Emergency work (Priority 1) is normally completed within 2 days, but this report listed, by depot, all emergency work with issue dates over 14 days old. If a particular work order remained in the open file after 14 days, work had likely been completed, but the completing work order was incorrectly processed. Of course, if the work actually remained unfinished, the report alerted the depot scheduler to this fact.

DATE: 08/09/XX

Golden Oldie Report

Sect.	Depot	Crew Type Description	Work Order	Crew Size	Crew Type	Priority Code	Page Grid	Address	Job Type	Issue Date	Std. Hours	# Weeks on Report
43	02	Mainline	7198799	01	03	01	08/G07	2900 BLK. Hamilton St.	2A05	05/10/06	0.5	04
43	02	Service	7338799	03	09	04	08/G10	4208 32nd St.	3B04	08/16/06	4.0	01
43	02	Fire hydrant	8051237	03	04	01	08/J09	4500 42ST Ave.	2a06	01/06/06	3.0	01
43	02	Meter	8051773	01	10	04	19/K02	3922 Triton Ct.	4A01	03/05/06	1.0	01

01 PRIORITY REPORT

Sect.	Depot	Crew Type Description	Work Order	Crew Leader No.	Crew Type	Page Grid	Address	Issue Date	No. Weeks on Report
43	01	Mainline	8064127	1467	03	13/L09	2100 Blk. Laurel Ave.	02/10/07	2
43	01	Service	8156023	2168	09	08/G10	660 33rrd St.	02/15/07	1
43	01	Mainline	0276619	1832	02	07/J01	3300 Nicky Ct.	02/22/07	1

Figure 4-17 System control reports

The last of the three control reports, the Started-But-Not-Completed report, was intended to accomplish the same goal for routine work as the 01 Priority report did for emergency work. Investigation determined that most routine work orders listed as open should in fact be closed if the last time reported against them was at least 15 days before the current date. The Started-But-Not-Completed report identified work orders in this category. These reports were developed a number of years ago and may now be replaced by newer versions, but the message is still pertinent. Work orders *must* be tracked and accounted for if the MMS is to remain viable.

The next generations of control reports are not printouts but displays on the crew chief's computer monitor in the depot office or as displayed on a mobile terminal in his or her vehicle. The crew chief can gain an immediate status of outstanding work orders by reviewing a report such as the one displayed in Figure 4-18.

Other changes were also made to this MMS to limit errors that accumulated as information flowed through the system. After a system is first designed and installed, several initial assumptions about the development of a management reporting system may be modified. For instance, in reality, information may not flow as smoothly as the system design assumes.

```
03/18/XX  OPEN EMERGENCY WORK ORDERS            TERM LZ2142A2
                         SECTION: 043   ASSIGNEE: SMO8   MM966
WORK     ADDRESS                 C/P/G       RCVD DATE STA
ASSGN
ORDER    WORK DESCRIPTION        TYPE/HRS    CMIT DATE PRI
RADIO
----------------------------------------------------------------
0183210 15046   CHERRYWOOD DR    P 04 C04    03/03/XX    H  SMO8
        REPAIR BROKEN MAIN       02 021.0    03/22/XX   01  115

0210153 5704    LINCOLN AVE      P 14 B01    03/17/XX    0  SM08
        INSPECT SEWER MAIN       53 000.4               01  125

0214478 8317    OGLETHORPE ST    P 13 DO3    03/18/XX    O  SM08
        REPAIR BROKEN MAIN       02 021.0    03/31/XX   01  111

                        PAGE 1 OF 1
   PF1=WO INQ  PF2=VIEW OPTS  PF10=PB BKWD  PF11=PG FWD
```

Figure 4-18 Onscreen exception report

A maintenance information system installed by a small water utility may not need the extensive controls required by the system described in this section, but the MMS team designing any automated system needs to keep three principles in mind when determining the needs of the maintenance organization:

1. The system must be designed to be as flexible as possible.
2. System control should be built into the initial design.
3. Periodic analysis of the entire system should assess the effectiveness of the system and evaluate the potential for introducing new techniques.

Performance Monitoring

Scheduling Work on the Computer

The use of the computer to schedule maintenance work, particularly PM, presupposes that the maintenance manager has at least some knowledge of the time requirements for various types of maintenance work. Work scheduling also requires tabulation of available labor hours in each skill category. This information is relatively easy to obtain, while very complicated analysis may be needed to determine the time a field crew should take to carry out a specified task.

Once the method for scheduling work has been established and tested, the next step is often to introduce mechanisms to track personnel and section performance. Performance monitoring is intended to allow the maintenance manager to analyze the performance and productivity of field crews.

Work Measurement

Productivity is measured as the ratio of the time a crew reports against work orders to the total time available for work. Performance is measured as the ratio of the time needed to carry out a job to some time standard. The standard time is the key to a successful performance monitoring program. Utilization, defined as the product of the two ratios, provides a single number to measure the progress of the maintenance effort over time through the use of, for example, graphic techniques.

Several methods have been used to develop standard times:

1. Time studies—On-site measurement of the time needed to carry out specific tasks. The analyst records the productive and nonproductive time of each crew member, breaking the times down to the level of discrete tasks.
2. Predetermined time values—These times are established in advance for all manual operations, and the standard time for any task, say, excavating a ditch to repair a broken water main, is the sum of the times of the operations needed to carry out the task.
3. Work sampling—This technique involves taking a random sample of the work of field crews in order to establish standard times.
4. Past records—Documents that record the experience of maintenance supervisors can help to develop a history of estimated times for the various tasks carried out by field crews.

The descriptions of the techniques for establishing time standards are deliberately sketchy. To investigate the use of performance monitoring by using these methods, a maintenance manager is likely to need the services of a specialist in the field of work measurement in order to set up an effective program.

Performance Monitoring of Maintenance Work

A review of the maintenance functions considered in this manual reveals some important differences among them that affect development of standard times.

Distribution System. Since the work of this maintenance group does not require significant time for troubleshooting, time standards can be developed for the majority of their work. The best approach is to establish standard times for their most common tasks, such as repairing broken water mains and valve leaks and replacing fire hydrants. The next step is to develop management reports on the performance for these specific tasks in order for management to gain experience in analyzing the data generated. The program can then expand to include the balance of the crew's work.

Building and Grounds. Time standards can be developed for most work carried out by this group. It is a good candidate for performance monitoring.

Equipment Maintenance. Since PM will account for 70–80 percent of the work performed by equipment maintenance crews in an effective maintenance program, time standards can readily be established for much of their work. The difficulty arises in trying to establish standards for CM work, because significant problem analysis (troubleshooting) may be required to identify the nature of the problem. One performance monitoring approach is to develop time standards for PM work and rely on field supervisors to review labor hours for CM work to assess whether the time reported seems reasonable.

Benchmarking

Benchmarking is a technique for measuring an organization's performance against others based on a variety of criteria. The concept of *representative best practice* is a common benchmarking term that represents a typical value reported by utilities. For example, the maintenance manager should consider it a warning sign if the utility expends 40 percent of its available equipment maintenance hours on preventive and predictive maintenance instead of the 70 percent considered to be a best practice target. This same target value does not apply to pipeline maintenance because much of the distribution system work is reactive maintenance. A better target number for PM/PDM hours on pipelines might be less than 20 percent. Dunn (1999) identified other representative best practice values that are applicable to utility maintenance programs, including:

- Planned maintenance/total maintenance hours benchmark: >85 percent
- Equipment PM & PDM hours by operators/total maintenance hours benchmark: 25 percent
- Wrench time/total maintenance hours benchmark: 50 percent. Wrench time is the time that maintenance workers spend directly advancing completion of a maintenance task.

Other frequently measured and benchmarked data include overtime hours, unplanned downtime, safety incidents, equipment availability, and contractor hours. Benchmarking criteria related to costs also help maintenance managers evaluate organization performance.

Performance Report

Program Name: Water Main/Service Maintenance

	Current Month	Year-to-Date Monthly Average	Fiscal Year-to-Date	Budget Reference
Expenditures				
Salaries	$34,401	$27,692	$110,768	$465,300
Wages	67,607	54,502	218,008	690,700
Material	7,431	4,877	19,506	183,000
Total	$109,439	$87,071	$348,282	$1,339,000
Work-Hours				
Actual Productive Hours	3,711	3,274	13,098	
Actual Nonproductive Hours Allocated	3,757	2,795	11,181	
Equivalent Annual Work-Years	52.7	43.2	43.2	51
Percentage of Emergency Hours	64.0	44.1	44.1	
Percentage of Preventive Maintenance	17.6	13.4	13.4	
Percentage of Corrective Maintenance	26.0	55.9	55.9	
Completed Work				
Work Order Count	361	327	1,309	3,693
Standard/Estimated Hours	2,091	1,371	5,485	16,020
Total Work-Hours	4,809	3,200	12,802	
Percentage of Performance	53.0	51.0	51.0	
Backlog	Same Time Last Year			
Work Order Count	81	82		
Standard Hours	40	1,897		
Weeks	2.2	5.7		
Average (days)	268	130		
Date of Oldest Work Order	8/17/XX	05/01/XX		

Figure 4-19 Performance by program report for October, 20XX

Benchmarking standards are guidelines for performance and not stand-alone objectives for organizations. Managers should routinely assess their unit performance against that of other organizations performing the same type of function (i.e., other drinking water providers). Maintenance managers can use the results of this assessment to investigate specific areas of their operations where their performance differs significantly from representative best practice standards.

Purposes of Performance Monitoring

A large effort is often needed to establish time standards. Hence, the manager must be assured that the payback will justify the effort. Performance monitoring serves three purposes. The first is to identify crews that are not performing as well as others. The second is to provide a basis for analyzing the ways tasks are carried out to identify potential for improved procedures. The third purpose is to provide data to support requests for additional personnel or other resources.

Figure 4-19 is an example of a management report that could be developed from the data gathered from the application of performance standards. Managers can compare productive versus nonproductive hours to help assess if proper crew sizes are being utilized. If productivity levels are low, the possibility of using smaller crews should be considered. The use of single-person crews to respond to certain type of calls, such as small leaks, is one possible outcome of the analysis of performance reports. The productivity of individual crews can also be reviewed through the use of performance reports. Another important consideration is the number of emergency hours versus preventive maintenance hours, particularly when considered on a year-to-year basis. A reduction in PM hours may suggest that insufficient effort is being placed in this area.

References

American Water Works Association. 2009. *Source Book*, Computer hardware & software category. http://sourcebook.awwa.org. Denver, Colo: American Water Works Association.

Dahlberg, S. 1999. Maintenance information systems for midsize and larger organizations. *Maintenance Technology,* 12(7) (July/August).

Dunn, R. L. 1999. Basic guide to maintenance benchmarking. *Plant Engineering,* 53(1): 63–69.

Jordan, J. 1981. Preventive maintenance—Must a system be automated? *Journal AWWA* ,73(12): 617–621.

Jordan, J. and J. McLeod. 1979. System control: The key to a successful management information system. *Journal AWWA,* 71(3): 136–140.

Simmons, T., C. Johnson, S. Lehman, and V. Licausi. 2009. GIS–CAD interface enhances asset management. *Opflow,* 35(3): 20–21.

Singer, G. 2008. GIS Development: Prepare an effective RFP for data conversion. *Opflow,* 34(11): 8–9.

CHAPTER 5

Inventory Management

Because a reliable supply of water is a fundamental requirement for any community, a utility's maintenance section must pay special attention to the inventory of spare parts and supplies. This process is critical for a water utility, because lack of access to quality water while workers wait for a replacement part is a much more serious problem than temporary inability to obtain, say, a particular food product. Senior management have reason to question the capability of a maintenance manager who permits a water pumping station to operate without a backup pumpset because one unit is out of service due to the lack of a spare part.

On the other hand, if multiple backup units are in place, extraordinary efforts such as unscheduled deliveries by suppliers probably would not be justified. The maintenance manager should seek a balance between the necessity of stocking the right kinds and quantities of spare parts and materials to carry out repairs in a timely manner versus the cost to the utility of maintaining an extensive inventory. One author recommends that "[i]n-plant maintenance stores should be run like a good retail operation: clean, efficient, everything in its place, not too much or too little, and supervised by a manager with a focus on customer service" (Moore 1998).

General Concepts

An effective inventory system for a water utility will ensure ready availability of the parts, materials, and tools necessary to minimize downtime and service interruptions for the utility's equipment and structures, while keeping the cost of maintaining these supplies as low as possible. Since a multitude of books and reports have been written on specific methods of setting up and operating inventory systems, this chapter provides guidelines and examples for reference by maintenance managers working to plan or revise their systems. The operation itself will dictate the particular kind of system that should be implemented.

In reviewing an inventory management function, a maintenance department manager should begin by fully understanding the existing system for obtaining spare parts and supplies. Some questions to be addressed are:

- Who is responsible for purchasing and storing supplies?
- What is the procedure through which various maintenance functions obtain parts and materials?
- What are the problems associated with ordering supplies?
- Should the maintenance sections have their own storerooms?
- Should the inventory system be centralized? Decentralized? Some combination?
- Is an automated system justified?

The answers to a number of these questions depend on the size of the utility and its service area. For a large utility with several sites spread over a wide geographical area, multiple storerooms may be justified, despite the additional cost of maintaining them. For a smaller water utility, a single storeroom located at the treatment plant is likely to be adequate.

Since the principles for establishing a satisfactory inventory system apply to any water utility, irrespective of size, this book discusses the requirements for a large utility. These principles, particularly the discussion of control mechanisms, apply to any inventory management program.

Maintenance Group Requirements

To install an inventory system that will serve all functions, the maintenance department manager should start by differentiating between equipment downtime and service interruptions. These differences affect the methods and cost of maintaining an adequate stock of spare parts and supplies.

Inventory Management for Equipment Maintenance

When maintaining equipment, the goal of minimizing downtime does not require having enough supplies on hand to restore every piece of equipment immediately to service. This is a much too costly approach! Instead, the equipment maintenance group should look at each operating system and assess several factors with respect to the equipment in that system:

- Availability of standby equipment—Perhaps available backup gear, such as source-water pumps, ensures that one unit can be out of service without threatening water delivery until repairs are completed. Perhaps spare parts can easily be obtained. In such cases, a utility need not carry expensive spares in stock. Conversely, if a part is difficult to obtain or backup equipment is not available, then keeping one or more units in stock is an essential precaution.
- Importance of equipment to primary water plant operations—While a roof exhaust fan may remain out of service for an extended period without affecting water production, the same is not true of most plant and pumping station equipment. Operations and maintenance personnel must determine how long each piece of equipment can be out of service before plant operations are seriously hampered.
- Frequency of part use—If a piece of equipment requires frequent service involving the replacement of a particular part, or if the part is used on a number of pieces of equipment, keeping some minimum quantity of stock is probably a cost-effective way to avoid delaying the completion of work orders. The overall productivity of the maintenance workforce is also affected if staff must wait while parts are ordered as needed rather than being drawn from stock.

These factors relate more to corrective maintenance (CM) than to preventive maintenance (PM) work. Since PM actions are carried out at regular intervals with known requirements for parts and supplies, the inventory system should be designed to ensure that the requisite parts and supplies are always available when needed.

Inventory Management for Distribution System Maintenance

For the manager of the distribution system maintenance section, reducing the time that customer water service is interrupted by a problem is a vital need. Thus, the parts and materials needed to restore service to customers must be available when the need arises. Many utilities have designed looped distribution networks with multiple routes to supply water to particular locations. Still, some customers wait without water for the time a crew takes to repair a break in the distribution system. Service line breaks cause similar problems for smaller numbers of customers. In addition, since many main water lines run beneath roadways, the utility will receive unwanted publicity if slow repairs result in inconvenience to the general public.

Water meters and fire hydrants are special cases for the distribution system maintenance section. Obviously, fire hydrants must be operational all of the time. Since they are above ground and susceptible to damage from vehicles as well as malfunctions due to part failure, spare components must be available when needed.

Water meters are not as likely to cause major damage if they fail (e.g., through running water), and they can be bypassed if they malfunction. For these reasons, components for meter repairs are less critical than those for hydrant maintenance. Of course, adequate replacement parts and units are clearly important to maintain revenue, since one of the most important issues with water meters not operating properly has to do with their under- or overregistering customer flows, resulting in inaccurate charges.

Inventory Management for Building and Grounds Maintenance

Stocks of materials needed to support this group depend on the activity required. Lack of general supplies such as paint and groundskeeping supplies does not affect delivery of water; the amount of material kept in the storeroom can be limited. However, since work schedules may be disrupted if these supplies are not available when required, a prudent manager would ensure that a minimum amount of materials and supplies are held in inventory.

However, items related to safety and security need to be available when needed. These supplies are as important to the utility as those required for reliable delivery of water.

Determining Quantities in Inventory

Deciding the quantities of supplies needed to properly and effectively maintain the utility's equipment and structures is a time-consuming and sometimes difficult task. It requires evaluating basic maintenance requirements, assessing the uses of equipment and structures, and knowing the availability of parts and supplies.

It is neither necessary nor desirable to stock all supplies or spare parts used for maintenance. Actual amounts or quantities held in stock are influenced by a number of conditions:

- Long lead times—How long must crews wait to receive ordered parts? As this time increases, so does the need to keep supplies on hand.
- Obsolete equipment—If a piece of equipment is no longer made, overstocking of spare parts or materials used to maintain it may be a desirable precaution.
- Local availability—A cost-effective solution might be to let a local vendor stock some items, particularly for costly items normally available from several local vendors.
- Stockroom space—How much space is available for storage? Can the size of the stockroom be increased?
- Use of contractors—If contractors are to make repairs and/or provide PM services, will they keep stocks of the parts and supplies they use?
- Equipment or structure life—If a piece of equipment or structure is scheduled for removal or abandonment, inventory management decisions should reconsider stocks of parts and material needed to maintain it. This obvious point is still an important part of assessing inventory procedures and should not be overlooked.

The final question to be addressed when establishing inventory quantities is cost. Since many water utilities are operated by local government agencies without profit-seeking motives, maintenance managers may prefer to stock as many items as possible to avoid delays in maintenance work due to the unavailability of spare parts or supplies. However, this premise is certainly an incorrect guideline. Not only will this approach result in an unwieldy stockroom, but it will have an impact on water rates, as well. Upward pressure on rates will result, in turn, in a negative reaction from senior management.

How, then, are quantities established? A four-step approach is recommended.

1. On the basis of the factors discussed so far (primarily importance to reliable functioning, number of pieces in service, and rate of usage), establish the minimum number of units that should be readily available. Manufacturers' data sheets help, but experience is probably the best guide.
2. Determine the lead time needed to obtain the item after an order is placed. Is it available locally, for example?
3. On the basis of cost and space considerations, determine the amount that should be ordered to replenish stock. The cost factors include the following:
    - Cost of keeping and handling inventory (e.g., space, staff time)
    - Availability of quantity discounts
    - Cost to place an order
    - Value of the item
4. Finally, ascertain if other factors such as obsolescence or scheduled abandonment of equipment or systems impact on quantities kept in inventory.

Inventory Information Systems

The inventory system itself consists of the forms required for smooth flow of information through the system and the storeroom(s) where stocks are held. Ideally, parts, particularly ones that are costly, critical for plant operations, and/or difficult to obtain are tracked and linked electronically from requisition through purchasing and receiving, and disbursement from inventory for use in maintenance operations.

Purchase Requisitions

The first step taken by maintenance staff for obtaining spare parts or supplies is to prepare a purchase requisition (PR). Many utilities now allow the PRs to be submitted electronically to the purchasing department. A sample PR appears in Figure 5-1. This document is not

Requisition to Purchasing Office

The Purchasing Office shall obtain competitive bids to fill these needs. Request for different processing must be fully explained (attach sheet).

PR No. ____________

Page ___ of ___ Pages

Check One	If for Equipment (Subsidiaries 71, 72, 73, 74, 75, or 77), Check One:	Purchasing Office Use Only
____ To Be Delivered		IFB No.
____ To Be Picked Up	____ Replacement Item	
____ Service or Repair	____ Additional Item	Open Date

Account No.	Job No. (If Any)			Buyer
Requested By (Authorized Signature)		Date		PO No.
Section Name	Section No.	Phone No.		Deliver
Approved By (Authorized Signature)	Date	Estimated Cost $		Ship to

Item No.	Stock No.	Description Complete and accurate specifications should be given for each item listed. Failure to do so will cause delay. Double space between items. A separate requisition must be made out for each type of material listed.	Unit	Quantity	Unit Price (These columns for use of Purchasing Office)	Amount (These columns for use of Purchasing Office)

Do Not Write Below This Line. For Continuation, Use Plain Paper

Disposition

__ Phone Bid __ Informal __ Formal __Pickup __ Del. Request __ Confirming Order

Delivery Ticket No.	Invoice No.	Quoted By (Name)	Terms	F.O.B. ___ Origin ___ Dest.

Vendor Name

Vendor Address

Figure 5-1 Purchase requisition

internal to the inventory system, but it is key to proper identification of the required item. In a typical large water utility, the purchasing group is in a separate department from maintenance, and cooperation between the two sections is very important. Conversely, in many utilities, the purchasing and warehousing functions are managed by the same department. Upon receiving a requisition, the purchasing section determines the supplier for the items and prepares a purchase order (PO).

POs generally originate from one of two sources, depending on organization of the utility. The maintenance section (or its internal inventory section) may order and store all spare parts and materials, or a centralized warehouse may buy and stock commonly used materials, while the maintenance group handles spares peculiar to certain pieces of equipment. The only real requirements are that the items in inventory must be available when needed, and system control mechanisms must be in place.

If maintenance personnel have responsibility for preparing PRs for certain parts, they can assist purchasing staff by preparing the PRs with care. In particular, item identifications should be as detailed as possible, and potential sources for purchasing the items should be given. The maintenance manager should also take steps to ensure that orders specify reasonable dates for delivery of ordered supplies. The maintenance section should assume responsibility for preparing PRs for parts that require special instructions, such as components of complex electrical/mechanical (E/M) systems. A clerk in the maintenance section must be assigned to track PRs to ensure that items are actually ordered and received. A tickler file (which may be a computer file) listing orders by expected delivery date is a reliable technique for monitoring items ordered and their delivery by the vendor.

Documentation

Inventory management staff uses three basic documents to control the flow of materials from the supplier to the maintenance section that needs the spare parts or material. The first document is the receiving order form. The normal procedure upon receiving an order is for the receiving clerk to verify that the number of cartons received (or other measures such as truckloads or containers) matches the shipper's bill of lading. The next step is to prepare the receiving ticket and match it against the vendor's list of items shipped. An example of a receiving record is provided in Figure 5-2. This form may also be used to authorize payment to the vendor.

The receiving record triggers opening or adding to the parts/material history file, also called the master file or inventory ledger. Like the equipment history file described in chapter 4, data from the parts/materials file is used to track the source and usage of a spare part. The file should contain pertinent basic information including:

- Warehouse stock number
- Name and description of the part or material
- Part number, manufacturer, and suppliers for spare parts
- Generic description and suppliers for other material
- Storage location
- Location where the part or material is used, if it serves a specialized purpose
- Reorder point (the inventory level at which a new order should be placed)
- Reorder quantity

Receiving Ticket

Vendor | Date

Shipper

PO Number

Item	Qty.	Unit	Description	Total	Stock No.

Received by:

Figure 5-2 Receiving ticket

The parts history file also records a history of the movement of the part from receiving to use by maintenance staff. This file is most useful when it is linked electronically to the stores requisition procedure. The history of usage of the part is developed as it is withdrawn from inventory. Figure 5-3 shows an example of this file; a similar file is set up for materials. As items are received, they are placed in their appropriate warehouse or store yard locations (for stock items), or the maintenance section that placed the order is notified to pick up a specially ordered shipment. In the latter case, the maintenance section receiving the part should maintain a separate part data file.

Parts History File

Description: ______________________________
Stock No.: ______________________________

Original Source:

Mfr.: ______________________________
Part No.: ______________________________

Host Equipment: ______________________________
Supplier: ______________________________

Reorder Point: ______________ Reorder Quantity: ______________
Location: ______________________________

Received:				Issued To:				
Date	PO No.	Qty.	Cost/Unit	Date	Req. No.	Qty.	Sect.	Balance

Figure 5-3 Parts history file

The maintenance sections should advise inventory management staff if they expect the usage of a particular part to increase or decrease. This input allows for adjustment of the reorder point and the reorder quantity, possibly avoiding stockout or oversupply conditions. Taking this type of action when needed may avoid problems between the sections and foster effective relations between maintenance and warehousing.

Another form commonly used for inventory management is a materials requisition form, which is completed when issuing parts and supplies to requesting sections. A form such as the one shown in Figure 5-4 is used to track material usage and to ensure that the receiving section is properly charged for the items received.

The receiving ticket and the material requisition are used to track spare parts and materials purchased and used by the utility. Information from the parts or material history file guides reordering items as minimum stock levels are reached. Another form, the credit slip, is

<table>
<tr><th colspan="6">Stores Requisition</th></tr>
<tr><td colspan="5">Date Issued:</td><td>Section No.:</td></tr>
<tr><td colspan="5">Depot:</td><td>Account No.:</td></tr>
<tr><td colspan="6">Work Order or Stock No:</td></tr>
<tr><td>Item</td><td>Stock No.</td><td>Qty.</td><td>Description</td><td>Cost each</td><td>Total</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Received by:</td><td>Employee No.:</td><td colspan="2">Date:</td></tr>
<tr><td colspan="3">Issued by:</td><td colspan="3">Recorded by:</td></tr>
</table>

Figure 5-4 Stores requisition

used by a maintenance section to return any unused item to stock for credit.

In a perfect situation, then, all goods that flow into the warehouse or stockroom can be accounted for as either stock on-hand or items delivered to the sections that use them. However, since stock can be lost, the inventory management system must incorporate mechanisms to check the amount of stock that can be accounted for versus that which is actually present or has been used.

Inventory Accountability

In a large utility, thousands of transactions will take place to ensure that the spare parts and supplies needed by maintenance staff are available. Errors in recording additions to or subtractions from inventory will very likely result in apparent losses or gains. In addition, pilferage is often a problem. For this reason, and possibly to satisfy legal requirements, inventory management staff must carry out periodic physical checks on the stores in the warehouse. A maintenance manager must coordinate similar reviews for any decentralized storerooms.

Techniques for assessing the accuracy of history files are essential. To do this effectively, it is necessary for practical steps to differentiate between general and specialized stock. General stock consists of inexpensive items that are used regularly by field personnel. Included in this class are items such as wire nuts, light bulbs, small pipefitting, and some paint supplies. Precise accounting for these items is not a cost-effective option. Instead, the accounting group should spread the cost of these types of items over the various user sections or jobs. Specialized stock consists of relatively costly and/or infrequently used parts or supplies, lack of which could result in service interruptions.

If equipment is no longer in use or if a process is abandoned, parts and supplies may become surplus stock; generally these items must be disposed of at a fraction of the original cost.

To track the number of items in stock compared with the number recorded on file, a combination of two methods seems to work well for most inventory systems. The first method involves random checks of 5–10 percent of total stock at intervals, perhaps every three months. For a check of a general stock item, an estimate of the number in stock is made and compared with the part history file to determine if the amounts approximately match. For each specialized stock item, a 100 percent check is made of physical inventory and compared with the part history file. Any notable discrepancies indicate that the section manager should evaluate the control and security procedures used for the stockroom.

The second part of the inventory control method requires a complete inventory of all stock, usually carried out annually using the same counting techniques as for the partial sample. Note: This count may require a shutdown of the stockroom for one or more days, and all personnel who may be affected by the closing should be notified in advance.

Storeroom Design and Location

Large water utilities usually implement the inventory system designs that balance control realized with centralized warehouses where all parts are stored against the convenience of regional stockrooms to save travel time. The regional stockroom concept can be carried further if individual maintenance sections maintain their own small storerooms at convenient locations. For distribution system maintenance activities, stockrooms would be located at major depots; for equipment maintenance sections, spare parts and supplies could be stored at plant sites.

While the decentralized operation is logistically sound, it does have drawbacks. Every stockroom must be carefully designed so proper controls can be maintained. Figure 5-5 lists guidelines for proper storeroom organization (AWWA 1982).

In addition to these physical requirements, a cost-effective design for a network of satellite storerooms must consider the staffing required to operate the inventory system. One further disadvantage of decentralized storage is the likelihood that duplicates of parts and supplies will be held at the different locations, adding to the cost of carrying inventory.

The maintenance manager must balance these considerations and choose the best design for the particular operation. Certainly, one possible advantage to the decentralized approach is the potential to operate the regional storeroom using inexpensive manual techniques and still maintain proper control over stock movement. For a large utility, however, an automated system is a necessity for the inventory system used to control the central warehouse.

Storeroom Organization

1. Select a clean, dry room or shed with locking doors and windows.
2. Clean out the storeroom. Dispose of unneeded or obsolete items and all junk.
3. Obtain shelving units suitable for storing parts and supplies in an organized fashion.
4. Place all suitable items together on the shelves. For example, all vehicle parts should be placed on one set of shelves and all pipe fittings on another. Similar items should be placed together and identified with a 3 × 5 card placed near the item.
5. Label the shelf sections with numbers and letters for guide location of parts.
6. Leave supplies in their original packaging. The packaging protects supplies and parts from rust and dirt and aids in quick identification. Store unopened containers of items such as pipe fittings, nuts, and bolts in boxes, trays, or other containers.
7. Store heavy items, such as large valves or bags of cement, on wooden pallets near the storeroom door to minimize handling and lifting.
8. Store frequently used items close to the points where they will be issued to minimize the time needed to get them.
9. Store large, weather-resistant materials, such as culvert sections and lumber, outdoors (preferably in a fenced yard).
10. Store all tools, other than those routinely carried in toolboxes, on a shadow board or wall board.
11. Keep extension cords, hoses, and rope neatly coiled on wall hooks.
12. Store flammable materials in a separate shed.

Figure 5-5 Guidelines for organizing a storeroom

Automated Inventory Systems

The forms and procedures described so far as part of a manual inventory system have been very effectively duplicated by specialized computer software that

- records the parts and supplies in incoming shipments,
- maintains records of the quantities of stock in the warehouse,
- flags items that have reached their reorder points,
- tracks the value of the items in inventory,

- records disbursements and printing material requisitions,
- monitors part and material quantities to detect unusually high or low use of items in inventory,
- maintains the part/material history files, and
- interfaces with both the maintenance and procurement departments to coordinate uses of spare parts with purchases of new supplies.

In general, most paperwork needed to operate and control an inventory system can be produced and tracked by computer. The remaining figures in this chapter show examples of outputs from an automated inventory control system implemented by one large utility. One important enhancement to consider when the maintenance manager is implementing a new or upgrading an existing maintenance system is to include an automated inventory system. Many of the newer maintenance systems have provision for adding inventory modules to the basic work order generation and tracking and report generation modules that are fundamental components to every maintenance management system.

Figure 5-6 shows a report of general data on a specific part kept in the warehouse inventory, including the last price paid, the expected lead time for new orders, and the number of days of supply based on usage rate. This report also provides information on the pattern of usage of the item and its procurement schedule.

Figure 5-7 displays a report that identifies items to be reordered. The usage information can be used to revise the reorder point if the need for a particular item either increases or decreases.

The report on essential spare parts and supplies, Figure 5-8, lists components that receive first priority for preparing purchase requests by warehousing and for action by purchasing. Ample stocks remain of all three items shown on this portion of the report, but the report shows less than one week's supply of Items 1 and 3, and no requisitions have been prepared to restock these parts.

Another useful report (Figure 5-9) displays the status of outstanding PRs and POs, including their due dates. Maintenance managers and supervisors can quickly determine the expected delivery dates of their ordered parts from such a report.

Each of these reports is designed either to collect general information and make it available for quick reference or to alert management

```
IF006  V:2000            18:05          NORMAL REPORT ORDER PLANNING FOR FOURTH STREET (PLANT 001)         6/29/XXXX            PAGE    3
PART: 1061-5200-2  STOP, CURB, FEMALE IPT, 2 DIA  UOM:EA  MCC:S5  LEAD TIME : 67 ABC:B  TYPE:1 CLASS:W  CONTRACT INDEX:00
AVAIL QTY        : 39   PAST DEMAND DUE   : 0   PART SHORTAGE    :        0   PURCHASING  :  7   LAST PRICE   :   $68.00   DAYS OF SUPPLY
AC INSPECTED     :  0   PAST SUPPLY DUE   : 0   TRANSFER DMD     :        0   VENDOR DAYS : 60   MIN ORDER    :        0   TO    :   10/05/XX
IN INSEPCTION    :  0   TOTAL DUE   REQ   : 0   LEAD TIME DATE   :  9/05/XX   STOCK DAYS  :  3   MAX ORDER    :        0   DAYS :         96
IN RECEIVING     :  0               PO    : 0    (VENDOR DUE DATE)                                PACKAGING    :        3
RECEIVED HOLD    :  0               TO    : 0   STOCK DATE       :  9/09/XX

           AVAILABLE QTY       NON-NET QTY      MONTHLY AVG        HISTORY AVAIL.       FORECAST METHOD         WINDOW  TRIPS TO  RESELECT/FREQUENCY
PLANT 001       39                  0              5.500                36                   E 10                   0       3       0000000000000
PLANT 002        0                  0              0.000                36                   M  4                   3       6       0000000000000
PLANT 003        1                  0              0.250                36                   M  4                   3       6       0000000000000
PLANT 004        3                  0              0.000                36                   M  4                   3       6       0000000000000

SATELLITE PLANT REQUIRED ORDER QUANTITIES (ROQ):
002          0        0        0        0        0        0        0        0        0        0        0        0
003          0        1        0        0        0        0        0        0        0        0        0        0
004          0        0        0        0        0        0        0        0        0        0        0        0

FCS          8        3        6        7       11        6        6        7        6       12        4        6
CF      (   0)   (   0)   (   0)   (   0)   (   0)   (   0)   (   0)   (   0)   (   0)   (   0)   (   0)    ( 0)
DMD          2        0        0        0        0        0        0        0        0        0        0        0
DUE          0        0        0        0        0        0        0        0        0        0        0        0
   JUNE      JULY     AUGUST   SEPTEMBER  OCTOBER  NOVEMBER  DECEMBER   --JAN--  FEBRUARY   MARCH     APRIL      MAY
LLLLLLLLL LLLLLLLLL LLLLLLLLL LLLLLLLLL LLLLLLLLL LLLLLLLLL LLLLLLLLL LLLLLLLLL LLLLLLLLL LLLLLLLLL LLLLLLLLL LLLLLLLLL
             *                   F                   S
                                    REQUIRED ORDER QUANTITY & BUY SCHEDULE
ROQ          0        0        0        0        0        3   E<   6>        7        6       12        4        6
CUM                   0        0        0        0        3        9       16       22       34       38       44
CQ           0        0        0        0        0        3        6
BUY>         0        0        0        0        0        3   E<   6>        7        6       12        4        6
TOT                   0        0        0        0        3        9       16       22       34       38       44
                                    PLANNED END OF MONTH SURPLUS
            31       27       21       14        3        0        0        0        0        0        0        0
          387%     675%     350%     200%      27%       0%       0%       0%       0%       0%       0%       0%
------------------------------------------------------------------------------------------------------------------------
                                                USAGE HISTORY
                                  YEAR 1            YEAR 2             YEAR 3             YEAR 4
            JANUARY              -------             0.000              6.000              7.000
            FEBRUARY             -------             0.000              0.000              9.000
            MARCH                -------            11.000             12.000              6.000
            APRIL                -------             2.000              0.000              4.000
            MAY                  -------             0.000              7.000              0.000
            JUNE                   8.000             4.000              5.000             -------
            JULY                   0.000             2.000              0.000             -------
            AUGUST                 0.000             7.000              3.000             -------
            SEPTEMBER              0.000             3.000             11.000             -------
            OCTOBER               13.000             5.000              6.000             -------
            NOVEMBER               4.000             0.000              5.000             -------
            DECEMBER               0.000                               10.000             -------
                   * ZERO WEIGHT                              (PAST 12 MONTHS)              5.50
            ------- NO DATA AVAILABLE                         AVG FOR ALL PLANTS            5.75
```

Figure 5-6 Sample part report from automated inventory management system

STOCK REORDER NOTIFICATION WAREHOUSE 6000 ALLEGHENY												
								QUARTERLY USAGE				
								JAN	APR	JUL	OCT	
STOCK NUMBER		LEAD TIME	QTY ONHAND	AMT ON ORDER	REORDER POINT	SAFETY STOCK	MONTHLY AVG	MAR	JUN	SEP	DEC	PKG PRICE
1067-1400-9 EA								6	3	10	4	1
COUPLING, COPPER/GALVANIZED FEMALE, 1-1/2" DIA												14.3
	6000 ALEGHENY	60	6	10	8	3	2.7					
	6020 PATUXENT		4			1	0.5					
	6030 COLUMBIA		8			1	0.75					
	6040 POTOMAC		5			1	0.75					
1130-1200-8 EA												
WYE, MECHANICAL JOINT, 8" X 8"												
	6000 ALEGHENY	50	1	3	2	1	1	3	1	1	4	1
	6020 PATUXENT		0			0	0					175
	6030 COLUMBIA		0			0	0.5					
	6040 POTOMAC		1			1	1					
4340-9052-8 EA								65	60	45	55	12
PROTECTIVE HELMET, SLOTTED, BLUE												9.95
	6000 ALEGHENY	20	24	60	25	10	20					
	6020 PATUXENT		9			5	10					
	6030 COLUMBIA		15			5	4					
	6040 POTOMAC		8			5	12					
5381-0300-3 EA								32	20	15	30	1
GASKET, PLAIN, MECHANICAL JOINT, 3" DIA												1.5
	6000 ALEGHENY	33	15	0	12	8	8					
	6020 PATUXENT		5			5	3.1					
	6030 COLUMBIA		22			5	3.1					
	6040 POTOMAC		8			2	4					

Note: The warehouse section of this utility maintains four warehouses. The Allegheny site is the main warehouse, and all shipments are received there. Thus, data on lead time, quantity due, and reorder point are kept for this location only.

Figure 5-7 Stock reorder report

```
PO052                                                                                                        PAGE:   2
RUN DATE: 06/25/XX                    CRITICAL ITEM/STOCKOUT: REQUISITION & P.O. REPORT              RUN TIME: 18:15:04
                                                     FOR PLANT 001
-----------------------------------------------------------------------------------------------------------------------
CONT: 00  PART: 4211-9033-1    REPAIR KIT, REBUILT 5  FH        DAYS OF SUPPLY:  4       LEAD TIMES: PURCH:  7  VEND:  45   STOCK: 3
SHORTAGE:         0       COMMITTED:        0       MCC:S3
RECEIVED QTYS   :  PI:         0        AC:           0  DR:             0  HD:           0  RE:          0
AVAILABLE QTYS  :  PLT 001     5        PLT 002       1  PLT 003         4  PLT 004       3
                                       ORDER                                   DOCK      MULT
               ORDER       LINE        STATUS     OPEN      ORDER      BAL      DUE      DUE      PROMISE
                NO          NO         HD  LN     DATE        QTY      DUE      DATE     DATES     DATE      BUYER
               _____       ___         ___  __    ___        ___       ___      ___      ___       ___       _____

           *** THIS PART HAS NO REQUISITIONS OR P.O.S ***
-----------------------------------------------------------------------------------------------------------------------
CONT: 00  PART: 4320-9002-5    PUMP, BILGE, 5 HT                DAYS OF SUPPLY: 15       LEAD TIMES: PURCH:  7  VEND:  20   STOCK: 3
SHORTAGE:         0       COMMITTED:        0       MCC:S3
RECEIVED QTYS   :  PI:         0        AC:           0  DR:             0  HD:           0  RE:          0
AVAILABLE QTYS  :  PLT 001     3        PLT 002       2  PLT 003         4  PLT 004       0
                                       ORDER                                   DOCK      MULT
               ORDER       LINE        STATUS     OPEN      ORDER      BAL      DUE      DUE      PROMISE
                NO          NO         HD  LN     DATE        QTY      DUE      DATE     DATES     DATE      BUYER
               _____       ___         ___  __    ___        ___       ___      ___      ___       ___       _____
             P00047800     001         0    0    0607XX       15        15     0628XX     N                  WILLCOX
-----------------------------------------------------------------------------------------------------------------------
CONT: 00  PART: 4840-0003-9    EXTENSION STEM, GATE VALVE, 6    DAYS OF SUPPLY:  3       LEAD TIMES: PURCH:  7  VEND:  20   STOCK: 3
SHORTAGE:         0       COMMITTED:        0       MCC:S3
RECEIVED QTYS   :  PI:         0        AC:           0  DR:             0  HD:           0  RE:          0
AVAILABLE QTYS  :  PLT 001     7        PLT 002       0  PLT 004         0
                                       ORDER                                   DOCK      MULT
               ORDER       LINE        STATUS     OPEN      ORDER      BAL      DUE      DUE      PROMISE
                NO          NO         HD  LN     DATE        QTY      DUE      DATE     DATES     DATE      BUYER
               _____       ___         ___  __    ___        ___       ___      ___      ___       ___       _____

           *** THIS PART HAS NO REQUISITIONS OR P.O.S ***
```

Figure 5-8 Report on essential parts and supplies

P0051 PAGE: 3
RUN DATE: 06/29/XX OUTSTANDING REQUISITION/PURCHASE ORDERS REPORT RUN TIME: 17:17:39
FOR PLANT 001

REQ NO	LINE NO	REQ STATUS HD	REQ STATUS LN	OPEN REQ DATE	REQ QTY	REQ BAL	PO NO	LINE NO	PO STATUS HD	PO STATUS LN	OPEN PO DATE	PO QTY	QTY DUE	EARLY SHIP FLAG	DOCK DUE DATE	MATL STATUS
PART: 1060-9075-6				ADAPTOR, LEAD FLANGE, 3/4 INLET												
PR0051289	001	O	O	0528XX	6	0	P00047790	001	O	O	0609XX	6	6	N	0722XX	N
PART: 1061-1000-0				STOP, CURB, CU/CU, 1 DIA.												
					0	0	B00745003	007	O	O	0407XX	668	180	N	0607XX	N
					0	0	B00745005	007	O	O	0528XX	760	760	N	0723XX	N
PART: 1061-2000-9				STOP, CURB, CU/CU, 2 DIA.												
PR0047862	001	O	O	1020XX	38	0	P00044730	001	O	O	1030XX	38	0	N	1120XX	N
PR0051295	001	O	O	0528XX	62	0	P00047720	001	O	O	0608XX	62	62	N	0803XX	N
PART: 1065-1400-3				COUPLING, GALVANIZED, 1-1/2												
PR0051026	006	O	O	0510XX	15	0	P00047488	006	O	O	0513XX	15	15	N	0524XX	AC
PART: 1066-1000-9				COUPLING, COPPER/COPPER, 1												
					0	0	B00746007	012	O	O	0608XX	360	360	N	0708XX	N
PART: 1066-1400-1				COUPLING, CU/CU, 1-1/2 DIA.												
					0	0	B00744005	014	O	O	0601XX	150	47	N	0730XX	N
PART: 1066-2000-8				COUPLING, COPPER/COPPER, 2												
					0	0	B00745005	015	O	O	0528XX	30	30	N	0723XX	N
PART: 1068-1400-7				CPLG, COPPER/MALE IPT, 1-1/2 D												
					0	0	B00745002	022	O	O	0304XX	12	12	N	0503XX	N
PART: 1068-2000-4				CPLG, COPPER/MALE IPT, 2 D												
					0	0	B00745005	023	O	O	0528XX	5	5	N	0723XX	N
PART: 1069-4000-0				COUP., STEEL PIPE, 4 DIA.												
PR0051385	001	O	O	0607XX	4	0	P00047863	001	O	O	0614XX	4	4	N	0621XX	AC
PART: 1072-1006-4				COUP., BRASS RED., 1 TO 3/4												
					0	0	B00715024	010	O	O	0617XX			N	0705XX	N
					0	0	B00715025	010	O	O	0623XX			N	0706XX	N
PART: 1076-0808-5				CROSS, M.J., 8 X 8 DIAS.												
					0	0	B00714035	057	O	O	0617XX			N	0719XX	N

Figure 5-9 Report on outstanding parts orders

of potential problems. Other reports, such as those that identify items that are no longer used, can be specified once basic data have been gathered. The initial effort to collect the necessary information for the database is a time-consuming task for a large warehouse, but this procedure is the only practical method for establishing an effective inventory control system. Maintenance groups can make effective use of information gathered by the central warehouse to set up their own stockrooms, whether these facilities operate manual or automated information systems.

Other water utilities may find other approaches satisfactory, depending on their sizes and locations of sites. In any case, the principles outlined in this chapter are meant to be general guidelines for any effective system of inventory control.

References

American Water Works Association. 1982. *Basic Management Principles for Small Systems*. Denver, Colo.: American Water Works Association.

Moore, R. 1998. Fundamentals of effective stores management. *Plant Engineering* 52 (9).

CHAPTER 6

Maintenance Costs and Budget

One of the most important responsibilities of a maintenance manager is to minimize cost while ensuring that the utility's equipment and structures are reliably maintained. In addition, effective managers work to convince senior management to support legitimate budget requests and funding for innovative programs. Each of these tasks requires in-depth knowledge of the costs incurred to operate a maintenance department.

The Cost of Maintenance

Senior water utility management often views maintenance as a major cost center. They generally conduct very careful reviews when the annual maintenance budget is submitted. This scrutiny requires a maintenance manager to have a thorough understanding of the costs incurred by the organization. The manager, therefore, needs data in a concise, well-organized format to be able to present cost information as well as budget requests to senior management in an intelligible manner.

Types of Maintenance Costs

Maintenance expenses fall into five primary categories:

1. Capital investments—This class includes costs for new and replacement equipment and structures. Water pumps and large motors are examples.

2. Maintenance actions—The costs of preventive maintenance (PM) and corrective maintenance (CM) activities (e.g., labor and spare parts) are included in this category.
3. Utilities—Water, sewer, gas, power, and communications services make up this group of costs.
4. Fuel—The cost of fuel to power the vehicular fleet as well as equipment at treatment plants and pumping stations is such a significant factor in operations and maintenance costs that it is identified separately in the utility's budget.
5. Miscellaneous—This category includes, for example, costs for service contracts, dismantling equipment, and special studies. Expenses to develop or modify a maintenance management system (MMS) would be included in this category.

Information about expenses incurred by the maintenance sections under these categories should be captured in a way that satisfies as well as possible the needs of both the utility's accounting function and the maintenance department. The accounting group requires relevant data in a suitable format to maintain records. Cost data help accountants to determine appropriate rate structures, for example. A maintenance manager needs data for cost control (e.g., comparison of actual costs with estimated costs) and for budget preparation.

Accounting for Maintenance Costs

Many water utilities try to satisfy the needs of both the maintenance and accounting groups by classifying maintenance cost data into some standard groupings.

Labor. The time spent by field personnel carrying out their duties is one cost element. The total is usually further divided into costs for salaried and hourly personnel.

Equipment. Major pieces of equipment are generally included in this category. Such costs are capitalized and depreciated over their service lives.

Spare Parts/Supplies. Items that are normally kept in central inventory or maintenance section storerooms make up this cost group. Small pieces of equipment, such as fractional horsepower motors, may also be considered in this category.

Services. This element covers costs for outside contractors or consultants, possibly including labor and material.

Overhead. This category includes costs that cannot be assigned to specific jobs, such as the salaries of management personnel and the nonproductive time of field personnel. Normally, maintenance and general utility overhead are segregated to allow managerial analysis, because the maintenance manager should be able to exert considerable control over at least a portion of the section's overhead, despite minimal influence on the overall utility overhead. Maintenance overhead includes expense items specific to the department, such as the cost of operating workshops for training purposes and providing safety gear (e.g., safety gloves). The costs of operating departments such as finance and personnel that provide services to all sections of the utility are examples of general utility overhead, and these costs are shared by all departments.

With this type of accounting system, cost information for selected utility operations is gathered. For example, the elements of cost listed earlier may be reported to the maintenance manager for each of the following categories:

- Filtration plant or well sites
- Impoundments
- Pumping stations
- Storage facilities
- Distribution system

For each type of operation, the maintenance manager receives reports for both direct and indirect costs. Direct costs are those that can be charged against specific jobs, whereas indirect costs are overhead costs. Indirect costs should be further broken down by individual section and general utility costs to enable the section manager to exercise control over the overhead costs specific to the group. For example, the cost of operating a maintenance storeroom would be recorded as an indirect maintenance cost, whereas the cost of running the main storeroom serving all utility departments would be reported as a general utility indirect cost.

Other utilities, particularly those in the public sector, do not report overhead costs to section managers; instead, they establish expense categories for all cost elements. For example, the maintenance section may budget for power costs. Figure 6-1 shows the monthly cost summary for a utility that uses this technique for reporting costs. Each office is assigned a section number, and costs are reported to the manager by expense element (e.g., materials used) and further broken down by account number. Account numbers are assigned to capture cost data for general purposes such as vacation or sick leave expense.

Specific identifiers such as location, activity, or transaction codes can be used to group data for specific utility operations. For example, data for labor costs incurred by the maintenance section to service a particular pumping station could be determined by assigning a location code to that station.

Either of these approaches may satisfy the requirements of the accounting group and senior management for cost information. However, neither is likely to completely fulfill the requirements of the maintenance manager for monitoring section costs. However, a single system can categorize expenses by either section within the utility or expense category for the entire utility, creating the possibility of using a common database. A maintenance manager must determine whether the accounting database provides enough detail or a separate system is required to track maintenance expenses.

Since the water utility probably already operates an established accounting system for gathering and reporting cost information, the maintenance manager must understand the current methods for gathering and reporting the data. The next step is to ascertain, in conjunction with other maintenance control techniques, additional requirements (if any) for cost data, and how to collect and report this data. Certainly, a maintenance manager should plan to make use of data already gathered for accounting purposes, building on this base of information to develop cost-control methods suitable for maintenance.

Controlling Maintenance Costs

In general, the maintenance manager can investigate two approaches for controlling and possibly reducing the cost of maintaining the utility's property. The first is to ensure that only required maintenance activities are carried out, that is, to avoid *over* maintaining equipment and structures. The second approach is to make certain that available resources are used as efficiently as possible.

MONTHLY SECTION REPORT
JUNE 20XX

		CURRENT MONTH CHARGES	FISCAL TO DATE CHARGES	FISCAL BUDGET	AVAILABLE BUDGET BALANCE
037	DISTRIBUTION SYSTEM MAINTENANCE OFFICE				
002	SALARIES				
01601	MAIN DISTRIBUTION SYSTEM	4,345	68,029		
06437	DISTRIBUTION MAINTENANCE OFFICE		1,265		
06465	DISTRIBUTION MAINTENANCE ADMINISTRATION	8,390	134,276		
06471	I/I EVALUATION OFFICE		21		
06760	BILLED WORK CHARGES X JOB NOS.		379		
06930	EDUCATIONAL AND TRAINING TIME	1,665	5,143		
06939	ADMINISTRATIVE LEAVE WITH PAY	28	292		
06941	VACATION PAY	1,522	25,104		
06942	SICK LEAVE PERSONAL ILLNESS	178	4,988		
06943	HOLIDAY PAY	1,287	16,520		
06949	SICK LEAVE OTHER	2,790	3,826		
07112	WATER SUPPLY CONST DIRECT CHARGES	4,155	8,633		
		24,304	268,476	271,133	2,657
003	MATERIALS				
01601	MAIN DISTRIBUTION SYSTEM		490		
06437	DISTRIBUTION MAINTENANCE OFFICE	5	146		
06760	BILLED WORK CHARGES X JOB NOS.	9,516	17,512		
		9,521	18,148	21,200	3,052
008	SERVICES BY OTHERS				
01601	MAIN DISTRIBUTION SYSTEM		326,453		
01603	HOUSE CONNECTION MAINTENANCE	45			
06437	DISTRIBUTION MAINTENANCE OFFICE	1,320	29,630		
06465	DISTRIBUTION MAINTENANCE ADMINISTRATION		806		
06760	BILLED WORK CHARGES X JOB NOS.	14,589	200,994		
07112	WATER SUPPLY CONSTRUCTION DIRECT CHAR	2,274	9,423		
		18,138	567,306	553,500	13,806
010	CONTRACT WORK				
07112	WATER SUPPLY CONSTRUCTION DIRECT CHAR	1,451,219	5,230,620		
		1,451,219	5,230,620	5,380,000	149,380
014	OFFICE SUPPLIES, SERVICES, AND EXPENSES				
06436	MAINTENANCE BUREAU OFFICE		196		
06437	DISTRIBUTION MAINTENANCE OFFICE	266	1,610		
06454	MAIN LINE SECTION		78		
06465	DISTRIBUTION MAINTENANCE ADMINISTRATION		265		
		266	2,149	2,500	351

Figure 6-1 Monthly expense report

The potential for adverse health impacts gives a water utility a special responsibility toward its customers to deliver a quality product. Thus, utilities must not risk *under* maintaining equipment and structures as a way to cut costs. However, the utility has the responsibility for minimizing the cost of delivering water to its customers. To maintain this balance, managers must assess the importance of each component of the water processing and delivery system and evaluate the reliability of each system. Drawing on this information, previous experience, and manufacturers' recommendations, a maintenance manager can then strike an effective compromise in system maintenance.

If the maintenance section has resolved general questions concerning the required level of maintenance, the manager should take steps to ensure productive use of the section's personnel, equipment, and supplies. In the absence of performance monitoring tools such as time standards for maintenance tasks, cost data offer the most reliable source of information on the efficiency of the maintenance operation. Even when data on performance standards have been developed, collection and analysis of data on maintenance costs remain an important source of information for three types of activities:

1. Preparing the section's annual budget.
2. Gathering information on other expenditures required to complete a maintenance task, such as the cost of repair parts and supplies and the time charged by other utility personnel, including engineering and support staff.
3. Identifying high-cost maintenance activities that may require more intense analysis, particularly those for which standard work hours are difficult to predict.

To satisfy the section's cost-reporting requirements, the maintenance manager may need to develop new forms or modify existing ones. The next step is to determine which cost data to gather and how to collect it.

Collecting Cost Data

In determining the type of cost data to be gathered by the maintenance section for internal analysis, a manager must decide how that data will be used. These decisions, in turn, will help in identifying the mechanisms for collecting the information. For example, if a breakdown of expenses by site is needed, then maintenance work orders need space for recording account numbers, as seen in the work order in Figure 4-5. Similarly, utility service and equipment costs as well as other types of expenses will be charged against the appropriate account numbers. Techniques for collecting data and reporting accurately vary for the different cost categories.

Labor Costs

In virtually every case, the worker time sheet is the basic document for capturing data on labor costs. These costs can be recorded with account and job numbers. In the example shown in Figure 6-2, the account number is used as described earlier in the chapter under the heading "Accounting for Maintenance Costs" (i.e., it is used for gathering data for general information). The job number can be used to capture labor costs for particular types of activities carried out by the utility. For example, the developer of a new housing subdivision may call on utility personnel to perform certain specialized work such as making connections to the main line. Assuming that utility policy requires the developer to pay for this work, the job number is used to gather the associated costs in one account. Work done by personnel from different sections of the utility can be accumulated in one total, although the accounting device is not designed to gather cost data on individual work orders. In general, the sheer number of maintenance actions carried out prohibits the use of the job number for recording maintenance costs in such detail.

Although the time sheet is useful to gather and report labor costs for both accounting and maintenance, it is inadequate to provide information on the total cost of any individual work order. To determine the costs by specific job, by category of work (e.g., pump repair), by skill, or by some other classification, more data are required. For this information, the logical documents to use are work orders or job tickets. Both may be designed to help in recording all hours devoted to particular maintenance jobs. The work order in Figure 4-5 calls for total crew hours, allowing cost-of-labor estimates that use cost-per-hour averages for the skill levels of the technicians who completed the work. Then, if the number of work orders is relatively small, an estimated cost for each work order completed during the reporting period can be developed.

BIWEEKLY TIME SHEET

SECTION   EMPLOYEE NO.   NAME   PAY PERIOD ________ TO ____

ACCOUNT NUMBER	JOB NUMBER	JOB LOCATION	DATE / HOURS	S	M	T	W	T	F	S	S	M	T	W	T	F	S
69 4 1 A		VACATION LEAVE															
69 4 2 A		SICK LEAVE PERSONAL															
69 4 9 A		SICK LEAVE OTHER															
69 4 3 A		HOLIDAY															
		OTHER															
REGULAR TIME																	
		TOTAL HOURS															
		EMERGENCY/SPECIAL DUTY PAY	$														
OVERTIME HOURS ONLY																	
		TOTAL OVERTIME HOURS															

APPROVED ____________________   SIGNED ____________________________

Figure 6-2 Labor time sheet

Only small water systems can practically implement manual approaches for collecting this data. To analyze cost data, a large water utility will need to consider automating its data collection mechanisms. An automated maintenance information system aids in the preparation of a number of useful reports. The formats of these reports depend, of course, on the needs of the maintenance manager and the resources in time and money available to develop them. The report shown in Figure 6-3 is likely to be useful to any maintenance organization. This report gives labor and cost information on specific jobs, and additional manipulation of this data can generate exception reports listing, for example, jobs in which the actual costs exceeded estimates by predetermined limits.

Another useful report lists nonproductive time for field crews. Figure 6-4 shows a report that summarizes such data by depot. Note that management has made the decision to record travel time as a nonproductive activity, despite the obvious fact that crews usually require time to get to work sites. This distinction enables management to separately analyze travel time to determine whether the number of hours reported in this category could be reduced by, for example, assigning crews to different depots. Further, comparisons of crew performance against standard times is complicated if travel or other nonproductive time is included in the standard. By excluding nonproductive hours from cost reports on individual jobs, management can determine the actual labor costs for specific jobs and identify those for which the costs appear to be excessively high.

Equipment Costs

The cost of a piece of equipment is easily determined from either the purchase order or the supplier's invoice. A technique must then be developed to charge the cost against the job in which the equipment will be used. The work order number is frequently used to accomplish this goal, while assigning an account number ensures that the correct account and department are charged.

Spare Parts/Supplies Costs

The costs of spare parts and supplies used to carry out maintenance work are more difficult to allocate than equipment costs. No practical system can account for low-cost supplies such as nuts and bolts that

PLANT MAINTENANCE MANAGEMENT SYSTEM
MONTHLY CORRECTIVE MAINTENANCE SUMMARY
SEPTEMBER 20XX

RUN DATE: 9/30/XX

JOB NUMBER EQUIP AREA/ID	EQUIPMENT NAME LOCATION	APPARENT CAUSE OF MALFUNCTION	COMPLETION DATE	HOURS: REGULAR OVERTIME	COSTS: LABOR PARTS CONTRACT
003522 01 04023203	RAW PUMP NO. 3 MOTOR RAW WATER PUMPING STATION	OVERLOAD OVERHEATED	9/14/XX	8.00 0.00	$166 0 0
		EQUIPMENT MALFUNCTION: OVERLOAD RELAY OVERHEATED			
		CORRECTIVE ACTION TAKEN: REMOVE/REPLACE OVERLOAD RELAY			
003535 33 04034202	NO. 2 PUMP MOTOR MONT ALTO WPS	BEARING WORN	9/15/XX	10.50 8.00	$190 $135 0
		EQUIPMENT MALFUNCTION: OUTBOARD BEARING WORN			
		CORRECTIVE ACTION TAKEN: REMOVE/REPLACE BEARING			
003539 01 12043303	NO. 3 MOTOR CONTROL CENTR FINISHED WATER BLDG	PHASE BALANCE RELAY OUT OF ADJUSTMENT	9/18/XX	6.00 0	$120 0 0
		EQUIPMENT MALFUNCTION: RELAY OUT OF CALIBRATION			
		CORRECTIVE ACTION TAKEN: ADJUST RELAY CALIBRATION			

Figure 6-3 Cost report

DISTRIBUTION SYSTEM MAINTENANCE
NONPRODUCTIVE TIME SUMMARY REPORT
JULY 20XX

NONPRODUCTIVE ACTIVITY	NUMBER OF HOURS	% OF ALL HOURS	NUMBER OF HOURS	% OF ALL HOURS	NUMBER OF HOURS	% OF ALL HOURS	NUMBER OF HOURS	% OF ALL HOURS
DEPOT	980	9.9	937	9.8	557	5.6	602	6.7
TRAVEL	1,223	12.3	1,027	10.8	1,521	15.2	1,365	15.3
TRUCK/EQUIPMENT BREAKDOWN	139	1.4	140	1.5	187	1.9	146	1.6
INSTRUCTION DELAY	80	.8	63	.7	47	.5	134	1.5
MATERIAL DELAY	177	1.8	71	.7	66	.7	52	.6
EQUIPMENT DELAY	82	.8	39	.4	65	.6	24	.3
TOOL DELAY	0	0	0	0	19	.2	10	.1
INCLEMENT WEATHER DELAY	117	1.2	73	.8	175	1.7	66	.7
CUSTOMER/MISS U DELAY	13	.1	65	.7	92	.9	43	.5
MEETINGS	133	1.3	141	1.5	122	1.2	195	2.2
INJURY	0	0	43	.5	0	0	0	0
EMERGENCY STANDBY	43	.4	6	.1	2	0	11	.1
INVENTORY	273	2.7	151	1.6	206	2.1	243	2.7
CLEANING YARD/EQUIPMENT	490	4.9	7	.1	116	1.2	175	2.0
WAREHOUSE DELAY	43	.4	69	.7	37	.4	140	1.6
CONTRACTOR DELAY	11	.1	24	.2	61	.6	35	.4
TRANSPORT MTRL/EQUIP	498	5.0	633	6.6	633	6.3	790	8.8
TEMP PATCH MAINT	201	2.0	299	3.1	310	3.1	101	1.1
SAFETY MEETING	3	0	68	.7	57	.6	197	2.2
FORMAL TRAINING	1,035	10.4	1,000	10.5	847	8.5	758	8.5

Figure 6-4 Report of nonproductive time

may be used to complete a work order. Also, more expensive spare parts that should be tracked individually may be held in inventory until they are designated for particular jobs and charged against work orders as they are used.

Typically, accounting for low-cost supplies treats the cost as section overhead, spreading it over all maintenance work in which such supplies are used. More costly items are charged against individual jobs, either as they are withdrawn from stock or after the jobs are completed. Allocating cost as parts are withdrawn from stock is probably an easier way to record the actual item cost and charge it to the proper job number. However, a system that accounts for the cost of spare parts used as the work order is processed after completion ensures that only items actually used are charged against the job. Figure 6-5 shows a work order in which the estimated cost of spare parts is added after the technician records the parts actually used to complete the work order.

Costs for Outside Services

Maintenance sections frequently employ consultants and service contractors to carry out work involving special knowledge or equipment. A project to redesign a heating/air conditioning system, for example, might involve hiring a consulting engineering firm, while maintenance of elevators might be completed under a service contract. The cost of these activities can most easily be recorded from invoices and charged to an account designated for outside services.

A cost-tracking system should record each incident of this type of work separately. Also, it should record any parts used independently from labor costs, particularly for parts that are additions to basic service contracts. This detail can be achieved by assigning location codes established for the cost accounting system when the invoice for a specific task is processed.

Overhead Costs

A utility's accounting section normally has responsibility for establishing rates for allocating overhead, both throughout the utility and in specific sections. The responsibility of the maintenance manager in this area is to confirm that the overhead rates for the section are consistently applied, if reporting practices allow this analysis. For example, some utilities charge the cost of engineering services rendered by

CORRECTIVE MAINTENANCE WORK ORDER

Date printed _____ BLDG. NAME _____________ JOB NUMBER _____
Date requested _________ Priority _____
Requested by _________ Malfunc. no. _____
EQUIP. NAME & NO. ____________________ Plant area _____
Part or model no. ____________________ Bldg. no. _____
Serial no. ____________ Level _____
SKILL CODE ____________
INSTRUCTION BOOK/FILE NO. ____________ CI no. _____
Electric motor data:
HP _____ Frame no. _____ Volts _____ Amps _____
Pump packing ___________
GENERAL INFO. ____________________________________
____
____
Indication of trouble _____________ When discovered _______
Apparent cause ____________________
Effect ____________________
CORRECTIVE WORK REQUIRED:
____
____
Sketch required? ____ Estimated cost _____ Estimated time _____
REMARKS ____

Card code 01 (1–2) Tran. code RA (3–4) Job no. __ (5–10) Type job __ (36–37) Equip. ID. __ (38–50)

Parts used:

Part no. (11)	Description (12–23)	Contr. Reqd? (24)	Quantity Used (25–27)	Unit of Measure (28–29)	Office use only Estimated Cost (30–35)
_____	__________	____	_____	_____	_____
_____	__________	____	_____	_____	_____
_____	__________	____	_____	_____	_____
_____	__________	____	_____	_____	_____

Card code 01 (1–2) Trans. code CC (3–4) Job no. _____ (5–10) Equip. ID. _____ (11–23)
What was found wrong? ________ How was it fixed? ___________
______________________ ______________________
______________________ ______________________
Outside contractor required? __ Yes __ No
Date out of service ________ Date job completed ___________
Contractor cost ___________ Requestor ___________

______________ Mechanic ___________ ID. no. ______________ Maint. supervisor

Figure 6-5 Work order with space for cost-allocation information maintenance staff to the departments for which the work is carried out, whereas others treat the cost of engineering as maintenance section overhead. Another possibility is to assign a work order for each task of this type and gather cost data in the same manner as for other maintenance activities. The particular method chosen depends on the utility's accounting practices; the maintenance manager must understand how overhead is applied in order to monitor these costs.

Energy Costs

Many water utilities find that the energy expense, particularly for electrical service, constitutes a significant portion of the cost to operate treatment plants and pumping stations. To closely monitor energy costs, these outlays are frequently captured under one account, because significant variations are most easily detected if one unit in the utility is responsible for oversight. The maintenance section is the logical choice for this oversight, because maintenance technicians are most likely the staff who must follow up on any unusual charges from other utilities. The invoices from utility companies provide cost data, which should be gathered by site using location codes. Each code may refer to a pumping station, or for a treatment facility, to a section of the plant.

Once the maintenance section has decided which techniques to use to gather cost data, the next step is to determine how to report this information.

Management Reporting

Once management has decided which cost data to gather and how to collect it, the next step is to determine reporting needs.

Management Cost Reports

As with performance reports, management reports of costs incurred by the maintenance department fall into two categories. The first gives summary data on all costs for the entire section for the reporting period, broken down by individual jobs, site, and other classifications needed to track costs in a specific operation. Included in this classification are budget variance reports such as the one shown in Figure 6-1, which reports actual versus budgeted expenses. The second type of management reports consists of exception reports, which relate information on costs that differ from expected levels. This type of report is produced only if costs fall outside previously established limits. For example, a particular job may appear in an exception report only if it exceeds the estimated cost of the work by 20 percent.

Manual Cost Reporting Systems

Since most water utilities have implemented automated accounting systems, a maintenance manager generally receives computer-generated reports like the one in Figure 6-1. The utility's information technology section generates these reports, giving cost data classified by expense type, department or section, and possibly other criteria. If a maintenance manager has no access to an automated maintenance information system, manual techniques still allow applications of graphs and other techniques to track costs over time. For example, labor costs, power costs, spare parts costs, and other categories could be plotted or recorded on a monthly basis. These tools can highlight significant departures from, say, the averages over the previous six months, which would result in further investigation by maintenance personnel. Any substantial deviations from expected averages noted would be the basis for an exception report to the maintenance section manager.

Clearly, any such efforts are practically limited by the effort and cost required to develop useful cost reports. Few manual reporting systems allow for cost-effective analyses of individual work orders, except for those with unusually high costs. However, most routine jobs fall in the low-cost category, allowing practical processes for investigating high-cost jobs and their conformance with the limits established by the manager. Jobs outside the range would be reported to the maintenance manager on an exception report. Since the maintenance section of a large water utility completes many work orders annually, use of the computer is no longer simply a desirable added feature in a system to gather and report on cost information; rather, it is a necessity.

Automated Cost Information Systems

An automated cost information system enables the maintenance manager to gather cost data quickly and generate accurate reports. For example, the report shown in Figure 6-6 gives the reviewer cost data on 680 work orders, breaking it down among in-house preventive and corrective maintenance and contractor costs. Costs for both labor and spare parts are given. In addition, other reports can be developed from the database developed for this maintenance information system.

Preparing a Budget

The historic cost data gathered from the accounting and maintenance sections form the basis for developing the annual maintenance budget. In addition, actions proposed or undertaken by other departments, such as operations and engineering, may influence the maintenance budget. For example, changes planned or already implemented by operations may affect maintenance costs. Engineering may have new systems coming on line that will have an effect on maintenance operations. Senior management may be planning a major reorganization involving substantial building modifications. A maintenance manager must keep in contact with all other departments of the utility to prepare a realistic budget for the next fiscal year.

The preparation of the maintenance budget can be a straightforward process if the section manager plans the steps, gathers all necessary

Plant Maintenance Management System
Work Accomplished Summary
July, 2008

Zone/Plant: Zone Name:	Preventive Maintenance	Corrective Maintenance	Totals
Number of Actions Completed	588	92	680
Regular Hours	1,48.25	972.90	2,921.15
Overtime Hours	0.00	20.00	20.00
Total Hours	1,948.25	992.90	2,941.15
Labor Costs	$19,363.93	$9,857.36	$29,221.29
Parts Costs Estimated	400.93	17,954.62	18,355.55
Outside Contractor Costs	0.00	6,903.00	6,903.00
Total Costs	$19,764.86	$34,714.98	$54,479.84

Figure 6-6 Work accomplished summary report

information, and allows sufficient time to prepare a well-documented, defensible case for any funding requests. Such a process might follow these steps:

1. Prepare a schedule of the activities (e.g., items 2 through 7 of this list) needed to meet the due date for the budget submittal.
2. Collect data on the previous year's expenditures. These data will come primarily from the accounting section, but sources will also include maintenance records.
3. Identify extraordinary expenses from the previous budget and assess whether similar needs will arise in the future. If not, reduce the appropriate line items in the previous budget by the amounts expended on these items.
4. Prepare a list of major work activities or costly capital investments by the maintenance section itself scheduled for the coming year. Estimate their cost, and anticipate justifications for the requests. A project to implement a new or modified MMS is likely to fall into this category.
5. Arrange meetings with representatives of other sections whose activities typically affect the maintenance budget to determine if these groups' plans will influence maintenance expenses during the next year. These plans could affect labor, supplies, service contracts, utility costs, and other expense items. Another approach could be to develop forms to be sent to other sections to assess specialized requirements that should be included in the maintenance budget. The form shown in Figure 6-7 is an example of this method of obtaining information for budget purposes.
6. Incorporate inflation and overhead factors as appropriate, as well as proposed increases in labor costs for section personnel. Senior management will normally dictate figures for these expense categories.
7. Prepare a draft of the budget for review by the next step of management. It is advisable to present the proposed budget to the immediate supervisor for review before preparing the final draft for senior management review.

FY09
Radio Equipment Request Form

THIS SECTION TO BE COMPLETED BY REQUESTING DIVISION

DIVISION NUMBER: ____________ DIVISION NAME: ______________________________

TOTAL NUMBER OF RADIOS REQUESTED: ______________________________

NUMBER TO BE INSTALLED IN NEW VEHICLES: ______________________________

These radios are required for the following reasons:

____

____

____

NUMBER OF RADIOS TO BE INSTALLED IN EXISTING VEHICLES: ______________

These radios are required for the following reasons:

____

____

____

PLEASE REASSIGN THE FOLLOWING RADIOS TO ANOTHER DIVISION AS THEY ARE NO LONGER NEEDED:

____

____

____

OTHER RADIO TYPE EQUIPMENT, PAGERS, WALKIE-TALKIES, ETC. REQUESTED:

____

____

The above equipment is requested for the following reasons:

____

____

____

DIVISION HEAD REQUESTING ____________________ DATE

DEPARTMENT HEAD APPROVAL ____________________ DATE

- -

THIS SECTION TO BE COMPLETED BY MAINTENANCE DEPARTMENT

Estimated Cost of Radios: $______________________________

Maintenance Department Recommendations: ______________________________

- -

_____ APPROVED _____ DISAPPROVED BY: ______________________________

DATE: ______________________________

Figure 6-7 Radio equipment request form

The result of this effort will be a budget package for submission to senior management for final review. Figure 6-8 shows the summary sheet of a typical budget proposal. Detailed documentation is also required by upper management. Attachments such as that shown in Figure 6-9 are typical of the additional information required to complete the budget package.

The maintenance manager should allocate sufficient time for preparing the section's budget in a thorough manner. Expenses for equipment and projects that are specified and justified in the yearly budget are more likely to have funding set aside to purchase and execute than expenses for unallocated projects that come up during the year. While much of the information needed to complete the budget comes from collections of historical data, in some cases, estimates of maintenance costs for a new system or site will need to be made.

Estimating Maintenance Costs

One responsibility of the maintenance section identified in chapter 1 is to review specifications and plans for new systems, such as buildings, pumping stations, extensions to the distribution network, and equipment. An important element of this review is the development of estimates of the funds needed to maintain the new system.

If the new system essentially duplicates an existing one, maintenance costs are relatively easy to estimate. The only exception is the cost of unscheduled maintenance. However, even in this case, past experience will provide reasonably reliable numbers. More difficulty surrounds the question whether a modest addition to the utility's system is sufficient to justify a request for additional personnel. For example, if a new housing development is constructed, are extra personnel needed to maintain the additional distribution facilities? If a new pumping station is also required to service the development, can the equipment maintenance section handle it with existing personnel?

To answer these questions, the maintenance manager should estimate the labor hours needed to maintain the new system and add that total to the hours needed for existing operations. The sum dictates whether a request for additional staff is warranted. Appropriate information on labor requirements must be carefully gathered and documented in this way.

MAINTENANCE DEPARTMENT ELECTRICAL DIVISION

	Year 1 Actual	Year 2 Actual	Year 3 Budget	Year 4 Budget Request
Grand Total	$6,078,547	$8,261,747	$10,589,400	$11,683,600
Total salaries and wages	848,729	1,191,185	1,649,600	1,921,500
Total all others	5,229,818	7,070,562	8,939,800	9,762,100
Salaries and wages				
Regular time	818,972	1,120,278	1,609,700	1,877,500
Overtime	29,757	70,907	39,900	44,000
Total	848,729	1,191,185	1,649,600	1,921,500
Authorized positions	53	60	89	97
Materials	521,096	1,299,441	745,700	751,500
Heat, light, and power	4,328,353	5,163,195	7,512,600	8,405,000
Rental	36,737	53,779	39,500	46,000
Services rendered by others	257,218	401,194	498,000	435,000
Contract work	—	—	25,000	—
Office supplies, services, and expenses	982	3,699	1,000	1,200
Mileage	378	102	—	—
Oils, lubricants, and other petroleum distillates	200	186	300	200
Telephone and telegraph	71,651	88,568	91,600	95,000
Supper money	130	199	100	200
Refunds and adjustments	476	651	—	—
Radios and radio equipment	3,242	50,781	9,000	16,000
Shop tools, laboratory, and miscellaneous equipment	9,355	8,767	17,000	12,000

Figure 6-8 Budget estimate summary

FY07 Proposed Programs
Explanation & Justification
Maintenance Department: Electrical Maintenance Division

PROGRAM ANALYSIS

NORTHWEST ZONE—POSITIONS—The 19 currently authorized positions are divided into six crews. Each crew performs both preventive and corrective maintenance at various facilities in the zone. Of the 19 positions, the 5 electrical positions complete the 2400–3000 work orders generated each year. It is estimated that one person can complete approximately 500 work orders per year. One additional electrical technician is requested this year to prevent a backlog in work orders. Work orders for this year, while budgeted at 2400, are estimated to total 3000. It is estimated that all 3000 work orders will also be completed this year.

In addition to the position necessary to continue current service levels, one additional instrument/electrical position is requested to perform the preventive and corrective maintenance associated with the three water stations that will become operational this year.

ALL OTHER—The All Other items request for this program is $259,000; $113,000 for materials, $27,000 for rentals, $125,000 for services by others, and $2,000 for shop tools.

Figure 6-9 Budget support document

Sometimes past experience is not a reliable indicator of the maintenance requirements for a new system addition. If the new system represents a relatively small addition to the water utility's operations, the cost of maintaining it will be a small percentage of the maintenance budget, and the maintenance manager can safely handle this situation by adding a modest sum to the section's budget request. This action should be documented with the notation that future requests for funds to maintain the new system would be made as a result of data gathered through experience. Consultation with the manufacturer or engineers involved may help to develop the initial estimate.

If, however, a large installation is involved, greater care should be taken to develop a cost estimate closer to actual costs. One approach is to prepare cost estimating forms for various line items in the budget. Figures 6-10 and 6-11 are examples of forms developed for this purpose. These forms were developed to estimate the cost of maintaining a water treatment plant, but they are equally appropriate for use with other projects, such as water pumping stations, water storage tanks, and office buildings. Other estimating forms have been prepared for other expense items such as energy and spare parts costs. As always, estimates developed before project implementation should be reevaluated for accuracy as experience is gained from actual maintenance activities.

Controlling costs and preparing realistic budgets are critical elements for a successful maintenance management program. The maintenance manager needs, therefore, to ensure that the techniques used to gather and analyze cost information are carefully planned and executed.

SITE: ______________________ DATE: ________

PROJECT: ________________ PREPARED BY: _________

1) Direct Labor Regular Time

A) Management Supervision

Classification	No. in Class	Average Monthly Wage	% Time	Total

B) Skilled Labor

Classification	No. in Class	Average Monthly Wage	% Time	Total

C) Unskilled Labor

Classification	No. in Class	Average Monthly Wage	% Time	Total

Monthly Subtotal _____

Annual Subtotal _____

Note: A second page covers direct labor overtime and administration.

Figure 6-10 Labor estimate form

SITE: ____________________ DATE: ________

PROJECT: ______________ PREPARED BY: ________

____

1) Private Contractors

A) Scheduled

Task/Service Performed	Annual Frequency of Service/Contract	Service/ Contract Cost	Total
		Annual Subtotal	

B) Unscheduled

Task/Service Performed	Frequency of Service	Service/ Contract Cost	Total
		Annual Subtotal	
		Total Private Contractor Estimate	

2) Other Costs

Total Other Costs Estimate ____

Figure 6-11 Contractor/other costs estimate form

CHAPTER 7

Training

The 2008 AWWA State of the Industry Report highlighted some of the workforce issues facing the US water industry. The report noted that the industry will experience personnel shortages due to the retirement of key staff and a dearth of qualified and committed replacements. Furthermore, the article emphasized the importance of training, quoting one Region Six operations manager: "In the next three to five years, 60 percent of my staff will be eligible for retirement benefits. [We need] training to have new staff in place with enough experience to be able to maintain the system" (Runge and Mann 2008). Recent AWWA *Opflow* articles on workforce strategies also addressed the personnel issues facing the water industry and the important role of training in helping find solutions (Anderson 2008, Boepple and Meadors 2008).

Stated very simply, training enhances performance. It improves knowledge, skills, and motivation. Well-trained workers are the most valuable resource available for successful completion of the work of the maintenance section. Both formal training programs (e.g., classroom instruction, home-study programs) and informal programs (e.g., on-the-job, or OJT, training) are needed for the following:

- Remedying deficiencies in skills or knowledge required to perform assigned tasks with competence
- Informing new employees of the utility's rules and regulations and its code of conduct

- Aiding in the consistent transfer of the utility's operations and maintenance policies and practices. For example, Standard Operating Procedures (and Standard Maintenance Procedures) are generally included as resource material in maintenance training so that technicians understand how equipment and systems are supposed to function. These documents are a major tool for maintenance staff to use when troubleshooting malfunctions.
- Instructing maintenance personnel on modifications in the operation of the maintenance management program
- Informing senior management of the capabilities of the maintenance section to provide information via the maintenance management system (MMS)
- Informing operations and other interested sections within the utility of major changes in the operation of the maintenance program, with particular emphasis on the role of these other sections in executing program modifications
- Providing employees with new knowledge to qualify them for promotions
- Preparing staff to successfully complete maintenance technician certification programs, if the utility supports such programs
- Instructing personnel in the need for good safety habits

Clearly, successful training for these purposes requires careful planning to coordinate the efforts of many individuals.

Responsibility for Training

Each maintenance supervisor is responsible for instructing subordinates in the correct way to perform the duties of the section. However, this type of training, while potentially very valuable, is not adequate to ensure proper maintenance of the utility's infrastructure, especially as the complexity of available technology increases. Newer techniques are available for distribution system maintenance, such as the renewal of pipelines by relining and the use of GIS technology to help locate and maintain pipelines. Technicians maintaining water treatment equipment must be able to work more with electronic instrumentation such as programmable controllers as well as electrical/mechanical equipment, while building maintenance involves work with complex energy management systems.

Many water utilities have responded to the importance of proper training by establishing internal training sections. The role of the training supervisor is to coordinate requests for training received from the other utility departments and efficiently allocate available resources of personnel and funds. The training group may also participate in the planning and delivery of training programs, contract with consultant firms who specialize in training, and ensure effective participation in vendor training programs delivered as part of construction projects.

To ensure that maintenance workers receive required training, the maintenance manager may want to appoint an individual from the group to act as training coordinator. The responsibilities of the maintenance training coordinator include coordinating with the training section, verifying availability of resources (e.g., facilities and training aids), arranging for the selection of trainees, and keeping track of training delivered to individuals. This latter task is very important because the employees may receive training from a number of sources, for example, contractors providing new equipment, in-house and home-study courses, and others.

A small water utility may not be able to justify the cost of a full-time training section, but management still must make sure that employees have access to training programs. Every maintenance section should appoint a training coordinator. The maintenance manager may have to fill this important role in a small utility.

Assessing the Need for Training

The first step in executing a successful training program is to determine the role of training in the maintenance section. Often, perceived deficiencies in performance by field technicians result, not from lack of knowledge or skill, but rather from other factors such as poor equipment design. Planners should not, therefore, assume that training is always the answer.

Training section personnel determine whether training is likely to give the desired result. The maintenance manager and/or training coordinator should plan to take advantage of this resource. As a first step toward establishing a training program, the training group can assist the training coordinator in carrying out a needs assessment and in identifying resources available to satisfy training needs. The evaluations needed to identify training needs are shown in Figure 7-1.

Structuring Training Programs

When a needs assessment indicates that training is required, the next step is to decide how to structure the training program.

Planning the Training Program

Before determining the type of training program to implement, the training section and training coordinator must do the following:

- Prepare a detailed statement of the program's goals and objectives
- Identify the participants in the program
- Determine what resources are available to carry out the training. For example, can someone on the maintenance staff fill the role of trainer? Are manufacturers' or suppliers' representatives available to carry out the training? What restrictions apply to funds available for training programs?

Training Needs Assessment

1. *Management support*—Inform management of the purpose of the needs assessment and gain their support for and participation in the process.
2. *Job performance*—Determine if that which is expected by maintenance management of its personnel is different from that which is produced. A review of job descriptions should be part of this step.
3. *Skill requirements*—Determine what skills are needed by the utility's maintenance section to carry out its work.
4. *Training program planning*—Identify the type of training programs that are required to develop the necessary skills.
5. *Management report*—Provide management with recommendations on how the training needs can be met and what resources are needed to meet these needs.

Figure 7-1 Steps for assessing training needs

- Decide whether training or maintenance personnel will have primary responsibility for the training effort

Resolving these issues helps planners to select appropriate training programs to fulfill the requirements of the maintenance section.

Utility Policies for Training

Because the maintenance section will need to follow the utility's general policies for training, the training coordinator first needs to understand available options before trying to develop a new training program.

Among the policy issues that should be resolved are senior management support for formal training courses or workshops during working hours. Without this approval, training must be offered at other times. One of the criteria frequently used to make this decision is whether the training course fills a basic need of utility staff (e.g., familiarizing maintenance personnel with a new process) or whether the course is intended to enable personnel to qualify for promotion. Some utilities have adopted the philosophy that training intended to improve the ability of personnel to perform their work should be given during working hours, as long as necessary work is completed in a timely manner.

Another question concerns the utility's policy for funding of external training courses, such as those offered at trade schools. Some water utilities provide full or partial payment for outside courses, as long as they are work related and completed satisfactorily by employees.

Types of Training Programs

Figure 7-2 lists the types of training typically considered by utilities' maintenance sections. The maintenance manager and training coordinator must decide which mix of these training techniques will prove to be most beneficial to the maintenance operation and feasible with available funds. One of the more important factors affecting this decision is the availability of suitable trainers.

Selecting Trainers

Selection of a trainer is a crucial decision for the success of a training program. In general, only experienced presenters can deliver effective formal training. The maintenance coordinator has several options to consider in trainer selection, depending on whether or not the utility wants to develop its own in-house training program, and of course, on the funds available for training.

Because they are familiar with the water utility's operations, internal staff could deliver training presentations. However, individuals from the maintenance staff often lack preparation as trainers, so expecting them to plan and carry out a workshop may well result in inadequate training and a waste of funds.

If a utility desires to develop its own cadre of trainers, it must be prepared to allocate funds to develop presentation skills in personnel who will deliver the course materials. A number of resources are

Types of Training

Informal

1. *On-the-Job (OJT)*—Given by supervisors and senior technicians on technical aspects of maintenance.
2. *Tailgate meetings*—Brief scheduled meetings to discuss such topics as safety or specific maintenance actions.
3. *Brown bag meetings*—Informal discussions held during lunch hours concerning topics of interest to the participants. A formal presentation to introduce the subject followed by open discussion is a common format.

Formal

1. *Classroom training*—Generally, training for management and supervisory personnel in either management principles or in MMS operations is conducted entirely in the classroom, while technical training for field personnel combines classroom studies and field demonstrations.
2. *Courses at training institutes*—These courses are frequently taken by employees to enhance their promotion opportunities, improve their job skills, or prepare for certification examinations.
3. *Home-study courses*—Many maintenance managers permit their personnel to take home-study courses on their own time to qualify for promotion. Competence may be administered by the employees' supervisor. It is essential that these types of programs be accompanied by on-site training on the equipment and devices that the maintenance department is expected to maintain.

Figure 7-2 Types of training

available to carry out these training of trainers (TOT) programs, including the utility's own training group, private consulting firms, universities, and professional organizations. A large water utility should at least consider this option, because it is likely to be the least costly one in the long term.

Preparing In-House Training Programs

One effective scenario may involve developing in-house trainers for frequently offered courses, such as those given to field mechanics to upgrade their technical skills and training for new supervisors. Supervisors from a number of different sections within the utility might participate in training for newly promoted supervisors. This input would help the new supervisors gain a broader perspective of the problems facing other groups.

Training that is given infrequently may be presented by outside training consultants. Management courses for senior managers are frequently handled in this manner.

Because training funds are usually limited, a program may combine methods such as limited in-house training, home-study courses, and possibly partial reimbursement for outside courses. In such a program, maintenance supervisors should play an active role in monitoring participants' progress. This approach may not provide the most effective instruction possible, but it does limit the need for developing in-house trainers or the use of outside consultants to deliver training. However, because such programs are usually voluntary, the utility takes the risk that staff will not develop the skills they need to handle new assignments or changing technologies.

If the utility decides to offer formal training programs by its own staff, steps must be taken to ensure that quality training programs are prepared and delivered. The material included in the course is just as important as the capability of the trainer. The maintenance training coordinator can consider two alternatives for preparation of training material.

First, the trainer can develop specialized instructional material based on personal experience and the needs of the department. This approach is likely to result in a course tailored to the utility's operation. However, the trainer may need help in preparing for the actual delivery of the material, while retaining responsibility for the technical content of the course. In particular, instructional techniques must foster participant involvement. Small-group activities, role playing, and field trips are effective in the proper circumstances. Someone skilled in course preparation may be needed to help the trainer delivering the course to incorporate such methods.

The second alternative is for the trainer to present materials prepared by outside organizations, adapted to the utility's specific operations. For example, Figure 7-3 presents an excerpt from a brochure on technical training programs offered by a training firm. Such training programs, incorporating examples using the utility's own equipment as models, have proven to be very effective in improving the skills of maintenance staff.

Management training programs differ from technical training. Instructional material is often presented entirely in the classroom. Management training also may rely less on lecturing and more on participant involvement, and the trainees are likely to be drawn from different departments of the utility. The requirement for careful preparation by the trainer remains, however. This type of course often employs techniques such as small-group discussions.

In addition to ongoing skills development, training may be needed to acquaint both field and supervisory personnel with the operations of a newly developed MMS. This type of training will be conducted either by the maintenance section or by a consulting firm that helped to develop the system. Trainees will come from both within and outside the maintenance group. Training to introduce an MMS must be prepared and delivered with the same attention to quality as any other training program, because the success of the MMS depends on the understanding and cooperation of all sections of the utility.

Training Aids

All training courses require training aids to be successful. These aids may include printed materials, PowerPoint slides, videos, Web-based exercises, and equipment models. Skilled trainers use a number of aids, depending on the messages they are trying to convey and the audiences they must reach. The checklist in Figure 7-4 is intended to help a trainer assess the impact and cost of different training aids.

Significant upgrades in the speed and storage capacity of computers has made them increasingly valuable as training tools, often

General and Mechanical Maintenance Pumps

Centrifugal Pumps—1
The function, operation, and maintenance problems of centrifugal and associated components are covered. This unit provides a thorough overview of all aspects of this type of pump as a basis for understanding the specifics of pump maintenance covered in the next unit.

Centrifugal Pumps—2
Building on the introduction in the preceding unit, Centrifugal Pumps—2 enables trainees to overhaul and pack a pump under the supervision of a skilled mechanic. Specific topics addressed include job preparation, safety precautions, pump disassembly, impeller inspection, bearing inspection, packing problems, rotating element disassembly, component inspection, taking clearances, pump reasonably, pump packing, and operational checking.

Positive Displacement Pumps—1
This unit details the operation of various types of positive displacement pumps (gear, screw, lobe, and reciprocating) and associated components. It also describes gear and screw pump maintenance and repair problems.

Positive Displacement Pumps—2
This unit focuses on the specifics of overhauling a positive displacement pump-job preparation, safety precautions, pump disassembly, rotor and bearing inspection, pump reasonably, and mechanical seal replacement.

Couplings and Shaft Alignments
Several types of couplings and their components are covered in this unit, which is designed to ready students to align a pump and motor using dial indicators under the supervision of a skilled mechanic. Among the topics covered are the function of flexible coupling; types of couplings (jaw, steel grid, gear); disassembly and inspection; reasonably and continuing maintenance; types of component misalignment (parallel and angular); and techniques for aligning components.

Each unit of the program is designed to support four hours of instruction, and includes a one-hour color videotape, student textbooks and instructor's guide.

Source: Adapted from Training Partner Catalog. Video-Based Training Systems. NUS Training Corp. Gaithersburg, MD (1989).

Figure 7-3 Types of technical training programs for maintenance of pumps

Checklist for Selecting Training Media

Media	Production Costs	Types of Audiences	Suitable Content			Senses Used
			Cognitive	Affective	Psychometric	
Printed materials	Very low	Individual	Excellent	Fair	Good	Sight
Lecture	Low	Group	Fair	Good	Poor	Sight and hearing
Power Point Presentation	Low	Group or individual	Fair	Good	Good	Sight and hearing
Webinar	High	Group or individual	Good	Good	Good	Sight and hearing
DVD/Video	High	Group or individual	Fair	Excellent	Excellent	Sight and hearing
Web-based training	High	Individual	Excellent	Excellent	Excellent	Sight, hearing, and body movement
Simulation	Very high	Individual	Excellent	Excellent	Excellent	Sight, hearing, smell, touch, body movement

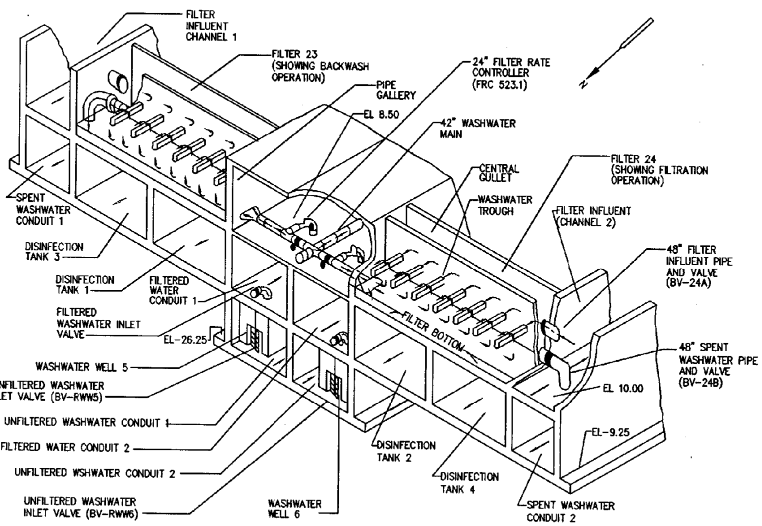
Figure 7-4 Checklist for selecting training media

through simulations for hands-on training and greater use of pictures and sketches. Figures 7-5 and 7-6 are examples of training materials incorporating pictures taken at job sites, process schematics, and specialized software to enhance the development and value of training lessons. Cutaway models of equipment and cross-sections of pipelines are also useful training aids.

Evaluation of the Training Program

Regular follow-up is important in all training programs. Feedback improves a trainer's understanding of any deficiencies in the program

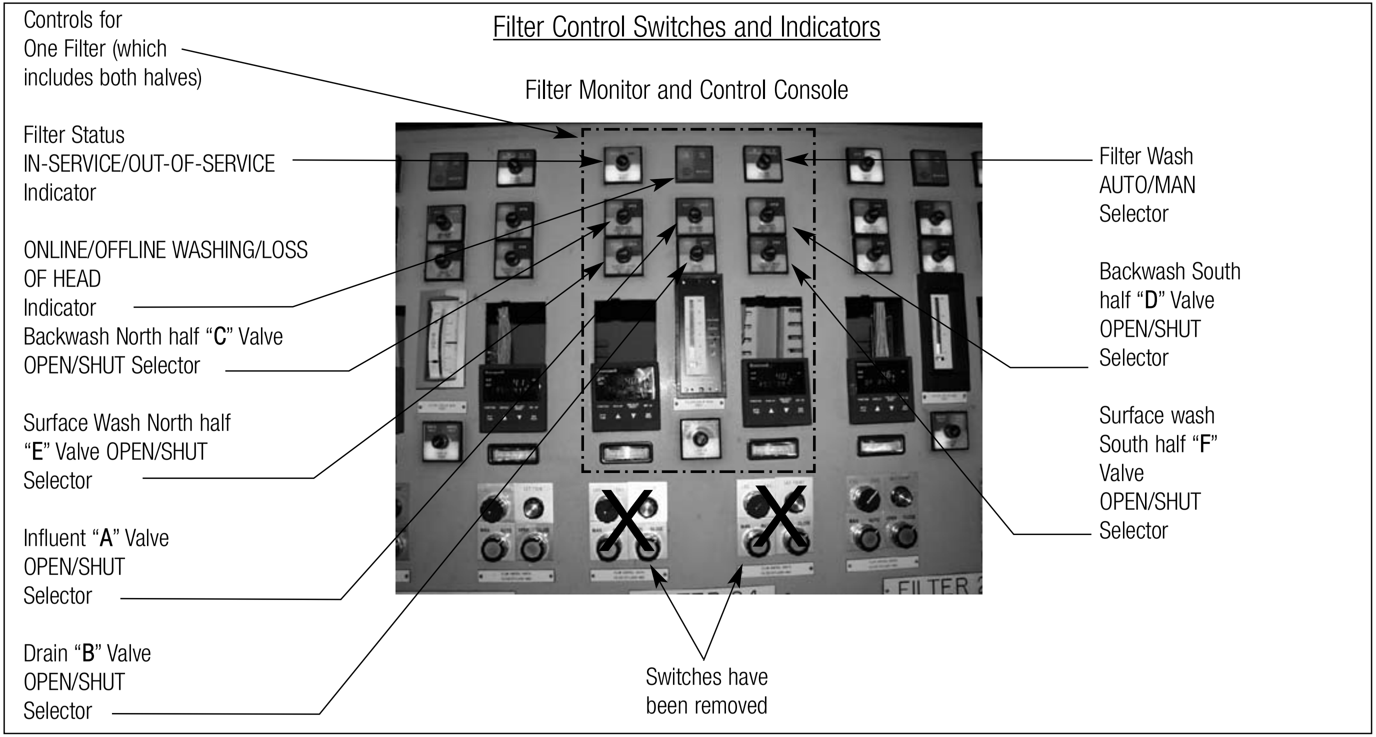
Filtered Water Conduit



- Filtered water is discharged into the filtered water conduits which lie beneath the pipe gallery.
- Filtered water conduit 1 serves the oddside filters, while filtered water conduit 2 serves the evenside filters.
- These conduits can be hydraulically balanced by opening butterfly valve BV-FI. This valve is located in the common wall between the two conduits between filter 9 & 10 and can be remotely operated from the Master Control Console.

Source: Noakes, D. 1999. Operations Study Guide—Multimedia Filtration. Washington, D.C.: Operation and Maintenance Assistance Project.

Figure 7-5 Multimedia training aid



Source: Noakes, D. 1999. Operations Study Guide—Multimedia Filtration. Washington, D.C.: Operation and Maintenance Assistance Project.

Figure 7-6 Training aid created by computer integration and provides an opportunity to make training more responsive to the needs of the utility's employees. Any training program requires an assessment of the effectiveness of instruction. Both participants and maintenance supervisors should have opportunities to offer constructive criticism of training courses.

Trainees should evaluate a course immediately after its conclusion. Maintenance management will evaluate the benefits of training by looking for improved performance from trainees. Beyond these evaluations, the maintenance manager and training program coordinator will gain worthwhile insight through periodic visits to training sites. As they evaluate the effectiveness of the training program firsthand, they also indicate their support for training.

Evaluation of the training program should include assessment of the trainer's role. In addition to the feedback received during the training session, the trainer should plan follow-up visits with participants to determine if they are effectively applying the information delivered during training.

Maintenance Training Needs Throughout the Organization

A successful training program for the maintenance section requires planning to provide effective technical instruction to help field personnel develop skills needed to properly maintain equipment and structures. A successful program also must allow for supervisory training. In addition, the maintenance manager needs to schedule training workshops if major changes in the operation of the maintenance section are planned. Each training session must be structured to reach the appropriate audience. Four groups normally require training:

- Field personnel
- Maintenance management team
- Senior management
- Operations personnel

Field Personnel Training

The mechanics, electricians, carpenters, and other technicians who complete work orders for preventive and corrective maintenance require both technical and supervisory training. First, new employees need long-term technical training to direct the skills they bring to the utility toward the particular maintenance needs they must satisfy in their jobs. Experienced personnel need this type of training to learn state-of-the-art skills for working with new technology. This instruction must be an ongoing effort, often accomplished effectively by a combination of classroom training with appropriate field exercises plus continual OJT by supervisors and crew leaders. Home-study courses also can play a role in technical training. However, these programs must be combined with OJT to be effective.

Field personnel also require training concerning their roles in the operation of the MMS. In particular, because they make key contributions to accurate record keeping for the MMS, these personnel need to understand how the MMS is designed to function. A training program should be designed to develop this understanding and to convey the following information:

- Specific paperwork requirements
- The importance of the MMS for the effective operation of the maintenance section, including its expected benefits
- The rationale for paperwork requirements
- The importance of accurate record keeping
- The need for timeliness and completeness, in addition to accuracy
- The role of operations personnel in the MMS
- The use of MMS records to track employees' work, if applicable

For example, a worker's performance evaluation may include a comparison of actual versus estimated time for completing work orders. If personnel are held accountable for the time they take to complete their work on the basis of data from the MMS, they must be informed of the techniques used to gather and assess such information.

Training should also introduce field employees to examples of management reports to give them greater understanding of the goals of the program. Field personnel are typically not enthusiastic about filling out paperwork. Therefore, during the first few months when program changes are being tested, management must carefully monitor work orders, correct and explain errors, and reinforce the need for the new maintenance system.

Training sessions conducted at the maintenance workshop by a maintenance supervisor should be adequate to transmit necessary information. Training needs are reduced if field personnel are given the opportunity to suggest modifications as the MMS is developed.

Maintenance Management Team Training

A water utility should incorporate training of maintenance section managers and supervisors as an integral part of its method of operating. Senior managers sometimes make the mistake of assuming that skilled engineers and technicians will make good managers without training. Formal management training is vital for the success of a water utility.

Informal discussions among utility managers also provide valuable opportunities for exchanging information. Many organizations recognize and encourage regular brown bag meetings. These gatherings are typically held during lunch to discuss management and other issues of interest to the utility.

The supervisory staff of the maintenance section has a major role to play if changes are made in the MMS. Therefore, they must understand all aspects of the program, including paperwork requirements, management reports, and system review and maintenance.

Paperwork. Supervisors need to fully understand the operation of the MMS to provide guidance to clerical and field staff, particularly if the information system component is automated.

Management Reports. Many maintenance programs are designed to produce progress reports on group activities. Understanding these reports, and knowing the system's capabilities for generating special reports, is essential for tracking maintenance activities.

System Review and Maintenance. A maintenance information system must provide current information to give the most effective possible support for maintenance managers. Updating requires adding and subtracting equipment from the database, modifying maintenance procedures, reviewing time estimates, and investigating useful enhancements to the MMS. Field and clerical personnel can provide very beneficial information for the review task.

The need for updating the MMS database is frequently overlooked by management. An effective system must assign this work to a specific individual and provide for periodic reviews of updating practices. The MMS database can quickly become outdated if new equipment is not added and obsolete equipment removed from service is not deleted from the files as appropriate.

Senior Management Training

Training programs developed for senior utility management usually do not affect the training agenda for the maintenance group, and they are not discussed in this book. This situation changes, however, when maintenance management is proposing significant modifications in the operation of the maintenance program. Since senior management support is vital to the success of the new MMS, brief training classes should be scheduled for them during the planning and implementation stages of a new or modified system to describe proposed changes. These training sessions also offer an opportunity for the maintenance manager to restate the objectives of the section, explain the management reporting system, and provide detailed explanations of the reports on maintenance operations that senior management will receive.

Operations Personnel Training

As discussed earlier, the maintenance and operations sections within water utility need to work closely together. Operations personnel typically report equipment problems at treatment plants and pumping stations to the maintenance group, and operations supervisors require information from maintenance, for example, on the status of equipment repairs. Thus, operations managers should give input for decisions regarding changes in equipment maintenance programs. The maintenance manager should plan to hold briefings with operations personnel, particularly supervisors, for several reasons:

- Explain changes in maintenance department procedures
- Solicit ideas/comments from operations personnel on proposed modifications to the MMS
- Describe the benefits of proposed changes to utility staff
- Request assistance in ensuring that plant operating personnel cooperate with the program by using designated forms and supplying required data, such as equipment ID numbers

- Determine requirements of operations staff for management reports (e.g., a status report for corrective maintenance work orders could help operations to effectively monitor equipment activities and availability)

Safety Training Programs

Maintenance management should regard the goal of promoting safe working practices among section personnel as one of their more important responsibilities. They should insist that safety training be an integral part of any maintenance training program. Many water utilities consider safety so important that they carefully monitor violations of safety rules and treat safety incidents as cause for disciplinary action, even if the incident doesn't result in harm. They also establish programs to reward the units with the best safety records for specified periods. Some water utilities employ safety inspectors to visit job sites and monitor safety practices as well as prepare handbooks detailing safety rules. If the utility does not have a safety manual, the maintenance manager should consider preparing one covering maintenance activities.

The objectives of safety training are to ensure that all personnel are aware of and follow the utility's safety regulations and that safety equipment is properly used. One of the first steps in the orientation of a new employee is to make sure that the utility's safety rules are thoroughly understood. The same is true when new processes are installed at plants or other facilities. Personnel need training to handle these situations safely.

Types of Safety Training Programs

Safety Meetings. The maintenance training coordinator should plan to hold regular meetings with field personnel to discuss safety issues. One common approach is to ask a supervisor or crew leader to prepare a program covering one safety-related topic and present it to the other maintenance personnel. For a large water utility with multiple maintenance workshops or depots, meetings are held at each site. Typical topics include, for example, proper techniques for shoring trenches, the correct way to handle lockout and tag out equipment, and proper techniques for using power lawnmowers. These training sessions should be relatively brief—30 min is usually sufficient—and all employees should attend. The maintenance manager is advised to attend these meetings regularly to reinforce the importance of safety to the utility.

Tailgate Meetings. Informal discussions conducted by field supervisors or crew leaders often emphasize particular safety-related issues. These sessions are conducted at job sites, usually lasting less than 30 min, to discuss safety issues of immediate concern. For example, if the safety inspector or another observer has identified a safety violation, a tailgate meeting would be an appropriate occasion to discuss the safe technique for doing the work in question. Another topic could be a discussion of the safety actions required to carry out a particular maintenance procedure, such as the one detailed in Figure 3-1. These meetings should be held as needed to clarify safety rules. Even when no topics require immediate attention, regular tailgate meetings help to ensure that personnel are frequently reminded of the importance of safety on the job. The safety coordinator should be involved in these training programs by reviewing proposed topics, making sure that the tailgate sessions are conducted regularly, and periodically attending the meetings.

References

Anderson, S.M. 2008. Workforce strategies—Take time to evaluate behavior problems. *Opflow,* 34(10): 8–9.

Boepple, T.M., and D. Meadors. 2008. Workforce strategies—Beware of the "Perfect Storm." *Opflow,* 34(4): 10.

Runge, J., and J. Mann. 2008. State of the Industry Report 2008: Charting the course ahead. *Journal AWWA,* 100(10): 61–74.

Index

Note: The letter "f" following page numbers indicates reference to figures.

D

E

N

O

P

R

S

T

U