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Collection Systems O&M Fact Sheet
Sewer Cleaning and Inspection

DESCRIPTION

As sewer system networks age, the risk of deterioration, blockages, and collapses becomes a major concern. As a result, municipalities worldwide are taking proactive measures to improve performance levels of their sewer systems. Cleaning and inspecting sewer lines are essential to maintaining a properly functioning system; these activities further a community's reinvestment into its wastewater infrastructure.

Inspection Techniques

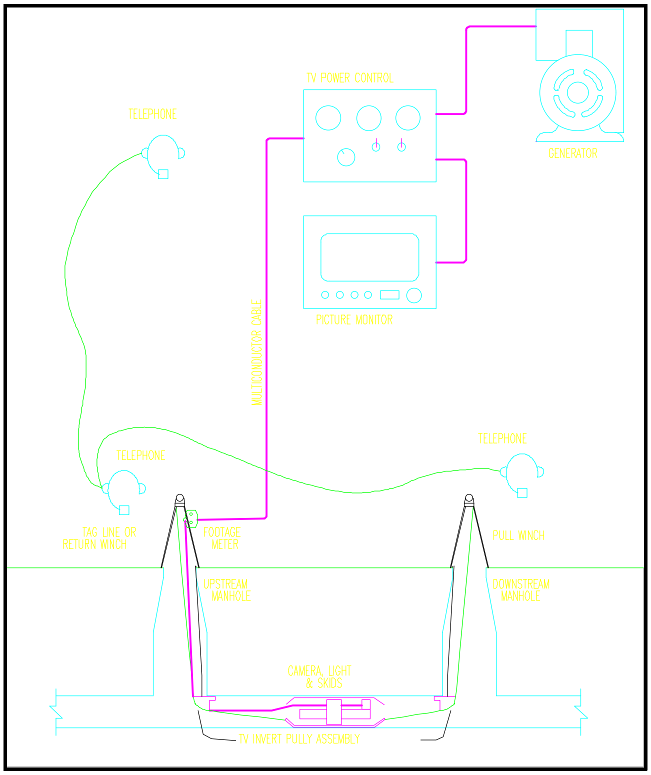
Inspection programs are required to determine current sewer conditions and to aid in planning a maintenance strategy. Ideally, sewer line inspections need to take place during low flow conditions. If the flow conditions can potentially overtop the camera, then the inspection should be performed during low flow times between midnight and 5 AM, or the sewer lines can be temporarily plugged to reduce the flow. Most sewer lines are inspected using one or more of the following techniques:

- Closed-circuit television (CCTV).
- Cameras.
- Visual inspection.
- Lamping inspection.

Television (TV) inspections are the most frequently used, most cost efficient in the long term, and most effective method to inspect the internal condition of a sewer. Figure 1 shows the typical setup of equipment for a TV inspection. CCTV inspections are recommended for sewer lines with diameters of 0.1-1.2 m (4 - 48 inches.) The CCTV camera must be assembled to keep the lens as close as possible to the center of the pipe. In larger sewers, the camera and lights are attached to a raft, which is floated through the sewer from one manhole to the next. To see details of the sewer walls, the camera and lights swivel both vertically and horizontally. In smaller sewers, the cable and camera are attached to a sled, to which a parachute or droge is attached and floated from one manhole to the next. Documentation of inspections is very critical to a successful operation and maintenance (O&M) program. CCTV inspections produce a video record of the inspection that can be used for future reference.

In larger sewers where the surface access points are more than 300 m (1000 linear feet) apart, camera inspections are commonly performed. This technique involves a raft-mounted film camera and strobe light. This method requires less power than the CCTV, so the power cable is smaller and more manageable. Inspections using a camera are documented on polaroid still photographs that are referenced in a log book according to date, time, and location.

Visual inspections are vital in fully understanding the condition of a sewer system. Visual inspections of manholes and pipelines are comprised of surface and internal inspections. Operators should pay specific attention to sunken areas in the groundcover above a sewer line and areas with ponding water. In addition, inspectors should thoroughly check the physical conditions of stream crossings, the conditions of manhole frames and covers or any exposed brickwork, and the visibility of manholes and other structures. For large sewer



Source: Water Pollution Control Federation, 1989.

FIGURE 1 SETUP OF CCTV EQUIPMENT

lines, a walk-through or internal inspection is recommended. This inspection requires the operator to enter a manhole, the channel, and the pipeline, and assess the condition of the manhole frame, cover, and chimney, and the sewer walls above the flow line. When entering a manhole or sewer line, it is very important to observe the latest Occupational Safety and Health Administration confined space regulations. If entering the manhole is not feasible, mirrors can be used. Mirrors are usually placed at two adjacent manholes to reflect the interior of the sewer line.

Lamping inspections are commonly used in low-priority pipes, which tend to be pipes that are less than 20 years old. Lamping is also commonly used on projects where funds are extremely limited. In the lamping technique, a camera is inserted and lowered into a maintenance hole and then positioned at the center of the junction of a manhole frame and the sewer. Visual images of the pipe interior are then recorded with the camera.

Several specialized inspection techniques have been recently developed worldwide. AMTEC, a British sewer inspection company, has deployed light-line-based and sonar-based equipment that measures the internal cross-sectional profile of sewer systems. Karo, a German R&D company, is working on enhancing CCTV technology with new sonar sensors, but this method has yet to be proven successful. Sonar technology could be very useful in inspecting depressed sewers (inverted siphons), where the pipe is continually full of water under pressure. Melbourne Water and CSIRO Division of Manufacturing Technology have introduced a new technology called PIRAT, which consists of an in-pipe vehicle with a laser scanner. This instrument is capable of making a quantitative and automatic assessment of sewer conditions. The geometric data that is gathered is then used to recognize, identify, and rate defects found in the sewer lines.

Sonex has also designed a new technology called the ROTATOR sonic caliper, which is capable of taking a reading for every foot of pipe. This device is pulled through the sewer pipes from one manhole to the next and collects data that can be used to calculate the volume of debris underwater, measure the corrosion from the crown of the pipe to the waterline, and determine the percent of deflection at all points around a flexible pipe. The data collected is based on the time it takes a sonic pulse to travel to and from a target.

Cleaning Techniques

To maintain its proper function, a sewer system needs a cleaning schedule. There are several traditional cleaning techniques used to clear blockages and to act as preventative maintenance tools. When cleaning sewer lines, local communities need to be aware of EPA regulations on solid and hazardous waste as defined in 40 CFR 261. In order to comply with state guidelines on testing and disposal of hazardous waste, check with the local authorities.

Table 1 summarizes some of the most commonly used methods to clean sewer systems.

Hydraulic cleaning developments have also been emerging on the international frontier. France and Germany have developed several innovative flushing systems using a 'dam break' concept. France has developed a flushing system called the Hydrass. The design of the Hydrass consists of a gate that pivots on a hinge to a near horizontal position. As the gate opens and releases a flow, a flush wave is generated that subsequently washes out any deposited sediments. Germany has also developed a similar system called GNA Hydroself®. This is a flushing system that requires no electricity, no maintenance and no fresh water. The Hydroself® consists of a hydraulically-operated gate and a concrete wall section constructed to store the flush water. This system can be installed into a large diameter sewer ($\geq$2000 mm or $\geq$79.4 inches). There appears to be no limit on the flushing length, as more flush water may be stored without incurring any additional construction or operating costs. Another example of such a technology is seen in the Brussels Sewer System. A wagon with a flushing vane physically moves along the sewer and disturbs the sediments so that they are transported with the sewer flow.

Although all of these methods have proven effective in maintaining sewer systems, the ideal method of reducing and controlling the materials found in sewer lines is education and pollution prevention. The public needs to be informed that common household substances such as grease and oil need to be disposed in the garbage in closed containers, and not into the sewer lines. This approach will not only minimize a homeowner's plumbing problems, but will also help keep the sewer lines clear.

APPLICABILITY

In recent years, new methodologies and accelerated programs have been developed to take advantage

TABLE 1 COMMON SEWER CLEANING METHODS

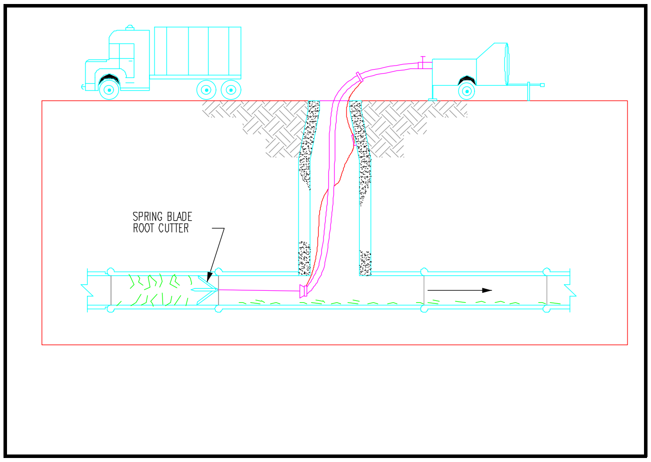
Technology	Uses and Applications
Mechanical	
Rodding (See Figure 2)	• Uses an engine and a drive unit with continuous rods or sectional rods. • As blades rotate they break up grease deposits, cut roots, and loosen debris. • Rodders also help thread the cables used for TV inspections and bucket machines. • Most effective in lines up to 300 mm (12 inches) in diameter.
Bucket Machine	• Cylindrical device, closed on one end with 2 opposing hinged jaws at the other. • Jaws open and scrape off the material and deposit it in the bucket. • Partially removes large deposits of silt, sand, gravel, and some types of solid waste.
Hydraulic	
Balling	• A threaded rubber cleaning ball that spins and scrubs the pipe interior as flow increases in the sewer line. • Removes deposits of settled inorganic material and grease build-up. • Most effective in sewers ranging in size from 13-60 cm (5-24 inches).
Flushing	• Introduces a heavy flow of water into the line at a manhole. • Removes floatables and some sand and grit. • Most effective when used in combination with other mechanical operations, such as rodding or bucket machine cleaning.
Jetting	• Directs high velocities of water against pipe walls. • Removes debris and grease build-up, clears blockages, and cuts roots within small diameter pipes. • Efficient for routine cleaning of small diameter, low flow sewers.

TABLE 1 (CONTINUED) COMMON SEWER CLEANING METHODS

Technology	Applications
Scooter	• Round, rubber-rimmed, hinged metal shield that is mounted on a steel framework on small wheels. The shield works as a plug to build a head of water. • Scours the inner walls of the pipe lines. • Effective in removing heavy debris and cleaning grease from line.
Kites, Bags, and Poly Pigs	• Similar in function to the ball. • Rigid rims on bag and kite induce a scouring action. • Effective in moving accumulations of decayed debris and grease downstream.
Silt Traps	• Collect sediments at convenient locations. • Must be emptied on a regular basis as part of the maintenance program.
Grease Traps and Sand/Oil Interceptors	• The ultimate solution to grease build-up is to trap and remove it. • These devices are required by some uniform building codes and/or sewer-use ordinances. Typically sand/oil interceptors are required for automotive business discharge. • Need to be thoroughly cleaned to function properly. • Cleaning frequency varies from twice a month to once every 6 months, depending on the amount of grease in the discharge. • Need to educate restaurant and automobile businesses about the need to maintain these traps.
Chemicals *Before using these chemicals review the Material Safety Data Sheets (MSDS) and consult the local authorities on the proper use of chemicals as per local ordinance and the proper disposal of the chemicals used in the operation. If assistance or guidance is needed regarding the application of certain chemicals, contact the U.S. EPA or state water pollution control agency.*	• Used to control roots, grease, odors (H_2S gas), concrete corrosion, rodents and insects. • *Root Control* - longer lasting effects than power rodder (approximately 2-5 years). • *H_2S gas* - some common chemicals used are chlorine (Cl_2), hydrogen peroxide (H_2O_2), pure oxygen (O_2), air, lime ($Ca(OH_2)$), sodium hydroxide (NaOH), and iron salts. • *Grease and soap problems* - some common chemicals used are bioacids, digester, enzymes, bacteria cultures, catalysts, caustics, hydroxides, and neutralizers.

Source: Information provided by Arbour and Kerri, 1997 and Sharon, 1989.

of the information obtained from sewer line maintenance operations. Such programs incorporate information gathered from various maintenance activities with basic sewer evaluations to create a system that can remedy and prevent future malfunctions and failures more effectively and efficiently. Garland, Texas, has attempted to establish a program that would optimize existing maintenance activities to reduce customer complaints, sanitary sewer overflows, time and



Source: Sharon, 1989.

FIGURE 2 EQUIPMENT SETUP FOR RODDING

money spent on sewer blockages, and other reactive maintenance activities. Their plan is based on maintenance frequencies, system performance, and maintenance costs over a period of time. This plan was developed using Geographical Information System (GIS) and historical data to show areas of complaints, back ups, and general maintenance information for the area. The City of Garland was able to determine that as the maintenance frequency increased, there was an increase in system performance. Garland recommended 70 inspections and maintenance activities for every 30 cleanings. Inspections are considered more important because they help define and prevent future problems.

A study performed by the American Society of Civil Engineers reports that the most important maintenance activities are cleaning and CCTV inspections. Table 2 shows the average frequency of various maintenance activities.

TABLE 2 FREQUENCY OF MAINTENANCE ACTIVITIES

Activity	Average (% of system/year)
Cleaning	29.9
Root removal	2.9
Manhole inspection	19.8
CCTV inspection	6.8
Smoke testing	7.8

Source: ASCE, 1998.

A maintenance plan attempts to develop a strategy and priority for maintaining pipes based on several of the following factors:

- Problems- frequency and location; 80 percent of problems occur in 25 percent of the system (Hardin and Messer, 1997).
- Age- older systems have a greater risk of deterioration than newly constructed sewers.
- Construction material- pipes constructed of materials that are susceptible to corrosion have a greater potential of deterioration and potential collapse. Non-reinforced concrete pipes, brick pipes, and asbestos cement pipes are examples of pipes susceptible to corrosion.
- Pipe diameter/volume conveyed- pipes that carry larger volumes take precedence over pipes that carry a smaller volume.
- Location- pipes located on shallow slopes or in flood prone areas have a higher priority.
- Force main vs. gravity-force mains have a higher priority than gravity, size for size, due to the complexity of the cleaning and repairs.
- Subsurface conditions- depth to groundwater, depth to bedrock, soil properties (classification, strength, porosity, compressibility, frost susceptibility, erodibility, and pH).
- Corrosion potential- Hydrogen Sulfide (H_2S) is responsible for corroding sewers, structures, and equipment used in wastewater collection systems. The interior conditions of the pipes need to be monitored and treatment needs to be implemented to prevent the growth of slime bacteria and the production of H_2S gases.

ADVANTAGES AND DISADVANTAGES

The limitations of various inspection techniques used by sanitary sewer authorities are summarized in Table 3. Table 4 shows the limitations of some of the cleaning methods used by sanitary sewer authorities.

TABLE 3 LIMITATIONS OF STANDARD INSPECTION TECHNIQUES

Inspection Technique	Limitation
Visual Inspection	In smaller sewers, the scope of problems detected is minimal because the only portion of the sewer that can be seen in detail in near the manhole. Therefore, any definitive information on cracks or other structural problems is unlikely. However, this method does provide information needed to make decisions on rehabilitation.
Camera Inspection	When performing a camera inspection in a large diameter sewer, the inspection crew is essentially taking photographs haphazardly, and as a result, the photographs tend to be less comprehensive.
Closed Circuit Television (CCTV)	This method requires late night inspection ans as a result the TV operators are vulnerable to lapses in concentration. CCTV inspections are also quire expensive and time consuming.
Lamping Inspection	The video camera does not fit into the pipe and during the inspection it remains only in the maintenance hole. As a result, only the first 10 feet of the pipe can be viewed or inspected using this method.

Source: Water Pollution Control Federation, 1989.

The primary benefit of implementing a sewer maintenance program is the reduction of SSOs, basement backups, and other releases of wastewater from the collection system due to substandard sewer conditions.

Improper handling of instruments and chemicals used in inspecting and maintaining sewer lines may cause environmental harm. Examples include:

- Improperly disposing of collected materials and chemicals from cleaning operations.
- Improperly handling chemical powdered dyes.
- Inadequately maintaining inspection devices. Some instruments have a tendency to become coated with petroleum based residues and if not handled properly they can become a fire hazard.

PERFORMANCE

Table 5 defines the conditions under which certain cleaning methods are most effective. The following case studies provide additional case study data for sewer cleaning methods.

Fairfax County, Virginia

The Fairfax County Sanitary Sewer System comprises over 3000 miles of sewer lines. As is the case with its sewer rehabilitation program, the county's sewer maintenance program also focuses on inspection and cleaning of sanitary sewers, especially in older areas of the system. Reorganization and streamlining of the sewer maintenance program, coupled with a renewed emphasis on increasing productivity, has resulted in very significant reductions in sewer backups and overflows during the past few years. In Fiscal Year 1998, there were a total of 49 such incidents including 25 sewer backups and 24 sewer overflows.

The sewer maintenance program consists of visual inspections, scheduled sewer cleanings based on maintenance history, unscheduled sewer cleanings as determined by visual or closed circuit television inspections, and follow-up practices to determine the cause of backups and overflows. Visual inspections are carried out by using a mirror attached to a pole; however, use of portable cameras has been recently introduced to enhance the effectiveness of visual inspections. Older areas of the sewer system are inspected every two years; whereas, the inspection of relatively new areas may be completed in 3 to 4 years.

Cleaning is an important part of pipe maintenance. Sewer line cleaning is prioritized based on the age of

TABLE 4 LIMITATIONS OF CLEANING METHODS

Cleaning Method	Limitation
Balling, Jetting, Scooter	In general, these methods are only successful when necessary water pressure or head is maintained without flooding basements or houses at low elevations. Jetting - The main limitation of this technique is that cautions need to be used in areas with basement fixtures and in steep-grade hill areas. Balling - Balling cannot be used effectively in pipes with bad offset joints or protruding service connections because the ball can become distorted. Scooter - When cleaning larger lines, the manholes need to be designed to a larger size in order to receive and retrieve the equipment. Otherwise, the scooter needs to be assembled in the manhole. Caution also needs to be used in areas with basement fixtures and in steep-grade hill areas.
Bucket Machine	This device has been known to damage sewers. The bucket machine cannot be used when the line is completely plugged because this prevents the cable from being threaded from one manhole to the next. Set-up of this equipment is time-consuming.
Flushing	This method is not very effective in removing heavy solids. Flushing does not remedy this problem because it only achieves temporary movement of debris from one section to another in the system.
High Velocity Cleaner	The efficiency and effectiveness of removing debris by this method decreases as the cross-sectional areas of the pipe increase. Backups into residences have been known to occur when this method has been used by inexperienced operators. Even experienced operators require extra time to clear pipes of roots and grease.
Kite or Bag	When using this method, use caution in locations with basement fixtures and steep-grade hill areas.
Rodding	Continuous rods are harder to retrieve and repair if broken and they are not useful in lines with a diameter of greater than 300 mm (0.984 feet) because the rods have a tendency to coil and bend. This device also does not effectively remove sand or grit, but may only loosen the material to be flushed out at a later time.

Source: U.S. EPA, 1993.

the pipe and the frequency of the problems within it. The county uses rodding and pressurized cleaning methods to maintain the pipes. Bucket machines are rarely used because cleaning by this method tends to be time consuming. The county uses mechanical, rather than chemical, methods to remove grease and roots. Introducing chemicals into the cleaning program requires hiring an expert crew, adopting a new program, and instituting a detention time to ensure the chemicals' effectiveness.

Record keeping is also vital to the success of such a maintenance program. The county has started tracking the number of times their sewer lines were inspected and cleaned and the number of overflows and backups a sewer line experienced. This information has helped the county re-prioritize sewer line maintenance and adapt a more appropriate time schedule for cleaning and inspecting the sewer lines.

The cost per foot for maintaining the Fairfax facility has decreased over the years because of streamlining and increasing efficiency and productivity of field staff. In 1998, pressurized cleaning cost $1.44/meter ($0.44/foot); rodding cost $2.82/meter ($0.86/foot); and television inspections cost $3.18/meter ($0.97/foot). These costs include labor costs, fringe benefits, equipment and material costs, and overhead charges for administrative services.

City of Fort Worth, Texas

The City of Fort Worth has started to use sewer cleaning as a diagnostic tool, rather than just a maintenance task. The city's sewer system comprises 3540.5 kilometers (1850 miles) of line and serves approximately 1.2 million customers. The diameter of the sewer pipes ranges from 0.1-2.4 meters (3.9-.4.5 inches). The sewer system in the city is currently diagrammed in a series of hard-copy map books; the City hopes to establish a GIS system within the next year.

In the last three years, the City of Forth Worth has extensively upgraded its sewer systems. As a result their sewer maintenance group has expanded to include three new divisions, which include:

TABLE 5 EFFECTIVENESS OF CLEANING TECHNIQUES

Solution to Problem	Type of Problem				
	Emergency Stoppages	Grease	Roots	Sand, Grit, Debris	Odors
Balling		●		●	●
High Velocity Cleaning	•	●		●	●
Flushing					●
Sewer Scooters		●		●	
Bucket Machines, Scrapers				●	
Power Rodders	●	•	●		
Hand Rods	●	•	●		
Chemicals		●	●		●

● = Most effective solution for a particular problem

• = Least effective solution for a particular problem

Source: U.S. EPA, 1993.

- Sewer Cleaning and Stoppage Section- this section responds to customer complaints, pinpoints problems within the lines, and clears all blockages.

- TV Section- this section locates defects and building sewer connections (also referred to as taps) within the system.

- Preventive Maintenance Section- this section cleans and inspects the lines and also provides for Quality Assurance and Quality Control (QA/QC).

Most of Fort Worth's inspections use the CUE CCTV system. However, about 40 percent of the lines in the worst and oldest sections of the system are inspected visually. Visual inspections are also used in the most recently installed lines and manholes.

The city uses a variety of cleaning methods including jetting, high velocity cleaning, rodding, bucket machining, and using stop trucks (sectional rods with an attached motor). As part of their preventive maintenance approach, the city has also been using combination trucks with both flush and vacuum systems. To control roots, the city uses a vapor rooter eradication system which can ensure that no roots return to the line for up to five years.

The cleaning and inspection crews consists of two members to operate each of the combination trucks and TV trucks. The City of Forth Worth has cleaned approximately 239 kilometers (145 miles) of line and has TV inspected approximately 70 kilometers (44 miles) of line from 1996 to 1998. The cleaning cost for 1998 was determined to be $1.38/meter ($0.42/foot) and the TV inspection cost was determined to be $1.28/meter ($0.39/foot).

The City of Fort Worth is working on cleaning its entire system every seven to eight years. The cleaning frequency of the lines is prioritized based on the number of complaints received in each area.

City of Los Angeles, California

The Los Angeles Wastewater Collection System is one of the largest and most complex systems in the world. It serves approximately four million people over 600 square miles. The system is made up of 6,500 miles (6950 kilometers) of sewer lines. The diameter of the sewer lines ranges from 6 to 150 inches (0.1-3.8 meters) and about half of the system is more than 50 years old.

The continuing success of this system has been attributed to a preventive and proactive operation and maintenance program. This program has implemented a computerized maintenance management plan emphasizing preventive and corrective maintenance; this system tracks all maintenance activities.

For preventive maintenance, Los Angeles has adopted a Sewer Condition Assessment Program. This program prioritizes the inspection, cleaning, and rehabilitation of the sewer system, based on a scoring system that uses the age, size, and the construction material of the pipe to schedule inspections. Scores are determined using GIS and specially-designed computer and logic programs. High-priority inspections are conducted using CCTV; lower-priority ones use the lamping technique. Lamping may be followed up by a CCTV inspection if more information is required.

Los Angeles performs approximately 145 kilometers (90 miles) of CCTV inspections per year. The cost of CCTV inspections is approximately $1.00/foot, including labor and equipment. The City also performs about 4506 kilometers (2800 miles) of visual inspections per year at $0.07/foot.

Los Angeles cleans about 2,032 kilometers (1,900 miles) of sewer per year. The cleaning frequency is based on inspections and field conditions. The City removes roots by means of mechanical rodding machines ($1.71/meter or $0.52/ft), chemical applications, hydraulic winch machines, and hand rods ($3.12/meter or $0.95/foot). Los Angeles's Corrosion Abatement Maintenance Program uses magnesium hydroxide crown spraying to treat about 129 kilometers (80 miles) of sewer per year at a cost of $700,000 to prevent corrosion. Los Angeles's program to control H_2S odor uses caustic shock dosing, which costs about $1,000,000/year.

COSTS

Table 6 summarizes the annual maintenance costs per mile for cleaning and inspecting.

TABLE 6 NATIONAL SUMMARY OF MAINTENANCE COSTS

Identifier	Range of Costs	Average Cost
Total O&M cost/mile/year	$951-$46,973[1]	$2,823[3]
Labor (cost/mile/year)	$695 -$19,831[1]	$3,626[1]
Fringe Benefits (cost/mile/year)	$192 -$9,033[1]	$1,185[1]
Chemicals (cost/mile/year)	$0.3 -$7,616[1]	$512[1]
Hydroflush Cleaning (cost/mile)	$475 -5,230[2]	$1,700[1]
Television Inspection (cost/mile)	$1,000 -$11,450[2]	$4,600[1]
Preventive Maintenance	63% of Total Maintenance Costs (excludes depreciation)	

Source: 1 Water Environment Research Foundation, 1997.
2 Arbour and Kerri, 1997.
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ADDITIONAL INFORMATION

California State University, Sacramento
Ken Kerri
6000 J Street
Sacramento, California 95819

Fairfax County, Virginia
Ifty Khan
Department of Public Works
6000 Freds Oak Road
Burke, Virginia 22015

City of Fort Worth, Texas
Cory Hanson
Fort Worth Water Department
1608 11th Avenue
Fort Worth, Texas 76102

City of Los Angeles, California
Barry Bergren
Los Angeles Bureau of Sanitation
2335 Dorris Place
Los Angeles, California 90031

City of Topeka, Kansas
Tim Green
Department of Public Works
515 S. Kansas Avenue
Topeka, Kansas 66603

For more information contact:

Municipal Technology Branch
U.S. EPA
Mail Code 4204
401 M St., S.W.
Washington, D.C., 20460

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