chapter seven

Operations of water, sewer, and stormwater systems

Introduction

Once a facility is installed or built, it requires operations, security, and maintenance management. Now, information technology is becoming more important in each of these functional areas. These topics converge in the skill requirements of operators, who must be competent in one or more of the four areas — operations, maintenance, emergency management, and information technology. This chapter explains operations, and the next three explain security and disaster prevention, maintenance management, and information technology in system management. Taken together, the four chapters explain the major requirements to operate, protect, and maintain water, sewer, and stormwater infrastructure systems.

Operations management

The goal of operations management is productivity in use of resources, such as physical infrastructure. Productivity is producing something of value, such as clean water or wastewater service. Measuring productivity compares output to input, which involves effectiveness and efficiency. Effectiveness is doing the right thing or producing something of value efficiently. One can be efficient but not do the right thing, or be counterproductive and produce nothing of value. In water, sewer, and stormwater services, value is providing customers with services they need, keeping costs low, and avoiding regulatory problems.

The word “operations” means what it says. One can “operate a vehicle,” or “operate a business,” or “be an operator.” It simply means the process of getting something done.

At a higher economic level, productivity measures performance of the whole economy, including labor. Productivity can have positive and negative connotations. To be productive sounds positive, but unless handled right,
workers may suspect that productivity is a ploy of managers to make them work harder for less pay, or even to eliminate jobs.

The beginnings of operations management is in industrial engineering and industrial management. These have roots in “scientific management,” developed in the late 19th and early 20th centuries to improve operations efficiency and effectiveness. Early pioneers of the movement include Frederick Taylor and Frank and Lillian Gilbreth. Frederick Taylor is widely credited with introducing methods of efficiency, and the Gilbreth story is featured in the movie *Cheaper by the Dozen*.

Scientific management and industrial engineering have developed many innovations in operational tools, especially computer models and manufacturing processes such as the assembly line, “just-in-time” manufacturing, and quality control. As the focus shifted to more humane treatment of workers, industrial psychology became a branch of management aimed at creating a better and safer workplace. These topics now drive change in water and wastewater utilities. The AWWA and WEF have teamed with the Kenan–Flagler Business School at the University of North Carolina at Chapel Hill to institute a Water and Wastewater Utility Leadership Center (see Chapter 12).

At its root, operations management requires the following:

- A clear purpose
- An effective organizational structure
- Effective communications and information
- Missions and objectives for the organization’s units
- Job descriptions
- Plans and production targets for units
- A work management system
- Methods for checking performance
- Procedures for continuous improvement

These requirements create the managerial environments for facility operation. Once a job description is formed, an operator is ready to perform the tasks of management, monitoring, making decisions, controlling, and improving. These tasks involve many aspects, as outlined later in a discussion of training requirements.

Operations involves “command, communications, control, and intelligence,” which can be abbreviated as “C3I” for military applications. Command means decision making and issuance of orders. Control means capability to operate systems. Forms of communications include data flow, telecommunications, written orders, and others. Intelligence is collection of data for decision making. All of these concepts are inherent in facility operations.

In a public works organization, output is a public service or good and is measured by service level. Thus productivity can be measured for the services of solid waste, public transit, transportation, water supply, wastewater, and storm drainage. To measure their productivity, multiple objectives
and indicators are required. Indicators can be used in performance reporting and budgeting, as are required by many utilities today.

For water or wastewater, the product is treated water, and operators may say, “We make water.” In a practical sense, productivity of water, sewer, and stormwater systems means how well a system meets its goals, measured at a basic level by compliance with regulations and cost of service. But operations management that involves performance measurement may deliver better results for the same cost. This trend is evident in the industry, along with greater concern for customer satisfaction (see Chapter 12 for industry trends).

Operations require checks to ensure that the product or service is adequately delivered, regarding timing, quantity, quality, and whether the condition of facilities is acceptable. The first check is the primary concern of operations and the second is the concern of maintenance. Operations management classifies these as production management and facilities management.

Quality control (QC) became a priority for industry when it learned that high product quality is not only competitive, but essential. U.S. industry abandoned its focus on inspections and repairs in favor of the approach of doing things right the first time and seeking “six sigma” quality in products, or few failures. A number of different terms are used for quality management, including “quality assurance” and “total quality management,” or TQM.

QC goals for water or wastewater treatment are necessary to meet regulatory requirements. They involve monitoring, sampling, laboratory work, and record-keeping.

In stormwater, if the goal is to prevent flooding, the measure of success might be the absence of complaints, but the organization could organize a monitoring and reporting program for quality measurement.

Operations audits are a form of quality control. A technique called diagnostic analysis, or diagnostic evaluation, has been used to study performance in systems and to provide a comprehensive performance audit. For example, diagnostic analysis of wastewater utilities was recommended in four phases:

1. A preliminary investigation which identifies problems and sets the stage for the remainder of the study. In effect, this is the problem identification phase of the planning and management process.
2. An on-site evaluation of the general management, the support services, and the operations and maintenance activities of the utility.
3. Individual findings are compiled into an overall utility evaluation, and evaluations of problems and potential solutions are made.
4. Solutions identified are reviewed with the management of the utility and implementation plans are developed.

Comprehensive improvement programs

Because operations management involves many activities, a number of comprehensive improvement programs have been developed. Generally, these
are multi-faceted programs involving planning, implementation, assessment, and improvement. They fit the model for continuous improvement under TQM approaches.

For example, the EPA has proposed the capacity, management, operations, and maintenance (CMOM) program as part of the sanitary sewer overflow (SSO) rule. The EPA’s goal in the rule is to provide “best practices” information without issuing too many regulations.4

The SSO rule has three parts — a prohibition provision to prohibit unpermitted discharges from sewer systems; requirements for record-keeping, reporting, and public notification requirements for SSOs; and the CMOM program.

The SSO rule is aimed at curbing unintentional discharges of raw sewage from municipal sanitary sewers. These are caused by weather, improper system operation and maintenance, and vandalism. The EPA estimates that there are at least 40,000 SSOs each year. These can contaminate waters, cause water quality problems, backup into basements, cause property damage, and threaten public health.5

The CMOM program involves planning, assessment, training, and implementation of needed measures, such as regulations. While utilities already undertake some of the CMOM tasks, the program has four elements that may require new efforts:

1. Establishing relevant legal authority over issues such as I&I, design and construction standards, and new sewer testing
2. Assessing current system capacity in which measured flows would be compared to design flows
3. Identifying and prioritizing structural deficiencies, an inventory and priority-setting provision that might involve linking to maps and perhaps GIS
4. Training staff

Other CMOM requirements include:

- Identifying program goals and responsible individuals
- Maintaining adequate inventories of parts
- Having an overflow response plan
- Having a system evaluation and capacity assurance plan
- Doing self-audits when NPDES permits are up for renewal

As an example of CMOM, consider the Wastewater Collection Division (WCD) of the Fairfax County (Virginia) Department of Public Works and Environmental Services, which was concerned about SSOs and related problems, including backups, customer satisfaction, environmental quality, and financial claims.6 The WCD, which serves 840,000 residents, has administration, gravity sewers, and pumping station branches. The pumping station branch operates a pressure sewer network, pumping stations, flow
meters, and stations where chemicals are added for odor and corrosion control. Water and wastewater systems involve many pumps. Figure 7.1 shows a pumping station in a treatment plant, and Figure 7.2 shows a backwash pump that must be operated. The gravity sewers branch handles routine maintenance, CCTV inspections, sanitary sewer repair and rehabilitation, and line location and marking. These operations are described in Chapter 9.

The county performed its own self-audit in 1995 to benchmark its performance, prepare to reduce I&I, extend service lives, and reduce backups and overflows by better management. Based on the self-audit, it made several operational improvements, including a streamlining process that featured outsourcing, consolidation, and refocusing to realize a significant increase in productivity, with 30% downsizing due to attrition.

The WCD found that outsourcing rehabilitation worked better than having it done in-house and included slip-lining, chemical grouting, and easement clearing. All of these construction-related activities are now outsourced. They found, however, that O&M works better in-house, and switched from reactive to proactive maintenance (note that some utilities advocate moving away from proactive maintenance to reliability-centered maintenance; see Chapter 9). The WCD separated inspection from cleaning operations and increased the number of inspected miles by 61% in 1999. Cleaning now focuses on high-priority lines. The WCD also got new equipment and arranged for vendors to train crews.
Capacity assurance uses a computer model of the primary sewer network to project system capacity in 5-, 10-, and 15-year increments. Flow metering is used to verify the model. The I/I abatement program uses CCTV and rehabilitation with a cured-in-place pipe-relining process. Trenchless technologies are used, including cured-in-place pipe-relining, fold-and-form, and robotic point repair. Manhole rehabilitation is by spin-cast and cast-in situ processes. A sanitary sewer maintenance management system is now in place (see Chapter 9).

Performance indicators include backups and overflows per 1000 miles, and number of pumping station failures that create overflows, bypasses, and backups. The overflow response plan found 177 critical segments that are now carefully monitored.

Human resource management is a priority, with increased responsibility for employees, awards, a program to empower employees and encourage initiative, self evaluations, and peer reviews.

After the Construction Grants program began in 1972 heavy investments in new wastewater treatment plants, the EPA found a combination of factors leading to poor plant performance. Based on 287 site visits and limited diagnostic analyses, they found that difficulties are caused by complex interactions and not by simple causes. The EPA found ten principal recurring difficulties:

1. Operator error
2. Inadequate process control testing procedures
3. Infiltration/inflow problems
4. Inadequate understanding of wastewater treatment
5. Improper technical guidance
6. Inadequate sludge wasting capability
7. Inadequate process controls
8. Inadequate flexibility of processes
9. Inadequate O&M manuals
10. Poor design of aerators

As a result, the EPA developed a “composite correction program” with procedures to evaluate and correct performance. The program consists of a diagnostic approach, with provisions for prescribing and implementing improvements. The program focuses on weak points in the system by identifying performance-limiting factors.

The composite correction method can also be used for water utilities. Hegg et al. described a small Washington utility that, when faced with a need to upgrade, hired a consultant to perform a composite correction review instead. The program focused on optimizing existing facilities with a comprehensive performance evaluation, followed by technical assistance. Unit processes were evaluated and performance-limiting factors were identified. The consultant found a lack of operating information, undocumented procedures, inadequate maintenance of some units, and a need to improve procedures. Staffing changes, automation, and shut-down capability were also needed. Comprehensive technical assistance included transfer of optimization skills to plant staff, demonstration of improved performance, and special studies. The EPA’s method is described in its 1998 handbook.

Utilities can develop their own customized comprehensive programs. For example, the Southern California Water Company developed a comprehensive “water quality control program” (WQCP). The WQCP is a comprehensive monitoring and response plan for source, treatment, storage, and distribution. It includes monitoring, maintenance, operations, and water quality programs. The monitoring plans detail why, how, when, and where monitoring is to be conducted. The program also includes treatment plant operation guidelines and guidance for maintenance issues such as cross-connection control, dead-end flushing, and maintenance of valves, hydrants, wells, and reservoirs. Emergency response and customer complaint response are also included. In effect, the WQCP is a coordinated, comprehensive management program.

Assessment programs are proving valuable in improving performance. The “QualServe” assessment program has been developed for the water and wastewater utility industry by the AWWA and WEF. QualServe is a voluntary quality improvement program designed exclusively for water and wastewater utilities. QualServe’s goal is simple: to help your utility achieve superior performance, maximum efficiency, and outstanding customer service. QualServe programs include self-assessment, peer review, benchmarking clearinghouse, accreditation, and customer service surveys. QualServe examines all utility operations and focuses on them in categories of “business processes,” as shown in Figure 7.3.
Figure 7.3 QualServe business systems and business process categories.
The Partnership for Safe Water is a related program, and involves commitment, data collection, use of assessment software, self-assessment, and peer review. The program can involve visits by outside peers.

**Tasks and skills of operators**

In operations, staff must clearly be “jacks of all trades,” or persons who are handy with many types of work. Operators of water, sewer, and stormwater systems work with maintenance staffs to perform all functions required to operate and maintain a wide range of systems and equipment. Figure 7.4 shows an operator checking the status of raw water.

Given the range of operating situations, a wide range of skills is required. In the future, these will change rapidly with automation and new processes. Table 7.1 outlines some of these operator requirements.

*Figure 7.4* Raw water operations checkup. (From American Water Works Association. Copyright 2001. All rights reserved.)
The range of operations discussed above requires knowledge ranging from basic skills to research levels. Table 7.2 outlines these skills briefly and may be useful in training programs. Associations and community colleges offer training for operators in these subjects.

<table>
<thead>
<tr>
<th>Table 7.2 Examples of Operator Requirements</th>
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<td>Decisions</td>
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**Table 7.2** Skill Levels for Operators

<table>
<thead>
<tr>
<th>Skill category</th>
<th>Basic levels</th>
<th>Advanced levels</th>
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</thead>
<tbody>
<tr>
<td>Math and science</td>
<td>Basic calculations, chemistry, physics, biology</td>
<td>Sophisticated knowledge to improve operations of treatment processes</td>
</tr>
<tr>
<td>System knowledge</td>
<td>Basic understanding of how to operate system components</td>
<td>Systemic knowledge of interactions of system components and performance</td>
</tr>
<tr>
<td>Information technology</td>
<td>Ability to use computers, telemetry systems, displays</td>
<td>Ability to specify, program, modify, and improve computers, telemetry systems, displays</td>
</tr>
<tr>
<td>Law</td>
<td>Familiar with regulatory controls in sphere of operations</td>
<td>Knows and works with laws, regulations, and regulatory agencies</td>
</tr>
<tr>
<td>Emergency operations</td>
<td>Familiar with and trained in emergency operations procedures</td>
<td>Able to recognize threats, modify procedures, work with others in improving system readiness</td>
</tr>
<tr>
<td>Management</td>
<td>Basic competence in supervision, communications, records, reports</td>
<td>Higher level management skills in supervision, communications, teamwork, reports, finance, public relations</td>
</tr>
</tbody>
</table>

**Operator training**

**Introduction**

The work of water, sewer, and stormwater operators is complex and requires high levels of knowledge, skill, and experience. Recognizing this, states began to organize certification programs and now these are required by law for some treatment applications. The 1996 Safe Drinking Water Act amendments, for example, include operator certification requirements, and stronger certification and recertification programs are proceeding in all 50 states. In the future, small water systems will also require certified operators.

**Training and certification**

Training, the companion to certification, is delivered by associations, centers, and community colleges. Certification provides a test of whether an operator has achieved a certain level of knowledge and competence, and training prepares a person for certification and work to ensure adequate knowledge, skill, and ability to perform.\(^{11}\)
Design of instructional systems will involve:

- Needs assessment
- Job analysis
- Task and learning analysis
- Requirements of entry-level performance
- Performance and learning objectives
- Instructional strategies, methods, and activities
- Instructional materials
- Evaluation of instructional strategies, methods, and activities

The Association of Boards of Certification (ABC) has a need-to-know task list under development for water distribution systems and it includes these tasks:

- Evaluate operation of equipment
- Operate equipment
- Perform preventive and corrective maintenance
- Install units
- Monitor water quality
- Collect samples and perform and interpret analyses
- Write reports
- Promote positive public relations
- Maintain facility area
- Establish record-keeping system and record information
- Establish and perform safety procedures
- Establish emergency preparedness plan and respond to emergencies
- Manage facility
- Inspect source water
- Design system

Each task has subtasks, and these describe specific types of equipment and capabilities. The task “Operate equipment” describes 27 types of equipment commonly found in distribution systems, including pumps, hydrants, valves, instruments, and tapping equipment.

A training needs assessment would rate each task by importance, frequency, and confidence of operator. Wise describes why cross-training is important, especially in emergencies. Other issues in certification are reciprocity and anti-backsliding.

Organizations

Organizations involved with training and certification include the ABC, which deals with drinking water, wastewater, labs, and distribution systems; the National Environmental Training Association; states; the AWWA and WEF sections; and the National Rural Water Association.
The Association of Boards of Certification shares information and resources and works on certification laws, certification, and transfer of certification. It offers training materials in wastewater treatment, distribution, collection, water treatment lab, and wastewater lab.

ABC identifies critical job tasks of operators and skills required. ABC also publishes a Model Act and Regulations, with guidance for certification legislation and regulations. It covers terms, classification systems, models for certification boards, regulations and procedures, prohibited acts and penalties, reciprocity, funding authority, utility classifications, qualifications, exams, certificates, and revocation.\textsuperscript{13}

As an example of a state certification activity, Maryland’s operator program was spurred in the late 1970s by an incident when an uncertified operator spilled excessive fluoride into a public water supply and harmed dialysis patients.\textsuperscript{14} At about the same time, EPA started funding state operator training centers, primarily for wastewater. The Maryland Center for Environmental Training was built at a community college, in the same period as another 40 state centers. The Maryland center expanded from offering wastewater programs to training in drinking water and other environmental and safety areas as well. Examples of courses and training aids at the Maryland Center are shown on Table 7.3.

Maryland enacted a process-specific certification law for operators of water treatment plants and distribution systems. The law specifies four levels of water treatment and one for distribution systems.

Kenneth Kerri, who has developed operator training materials, discussed how to plan and organize an operator training program. Instructional

\begin{table}[h]
\centering
\caption{Courses and Training Aids at Maryland Center}
\begin{tabular}{ll}
\hline
Law & Safe Drinking Water Act compliance \\
Maintenance & Program assessment \\
Emergency planning & Risk assessment and emergency plans \\
Management & Public relations and drinking water \\
Planning & Life cycle planning \\
& Capital improvement planning \\
Finance & Five-year revenue and expenditure analysis \\
& Rate calculations \\
& Setting and implementing of fair and effective rates \\
& Financing and debt management \\
Organization & Restructuring and consolidation \\
Water treatment & Introduction to water treatment \\
& Lead in public drinking water \\
& Chlorination technology, use and safety \\
& O&M of chlorine systems \\
& Iron and manganese removal \\
& Water polymer technology \\
& Preparation of plant for sanitary survey \\
Distribution systems & Water distribution \\
Source of supply & Well system O&M \\
\hline
\end{tabular}
\end{table}
programs should be planned, organized, and assessed using proven educational methods.\textsuperscript{15}

For operator resources, the AWWA publishes \textit{Opflow} and the WEF includes a special Operations Forum in each issue of \textit{WE&T}, and both publish special operator training materials.

\textbf{System applications of operator skills}

While much operator knowledge is transferable, operators generally specialize in one of the subsystems of water, sewer, and stormwater systems.

\textbf{Source of supply}

Operators of reservoirs and other sources of supply make operating decisions about how, when, and at what rate to withdraw raw water supplies and furnish them to treatment plants or, in some cases, directly into distribution systems. The systems range from wells with on-site disinfection and direct pumping directly into the distribution system to large, multipurpose systems of reservoirs serving large areas. For the well supply system, the operators may concentrate on decisions about operations and maintenance, while the more complex system may involve coordinating with other users, managing quality of raw water supplies, and even dealing with public relations issues.

\textbf{Treatment plant operations}

Treatment plant operators need state licenses to operate their water and wastewater treatment plants. Figure 7.5 shows an operator at work in a water plant.

As these plants become more complex, the knowledge required by the operators increases in scope and sophistication. In addition to maintenance staff, treatment plant operators must be supported by laboratory personnel. Figure 7.6 shows a laboratory at the Washington Suburban Sanitary Commission.

In the case of water supply, plants will be operated within design guidelines for physical, biological and chemical treatment to produce high-quality potable water. Treatment plants involve operations of processes such as settling, filtration, chemical dosage, pumping, etc. Utilities have unique sources of water requiring different treatment. The quality of incoming water may change and require changed dosages. The laboratory will be used to check on the quality of finished water. Computer control of processes may be involved.

For wastewater treatment, the general approach is similar, but wastewater requires different treatment processes from those of drinking water, and they are governed by different regulations. Instrumentation is also more difficult in wastewater than in water supply.
Water supply has always been directly linked to public health, and regulatory controls started earlier than they did for wastewater. After the inception of the Clean Water Act, operational problems in wastewater treatment became visible. The problems are multi-dimensional and illustrate that effective operations involve many aspects of organizations.
In their study of the effectiveness of 1970s federal subsidies for wastewater, the General Accounting Office studied a random sample of 242 plants in ten states. They found that 87% were in violation of permits and that 31% were in serious violation. The problems they found included design and equipment deficiencies, infiltration/inflow overloads, industrial waste overloads, inadequate budget and staff training, ineffective maintenance, and operators used for other duties.

**Future treatment plant operations**

In the past 50 years, treatment plants have changed from simple facilities with few processes to sophisticated facilities with complex physical, chemical, and biological operations. All indications suggest that more changes are inevitable.

Carrie Lewis described her vision for the water supply treatment plant of 2050. It included the following:

- Limited public access to avoid security problems, but ability of public to take virtual tours of plants to check on their operations
- Redundant intakes with real-time data
- A plant intelligent system (IS) that uses data to recommend treatment modes
- A new meaning for multiple barriers, to include watershed and distribution system, as well as treatment plant
- Detection to automatically detect genus, species, and infectivity of microbes
- High reliability of operations
- Operator and chemist able to perform scheduled maintenance while plant is automatically operated most of the time
- A maintenance management system that has been in place for many years and has so much data and works so well that breakdowns are rare

She foresaw six stages of treatment, each capable of zero, low, intermediate, or high-intensity treatment, based on variable chemical types, dosages, and residence times. Stage 1 controls zebra mussels and nuisance organisms. Stage 2 removes coarse particulates with precoagulation, coagulation, settling, dissolved-air flotation, or rapid media filtration. Stage 3 removes coarse organic materials using low dosages of ozone, rapid filtration through coarse carbon, or aeration. Stage 4 provides disinfection with or without pH adjustment. Ozone, peroxide, chlorine, and UV are all available for disinfection. Stage 5 removes organics, inorganics, and fine particulates with biological GAC, membranes of varying porosities, or ion exchange. Stage 6 provides any needed stabilization.

Lewis concluded her article with a vision of the operating environment. She wrote that “flexibility of treatment processes and redundancy of equipment have served us well.” Changes such as global climate change and urban
Development had changed runoff characteristics. Regulations were continually modified. However, “with the care of capable and highly skilled staff, the plant performs to whatever level of treatment is necessary to protect public health.”

**Distribution and collection systems, including stormwater**

Operators of distribution and collection systems must know the objectives and constraints of operating their systems and must make sure the systems work as intended. This may range from simple systems with few operating decisions to vast, complex systems with many operating components such as pumps and regulating stations.

In distribution systems, the operator maintains adequate pressure and supplies for household, commercial, or fire flow. The system must be monitored for pressure and water quality. This requires pressure-sensing devices and problem detection using water audit methods (see Chapter 9). Water distribution system network models may be used to simulate conditions.

In wastewater collection systems, decisions involve maintenance more than operations. That is, in well-maintained gravity systems, few decisions are required for operations.

In stormwater systems, treatment is usually not required. The same types of facilities as in wastewater are usually involved, however, including channels, pipes, ponds, instruments, and possibly pumping facilities.

For distribution systems, Darrell Smith wrote that future operations will deal with raw water that goes through innovative treatment, including membranes, ozonation, GAC, and ultraviolet disinfection. But unless distribution systems improve, the water may still have questionable taste, odor, color, residual disinfectant, microbial growth, sediment, and corrosivity. The real question will be what it is like at the tap. Distribution systems will need new materials, monitoring, controls, hydraulic efficiencies, and operating procedures. Dual systems may be coming, providing another dimension to distribution system operations.

**SCADA systems**

Information technology will increasingly be used in water, sewer, and stormwater systems. Operators of supervisory control and data acquisition (SCADA) systems will be skilled in both computing and telemetry. This can range from the operator who enters data or monitors a central control room (but without much knowledge of the underlying system) to the sophisticated operator who participates in design of the SCADA system and uses that knowledge to work with other operators on a program of continuous improvement. Chapter 10 discusses SCADA systems in more detail.

**Operating engineers**

In the past, the plant operator was someone who was trained to operate equipment and facilities that someone had designed and built. The operator
role was lower on the technical scale than the engineer’s role. But operations will become more complex, and the line between operators and engineers will blur. The realm of operations will include a role for operating engineers who work with operators to plan, design, and install control and monitoring equipment. They must be familiar with operating requirements and with technologies available, and will have responsibility for implementing innovations to make systems work better. A large and complex organization may have a staff of operating engineers.

Safety

APWA publishes a manual on safety programs for municipal or industry-based water or wastewater plants. It covers OSHA regulations, safety audits in wastewater plants, new lock-out/tag-out procedures, and ergonomic safeguards.\(^{19}\)

Contract operations

Operations can be outsourced in the form of contract operations, and the jury is still out as to whether this management approach is better than in-house operations. The answer remains “it depends.” Barry Liner et al. reported on a survey that showed that contract operations are in place at more than 1200 water and wastewater plants in the U.S.\(^{20}\) Contract operations do in fact produce a 15–35% lower cost. Their survey studied variables including regulatory compliance, asset condition, utility costs, staff and utility management, staff morale, and customer satisfaction. Large cities cited high costs and poor management as reasons to contract out operations, and small cities cited lack of qualified operators. Although the survey suggested that contract operations are superior overall, the writers cautioned that employee issues and working environments are also factors and that more evaluation is needed.

Privatization as a management approach will certainly be a topic for the future. Geoff Greenough et al. described three perspectives on delivery of public works services — the traditional model, privatization, and managed competition.\(^{21}\) While none of the perspectives was a complete exposition of an approach, each presented insight into actual methods, advantages and disadvantages, and trends.

St. Paul, Minnesota was presented as an example of the “traditional model,” but St. Paul is clearly adapting beyond traditional approaches to meet public expectations. “The only thing that seems constant in St. Paul is change, and after ten years of doing more with less, the city is continuing to do more with less.”

The discussion of privatization provided insight into turning over services completely or partially to the private sector, and gave examples of services that are appropriate to privatize. It discussed some decision factors, such as risk, cost, frequency of use, legal environment, and expertise.
Managed competition might be viewed as a compromise approach that maximizes advantages and minimizes disadvantages. Managed competition allows government services, privatization, or a mixture. Charlotte, North Carolina, has found that it improves the city’s approach to public service delivery and allows the city to balance limited revenue sources against costs and demands for services.

**Trends in operations**

In 2000, the AWWA convened a roundtable to discuss how operations would change. High points of the discussion indicated the following:

- Solving financing problems for small systems will cause more consolidation.
- There will be a trend away from regulations to customer-driven treatment and designing operator-friendly plants; there will be fewer operators in the future, but plants will not be unattended, only different; operators will work with new technologies; laboratories will change, with on-line and kit monitoring and less work at central labs; operator and lab tech skills will merge; operators will be multi-skilled and more concerned with health.
- Use of brackish and marginal waters will increase; water use efficiency will increase.
- Risk will be reduced from all contaminants. There will be emphasis not only on microbiological but also chemical and aesthetics in water. Source water will be treated on a custom basis, catering to customer needs. Emerging pathogens will be a concern because microorganisms mutate. Reproductive systems will remain a big concern, along with cancer and other diseases. Point-of-use treatment and monitoring with kits will increase. Risk assessment from a public health view will be used more. New treatment technologies will include membranes, desalting, new disinfection, easier operation, and more cost-effective procedures. There will be a dual-membrane approach, the first using low pressure microfiltration or ultrafiltration to remove particulates and microbial elements, followed by tighter nanofiltration or RO to remove natural organic matter, some synthetic organics, and others. Inactivation (disinfection) will still be needed.
- Massive infrastructure funding will be required. Old plants will have to be retrofitted. Distribution systems will be a bigger concern than in the past. New noninvasive, nondestructive technologies for condition assessment will be developed. Dual systems will be used. Future pipes will locate themselves, be inert, monitor for contaminants, and have structural integrity for 200 years. Collaborative research to develop equipment with shorter time to market will occur.
- The multiple barrier approach will take on more dimensions. Security will increase, and there will be integrity against intrusion. Reservoirs
will be protected against intrusion and managed for water quality as well as quantity.

- There will be closer relationships with customers who will log in to check treatment plant.
- Differences in developing and developed countries will be addressed.

References