Emerging Technologies

for Conveyance Systems

New Installations and Rehabilitation Methods

EPA 832-R-06-004 JULY 2006

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FOR Conveyance Systems

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Office of Wastewater Management

U.S. Environmental Protection Agency

Washington, D.C.

Emerging Technologies for Conveyance Systems:
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Preface

The U.S. Environmental Protection Agency (U.S. EPA) is charged by Congress with protecting the nation's land, air, and water resources. Under a mandate of environmental laws, the Agency strives to formulate and implement actions leading to a balance between human activities and the ability of natural systems to support and sustain life. To meet this mandate, the Office of Wastewater Management (OWM) provides information and technical support to solve environmental problems today and to build a knowledge base necessary to protect public health and the environment well into the future.

This publication has been produced under contract to the U.S. EPA by Parsons Corporation and provides current state of development as of the publication date. It is expected that this document will be revised periodically to reflect advances in this rapidly evolving area. Except as noted, information, interviews and data development were conducted by the contractor. Some of the information, especially related to embryonic technologies, was provided by the manufacturer or vendor of the equipment or technology and could not be verified or supported by full-scale case study. In some cases, cost data was based on estimated savings without actual field data. When evaluating technologies, estimated costs, and stated performance, the user should collect current and more up-to-date information.

The mention of trade names or specific vendors or products does not represent an actual or presumed endorsement, preference, or acceptance by the U.S. EPA or the Federal government. Stated results, conclusions, usage, or practices do not necessarily represent the views or policies of the U.S. EPA.

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List of Abbreviations

3D	three dimensional
ADFc	critical average daily flow
ADF	average dry-weather flow
AMC	antecedent moisture conditions
ASCE	American Society of Civil Engineers
ASTM	American Society of Testing and Materials
BES	Bureau of Environmental Services
CCTV	closed-circuit television
CIP	capital improvement program
CIPP	cured-in-place pipe
CSO	combined sewer overflow
CWMP	Comprehensive Wastewater Management Plan
DEP	Department of Environmental Protection
DEQ	Department of Environmental Quality
DNR	Department of Natural Resources
DO	dissolved oxygen
EMC	Environmental Management Commission
EPA	Environmental Protection Agency
ERDC	Engineer Research and Development Center
ESRI	Environmental Systems Research Institute
FAC	Florida Administrative Code
FELL	Focused Electrode Leak Locator
g/ac/day	gallons per acre per day
GASB	Government Accounting Standards Board
GIS	geographic information system
gpcd	gallons per capita per day
gpd	gallons per day
gpdidm	gallons per day per inch-diameter mile
GRP	glass-reinforced plastic
GWI	groundwater infiltration
HDD	horizontal directional drilling
HDPE	high-density polyethylene
HRT	hydraulic residence time
I/I	infiltration and inflow
ISS	inline storage system

List of Abbreviations

LF	linear foot
MFP	Master Facilities Plan
MGD	million gallons per day
NASTT	North American Society for Trenchless Technology
NDPU	Non-Discharge Permitting Unit
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
O&M	operation and maintenance
OAP	Overflow Abatement Program
PF	peak flow
POTW	publicly owned treatment works
PVC	polyvinyl chloride
PWWF	peak wet weather flow
RDII	rainfall-derived infiltration and inflow
RWQCB	Regional Water Quality Control Board
SRF	State Revolving Fund
SSES	Sewer System Evaluation Survey
SSET	Sewer Scanner and Evaluation Technology
SSO	sanitary sewer overflow
SSOEP	Sanitary Sewer Overflow Elimination Program
SWMM	Storm Water Management Model
TISCIT	Totally Integrated Sonar & CCTV Integrated Technique
WEF	Water Environment Federation
WERF	Water Environment Research Foundation
WPAP	Water Pollution Abatement Program
WPCF	water pollution control facility
WWTF	wastewater treatment facility
WWTP	wastewater treatment plant

Executive Summary

In the year 2000, the United States operated 21,264 collection and conveyance systems that included both sanitary and combined sewer systems (EPA's Clean Watersheds Needs Survey 2000 Report to Congress). Publicly owned sewer systems in the country account for 724,000 miles of sewer pipe and privately owned sewer pipe comprises an additional 500,000 miles (EPA's Report to Congress: Impacts and Control of CSOs and SSOs, August 2004). Most of our nation's conveyance systems are beginning to show signs of aging, with some systems dating back more than 100 years (American Society of Civil Engineers, 1999). Over time, a wide variety of materials and practices have been used for maintenance and repair. Sanitary and combined sewer overflows may be the result of improper operation and maintenance of sanitary, combined, and/or storm sewer systems, which can include structural, mechanical or electrical failures, collapsed or broken pipes, and insufficient capacity. The outcome of programs for overflow control and infrastructure asset management has resulted in a search for reliable, cost-effective conveyance system technologies. The purpose of this document is to provide a source of information on the newer technologies available. This document:

- Identifies nearly 100 conveyance system rehabilitation, replacement, and evaluation technologies, including technologies that may extend the life of a conveyance system.
- Classifies their development as established, innovative, or embryonic.
- Provides a Technology Summary Sheet for each innovative or embryonic process with information about the description, state of development, associated contract names, and data sources.
- Compares innovative processes/methods with respect to various criteria.
- Identifies research needs to guide the development of innovative conveyance system management.

This document organizes the information regarding emerging conveyance technologies into three categories of development.

Embryonic – They are in the development stage and/or have been tested at laboratory, bench, or pilot-scale only.

Innovative – They have been tested at a demonstration scale, are available and implemented in at least some locations in the United States, or have some degree of initial use (i.e., implemented in less than 1 percent of rehabilitation/replacement projects throughout the United States).

Established – They have been utilized in many locations (i.e., more than 1 percent of the rehabilitation/replacement projects), or have been available and implemented in the United States for more than 5 years.

The document also provides information on each technology—its objective, its description, its state of development, available cost information, associated contact names, and related data sources. For each innovative technology, this document further evaluates the technology with respect to various criteria, although it does not rank or recommend any one technology over another. Research needs also are identified to guide development of innovative and embryonic technologies and improve established ones.

Chapter

1

Introduction and Approach

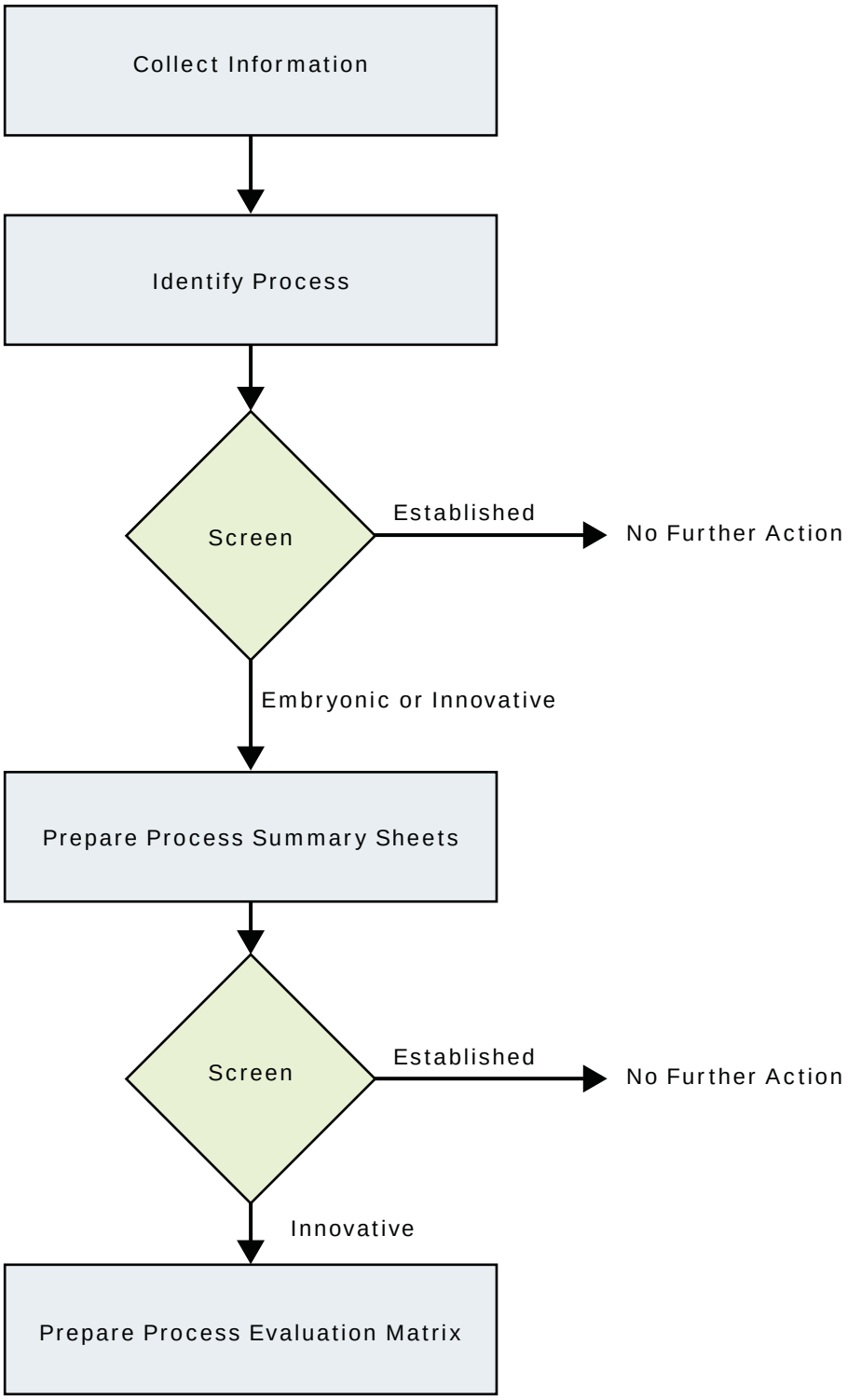
1.1 Introduction

In the year 2000, the United States operated 21,264 collection and conveyance systems that included both sanitary and combined sewer systems (EPA's Clean Watersheds Needs Survey 2000 Report to Congress). Publicly-owned sewer systems in the country account for 724,000 miles of sewer pipe and privately-owned sewer pipe comprises an additional 500,000 miles (EPA's Report to Congress: Impacts and Control of CSOs and SSOs, August 2004). Most of our nation's conveyance systems are beginning to show signs of aging, with some systems dating back more than 100 years (American Society of Civil Engineers, 1999). Over time, a wide variety of materials and practices have been used for maintenance and repair. One cause of sanitary and combined sewer overflows may be improper operation and maintenance. Improper maintenance can include sanitary, combined, and/or storm sewer systems, which can include structural, mechanical or electrical failures, collapsed or broken pipes, and insufficient capacity.

To meet the challenge of ongoing and even increasing needs for maintenance and repair, many utilities are seeking innovative technologies to replace, renew, or extend the life of their conveyance systems. Unfortunately, information on new and emerging technologies is not always readily available or easy to find. In light of this, and with the desire to make such information available, the EPA has authorized the development of this document. The goal of this document is straightforward—to provide a guide for people seeking information on innovative and emerging conveyance system technologies. The guide lists new technologies, assesses their merits and costs, and provides sources for further technological investigation. This document is intended to serve as a tool for conveyance system owners and operators.

To develop this guide, the investigators sought information from a variety of sources, identified new technologies, prepared planning-level cost summaries for innovative and embryonic technologies. This method is described below and in Figure 1.1.

Figure 1.1 Flow Schematic for Guide Development



1.2 Approach

1.2.1 Information Collection and New Process Identification

The information collection and new technology identification provided the foundation for subsequent work. To identify new conveyance system technologies, investigators gathered information from a variety of sources, including the following:

Published Literature – A comprehensive literature review was performed to identify new technologies, and to evaluate their performance and applications. Specifically, the review focused on relevant Water Environment Federation (WEF), Water Environment Research Foundation (WERF), American Society of Civil Engineers (ASCE) and North American Society for Trenchless Technology (NASTT) reports and conference proceedings, as well as monthly publications from these and other organizations.

"Gray" Literature – Vendor-supplied information, Internet research, and consultants' technical reports comprise the information collected in this category.

Patent Search – The U.S. Patent Office website has a very good search engine and patent application information is available online.

Technical and Trade Associations – Investigators contacted a variety of professional and technical associations in the United States to identify emerging conveyance systems technologies. A peer review was conducted by experienced municipal engineers, and consultants who provided input into the list of technologies included in this report and information on the application and demonstration of these emerging technologies. Trade Associations, such as North American Society for Trenchless Technologies (NASTT), were also contacted for information and are listed in Chapter 9.

Interviews and Correspondence – Individuals known to the project investigation team, including consultants, academia, and municipal conveyance system owners and operators, were consulted.

Technologies identified through a search of the above sources were screened to determine their classification as described below.

1.2.2 Initial Screening Technologies

Emerging technologies typically follow a development process that leads from laboratory investigations to pilot testing and, subsequently, to initial use or "full-scale demonstrations" and new applications before the technology is considered established. Not all technologies survive the entire development process. Some fail in the laboratory or at the pilot stage; while others see limited application in the field, due to poor performance or unexpected costs that cause them to lose favor with practitioners in the field. Even technologies that become established may also become dated, as technological advances lead to

obsolescence. In short, technologies are subject to the same evolutionary forces present in nature; those that cannot meet the demands of their environment fail, while those that adapt to changing technological, economic and regulatory climates can achieve long-standing success and survival in the market.

This project focuses on emerging technologies that are viable, but have not yet been accepted as established processes in the United States. Neither embryonic nor established technologies are considered in depth. Early in the development process (laboratory stage), data is usually insufficient to prove or disprove technology viability at full scale. Technologies on the other end of the developmental scale, those defined as established in North America, are also excluded from detailed assessments on the assumption that they are proven and widely used.

There may be differences between technologies established in Europe or Asia and those that have reached similar status in the United States. Technologies that have been applied successfully in other countries have not always flourished here. Because the viability of imported technologies is not guaranteed, established processes from overseas are classified as innovative technologies for this project unless they have been proven in North American applications.

Specific screening criteria used to define the state of development for processes are as follows:

Embryonic – These technologies are in the development stage and/or have been tested at laboratory or bench scale. New technologies that have reached the demonstration stage overseas, but cannot yet be considered to be established there, are also considered to be embryonic with respect to North American applications. Seven embryonic technologies have been identified for use in conveyance systems.

Innovative – Technologies that meet one of the following criteria were classified as innovative:

- They have been tested at a demonstration scale;
- They have been available and implemented in the United States for less than 5 years;
- They have some degree of initial use (i.e. implemented in less than one percent of rehabilitation/replacement projects throughout the United States); or,
- They are established technologies from overseas but not established in the United States.

Thirty-four innovative technologies were identified for conveyance systems.

Established – These processes have been used in many locations in North America. The category includes technologies that are widely used (e.g., pipe replacement) and technologies that have been available and are used in United States for more than five years (e.g., cured-in-place pipe). Fifty-one established technologies have been identified.

Some technologies fall into a "gray area" between the embryonic and innovative categories. Technologies that fall into this category are incorporated into the innovative category. The screening assessment summarized in Table 1.1 organizes the technologies in categories that are discussed in greater detail in the individual chapters. One organizational category represented in Table 1.1 is based on size. The large-diameter sewers or deep tunnels category represented in Table 1.1 is defined as any pipe or structure greater than 12 inches in diameter. The small diameter sewers or laterals category applies to any pipe 12 inches or less in diameter.

1.2.3 Development of Technology Summary Sheets

Technologies defined as embryonic or innovative are each summarized on an individual Technology Summary sheet. Each process includes the following information:

Objective – description of the goal of the technology.

Description – a brief overview of the technology.

State of Development – where and how the technology has been applied (i.e. laboratory study, demonstration scale, full scale, etc.)

Available Cost Information – an approximate range of capital and operations and maintenance costs, and assumptions made in developing them

Key Words for Internet Search – this document is not intended to provide a comprehensive list of vendors for the included technologies; therefore, key words have been added to aid the reader in finding additional vendors and current product information on the Internet.

Contact Names – names, addresses, and telephone numbers of contacts with additional information on the technology.

Data Sources – references used to compile the technology summary.

1.2.4 Evaluation of Technologies

Technologies defined as innovative in the initial screening were subjected to a detailed evaluation.

Each technology was evaluated with respect to the descriptive and comparative criteria described below. Descriptive criteria include:

State of Development – describes the stage of development for each technology, ranging from development to full-scale operations.

Table 1.1 Summary of Conveyance System Technologies

Technology and Advancement(s)	Classification			Application						
	Established	Innovative	Embryonic	Inflow Correction	Infiltration Correction	Sewer Rehabilitation	Sewer Replacement	New Sewers and Appurtenances	SSO and CSO Sewer Overflows	Capacity, Management, O&M
Large-Diameter Sewers and Deep Tunnels (Chapter 2)										
Coatings and Linings										
Thermo-Plastic Liners (anchored or glued)	•				•	•				
Glass-Reinforced Plastic (GRP) Panels		•								
Modified Cross-Section Lining (fold and form)	•				•	•				
Sliplining Noncircular w/New Noncircular Pipe			•		•	•				
Sliplining (segmental and spiral wound)	•				•	•				
Polymer/Epoxy Concrete Lining		•								
Spray-Applied Cementitious Lining	•				•	•				
Non-Portland Polymer Concrete			•							
Spray-Applied Epoxy Coating	•				•	•				
Cured-in-Place Pipe (CIPP)										
Composite/Fiberglass CIPP for Gravity Pipe	•				•	•				
Spot (Point) Repair CIPP	•				•	•				
Other Technologies										
Grout Injection	•				•	•				
Horizontal Directional Drilling (HDD)	•							•		
Gasketed PVC Pressure Pipe		•						•		
In-Line Pipe Expansion (i.e. pipe bursting)	•				•		•			
Internal Pipe Joint Seals	•				•	•				
Mechanical Spot Repair Sleeves	•				•	•				
Microtunneling	•							•		
Pipe Jacking	•							•		
Pipe Ramming	•							•		
Replacement (via excavation)	•			•	•		•	•	•	•
Sewer Odor and Corrosion Control Inserts (Vortex Flow)		•			•	•		•		
Tunneling	•							•		

Table 1.1 Summary of Conveyance System Technologies

Technology and Advancement(s)	Classification			Application						
	Established	Innovative	Embryonic	Inflow Correction	Infiltration Correction	Sewer Rehabilitation	Sewer Replacement	New Sewers and Appurtenances	SSO and CSO Sewer Overflows	Capacity, Management, O&M
Small-Diameter Sewers and Laterals (Chapter 3)										
Cured-in-Place Pipe (CIPP)										
Composite/Fiberglass CIPP for Gravity Pipe	•				•	•				
CIPP for Vertical Applications		•			•	•				
Lateral CIPP Liner (main to house)		•			•	•				
Lateral CIPP Liner (house to main)		•			•	•				
Lateral-Main Fiberglass CIPP Connection Inserts		•			•	•				
Spot (Point) Repair CIPP Liners	•				•	•				
Grout Injection										
Lateral Grout Injection		•			•					
Lateral Grout Injection from Mainline (up to 30 ft length)		•			•					
Other Technologies										
Horizontal Directional Drilling (HDD)	•							•		
Gasketed PVC Pressure Pipe		•						•		
Impact Moling – Steerable Moles		•						•		
In-Line Pipe Expansion (i.e. pipe bursting)	•				•		•			
Lateral Pipe Bursting		•			•		•			
Lateral Cleanout Connection		•						•		•
Mechanical Spot Repair Sleeves	•				•	•				
Microtunneling	•							•		
Modified Cross-Section Lining (i.e. fold and form)	•				•	•				
Modified Cross-Section Lateral Lining			•		•	•				
Pipe Jacking	•							•		
Pipe Ramming	•							•		
Replacement (via excavation)	•			•	•		•	•	•	•
Sanipor Technology (flood grouting)		•			•	•				
Sliplining (segmental and spiral wound)	•			•	•					
Lateral Sliplining		•		•	•					

Table 1.1 Summary of Conveyance System Technologies

Technology and Advancement(s)	Classification			Application						
	Established	Innovative	Embryonic	Inflow Correction	Infiltration Correction	Sewer Rehabilitation	Sewer Replacement	New Sewers and Appurtenances	SSO and CSO Sewer Overflows	Capacity, Management, O&M
Manholes (Chapter 4)										
Bench/Invert Rehabilitation										
Plastic Composite Invert System	•				•	•				•
Chimney Rehabilitation										
Flexible Sealant	•				•	•				
Mechanical Chimney Seals (interior or exterior)	•				•	•				
Polyethylene Chimney Form		•			•	•				
Coatings and Linings										
Cured-in-Place (CIP) Liners	•				•	•				
Poured-in-Place Concrete Liners	•				•	•				
Spray or Trowel-Applied Cementitious Lining	•				•	•				
Spray or Trowel-Applied Polymer Coating	•				•	•				
Joint Sealing										
Cementitious Grout/Patching	•				•	•				
Epoxy Grout/Patching	•				•	•				
Mechanical Joint Seals		•			•	•				
Other Technologies										
Fiberglass Rehabilitation Manholes		•			•	•				
Frame Adjustments (raise/reset)	•			•	•	•				
HDPE Frame Adjustment Rings		•			•	•				
Glass-Reinforced Plastic (GRP) Insert			•		•	•				
Lid (Cover) Inserts	•			•						
Replacement	•			•	•		•	•		
Sanipor® Technology (fill and drain)		•			•	•				
Sewer Odor and Corrosion Control Insert		•				•		•		
Conveyance System Management (Chapter 5)										
ESRI-Based One-Call Ticket Management		•								•
Mobile GIS		•								•

Table 1.1 Summary of Conveyance System Technologies

Technology and Advancement(s)	Classification			Application						
	Established	Innovative	Embryonic	Inflow Correction	Infiltration Correction	Sewer Rehabilitation	Sewer Replacement	New Sewers and Appurtenances	SSO and CSO Sewer Overflows	Capacity, Management, O&M
Public Outreach on Fats, Oils, and Grease (FOG)	•								•	•
Regional I/I Control Program		•		•	•				•	•
Sewer Maintenance Program	•			•	•				•	•
Capacity Restoration (Chapter 6)										
Sewer Cleaning										
Pigging (force main cleaning)		•							•	•
Culvert Cleaning System			•						•	•
HDD Attachments for Culvert Cleaning		•							•	•
Other Technologies										
Above-Grade Grit Removal System (bridge applications)		•								•
Basement Sump Pump Redirection	•								•	•
Foundation/Footer Drain Redirection	•								•	•
Interconnection Elimination	•								•	•
Roof Drain Redirection	•								•	•
Root Removal and Control	•								•	•
Storm Water Infiltration Pumps	•			•						
Conveyance System Assessment (Chapter 7)										
Closed-Circuit Television Inspection	•									•
Digital Camera Inspection (mobile)	•									•
Digital Camera Inspection (mounted)		•								•
FELL (Focused Electrode Leak Locator) Electro-Scanning		•								•
Ground-Penetrating Radar	•									•
Laser Profiling/3D Scan/Sonar		•								•
Pipe Mechanical/Strucural Reliability Analysis			•							•
Sewer Scanner and Evaluation Technology (SSET)		•								•
Smart Sewer Assessment Systems			•							•
TISCIT (Totally Integrated Sonar & CCTV Integrated Technique)		•								•
Wireless Monitoring Systems		•								•

Applicability – qualitatively assesses in which market the technology is designed to be utilized.

Benefits – considers the benefits gained (e.g., capital or operational savings) from implementation of the technology.

Designations for each descriptive criterion are presented in Table 1.2.

Comparative criteria include:

Impact on Homeowners – describes whether or not the technology requires the involvement of the homeowner, and the degree to which the homeowner's property will be disturbed. Excavation and replacement of a line is the baseline for comparison; technologies with less disturbance are rated as favorable.

Table 1.2 Descriptive Evaluation Criteria

Criterion	Designation	Description
State of Development	D	Demonstration project
	L	Limited municipal installations
	I	Full-scale industrial applications, with potential for application in municipal conveyance systems
	O	Full-scale operations overseas
	N	Full-scale operations in North America
Applicability	I	Industrial
	S	Municipal sanitary
	T	Municipal storm
	C	Municipal combined
	B	Municipal sanitary and storm
Potential Benefits	C	Capital savings
	O	Operational/maintenance savings
	I	Inflow/infiltration reduction
	S	SSO/CSO reduction
	R	Restored structural integrity
	M	Improved maintenance tracking/management

Maintenance Requirements – considers the amount of labor required to adequately maintain the technology. The baseline technology for a collection system is concrete gravity sewers; technologies with maintenance requirements comparable to concrete gravity sewers are considered neutral.

The above criteria compared individual technologies with other technologies in the same category (e.g., liners etc.), and were scored favorable, neutral/mixed, or unfavorable.

The criteria and ratings were applied to each innovative technology and the results are presented in matrix format. Where available information was insufficient to rate a technology for a criterion, no rating is given. The project team and reviewers assessed each technology based on the limited information gathered and their collective judgment, experience, and opinions. Results of the evaluation are presented in subsequent chapters.

1.3 Guidance Document Format and Use

The remainder of the document is divided into chapters based upon general technologies. One chapter is dedicated to each of the following categories:

- Large-Diameter Sewers and Tunnels (Chapter 2)
- Small-Diameter Sewers and Laterals (Chapter 3)
- Manholes (Chapter 4)
- Conveyance System Management (Chapter 5)
- Capacity Restoration (Chapter 6)
- Conveyance System Evaluation (Chapter 7)

Each chapter overviews the technologies included, classifies the state of development for each, presents an evaluation matrix for innovative technologies, and concludes with a Technology Summary sheet for each embryonic and innovative technology.

The technology summaries and evaluation matrices are the cornerstones of each chapter, broadly overviewing the innovative technologies. Neither the summaries nor the matrices should be considered definitive technology assessments. Rather, they should be considered stepping stones to more detailed investigations.

The research needs discussed in Chapter 8 display the specific technologies that may have a significant impact on conveyance system construction and management, and their relevant research needs. The new and improved technology solutions for wastewater collection systems are key components in the preservation of the collection system infrastructure. Research on the assessment of the system integrity, the operation, maintenance, and rehabilitation, and new construction must be considered.

For the reader's convenience, numerous trade associations, who are also excellent sources of information on emerging technologies in their respectful areas of expertise, are summarized in Appendix A.

This document should be updated from time to time. Technologies were reviewed in 2004–2005.

1.4 Chapter References

American Society of Civil Engineers. *Optimization of Collection System Maintenance Frequencies and System Performance* (1999)

U.S. EPA. *Report to Congress: Impacts and Control of CSO and SSOs*. EPA 833-R-04-001. Office of Water (2004)

U.S. EPA *Clean Watersheds Needs Survey 2000 Report to Congress*. EPA 832-R-03-001. Office of Water (2000)

Chapter 2

Large-Diameter Sewers and Deep Tunnels

2.1 Introduction

For the purpose of this report, a large-diameter sewer or deep tunnel is defined as any pipe or structure greater than 12 inches in diameter. This chapter focuses on both new construction and rehabilitation technologies that can be utilized to restore and maintain these critical conveyance system components.

2.2 Technology Assessment

A summary of emerging and established technologies for large-diameter sewers and deep tunnels is provided in Table 2.1. The installation and maintenance techniques for pipes and structures of this size are well-documented and understood, as they serve the basis for conveyance systems that date back to over 100 years ago. The list of established technologies in Table 2.1 reflects this knowledge base.

The large-diameter pipes and structures referred to in this report are greater than 12 inches in diameter. It is important to note that technologies mentioned in this chapter may be more common or practical when applied to a more specific size pipe. For example, the cured-in-place pipe (CIPP) technologies discussed in the chapter are more common for a medium-size pipe ranging from 15 to 36 inches in diameter. On the other hand, the glass-reinforced panels (GRP) mentioned are more common amongst the larger diameter pipes or tunnels with diameters greater than 36 inches. Polyvinyl chloride/high-density polyethylene (PVC/HDPE) thermoplastic liners using a variety of anchoring and gluing material, such as Ameron T-loc™,Linabond™, Amaerplate™, and Steuler P&S 400™, have been extensively used for lining water pipe for many years. Therefore, the application of these two-pass systems for lining tunnels and large sewer pipe, even though relatively new to the industry, are not considered innovative.

Technology development in this area is now focusing on products for rehabilitation of existing facilities. Properly maintaining large-diameter sewers and tunnels can be very expensive as compared with smaller diameter sewers and in many cases municipalities and organizations have delayed maintenance activities of their large sewer systems to the point of structural deterioration and failure. GRP panels have been identified as an

innovative technology aimed at restoring the structural integrity of large-diameter sewers and tunnels in a cost-efficient manner. Another innovative approach is the use of sewer pipes made with polymer or epoxy resins, such as Polycrete™ and Polymer Concrete FX-826™. These materials are extremely strong and corrosion resistant. Epoxy concrete can be applied in a one-step approach to provide a new interior surface as well as repair damaged pipe and restore structural integrity.

In addition to rehabilitation advances, progress has also been made to improve existing techniques so they are more suitable for non-traditional applications. A gasketed PVC joint has been developed that allows PVC to be used as practical alternative to HDPE pipe in horizontal directional drilling. Sliplining of a noncircular host pipe with a new, noncircular pipe has also come into the marketplace recently. In addition, the use of non-Portland cement based polymer concrete, such as Biocrete™, for rehabilitating has demonstrated significant cost savings in the foreign market.

An evaluation of the innovative technologies identified for large-diameter sewers and tunnels is presented in Figure 2.1. Summary sheets for each innovative and embryonic technology are provided at the end of this chapter.

Table 2.1 Large-Diameter Sewers and Deep Tunnels Technologies – State of Development

Established	Innovative	Embryonic
Composite/Fiberglass CIPP for Gravity Pipe Grout Injection Horizontal Directional Drilling (HDD) In-Line Pipe Expansion (i.e., pipe bursting) Internal Pipe Joint Seals Mechanical Spot Repair Sleeves Microtunneling Modified Cross-Section Lining (i.e., fold and form) Pipe Jacking Pipe Ramming Replacement (via excavation) Sliplining (segmental and spiral wound) Spot (point) Repair CIPP Spray-Applied Cementitious Lining Spray-Applied Epoxy Coating Thermoplastic Liners (anchored or glued) Tunneling	Gasketed PVC Pressure Pipe Glass-Reinforced Plastic (GRP) Panels Polymer/Epoxy Concrete Lining Sewer Odor and Corrosion Control Inserts (Vortex Flow)	Sliplining of Noncircular Pipe with New Noncircular Pipe Non-Portland Polymer Concrete

Figure 2.1 Evaluation of Large-Diameter Sewers and Deep Tunnels Innovative Technologies

INNOVATIVE TECHNOLOGY	EVALUATION CRITERIA							COMMENTS
	Development	Applicability	Benefit	Impact on Homeowners	Ease of Installation	Design Life	Maintenance Requirements	
Gasketed PVC Pressure Pipe	L	I S	C	▲	▲	▲	▲	As compared with replacement
Glass-Reinforced (GRP) Panels	L	B C	C R	▲	▲	▲	▲	As compared with replacement
Polymer/Epoxy Concrete Lining	L	B I		▲	▲	▲	▲	As compared with current practice
Sewer Odor and Corrosion Control Inserts (Vortex Flow)	L	S C	O	⊖	⊖	▲	▲	As compared with current practice

State of Development
KEY
D = Demonstration project
L = Limited municipal installations
I = Full-scale industrial applications, with potential for application in municipal conveyance systems
O = Full-scale operations overseas
N = Full-scale operations in North America

Applicability
I = Industrial
S = Municipal sanitary
T = Municipal storm
C = Municipal combined
B = Municipal sanitary and storm

Potential Benefits
C = Capital savings
O = Operational/maintenance savings
I = Inflow/infiltration reduction
S = SSO/CSO reduction
R = Restored structural integrity
M = Improved maintenance tracking/management

Comparative Criteria
▲ Positive feature
⊖ Neutral or mixed
▽ Negative feature

Technology Summary

Gasketed PVC Pressure Pipe

Objective:

Increase strength and integrity of polyvinyl chloride in systems.

State of Development: Innovative

This technology has been around since 2004 and is widely used in Canada (20–30 municipalities to date) as well as parts of the United States.

Description:

The gasketed PVC pressure pipe is assembled in way that is similar to the assembly of the standard PVC pipe, only the gasketed pipe is locked in place with a ring and pin system. The pipe is locked once the system is hammered in to place. The wide groove on the spigot end of the pipes allow joint bending in the pipe. The joint bending then allows the PVC pipe to be pulled into boreholes with the ability to withstand the forces involved.

Available Cost Information:

Approximate Capital Cost: 40% higher than regular PVC

Approximate O&M Costs: Low

O&M Costs are similar to any regular PVC systems around. In general, they are very low maintenance.

Vendor Name(s):

IPEX Inc.
2441 Royal Windsor Drive
Mississauga, Ontario J5J 4C7 Canada
Phone: 800-463-9572
FaxL 905-403-9195
E-mail: ricsta@ipexinc.com

Practitioner(s):

City of Springfield, Missouri
Public Works
P.O. Box 8368
Springfield, MO 65801

R. Stuart Royer & Associates, Inc.
1100 Welborne Drive, Suite 300
Richmond, VA 23229

Key Words for Internet Search:

Pressure, pipe, gasket, PVC, water, sewer

Data Sources:

"New Research Yields and Innovative Design for PVC Pipe." *Trenchless Technology* (7–8 August 2004)

Technology Summary

Glass-Reinforced Plastic (GRP)

Objective:

Structural rehabilitation of large-diameter gravity sewers and tunnels.

State of Development: Innovative

This technology has been installed in two municipalities nationwide. In 2003, GRP panel lining was used to rehabilitate 72-inch-diameter pipe in Fort Wayne, Indiana, and pipe ranging from 108 – 126 inches in diameter in Chicago, Illinois

Description:

Fiber reinforced, filled, thermo-set resin panels are custom designed to fit a variety of sewer and tunnel shapes, including oval, round, rectangular, square, horseshoe. The panels can be installed utilizing a man-entry procedure in conveyance facilities ranging from 54 to 144 inches and higher in diameter. Half-pipe panels are fitted together in place to form a full diameter segment. The annular space between the panels and the host pipe is filled with grout to complete the installation.

Available Cost Information:

Approximate Capital Cost: $10–$13/diameter-inch/LF

Approximate O&M Costs: Periodic maintenance and visual inspection

Capital cost information is provided for a line segment that is several hundred feet long (over 200 LF), and includes both material and installation costs. Using the lower end of the cost range as an example, the unit price for a 96-inch diameter pipe would be $960/LF.

Vendor Name(s):

Insituform Technologies, Inc.
17999 Edison Avenue
Chesterfield, MO 63005
Phone: 636-530-8000
Fax: 636-530-8744
E-mail: losborne@insituform.com

Practitioner(s):

City of Fort Wayne
Division of Water Utilities, Water Resources
Sewer Repair and Replacement
One Main Street, Room 480
Fort Wayne, IN 46802

Key Words for Internet Search:

Glass-reinforced plastics, GRP, panel, pipe fiber, water

Data Sources:

Hicks, M., T.J. Short, P.E., J. Teusch, P.E., L.E. Osborn, P.E. “Glass Reinforced Plastic (GRP): A New Rehabilitation Technique for Sewers in Indiana,” Proceedings of ASCE Specialty Conference Pipelines, ASCE Specialty Conference, San Diego, CA (1–4 August 2004)

Osborn, L., “Rehabilitation of Large Chicago Sewers with Glass Reinforced Panels,” Proceedings of North American Society for Trenchless Technology (NASTT) NO-DIG Conference, New Orleans, LA (22–24 March 2004)

Jason Consultants International, Inc. “New Pipes for Old: A Study of Recent Advances in Sewer Pipe Materials and Technology.” Alexandria, VA. Water Environment Research Foundation (WERF) (2000)

Vendor-supplied information

Technology Summary

Polymer/Epoxy Concrete Lining

Objective:

Sewer pipes lined with concrete made with polymer or epoxy materials are extremely corrosion resistant.

State of Development: Innovative

The basic technology of spray-applying concrete linings to repair of existing pipe has been available in the United States for many years. However, using a polymer or epoxy mixture is relatively new.

Description:

Polymer concrete is made using conventional Portland cement with the addition of 7–15% resin by weight. The resin is an orthopthalic, isopthalic, vinyl ester resin, or epoxy resins. The resin bonds the different materials together, giving the polymer concrete greater elasticity and safety against fracture as well as improved corrosion resistance. Polymer concrete can be used to line new pipe or to repair old pipe and can be applied at the factory or in the field. The polymer concrete can be applied either in a "dry gun – Gunite" or "wet gun – Shotcrete" approach. Epoxy concrete can be applied in a one step approach to provide a new interior surface, as well as, repair damaged pipe and to restore structural integrity.

Available Cost Information:

Approximate Capital Cost:	Cost ranges from 10%–20% more than conventional field-applied concrete lining such as Gunite or Shotcrete using Portland cement.
Approximate O&M Costs:	$0 – unit is self-cleaning. Improved corrosion protection and longer service life.

Vendor Name(s):

Fox Industries
3100 Falls Cliff Road
Baltimore, MD 21211

Practitioner(s):

See websites for practitioners: http://www.thomasnet.com/products/sealants-cement-concrete-96117932-1.html. or www.foxind.com

Key Words for Internet Search:

Polymer concrete, epoxy concrete, corrosion-resistant pipe lining

Data Sources:

Vendor-supplied information (www.meyer-polycrete.com)
Vendor-supplied information (www.foxind.com)
Association-supplied information (www.nastt.org)
Vendor-supplied information (www.rohmhaas.com)

Technology Summary

Sewer Odor and Corrosion Control Inserts (Vortex Flow)

Objective:

To prevent the release of odorous gases in drop structures and force main discharges to sewer manholes.

State of Development: Innovative

This technology has been available since 1998. It has been used in approximately 30 locations worldwide (ten to fifteen units in the United States, two units in Canada, and two units in Australia).

Description:

A sewer odor and corrosion control insert can be installed in a new or existing precast manhole, and each insert is custom designed and built for the specific application. A typical insert consists of a channel that is connected to the manhole influent line, a drop shaft, and a shaft base that allows wastewater to spill over to the manhole effluent pipe. Patented by IPEX Inc., the spiral flow design of the Vortex Flow pulls odorous gases downward toward the bottom of the cylindrical structure and promotes oxidation of these gases, which naturally reduces odor. Odorous gases are partially oxidized on the way down by the energy of falling flow, and are then entrained back into the wastewater. An elevation drop of 6 feet or more is required for proper operation of the insert. Thus, this technology is applicable for incorporation in drop manholes, chambers, and pumping stations.

Available Cost Information:

Approximate Capital Cost: Base price $5,000 plus $2,000 for each million gallons per day capacity

Approximate O&M Costs: $0 – unit is self-cleaning

Vendor Name(s):

IPEX, Inc.
2441 Royal Windsor Drive
Missassauga, Onatrio J5J 4C7 Canada

Practitioner(s):

Parsons Water & Infrastructure
10521 Rosehaven Street
Fairfax, VA 22030

Key Words for Internet Search:

Odor, corrosion, control, manholes, sewer, inserts, vortex, flow

Data Sources:

Vendor-supplied information

Technology Summary

Sliplining of a Noncircular Pipe with a New Noncircular Pipe

Objective:

Reconstruct sewer line and laterals without excavation using formed-in-place liner for sewers that are not circular.

State of Development: Embryonic

This technology has been used in Europe. Developmental work currently is taking place in the United States.

Description:

Sliplining is a rehabilitation process in which a slipliner pipe is placed inside the existing old lateral pipe. The non-circular method uses a liner pipe profile that is designed so that it will slip through the section of the sewer that is narrowest. Once the new pipe is in place the pipe is filled with water to discourage deformation and the space between the new and old pipe is filled with low density foam grout.

Available Cost Information:

Approximate Capital Cost: Unknown

Approximate O&M Costs: Unknown

Vendor Name(s):

Sekisui SPR Americes, LLC
7 Sunbelt Business Park Drive, Suite 2
Greer, SC 29650
Phone: 864-662-1329
Fax: 864-662-1350 (fax)
Email: info@sekisui-spr.com

Practitioner(s):

See website for practitioners:
http://www.sekisui-spr.com/

Key Words for Internet Search:

Sliplining, noncircular pipe, Romo-Line

Data Sources:

North American Society for Trenchless Technology site: www.trenchless-technology.org

Technology Summary

Non-Portland Polymer Concrete

Objective:

Sewer pipes made with polymer or epoxy materials are extremely corrosion resistant.

State of Development: Embryonic

This technology has been available in Germany since 1960. It has been used in many locations worldwide, including numerous cities in the United States, Canada, and Australia. Most applications to date have been for industrial sewers.

Description:

Polymer concrete is made using conventional Portland cement with the addition of 7–15% resin by weight. The resin is an orthopthalic, isopthalic, or vinyl ester resin. The resin bonds the different materials together, giving the polymer concrete greater elasticity and safety against fracture as well as improved corrosion resistance. Polymer concrete pipes have been manufactured by various processes including centrifugal and vibrating processes in both reinforced and non-reinforced sections. Circular and oval pipe as well as special cross-sections and manhole sections can be manufactured in the same way. Epoxy resins can also be used as an additive to the concrete mixture for pH ranges of 0.5 to 13. Pipes are joined using flexible elastomeric seals (ASTM D4 161), while widely used for new construction, the use of non-Portland or epoxy concrete for rehabilitation is a new application.

Available Cost Information:

Approximate Capital Cost:	Cost ranges from 10% to 20% more than conventional concrete pipe of the same size and strength.
Approximate O&M Costs:	$0 – unit is self-cleaning. Provides increased corrosion protection and extends service life.

Vendor Name(s):

Meyer Rohr
Otto-Brenner-Str. 5
D-21337 Lueneburg, Germany

Practitioner(s):

See website for practitioners:
http://www.meyer-polycrete.com/en

Key Words for Internet Search:

Polymer concrete, epoxy concrete, corrosion-resistant pipe

Data Sources:

Vendor-supplied information (www.meyer-polycrete.com)
Vendor-supplied information (www.foxind.com)
Vendor-supplied information (www.nastt.org)
Rohm and Haas Company (www.rohmhaas.com)

Chapter 3

Small-Diameter Sewers and Laterals

3.1 Introduction

A small-diameter sewer or lateral, as defined in this document, is a pipe 12 inches or less in diameter. This chapter focuses on both new construction and rehabilitation technologies that can be utilized to restore and maintain these critical conveyance system components.

3.2 Technology Assessment

Table 3.1 includes a categorized list of emerging and established technologies for small-diameter sewers and laterals. These pipes, especially laterals, have become the target of many municipal rehabilitation programs because they are the main sources of inflow and infiltration to conveyance systems. As a result, technological development in this area has focused mainly on rehabilitation of existing facilities.

Many innovative technologies and approaches for the rehabilitation of small-diameter sewers and laterals have been identified. These include technologies such as CIPP liners for vertical rehabilitation applications and fill and drain (Sanipor®) technology. Although several technologies for lateral rehabilitation are starting to emerge as forerunners in the marketplace, such as CIPP liners, the technologies themselves are not new and have been used sparingly throughout the United States for up to 10 years. As such, these technologies have been classified as "established" for the purposes of this report.

An evaluation of the innovative technologies identified for small-diameter sewers and laterals is presented in Figure 3.1. Summary sheets for each innovative and embryonic technology are provided at the end of this chapter.

Table 3.1 Small-Diameter Sewers and Laterals Technologies – State of Development

Established	Innovative	Embryonic
Composite/Fiberglass CIPP for Gravity Pipe Horizontal Directional Drilling (HDD) In-Line Pipe Expansion (i.e. pipe bursting) Mechanical Spot Repair Sleeves Microtunneling Modified Cross-Section Lining (i.e. fold & form) Pipe Jacking Pipe Ramming Replacement (via excavation) Sliplining (segmental and spiral wound) Spot (point) Repair	CIPP for Vertical Applications Gasketed PVC Pressure Pipe Impact Moling–Steerable Moles Lateral Cleanout Connection Lateral Grout Injection Lateral Grout Injection from Mainline (up to 30 ft in length) Lateral CIPP Liner (house to main) Lateral CIPP Liner (main to house) Lateral-Main Fiberglass CIPP Connection Inserts Lateral Pipe Bursting Lateral Sliplining Sanipor® Technology (flood grout)	Modified Cross-Section Lateral Lining

Figure 3.1 Evaluation of Small-Diameter Sewers and Laterals Innovative Technologies

INNOVATIVE TECHNOLOGY	EVALUATION CRITERIA							COMMENTS
	Development	Applicability	Benefit	Impact on Homeowners	Ease of Installation	Design Life	Maintenance Requirements	
CIPP for Vertical Applications	D	B C	R	▲	▲	⊖	▲	As compared with replacment
Gasketed PVC Pressure Pipe	L	I S	C	▲	▲	▲	▲	As compared with replacement
Impact Moling – Steerable Moles	L	B C I	C	▲	▲	⊖	⊖	As compared with replacement
Lateral Cleanout Connection	L	S	O	⊖	▲	⊖	⊖	As compared with new installation using T-section
Lateral Grout Injection	N	S	C I	▲	▲	▽	⊖	As compared with replacement
Lateral CIPP Liner (house to main)	N	S	C I R	▲	▲	⊖	▲	As compared with replacement
Lateral CIPP Liner (main to house)	N	S	C I R	▲	▲	⊖	▲	As compared with replacement

KEY

State of Development
- D = Demonstration project
- L = Limited municipal installations
- I = Full-scale industrial applications, with potential for application in municipal conveyance systems
- O = Full-scale operations overseas
- N = Full-scale operations in North America

Applicability
- I = Industrial
- S = Municipal sanitary
- T = Municipal storm
- C = Municipal combined
- B = Municipal sanitary and storm

Potential Benefits
- C = Capital savings
- O = Operational/maintenance savings
- I = Inflow/infiltration reduction
- S = SSO/CSO reduction
- R = Restored structural integrity
- M = Improved maintenance tracking/management

Comparative Criteria
- ▲ Positive feature
- ⊖ Neutral or mixed
- ▽ Negative feature

Figure 3.1 Evaluation of Small-Diameter Sewers and Laterals Innovative Technologies (continued)

INNOVATIVE TECHNOLOGY	EVALUATION CRITERIA							COMMENTS
	Development	Applicability	Benefit	Impact on Homeowners	Ease of Installation	Design Life	Maintenance Requirements	
Lateral Grout Injection from Mainline	L	S	C I	▲	▲	▽	⊖	As compared with replacement
Lateral-Main Fiberglass CIPP Connection Inserts	D	B C I	O	▲	▲	▲	▲	As compared with replacement
Lateral Pipe Bursting	L	S	C I	▲	▲	⊖	▲	As compared with replacement
Lateral Sliplining	P	I	V O	▲	▲	⊖	▲	As compared with replacement
Sanipor® Technology (flood grouting)	O	I	V	▲	▲	▲	▲	As compared with replacement

KEY

State of Development
- D = Demonstration project
- L = Limited municipal installations
- I = Full-scale industrial applications, with potential for application in municipal conveyance systems
- O = Full-scale operations overseas
- N = Full-scale operations in North America

Applicability
- I = Industrial
- S = Municipal sanitary
- T = Municipal storm
- C = Municipal combined
- B = Municipal sanitary and storm

Potential Benefits
- C = Capital savings
- O = Operational/maintenance savings
- I = Inflow/infiltration reduction
- S = SSO/CSO reduction
- R = Restored structural integrity
- M = Improved maintenance tracking/management

Comparative Criteria
- ▲ Positive feature
- ⊖ Neutral or mixed
- ▽ Negative feature

Technology Summary

CIPP for Vertical Applications

Objective:

Provide a smooth interior surface to a damaged vertical pipe.

State of Development: Innovative

Am-Drain has been on the market in the United States since 2003 and available for the rehabilitation of down spouts in Europe for 15 years prior to the United States' use.

Description:

CIPP Applications for vertical pipes differ from the lateral lining because of the difficulties accompanied with the resin application to a vertical pipe. Typically resin would run down from the upper to lower portions of the inverted liner. Am-Drain is a needle-punched, nonwoven polyester felt tube with a PVC coating. Am-Drain is cured to the vertical pipe when the liner harders. An inversion drum, with the help of an air compressor inserts the liner tube into the damaged pipe while inverting the liner throughout the process. One CIPP vertical method uses a woven liner rather than a normal CIPP liner. This woven liner holds the resin more and prevents it from slipping due to gravity.

Available Cost Information:

Approximate Capital Cost: $14–$24/LF dry materials and resin

Approximate O&M Costs: Periodic inspection and cleaning

Costs will vary depending on the degree of bends in the pipe, lining material, and resin mat.

Vendor Name(s):

MaxLiner, LLC
450 College Drive
Martinsville, VA 24112

Practitioner(s):

Ace Pipe Cleaning
Carylon Corporation
1509 Sylvania Court
Fort Worth, TX 76111

Key Words for Internet Search:

Vertical pipe lining, Am-Drain, vertical CIPP

Data Sources:

Griffen, Jeff. "Vertical Lining: Historic Forth Worth Church Has Downspout Repaired Without Destruction of Wall." *Rehabilitation Technology: Underground Construction* (July 2004)

Vendor-supplied information

Technology Summary

Gasketed PVC Pressure Pipe

Objective:
Increase strength and integrity of polyvinyl chloride in systems.

State of Development: Innovative
Technology has been around since 2004 and is widely used in Canada (20–30 municipalities to date) as well as parts of the United States.

Description:
The gasketed PVC pressure pipe is assembled similar to how a standard PVC pipe is assembled, only the gasketed pipe is locked with a ring and pin system. The inner and outer rings of the pipe are hammered into place locking the joints in the system. Due to the wide groove on the spigot end of the pipe bending at the pipe's joints is possible. This joint bending allows the PVC to be pulled into boreholes and to withstand the forces involved.

Available Cost Information:
Approximate Capital Cost: 40% higher than regular PVC.
Approximate O&M Costs: Low

Vendor Name(s):
IPEX, Inc.
2441 Royal Windsor Drive
Mississauga, Ontario J5J 4C7
Phone: 800-463-9572
Fax: 905-403-9195
Email: ricsta@ipexinc.com

Practitioner(s):
See website for practitioners:
http://www.ipexinc.com/Content/Common/2_0_Products/2_0_1_Case_Studies/case_study_list.asp

Key Words for Internet Search:
Pressure, pipe, gasket, PVC, water, sewer

Data Sources:
"New Research Yields an Innovative Design for PVC Pipe." *Trenchless Technology* (7–8 August 2004)

Technology Summary

Impact Moling – Steerable Moles

Objective:
Uses a compaction principle to create a bore in compressible soils in which pipe is then installed.

State of Development: Innovative
Innovative applications such as steerable moles allowing curves and direction changes.

Description:
Moling is based on a percussion or hammering action with a pneumatic piercing tool to create a bore by compacting and displacing soil rather than removing it. The impact mole consists of an enclosed steel tube containing an air powered piston that strikes the nose of the tool driving it forward. It has low operational costs, simplicity in operations with minimal excavation. Moling is limited by ground conditions. One steerable mole is offered in the market place. It uses walkover tracking and remote steering similar to that in the horizontal drilling industry. A sonde integrated within the forward end of the tool body is made rugged to withstand the impact of the mole. The current generation of steerable moles have a dual position steering head with two operating modes, one for straight and an asymetrical one for steering.

Available Cost Information:

Approximate Capital Cost: $35,000 per machine; price includes all parts and everything needed for impact moling.

Approximate O&M Costs: Included in capital cost.

Vendor Name(s):
TT Technologies of Illinois
2020 E. New York St.
Aurora, IL 60504
Phone: 800-533-2078
info@ttechnologies.com

Practitioner(s):
U.S. Army Corps of Engineers
Vicksburg, MS

Key Words for Internet Search:
Impact moling, pipe ramming, trenchless technology, bore, steerable mole

Data Sources:
"Guidelines for Impact Moling." TTC Technical Report #2001.03. U.S. Army Corps of Engineers, ERDC, Vicksburg, MS

Technology Summary

Lateral Cleanout Connection	
Objective: Install cleanout on existing lateral where one does not exist.	State of Development: Innovative Process has been commercially available for three years with the installation of several thousand feet of line.
Description: The lateral is located by TV camera that finds a location for the cleanout that will not require bends or fittings. A vacuum excavating unit is then used to dig an 18-inch hole that will expose the lateral, the vacuum will be used to remove all soil. A two-part epoxy mix is used to glue the bottom of the saddle to the lateral when it is dropped and snapped over the lateral pipe. After the 15 minutes the epoxy takes to set, a water hydrostatic test is performed, followed by the use of a coring tool to core out the lateral. The coupon is removed and a clean out cap is added. A new riser or clean out can be attached.	
Available Cost Information: *Approximate Capital Cost:* $750 to $1,500 each *Approximate O&M Costs:* Same as standard cleanout. Costs vary based on location, depth, and soil conditions.	
Vendor Name(s): LMK Enterprises, Inc.	Practitioner(s): Rock River Water Reclamation District 3333 Kishwaukee St. Rockford, IL 61109
Key Words for Internet Search: Vacatee, lateral liner system, CIPP, cleanout	
Data Sources: Vendor-supplied information	

Technology Summary

Lateral Grout Injection

Objective:
Seal the lateral-main connection and cracks and joints in laterals to prevent inflow and infiltration into the sanitary sewer system.

State of Development: Innovative

Description:
Seals lateral by creating a impermeable gel ring outside the pipe joint. Lateral grout injection is accomplished using a packer, which is inserted through a manhole and positioned in the line using a camera. The packer is rotated and a grouting plug is inflated up the lateral. Grout is injected, to fill the annular area, into the surrounding soil, creating a sand and gel ring outside the pipe and service connection. The packer elements are deflated and pulled back into packer, scraping excess gel from the service line.

Available Cost Information:
Approximate Capital Cost: $300–$500 per lateral
Approximate O&M Costs: Periodic visual inspections and cleaning recommended
Capital cost estimate is based on grouting each joint in the first 8 ft–10 ft of the lateral from the sewer main.

Vendor Name(s):
Avanti International
822 Bay Star Blvd.
Webster, TX 77598

Practitioner(s):
See website for practitioners: http://avantigrout.com

Key Words for Internet Search:
Grout rehabilitation, injection, lateral pipe, joint sealing

Data Sources:
"Methods to Control Leaks in Sewer Collection Systems." An informative White Paper written by C. Vipu, Ph.D., P.E., Director of CIGMAT, and Chairman of Civil Engineering Department, University of Houston, Houston, TX

Jason Consultants International, Inc. " New Pipes for Old: A Study of Recent Advances in Sewer Pipe Materials and Technology." Alexandria, VA. Water Environment Research Foundation (WERF) (2000)

Simicevic, Jadranka, Raymond L. Sterling, Ahmad Habibian, Rick Nelson, Roger L. Tarbutto, and Alan Johnson. "Methods for Cost-Effective Rehabilitation of Private Lateral Sewers." WERF (2006)

Vendor-supplied information

Technology Summary

Lateral Grout Injection from Mainline (Up to 30-ft in Length)

Objective:

Seal the lateral-main connection and cracks and joints in laterals up to 30 feet from the main sewer line to prevent inflow and infiltration into the sanitary sewer system.

State of Development: Innovative

A Packer and 30-foot grouting plug have been developed and tested in a laboratory setting. As of May 2005, 24 units have been installed.

Description:

Lateral grout injection is accomplished using a packer, which is inserted into a sewer main through a manhole. The packer is remotely positioned in the mainline at the lateral connection, and a grouting plug is inflated up the lateral. Grout is injected, or pumped, into the lateral up to the location of the group plug. Grout is forced through cracks and joints into the surrounding soil, where it solidifies to form a watertight seal outside the pipeline. This grouting can be applied to laterals up to 30 feet from the main sewer line.

Available Cost Information:

Approximate Capital Cost: Varies

Approximate O&M Costs: Varies

Vendor Name(s):

Logiball, Inc.
HC 76 P.O. Box 625
Jackman, ME 04945
Phone: 800-246-5988
Fax: 418-653-5746
E-mail: marc@logiball.com

Practitioner(s):

Heitkamp, Inc.
New England Pipe Cleaning Co.
99 Callender Road
P.O. Box 730
Watertown, CT 06795

Key Words for Internet Search:

Grout rehabilitation, injection, lateral pipe, joint sealing, mainline

Data Sources:

Jason Consultants International, Inc. “New Pipes for Old: A Study of Recent Advances in Sewer Pipe Materials and Technology.” Alexandria, VA. Water Environment Research Foundation (WERF) (2000)

Simicevic, Jadranka, Raymond L. Sterling, Ahmad Habibian, Rick Nelson, Roger L. Tarbutton, and Alan Johnson. “Methods for Cost-Effective Rehabilitation of Private Lateral Sewers.” WERF (2006)

Vendor-supplied information

Technology Summary

Lateral CIPP Liner (House to Main)

Objective:

Provide reconstruction of service lateral pipe without excavation by the installation of a resin conduit liner.

State of Development: Innovative

Description:

Woven or nonwoven material is impregnated with thermosetting resin and installed in an existing pipeline or conduit using an air inversion and curing process. Product designed to rehabilitate pipelines with diameters from 2 to 8 inches and negotiates curves (up to 90°) and lines through 4–6 inch transitions without changing structural properties of the liner. Installation through existing building sewer lines permit connection without stretching into sewer main.

Available Cost Information:

Approximate Capital Cost: Ranges from $2500 – $4500

Approximate O&M Costs: Periodic visual inspections recommended.

Costs are highly variable and will fluctuate based on pipe size, material, condition, depth, and accessibility (i.e. cleanout available).

Vendor Name(s):

Perma-liner Industries
6196 126th Avenue North
Largo, FL 33773
Phone: 727-507-9749
Email: dough@perma-liner.com

Practitioner(s):

Southwest Pipeline
539 West 140th Street
Gardena, CA 90248

Key Words for Internet Search:

CIPP lateral lining, sewer rehabilitation, resin, house cleanout, DrainLiner™, Formadrain®, INFlex Liner™, Inserv™, MaxLiner™, PermaLateral™, Primeliner™, and Verline Lateral, Saertex® Liner, PrimeLiner LC™, Insituform® Lateral, LMK T-Liner®

Data Sources:

Jason Consultants International, Inc. *New Pipes for Old: A Study of Recent Advances in Sewer Pipe Materials and Technology.* Alexandria, VA. Water Environment Research Foundation (WERF) (2000)

Black and Veatch Corporation. *Effective Practices for Sanitary Sewer and Collection System Operations and Maintenance.* Alexandria, VA. Water Environment Research Foundation (WERF) (2003)

Bergstrom, E., P.E., B. Swarner, P.E., M. Lopez, P.E., "Infiltration and Inflow (I/I) Reduction in 10 Pilot Projects, King County, Washington," Proceedings of the Water Environment Federation Collection Systems 2005 Conference, Sustaining Aging Infrastructure: System, Workforce and Funding (CD-ROM), Boston, MA (17–20 July 2005)

Simicevic, Jadranka, Raymond L. Sterling, Ahmad Habibian, Rick Nelson, Roger L. Tarbutton and Alan Johnson. "Methods for Cost-Effective Rehabilitation of Private Lateral Sewers." WERF (2006)

Vendor-supplied information

Technology Summary

Lateral CIPP Liner (Main to House)

Objective:
Provide reconstruction of service lateral pipe without excavation by the installation of a resin conduit liner.

State of Development: Innovative

Description:
The polyester resin-impregnated tube is installed into an existing service lateral through the mainline pipe. The resin and tube are inverted into place so that when installed the cured-in-place pipe will fit the internal circumference of the existing pipe. The resin and tube are held in place by internal pressure until cured into a impermeable continuous pipe within a pipe.

Available Cost Information:

Approximate Capital Cost:	$3,500 for installation in lateral up to 20 ft from main; $45 per ft beyond 20 ft
Approximate O&M Costs:	Costs will vary depending on quantity of materials, quality of installations, location, and other installation needs

Vendor Name(s):
Insituform Technologies, Inc.
702 Spirit 40 Park Drive
Chesterfield, MO 63005
Phone: 636-530-8000
Fax: 636-519-8010
Email: spearson@insituform.com

Practitioner(s):
Boston Water and Sewer Company
Boston, MA

Key Words for Internet Search:
CIPP lateral lining, sewer rehabilitation, resin, mainline

Data Sources:
Jason Consultants International, Inc. *New Pipes for Old: A Study of Recent Advances in Sewer Pipe Materials and Technology*. Alexandria, VA. Water Environment Research Foundation (WERF) (2000)

Black and Veatch Corporation. Effective Practices for Sanitary Sewer and Collection System Operations and Maintenance. Alexandria, VA. WERF (2003)

Bergstrom, E., P.E., B. Swarner, P.E., M. Lopez, P.E., "Infiltration and Inflow (I/I) Reduction in 10 Pilot Projects, King County, Washington," Proceedings of the Water Environment Federation Collection Systems 2005 Conference, Sustaining Aging Infrastructure: System, Workforce and Funding (CD-ROM), Boston, MA (17–20 July 2005)

King County Department of Natural Resources and Parks, Wastewater Treatment Division. Pilot Project Report, Regional Infiltration and Inflow Control Program, King County, WA. (October 2004)

Simicevic, Jadranka, Raymond L. Sterling, Ahmad Habibian, Rick Nelson, Roger L. Tarbutton, and Alan Johnson. "Methods for Cost-Effective Rehabilitation of Private Lateral Sewers." WERF (2006)

Vendor-supplied information

Technology Summary

Lateral-Main Fiberglass CIPP Connection Inserts

Objective:

Provide reconstruction of service lateral pipe without excavation by the installation of a resin impregnated, flexible felt tube.

State of Development: Innovative

Description:

Installation of a polyester or vinyl impregnated corrosion resistant fiberglass insert into a lateral opening to fit T and Y connections. Insert is factory-impregnated with an epoxy bonding component. The laminate is placed on an applicator, driven into the lateral opening and inserted by air inversion approximately 6 inches into the lateral and 3 inches in the mainline on either side of the lateral opening. The product is available for lines between 6 and 36 inches in diameter.

Available Cost Information:

Approximate Capital Cost: $1,300 to $1,700 per insert

Approximate O&M Costs: Capital and O&M costs will vary depending on quantity of materials, quality of installations, location, and other installation needs.

Vendor Name(s):

Top Hat Systems™
Cosmic Sondermaschinenbau GmbH
Steinabruck 35
3072 Kasten, Austria

U.S. Distributor – Amerik Supplies, Inc.
260 Ainsley Court
Marietta, GA 30066
Phone: 770-924-2899

Practitioner(s):

Town of Pinetops
Pinetops, NC

Southwest Pipeline
539 West 140th St.
Gardena, CA 90248

Key Words for Internet Search:

Top hats, connection inserts, CIPP lateral

Data Sources:

Materials and Technology." Alexandria, Virginia: Water Environment Research Foundation (WERF) (2000)

Larsen, P., P.E., G. Keibler, and E. Heijn. "Awakening From the Nightmare on 10th Street – Trenchless Repair to Prevent Deep Excavations in Closed Rear-Yard Easements," Proceedings of the 77th Annual Water Environment Federation Technical Exposition and Conference [CD-ROM], New Orleans, LA (2–6 Oct. 2004)

Bergstrom, E., P.E., B. Swarner, P.E., and M. Lopez, P.E. "Infiltration and Inflow (I/I) Reduction in 10 Pilot Projects, King County, Washington," Proceedings of the Water Environment Federation Collection Systems 2005 Conference, Sustaining Aging Infrastructure: System, Workforce and Funding [CD-ROM], Boston, MA. (17–20 July 2005)

King County Department of Natural Resources and Parks, Wastewater Treatment Division. Pilot Project Report, Regional Infiltration and Inflow Control Program, King County, WA (October 2004)

Vendor-supplied information

Technology Summary

Lateral Pipe Bursting

Objective:
Replace an existing lateral without excavation, with the same or larger diameter pipe (applicable for 4–8 inch diameter pipe).

State of Development: Innovative

Description:
A portable static bursting system (Grundotugger) with a direct bolt expander and optional pneumatic piercing tool is used to hydraulically pull a winch cable and the expander tool and new pipe through an existing line. The expander fractures the existing pipe and displaces the fragments into the surrounding soil while the new pipe is pulled in behind. Lateral bursting allows for a increase in the diameter from the original host size.

Available Cost Information:
Approximate Capital Cost: $25,000 for Grudotugger, estimated $40LF.
Approximate O&M Costs:

Vendor Name(s):
TT Technologies
2020 E. New York St.
Aurora, IL 60504
Phone: 800-533-2078
Fax: 630-851-8299
www.tttechnologies.com

Practitioner(s):
King County
Department of Natural Resources and Parks
Wastewater Treatment Division
201 S. Jackson St., Suite 505
Seattle, WA 98104-3855

Key Words for Internet Search:
Static pull, pipe bursting, lateral rehabilitation, Grundotugger

Data Sources:
Jason Consultants International, Inc. “New Pipes for Old: A Study of Recent Advances in Sewer Pipe Materials and Technology. Alexandria, VA. Water Environment Research Foundation (WERF) (2000)

Black and Veatch Corporation. Effective Practices for Sanitary Sewer and Collection System Operations and Maintenance. Alexandria, VA. WERF (2003)

Bergstrom, E., P.E., B. Swarner, P.E., and M. Lopez, P.E. “Infiltration and Inflow (I/I) Reduction in 10 Pilot Projects, King County, Washington,” Proceedings of the Water Environment Federation Collection Systems 2005 Conference, Sustaining Aging Infrastructure: System, Workforce and Funding (CD-ROM), Boston, MA (17–20 July 2005)

King County Department of Natural Resources and Parks, Wastewater Treatment Division. Pilot Project Report, Regional Infiltration and Inflow Control Program, King County, WA (October 2004)

District of West Vancouver and Dayton & Knight Ltf. (D&K). West Vancouver (Pipe Bursting) Case Study (Oct 6–Dec 18, 2003)

Vendor-supplied information

Technology Summary

Lateral Sliplining

Objective:

Reconstruct sewer line and laterals without excavation using formed-in-place liner.

State of Development: Innovative

Innovative application for house laterals. Essentially no longer used for small-diameter lateral repair.

Description:

Lateral sliplining is a rehabilitation process in which a slipliner pipe is placed inside the existing old lateral pipe. This method does not include any folding or heating of the slipliner, and will decrease the inner diameter of the existing pipe by the size of the new pipe. Sliplining is a more practical process for larger diameter laterals because of the possibility of pipe blockage in pipes smaller than six inches in diameter.

Available Cost Information:

Approximate Capital Cost: Estimated at $110–$120/LF

Approximate O&M Costs: Costs vary depending on the number of laterals being lined.

Vendor Name(s):

Miller Pipeline Corporation
P.O. Box 34141
8850 Crawfordsville Rd.
Indianapolis, IN 46234
Phone: 800-428-3742
Fax: 317-293-8502

Practitioner(s):

See website for practitioners/case studies:
http://nastt.net/NoDig/index.html or
http://www.millerpipeline.com

Key Words for Internet Search:

Sliplining, lateral pipe, rehabilitation, resin, liner, insertion renewal

Data Sources:

"Pipe Within a Pipe is a Winning Solution". *Australasian Society Trenchless for Technologies Newsletter*. (October 2004)

Telephone conversation with Simicevic, Jadranka, Raymond L. Sterling, Ahmad Habibian, Rick Nelson, Roger L. Tarbutton, and Alan Johnson. "Methods for Cost-Effective Rehabilitation of Private Lateral Sewers." Water Environment Research Foundation (WERF) Draft (2005)

Vendor-supplied information

Technology Summary

Sanipor® Technology (Floor Grouting)

Objective:

Non-structural rehabilitation of laterals, manholes, and mainlines by sealing to prevent leaking and/or infiltration.

State of Development: Innovative

Although it has only been used in the USA over the last year, Sanipor® Technology has been used in Europe for over 10 years. In Germany, Sanipor® technology has been used and has had positive results.

Description:

Repairs systems using two liquids (S-1 and S-2). After cleaning and closing off the main pipe, S-1 solution is pumped into the system. S-1 solution is able to get into the surrounding soil through leaking points. S-1 is pumped out after approximately an hour and S-2 solution is pumped in. S-2 will also get through the leak points and into the surrounding soil, where it mixes with S-1 and forms a conglomerate-like solution that seals the leak points. S-2 is pumped out after an hour and the line is then flushed clean and reconnected to the system.

Available Cost Information:

Approximate Capital Cost: $8,000/day (equipment)

Approximate O&M Costs: Unknown

Capital costs do not include items prior to Sanipor installation (i.e. mainline and lateral CCTV, clean outs, purchase of plugs

Vendor Name(s):

AKZO Nobel EKA Chemicals
Marietta, GA

Sanipor®
Feldkirchen, Germany
www.sanipor.de/sanipor.htm

Practitioner(s):

City of Lafayette
Lafayette Utilities System
705 W. University Avenue
Lafayette, LA 70506

Key Words for Internet Search:

Sanipor, No Dig, sewer renovation, trenchless, flood grouting

Data Sources:

Case study – Sanipor Pilot 2003 in Lafayette, LA (https://www.latech.edu/tech/engr/ttc/werf)

Jadranka Simicevic, Trenchless Technology Center (jandranka@coes.latech.edu)

Pipe Materials and Technology. Alexandria, Virginia. Water Environment Research Foundation (WERF) (2000)

Technology Summary

Modified Cross-Section Lateral Lining

Objective:
Line existing pipe without the need for excavation or time for cure-in-place, field-cured systems.

State of Development: Embryonic

Description:
A high-strength unplasticized PVC resin liner that is continuously inserted through existing manholes and into existing lines while being heated and softened. Once in place along the pipeline, it is expanded to fit tightly within the host pipe by applying both steam and pressure. The PVC pipe is then cooled by replacing the steam with air. This method differs from the CIPP by expanding the liner in place rather than curing it in place. This process is often referred to as pipe-within-a-pipe, though the diameter of the pipe is only slightly decreased.

Available Cost Information:
Approximate Capital Cost: Unknown
Approximate O&M Costs: Unknown
As of publication date, capital cost data was not available for this embryonic technology. It is anticipated that modified cross-section lateral lining will be comparable in price to Lateral CIPP Lining House to Main.

Vendor Name(s):
Miller Pipeline Corporation
P.O. Box 34141
8850 Crawfordsville Road
Indianapolis, IN 46234
Phone: 800-428-3742
Fax: 317-293-8502

Practitioner(s):
See website for practitioners/case studies:
http://www.millerpipeline, com/ex.html

Key Words for Internet Search:
Modified cross-sections, cured-in-place lateral lining, seals, sewer

Data Sources:
Vendor-supplied information

Chapter
4

Manholes

4.1 Introduction

Manholes serve as aboveground access points to the underground conveyance system. This chapter focuses on both new construction and rehabilitation technologies that can be utilized to restore and maintain manholes.

4.2 Technology Assessment

The state of development of technologies identified for manholes is summarized in Table 4.1. Similarly to large-diameter sewers and deep tunnels, much of the technology available for manholes is established, having been available and utilized in the United States for numerous years. However, six innovative technologies, as well as one embryonic technology, have been identified. Glass-reinforced plastic inserts made of the same material used to rehabilitate large-diameter sewers and tunnels, were in the development stage in 2004.

The Sanipor® (flood grouting) technology is considered to be an innovative method aimed at complete rehabilitation of an entire conveyance system section, including manholes. This technology is also described in Chapter 3 as it applies to small-diameter sewers and laterals.

An evaluation of the innovative technologies identified for manholes is presented in Figure 4.1. Summary sheets for each innovative and embryonic technology are provided at the end of this chapter.

Table 4.1 Manhole Technologies – State of Development

Established	Innovative	Embryonic
Cured-in-Place (CIP) Liners Flexible Sealant Frame Adjustments (raise/reset) Joint Sealing – Cementitious Grout Joint Sealing – Epoxy Grout/Patching Lid (cover) Inserts Mechanical Chimney Seals (interior & exterior) Plastic Composite Invert System Poured-in-Place Concrete Liners Replacement (via excavation) Spray or Trowel-Applied Cementitious Lining Spray or Trowel-Applied Polymer Coating	Fiberglass Rehabilitation Manholes HDPE Frame Adjustment Rings Mechanical Joint Seals Polyethylene Chimney Form Sanipor® Technology (fill and drain) Sewer Odor and Corrsion Control Insert	Glass-Reinforced Plastic (GRP) Insert

Figure 4.1 Evaluation of Mahole Innovative Technologies

INNOVATIVE TECHNOLOGY	EVALUATION CRITERIA							COMMENTS
	Development	Applicability	Benefit	Impact on Homeowners	Ease of Installation	Design Life	Maintenance Requirements	
Fiberglass Rehabilitation Manholes	L	B C I	O I R	⊖	▽	▲	▲	As compared with manhole replacement
HDPE Frame Adjustment Rings	L	B C I	O	⊖	⊖	▲	▲	As compared with concrete adjustment rings
Mechanical Joint Seals	L	B C	I	⊖	▽	▲	⊖	As compared to cementitious patching
Polyethylene Chimney Form	L	B C I	I	▲	⊖	▲	▲	As compared with concrete adjustment rings
Sanipor® Technology	L	B C I	I	▲	▲	▲	▲	As compared with manhole replacement
Sewer Odor and Corrosion Control Insert	L	S BC	O	▲	⊖	⊖	▲	

State of Development

KEY

D = Demonstration project
L = Limited municipal installations
I = Full-scale industrial applications, with potential for application in municipal conveyance systems
O = Full-scale operations overseas
N = Full-scale operations in North America

Applicability

I = Industrial
S = Municipal sanitary
T = Municipal storm
C = Municipal combined
B = Municipal sanitary and storm

Potential Benefits

C = Capital savings
O = Operational/maintenance savings
I = Inflow/infiltration reduction
S = SSO/CSO reduction
R = Restored structural integrity
M = Improved maintenance tracking/management

Comparative Criteria

▲ Positive feature
⊖ Neutral or mixed
▽ Negative feature

Technology Summary

Fiberglass Rehabilitation Manholes

Objective:
To provide a structural barrier within existing manholes.

State of Development: Innovative

Description:
Fiberglass Rehabilitation Manholes are made to be installed within existing concrete, brick, or precast manholes to provide a non-corrosive structural barrier to prevent infiltration and exfiltration. A unit is constructed of glass-fiber reinforcements, supplier-certified unsaturated isophthalic polyester resin, and chemically enhanced silica. Flowtite® is able to withstand 16,000 pound vertical load. Manufactured as one integral piece up to 25 feet deep.

Available Cost Information:

Approximate Capital Cost: $400 per vertical foot installed cost for a 4-foot-diameter, 10-foot-deep manhole

Approximate O&M Costs: Periodic visual inspections recommended

Vendor Name(s):
Containment Solutions, Inc.
Conroe, TX
www.containmentsolutions.com

Practitioner(s):
King County, Washington
Wastewater Treatment Division
201 S. Jackson St., Suite 505
Seattle, WA 98104

Key Words for Internet Search:
Fiberglass manholes, rehabilitation, Flowtite, glass-fiber reinforced

Data Sources:
www.containmentsolutions.com

Simicevic, J. “Currently Available Products and Techniques for Manhole Rehabilitation.” Trenchless Technology Center, Ruston, LA (www.latech.edu/tech/coes)

King County Department of Natural Resources and Parks, Wastewater Treatment Division. Pilot Project Report, Regional Infiltration and Inflow Control Program, King County, WA (October 2004)

Jason Consultants International, Inc. New Pipes for Old: A Study of Recent Advances in Sewer Pipe Materials and Technology. Alexandria, VA. Water Environment Research Foundation (WERF) (2000)

Technology Summary

HDPE Frame Adjustment Rings

Objective:
Eliminate manhole chimney degradation by replacing cracked concrete rings with high-density polyethylene rings.

State of Development: Innovative

Description:
HDPE lightweight-grade rings provide structure and maintain material quality to eliminate degradation in manhole chimneys. They are designed to be an alternative to replacing concrete rings that are damaged. They are a mortarless system allowing fast assembly. HDPE rings are lighter, safer to handle and eliminate the need for heavy equipment to install. Properly installed rings provide a watertight seal to control I/I. HDPE rings are made of 100% recycled plastic.

Available Cost Information:

Approximate Capital Cost: $18–$25 each for standard 1.25- to 2-inch deep, round adjustment rings;
$35-$42 each for 4-inch deep, round, adjustment rings;
$23-$24 each for standard catch basin adjustment rings.

Approximate O&M Costs: Periodic visual inspections recommended.
Round manhole adjustment rings are available in the following inside diameter sizes: 24-, 27-, 30-, 32-, and 34-inch.
Catch basin adjustment rings are either 24- by 36-inch or 24- by 24-inch
Grade adjustment rings are available with either a flat or sloped design and are manufactured to ASTM D4976.

Vendor Name(s):
Ladtech, Inc.
6704 Meadowlark Court
Lino Lakes, MN 55038
Phone: 651-415-1252
Fax: 651-415-1090
www.ladtech.com

Practitioner(s):
South Tahoe Public Utility District
Lake Tahoe, CA

City of Houston
Houston, TX

Key Words for Internet Search:
HDPE adjustment, rings, manhole, seals, sewer, frame

Data Sources:
"Plastic Manhole Adjustment Rings Improve the Quality of Sanitary and Storm Sewers" Water Engineering & Management (www.waterem.com)
Vendor-supplied information

Technology Summary

Mechanical Joint Seals

Objective:
A watertight rubber seal compressed against the inside of the frame and cone by expansion bands.

State of Development: Innovative

Description:
Several rubber seal products are available as internal sealing systems for stopping leakage in precast manhole joints. CretexWrap involves a flexible rubber sleeve that has multiple pleats that can be expanded into place. The top and bottom section of the sleeve compresses against the manhole producing a water tight seal. FlexRib seal is made from a rubber compound that seals the manhole when stainless steel expansion bands compress the rubber against the inside of the frame and cones.

Available Cost Information:
Approximate Capital Cost: $400 per one 48-inch-diameter seal
Approximate O&M Costs: Periodic visual inspections recommended

Vendor Name(s):
NPC, Inc.
Milford, NH
www.npc.com

Practitioner(s):
City of New Berlin
Utiities Division
3805 S. Casper Drive
New Berlin, WI 53151

Key Words for Internet Search:
Mechanical joint connections, joint seals, manholes, sewer, barrel

Data Sources:
Simicevic, J. "Currently Available Products and Techniques for Manhole Rehabilitation." Trenchless Technology Center, Ruston, LA (www.latech.edu/tech/coes)

Technology Summary

Polyethylene Chimney Form

Objective:

Eliminate water entering the manhole through the grade rings.

State of Development: Innovative

Patent by manufacturer still pending. Currently in use by 40 municipalities across the United States.

Description:

The Polyethylene Chimney Form is a molded polymer shield that is incorporated into the chimney section of a manhole assembly. The Polyethylene Chimney Form protects the manhole against inflow and infiltration of groundwater, storm water, and eroded soil, effectively preventing clean material from entering the collection system.

Available Cost Information:

Approximate Capital Cost: Retails for $110 – $120 depending on size

Approximate O&M Costs: None

Vendor Name(s):

Strike Products
31785 64th Ave.
Cannon Falls, MN 55009
Phone: 800-262-4129
Fax: 507-263-4891
Email: tool@striketool.com
www.striketool.com

Practitioner(s):

National Water Works
200 West Highway 6, Suite 620
Waco, TX 76712

Key Words for Internet Search:

Chimney seals, polyethylene, manholes

Data Sources:

www.striketool.com

King County Department of Natural Resources and Parks, Wastewater Treatment Division. Pilot Project Report, Regional Infiltration and Inflow Control Program, King County, WA (October 2004)

Vendor-supplied information

Technology Summary

Sanipor® Technology (fill and drain)

Objective:

Nonstructural rehabilitation of laterals, manholes and mainlines by sealing to prevent leaking and/or infiltration.

State of Development: Innovative

Although it has only been used in the United States over the past year, Sanipor® Technology has been used in Europe for over 10 years. In Germany, Sanipor® Technology has been used and has had positive results.

Description:

Repairs systems using two liquids (S-1 and S-2). After cleaning and closing off the main pipe, S-1 solution is pumped into the system. S-1 solution is able to get into the surrounding soil through leaking points. S-1 is pumped out after approximately an hour and S-2 solution is pumped in. S-2 will also get through the leak points and into the surrounding soil, where it mixes with S-1 and forms a conglomerate-like solution that seals the leak points. S-2 is pumped out after an hour and the line is then flushed clean and reconnected to the system.

Available Cost Information:

Approximate Capital Cost: $3,600/day (equipment and crew); $17.99/gallon (S-2 solution)

Approximate O&M Costs: Unknown

Vendor Name(s):

AKZO Nobel EKA Chemicals
Marietta, GA

Sanipor®
Feldkirchen, Germany
www.sanipor.de/sanipor.htm

Practitioner(s):

Lafayette Utilities Systems
1314 Walker Road
Lafayette, LA 70501

Key Words for Internet Search:

Sanipor®, no dig, manhole renovation, coatings, flood grouting

Data Sources:

Case Study-Sanipor Pilot 2003 in Lafayette, LA (https://www.latech.edu/tech/engr/ttc/werf/)

Telephone conversation with Jadranka Simicevic (Trenchless Technology Center)
jandranka@coes.latech.edu

Jason Consultants International, Inc. New Pipes for Old: A Study of Recent Advances in Sewer Pipe Materials and Technology. Alexandria, VA. Water Environment Research Foundation (WERF) (2000)

Technology Summary

Sewer Odor and Corrosion Control Inserts

Objective:

Prevent the release of odorous gases in drop manholes and force main discharges to sewer manholes.

State of Development: Innovative

This technology has been available since 1998 but only recently has been used in approximately 30 locations.

Description:

Patented by IPEX Inc., the spiral flow design of the vortex flow pulls odorous air downward towards the bottom of the structure. The entrained air raises the dissolved oxygen (DO) in the sewage and is able to partially oxidize the reduced gases in solution in the sewage. Because the process operates at a slight vacuum, odorous gases are not released from the liquid. The system requires a drop in elevation of at least 6 feet for the process to work correctly.

Available Cost Information:

Approximate Capital Cost: $5,000 plus $2,000 for each million gallons per day capacity

Approximate O&M Costs: $0 – unit is self-cleaning

The approximate capital cost of the unit is based on its size as each unit is custom fabricated for a given flow and drop height.

Vendor Name(s):

IPEX, Inc.
2441 Royal Windsor Drive
Mississauga, Ontario J5J 4C7
Canada
Phone: 800-463-9572
Fax: 905-403-9195
E-mail: ricsta@ipexinc.com

Practitioner(s):

Rummel, Klepper & Kahl, LLP
81 Mosher Street
Baltimore, MD 21217

Key Words for Internet Search:

Odor, corrosion, control, manholes, sewer, inserts, vortex, flow

Data Sources:

Vendor-supplied information

Technology Summary

Glass-Reinforced Plastic (GRP) Inserts

Objective:
Structural rehabilitation of brick and precast manholes.

State of Development: Embryonic
This technology is in the laboratory development stage.

Description:
Fiber reinforced, filled, thermoset resin manhole inserts are custom designed to be installed in manholes of various diameters and depths. The installation procedure includes excavating the existing manhole to a depth that facilitates removal of the frame and cone (or corbel). The new glass-reinforced plastic manhole insert is placed within the existing manhole barrel and the annular space between the two is filled with grout. The invert and bench are reformed and the rehabilitated manhole is backfilled to complete the installation.

Available Cost Information:
Approximate Capital Cost: Unknown
Approximate O&M Costs: Periodic visual inspections recommended.
As of publication date, capital cost data was not available for this embryonic technology. It is anticipated that GRP manhole inserts will be comparable in price to fiberglass manhole inserts.

Vendor Name(s):
Insituform Technologies, Inc.
17999 Edison Avenue
Chesterfield, MO 63005
Phone: 636-530-8000
Fax: 636-530-8744
E-mail: losborne@insituform.com

Practitioner(s):
See website for practitioners/case studies:
http://www.amitechuse.com/studies.htm

Key Words for Internet Search:
Glass-reinforced plastics, panel, pipe, manholes

Data Sources:
Vendor-supplied information

Chapter
5

Conveyance Systems Management

5.1 Introduction

Conveyance systems management includes two distinct types of management tools. Any technological tool that can be used for asset management purposes to track maintenance and inspection records, complaint and emergency response efforts, and utility information can be considered a conveyance system management tool. On the other end of the spectrum, a program, public outreach effort, or regional collaboration that has been established to assist in the decision-making process and planning for a given conveyance system has also been classified as a conveyance system management tool. Both of these identified conveyance systems management tools have the same goal, which is to reduce operation and maintenance efforts, and in turn costs, through effective planning.

5.2 Technology Assessment

With the release of the Governmental Accounting Standards Board (GASB) Statement No. 34 in June 1999, many municipalities have begun to focus on the importance of proper asset management, including utilities such as conveyance systems. Many of the technologies associated with conveyance systems management have been newly developed and can be considered innovative, including programs that broaden the use of geographic information system (GIS) for municipal applications. Others, such as proactive sewer maintenance program and public outreach on the impact of fats, oils, and grease (FOG), are well established, but may be underutilized on a national scale.

The state of development of conveyance system management technologies is summarized in Table 5.1. An evaluation of the innovative technologies identified is presented in Figure 5.1. Summary sheets for each innovative technology are provided at the end of this chapter.

Table 5.1 Conveyance System Management Technologies – State of Development

Established	Innovative	Embryonic
Public Outreach on Fats, Oils, and Grease (FOG) Sewer Maintenance Program	ESRI-Based One-Call Ticket Management Mobile GIS Regional I/I Control Program	

Figure 5.1 Evaluation of Conveyance System Management Innovative Technologies

INNOVATIVE TECHNOLOGY	EVALUATION CRITERIA							COMMENTS
	Development	Applicability	Benefit	Impact on Homeowners	Ease of Installation	Design Life	Maintenance Requirements	
ESRI-Based One-Call Ticket Management	L	I C B	M	⊖	▲	▲	▲	
Mobile GIS	L	I C B	M	⊖	▲	▲	▽	
Regional I/I Control Program	L	S	I	▲	N/A	N/A	N/A	

State of Development
KEY
D = Demonstration project
L = Limited municipal installations
I = Full-scale industrial applications, with potential for application in municipal conveyance systems
O = Full-scale operations overseas
N = Full-scale operations in North America

Applicability
I = Industrial
S = Municipal sanitary
T = Municipal storm
C = Municipal combined
B = Municipal sanitary and storm

Potential Benefits
C = Capital savings
O = Operational/maintenance savings
I = Inflow/infiltration reduction
S = SSO/CSO reduction
R = Restored structural integrity
M = Improved maintenance tracking/management

Comparative Criteria
▲ Positive feature
⊖ Neutral or mixed
▽ Negative feature

Technology Summary

ESRI-Based One-Call Ticket

Objective:

Managing the process of determining and validating the One-Call sites for buried or underground infrastructure

State of Development: Innovative

One-call ticket management is an established technology; however, one new product is compatible with Environmental Systems Research Institute (ESRI), a leading GIS software developer. The Dig-Smart Program has been available for approximately one year. There are six municipalities in New York State currently utilizing the technology, and the program has also been used in CA.

Description:

Dig-Smart works in conjunction with Arc View GIS program. It provides an automated process to locate areas on incoming One-Call ticket numbers. It determines if the area is near buried underground utilities based on GIS date. Dig-Smart will automatically use this data to determine if a stake-out is required. Using GIS, this program will create a map with the geographic location of the ticket number and route the ticket number(s) to the proper utility companies where physical stake-outs are needed and automatically generate work orders. ESRI-based one-call ticket management software is compatible with programs currently mandated in all 50 states.

Available Cost Information:

Approximate Capital Costs:	Dig Smart (professional) = $3,000 per license Dig-Smart (Enterprise) = $9,000 primary license with $3,000 for each secondary license
Approximate O&M Costs:	$500–$1,200 per year, based upon the type of license purchased (this includes technical support as well as upgrade services).

Vendor Name(s):

Bergmann Associates P.C.
40 La Riviere Drive
Waterfront Village Center
Buffalo, NY 14202
Phone: 71-852-3211
www.dig-smart.com

Practitioner(s):

Monroe County Environmental Services
50 West Main Street, Suite 7100
Rochester, NY 14614

Key Words for Internet Search:

Automated mapping, utilities GIS, Dig-Smart

Data Sources:

Schenkel, P., and J. Schoenberg. “Monroe County, New York, Maximizes Dig-Smart and the Enterprise GIS for Complete Ticket Management.” ESRI Water Writes (Winter 2004)

Vendor-supplied information

Technology Summary

Mobile GIS

Objective:

Maintains up-to-date records of systems integrity in a system that is installed on the palm pilot and allows the user(s) to create database applications (i.e. routine sewer inspection checklist).

State of Development: Innovative

The program itself has been around for approximately 5 years but only recently been used in the industry.

Description:

The program tool installed on a mobile device, such as a palm pilot, allows personnel to link data collected in the field to authorities using GIS programs. At the end of each day, the information collected is downloaded to a central computer. From there, the information is shared with all department authorities as well as persons involved in work on the system itself. The mobile device can be very cost effective and is primarily used for simple tasks, such as routine maintenance inspections.

Available Cost Information:

Approximate Capital Cost: ~$12,000 for palm pilots, applications, and Pen Dragon Program

Approximate O&M Costs: Capital costs include O&M costs

Note: Palm pilots cost approximately $50 to $60 each, which allows for variability of capital costs due to the number of palm pilots needed for a project. Pen Dragon costs approximately $2,000 and the application to run Pen Dragon is about $7,000.

Vendor Name(s):

Pendragon Software Corporation
1580 S. Milwaukee Ave., Suite 515
Libertyville, IL 60048

Practitioner(s):

Clayton County Water Authority
1600 Battle Creek Road
Morrow, GA 30260
Email: BTaylor@ccwal.com

Key Words for Internet Search:

Palm pilot software, GIS, handheld devices

Data Sources:

"CCWA Using New Technology to Inspect System Pipes." *Water & Wastes Digest*. 44 (August 2004)

Bey, G., G Ramon, C. Stern. "Empowering Utility Field Crews With a Mobile GIS and Field Service Management System." ESRI

Vendor-supplied information

Technology Summary

Regional I/I Program

Objective:

Quantify, locate and assess the most cost effective measures and infiltration and inflow goals that should be pursued by a given region.

State of Development: Innovative

King County, WA, is taking a unique regional approach to I/I control. A report summarizing the results of the 10 pilot I/I control projects was made available to the public in October 2004.

Description:

Regional Infiltration/Inflow (I/I) Control Program is based on a cooperative partnership between King County and 32 local component agencies. The six-year program included flow monitoring at over 800 locations to identify I/I in the overall system, ten pilot I/I control projects utilizing different rehabilitation techniques, evaluating financial options and solutions, and design of a long-term control program for the local agencies and the County. The program is aimed at reducing I/I in the County's wastewater conveyance interceptors and treatment facilities as well as local agency collection systems.

Available Cost Information:

Approximate Capital Cost: Pilot project construction cost: $7.8 million

Approximate O&M Costs: Pilot project total cost: $12 million

The pilot project total cost includes costs for construction, sewer system-evaluation study (SSES), design, pre- and post-rehabilitation flow monitoring, construction management, modeling and analysis. A reduction in I/I was observed as a result of eight of the ten pilot sanitary sewer rehabilitation construction projects undertaken. Through the program, the County successfully demonstrated that I/I cana be identified,located, and reduced through collection system monitoring and rehabilitation, as well as strong communication between public and private stakeholders.

Vendor Name(s):

Not applicable

Practitioner(s):

King County
Department of Natural Resources and Parks
Wastewater Treatment Division
201 S. Jackson St., Suite 505
Seattle, WA 98104-3184

Phone: 206-263-3184
Fax: 206-684-1741
E-mail: mary.lundt@metrokc.gov

Key Words for Internet Search:

Infiltration/inflow, I/I control program, sewer program

Data Sources:

Telephone communication with Mary Lundt, King County (15 September 2004)

http://dnr.metrokc.gov/wtd/i-i

Bergstrom, E., P.E., B. Swarner, P.E., and M. Lopez, P.E. "Infiltration and Inflow (I/I) Reduction in 10 Pilot Projects, King County, WA," Proceedings of the Water Environment Federation Collection Systems 2005 Conference, Sustaining Aging Infrastructure: System, Workforce and Funding (CD-ROM), Boston, MA (17–20 July 2005)

King County Department of Natural Resources and Parks, Wastewater Treatment Division. Pilot Project Report, Regional Infiltration and Inflow Control Program, King County, WA (October 2004)

Chapter
6

Capacity Restoration

6.1 Introduction

Capacity restoration refers to removing blockages, excess flow, or any hindrances that restrict flow through a conveyance system. Flow restrictions often are the cause of sanitary and combined sewer overflows.

6.2 Technology Assessment

A summary of innovative, emerging, and established technologies for capacity restoration is provided in Table 6.1. Capacity restoration can be achieved by implementing structural best management practices to prevent debris grit and excess flow from entering a conveyance system; conducting regular cleaning of the sewer system; and identifying and removing any illicit connections to a conveyance system that would contribute excess flow, such as roof drains, footer drains, basement sump pumps, and storm/sanitary sewer interconnections.

Many of the capacity restoration techniques listed in Table 6.1 are well established for municipal and industrial use. However, four technologies considered to be innovative or embryonic, were identified. These include an in-line grit removal system for use with bridge stormwater collection systems, and two new cleaning techniques for conveyance systems. An evaluation of the one innovative technology identified is also provided in Figure 6.1.

Summary sheets for each innovative and embryonic technology are provided at the end of this chapter.

Table 6.1 Capacity Restoration Technologies—State of Development

Established	Innovative	Embryonic
Basement Sump Pump Redirection Foundation/Footer Drain Redirection Interconnection Elimination Roof Drain Redirection Root Removal and Control Storm Water Infiltration Pumps	Above-Grade Grit Removal System (Bridge applications) HDD Attachments for Culvert Cleaning Pigging (force main cleaning)	Culvert Cleaning System

Figure 6.1 Evaluation of Capacity Restoration Innovative Technologies

INNOVATIVE TECHNOLOGY	EVALUATION CRITERIA							COMMENTS
	Development	Applicability	Benefit	Impact on Homeowners	Ease of Installation	Design Life	Maintenance Requirements	
Above-Grade Grit Removal System	D	T	O S	⊖	▲	▲	▲	
HDD Attachments for Culvert Cleaning	L	T	S	⊖	▲	N/A	N/A	
Pigging (force main cleaning)	L	T	O S	⊖	▽	N/A	N/A	

KEY

State of Development
- D = Demonstration project
- L = Limited municipal installations
- I = Full-scale industrial applications, with potential for application in municipal conveyance systems
- O = Full-scale operations overseas
- N = Full-scale operations in North America

Applicability
- I = Industrial
- S = Municipal sanitary
- T = Municipal storm
- C = Municipal combined
- B = Municipal sanitary and storm

Potential Benefits
- C = Capital savings
- O = Operational/maintenance savings
- I = Inflow/infiltration reduction
- S = SSO/CSO reduction
- R = Restored structural integrity
- M = Improved maintenance tracking/management

Comparative Criteria
- ▲ Positive feature
- ⊖ Neutral or mixed
- ▽ Negative feature

Technology Summary

Above-Grade Grit Removal System

Objective:

Simplify maintenance activities and minimize maintenance costs by preventing excess sand and debris from entering and clogging an existing storm water system.

State of Development: Innovative

One full-scale above-grade grit removal system has been installed on the Peace Bridge, the international border crossing between Buffalo, New York, and Fort Erie, Ontario.

Description:

The above-grade grit removal system consists of an above grade grit trap unit; concrete pad and curbing for overflow containment; and a deep catch basin that are designed to receive flows from a bridge scupper drain system. The grit trap unit is a standard roll-off container with a removable tarp cover. A square hole in the cover allows water to enter the container from the bridge deck above. Storm water flows to the front end of the grit trap, where it passes through a filter screen and is discharged to the catch basin through a series of outlets, attached to a watertight access door.

Available Cost Information:

Approximate Capital Cost: Under $10,000 for fabricated 20 cubic foot grit trap unit.

Approximate O&M Costs: Under $200 annually (assuming one cleaning per year)

The O&M Costs include labor, hauling costs, and disposal at landfill. Annual costs may vary based on classification of sediment material at landfill and municipal labor rates.

Vendor Name(s):

Parsons
180 Lawrence Bell Drive, Suite 104
Williamsville, NY 14221
Phone: 716-633-7074
Fax: 716-633-7195
E-mail: jaime.davidson@parsons.com

Practitioner(s):

Buffalo and Fort Erie Public Bridge Authority
One Peace Bridge Plaza
Buffalo, NY 14213

Key Words for Internet Search:

Grit removal system, above grade, Peace Bridge

Data Sources:

Practitioner-supplied information

Technology Summary

HDD Attachments for Culvert Cleaning

Objective:

Remove soil and debris from culverts without damage to the culvert or need for replacement of the structure.

State of Development: Innovative

Now considered recently established, as work has been done in over 800 municipalities. Recently patented horizontal directional drilling (HDD) attachment. As of 5/2005, 160 units sold to clean nearly 1,800 culverts in 38 states.

Description:

The first attachment in the patented process is a barrel reamer, a round tool with fins and water jets. The barrel reamer rotates through the pipe, mixing water with the debris. The tool also allows the operator to assess the integrity of the pipe and the type of debris. After the barrel reamer, operators attach either a push bucket or pull bucket, to move the material and dispose of it properly. Square box buckets are also available. The barrel reamers are strong enough to cut through tree roots and move large rocks. A brush attachment is also available to fine clean the culvert. Attachment sizes accommodate between 6 and 110 inch culverts. The attachments provide the advantage of a controlled environment by allowing the push or pull of debris, that may be contaminated, away from sensitive areas such as streams or creeks.

Available Cost Information:

Approximate Capital Cost: Proprietary equipment not for public sale. Cleaning services typically subcontracted.

Approximate O&M Costs: $1/diameter-inch/LF for cleaning by a licensed contractor

Note: For example, a 18-inch-diameter pipe would cost $18/LF to clean. Horizontal direction drilling (HDD) machines are also required. As with most costs, this is subject to change based on the type of material being removed (i.e. silt, rock, vegetation, broken pipe material, etc.), whether or not contamination is present, accessibility issues, etc.

Vendor Name(s):

Harr Technologies, LLC
Mosca, CO
Phone: 719-523-4090

Practitioner(s):

See website for practitioners/case studies:
http://www.harrtech.com/culvertcleaning.aspx

Key Words for Internet Search:

Culvert cleaning, pipe cleaning, horizontal directional drilling, attachments, nozzles

Data Sources:

Deering, Tara. “Attachments for HDD Machines” *Rocky Mountain Construction*

Vendor-supplied information

Technology Summary

Pigging (Force Main Cleaning)

Objective:

Cleaning, confirmation of pipeline integrity, increasing carry capacity, reduce pumping pressure required to maintain flow.

State of Development: Innovative

Although pigging has been around over 30 years, for natural gas and petroleum pipes, pigs have only recently been used in application for the wastewater systems industry.

Description:

A pipeline pig acts like a free moving piston inside the pipeline by sealing against the inside wall with a number of sealing elements. Pigs perform numerous tasks including cleaning debris from the line and removing residuals. This method begins by inserting various size, shape, texture, and/or density pigs into a launch that is either attached to the existing system or installed new. The diameter, texture, and density increase with each pass of the pig (also referred to as "progressive pigging") as several pigs are used. When launched, the pig is pushed through the system with a differential pressure that is greater than the pressure in front of the pig. The pig is ejected out the other end of the system leaving a clean pipe behind.

Available Cost Information:

Approximate Capital Cost:	Ranges from $2,000 and up for installation of an 8-inch-diameter launcher plus the cost of a Y connection and Y valve.
Approximate O&M Costs:	$23 per each 8-inch-diameter B-1/G-1 pig. Subcontractor cleaning cost ranges from $1 – $5 per foot depending on pipe length.

Costs for pigging are extremely variable based on pipe material, pipe diameter, and the material being cleaned (i.e. biological scaling, iron scaling).

Vendor Name(s):

Pipeline Pigging Products
P.O. Box 690052
Houston, TX 77269

Practitioner(s):

Montauk Services, Inc.
84A Johnson Avenue
Hackensack, NJ 07601

Key Words for Internet Search:

Pipeline pigging, industrial pipe, pig cleaning services, wastewater

Data Sources:

Vendor-supplied information

Technology Summary

Culvert Cleaning System

Objective:
Cleans culverts and vacuums emulsified material simultaneously.

State of Development: Embryonic
This technology has been around for less than one year and is still in the research and development stages.

Description:
A vacuum unit with variable sized cleaning tools with dual rotating nozzles that are constantly moving is used. This unit is extended into the culvert pipe. A rubber boot at the bottom assists with pushing debris while maintaining contact with the pipe. While this is running the vacuum sucks debris and stores it in a tank for later disposal.

Available Cost Information:
Approximate Capital Cost: $14,500 – $17,000
Approximate O&M Costs: Unknown
Costs are dependent upon auger system and accessories.

Vendor Name(s):
Ring-O-Matic Manufacturers, Inc.
P.O. Box 305
Pella, IA 50219
Email: infor@ringomatic.com

Practitioner(s):
Oklahoma Department of Transportation
2800 South 32nd Street
Muskogee, OK 74401

Key Words for Internet Search:
Culvert cleaning, pipe cleaning, vacuum, culvert maintenance

Data Sources:
Vendor-supplied information

Chapter 7

Conveyance System Assessment

7.1 Introduction

This chapter focuses on any technique or tool that is used to monitor, assess, and/or evaluate the condition of an existing conveyance system.

7.2 Technology Assessment

Being able to fully understand and monitor the condition of an existing system is critical to developing an appropriate maintenance program and to ensuring the integrity of an entire conveyance system. A summary of the state of development of conveyance system assessment technologies is provided in Table 7.1.

Conveyance systems evaluation technologies are continuously emerging as technological advancements are made. For example, systems are available for use in the field that can provide an accurate picture of the structural integrity and flow characteristics of a given pipe. Soon, this equipment will be permanently embedded into conveyance systems components, termed “smart infrastructure,” and will be capable of alerting a technician at a remote location of any critical structural failures or flow hindrances.

Figure 7.1 includes an evaluation of the innovative technologies identified. Summary sheets for each innovative and embryonic technology are provided at the end of this chapter.

Table 7.1 Conveyance System Assessment Technologies – State of Development

Established	Innovative	Embryonic
Closed-Circuit Television Inspection Digital Camera Inspection (mobile) Ground-Penetrating Radar	Digital Camera Inspection (mounted) FELL (Focused Electrode Leak Locator) Electro-Scanning Laser Profiling/3D Scanning,/Sonar Sewer Scanner and Evaluation Technology (SSET) TISCIT (Totally Integrated Sonar & CCTV Integrated Technique) Wireless Monitoring Systems	Pipe Mechanical/Structural Reliability Analysis Smart Sewer Assessment Systems

Figure 7.1 Evaluation of Conveyance System Assessment Innovative Technologies

INNOVATIVE TECHNOLOGY	EVALUATION CRITERIA							COMMENTS
	Development	Applicability	Benefit	Impact on Homeowners	Ease of Installation	Design Life	Maintenance Requirements	
Digital Camera Inspection	L	B C	M	N/A				
FELL (Focused Electrode Leak Locator)	L	B C	M	N/A				
Laser Profiling/3D Scanning/Sonar	L	B C	M	N/A				
Sewer Scanner and Evaluation Technology	L	B C	M	N/A				
TISCIT	L	B C	M	N/A				
Wireless Monitoring Systems	L	B C	M	N/A				

State of Development

KEY

D = Demonstration project
L = Limited municipal installations
I = Full-scale industrial applications, with potential for application in municipal conveyance systems
O = Full-scale operations overseas
N = Full-scale operations in North America

Applicability

I = Industrial
S = Municipal sanitary
T = Municipal storm
C = Municipal combined
B = Municipal sanitary and storm

Potential Benefits

C = Capital savings
O = Operational/maintenance savings
I = Inflow/infiltration reduction
S = SSO/CSO reduction
R = Restored structural integrity
M = Improved maintenance tracking/management

Comparative Criteria

▲ Positive feature
⊖ Neutral or mixed
▽ Negative feature

Technology Summary

Digital Camera Inspection

Objective:

Screen and prioritize cleaning, more detailed inspection and repairs to manholes, storm sewers, and sanitary sewers.

State of Development: Innovative

Service provided for municipalities in six states on the East Coast and 10 Indian Reservations.

Description:

The AquaZoom diagnostic camera is equipped with a tele-objective zoom lens used to gather information about the condition of storm water and wastewater collection systems. Manholes and pipes are inspected from the surface level, eliminating the risk and cost of confined space entry. The AquaZoom camera will pan 360° as it is lowered from street level for manhole inspection and view up to 75 feet in a 6-inch pipe segment and up to 700 feet for larger diameter pipelines.

Available Cost Information:

Approximate Capital Cost: Inspection and analysis services typically subcontracted

Approximate O&M Costs: Video Inspection: $35/manhole and $115/pipe
Diagnosis: $50/manhole and $125/pipe segment

Diagnosis includes viewing, rating, and ranking the operational and structural condition of each manhole and pipe segment.

Vendor Name(s):

InfoMetrix, LLC
500 Edgwater Drive, Suite 545
Wakefield, MA 01880
Phone: 781-245-4255
Fax: 781-245-5338
E-mail: info@inframetrix.com
ww.inframetrix.com

Practitioner(s):

Town of Tonawanda
Water Resources Department
Water and Sewer Maintenance Division
525 Belmont Avenue
Buffalo, NY 14223

Key Words for Internet Search:

Digital inspection camera, mounted, pipe, water, municipal equipment

Data Sources:

http://www.epa.gov/ne/assistance/ceit_iti/tech_cos/aquazoom.html

http://www.inframetrix.com/news.htm#EPA

Lenz, M., P.E. Sanitary Sewer Inspections Meet 21st Century Technology, presented at the New York Water Environment Association Spring Technical Conference & Exhibition; Grand Island, NY (6–8 June 2005)

Technology Summary

FELL (Focused Electrode Leak Locator) Electro-Scanning

Objective:
Generate maps that identify pipe defects and can be used to better assess infiltration/inflow (I/I) sources and amounts.

State of Development: Innovative

Description:
An electric current is used to determine the defects in the pipe that will be used to estimate I/I whether it is occurring at the time the inspection takes place or not. The electric current transfers data to an input device by measuring an electrical current flow between a probe that travels in the pipe and a surface electrode. Defects in the pipe cause a spike in the electrical signal because of the increase in conductivity where leaks may occur. Electro-scanning only works on nonconductive pipe and can be used for inspection of new sanitary sewer construction or for I/I assessments. Data results will identify size of defect and relative flow contribution.

Available Cost Information:
Approximate Capital Cost: Inspection and analysis services typically subcontracted
Approximate O&M Costs: $1–$3 per linear foot; $2–$6 per lateral 25–100 feet
Costs are highly dependent on size of pipe, accessibility to manholes, and other project specifics.

Vendor Name(s):
Metrotech
488 Tasman Drive
Sunnyvale, CA 94089

Practitioner(s):
See website for case studies
www.fell41.com

Key Words for Internet Search:
Electro-Scanning, FELL (Focused Electrode Leak Locator)

Data Sources:
Lenz, M., P.E. “Sanitary Sewer Inspections Meet 21st Century Technology,” presented at the New York Water Environment Association Spring Technical Conference & Exhibition; Grand Island, NY (6–8 June 2005)
Simicevic, Jadranka, Raymond L. Sterling, Ahmad Habibian, Rick Nelson, Roger L. Tarbutton, and Alan Johnson. “Methods for Cost-Effective Rehabilitation of Private Lateral Sewers,” Water Environment Research Foundation (WERF) (2006)
Vendor-supplied information

Technology Summary

Laser Profiling/3D Scanning/Sonar

Objective:
Identifies actual pipe conditions, structural shape, deformations, deflections, and debris accumulation from internal measurements.

State of Development: Innovative

Description:
The actual condition of the pipe is revealed by supplying data relating to the exact shape of the conduit, the magnitude, length, and location of deformations, location and position of laterals, and the area and perimeter of conduits' cross sectional areas. This data is collected by sending a laser generated source to the interior of a pipe and sending and receiving frequent data points. Sonar profiling is possible in wet areas and therefore is used in inspections of siphons and submerged/surcharged pipe. Laser profiling is performed with a point or line laser and may be enhanced with a technology including a rotating laser. The rotating laser collects a 360 degree view of the pipe to build a 3D virtual pipe model.

Available Cost Information:
Approximate Capital Cost: Inspection and analysis services typically subcontracted
Approximate O&M Costs: $2–$3 per linear foot.
The addition of the technology allowing 360-degree view of the pipe with laser profiling will increase costs to an estimated $10-$20 per linear foot.

Vendor Name(s):
Hydromax, USA LLC
1766 Brent Drive
Newburgh, IN 47630

Practitioner(s):
Redzone Robotics
www.redzone.com

Key Words for Internet Search:
Laser Profiling, Sewer, Pipe Profiling, 3D Scanning, Sonar

Data Sources:
Lenz, M., P.E. "Sanitary Sewer Inspections Meet 21st Century Technology," presented at the New York Water Environment Association Spring Technical Conference & Exhibition; Grand Island, NY. (6–8 June 2005)
Vendor-supplied information

Technology Summary

Sewer Scanner and Evaluation Technology (SSET)

Objective:
Inspect sewer lines using optical scanners and gyroscope technology.

State of Development: Innovative
SSET has been implemented in 20–35 cities throughout the United States.

Description:
This system scans and digitizes in forward direction and the total surface of the sewers that can be used to generate color coded computer images. This helps in getting better quality of images that can be magnified and viewed to assess the damage on the pipelines.

Available Cost Information:
Approximate Capital Cost: $80,000 system
Approximate O&M Costs: $4,000/week for data acquisition plus $200,000 for data analysis
The SSET system cost does not include the cost of the vehicle that carries the system.

Vendor Name(s):
Hydromax USA
9921 Spring Ridge Drive
Louisville, KY 40223

Practitioner(s):
See website for case studies
www.hydromaxusa.com

Key Words for Internet Search:
Evaluation of SSET (Sewer Scanner and Evaluation Technology), digital diagnosis, sewer pipes

Data Sources:
Lenz, M., P.E. "Sanitary Sewer Inspections Meet 21st Century Technology," presented at the New York Water Environment Association Spring Technical Conference & Exhibition; Grand Island, NY (6–8 June 2005)
http://www.new-technologies.org/ECT/Civil/sset.htm
http://www.cerf.org/ceitec/eval/ongoing/sset.htm
Vendor-supplied information

Technology Summary

TISCIT (Totally Integrated Sonar & CCTV Inspection Technique)	
Objective: To assess partially submerged pipes when by-passing the flow is not possible by assessing above and below the waterline.	State of Development: Innovative
Description: A combination of CCTV (closed circuit television) and sonar technologies are used to assess the pipe above and below the waterline. Sonar technology is operated with the high frequencies and rotating equipment to allow a scan of the full wet perimeter of the sewer. Simultaneously, the CCTV equipment is retrieving images producing information for the assessment of the structural and hydraulic conditions of the sewer.	
Available Cost Information: *Approximate Capital Cost:* Inspection and analysis services typically subcontracted. *Approximate O&M Costs:* $2.50–$3 per linear foot	
Vendor Name(s): Future Amtec http:\\fesuk.com	Practitioner(s): City of August, GA www.agustaga.gov/departments/utilities/current_projects.asp
Key Words for Internet Search: TISCIT, CCTV, sonar, trunk sewer, sewer maintenance, surcharged sewers	
Data Sources: Lenz, M., P.E. “Sanitary Sewer Inspections Meet 21st Century Technology,” presented at the New York Water Environment Association Spring Technical Conference & Exhibition; Grand Island, NY (6–8 June 2005) Andrews, M.E. P.E. “Large Diameter Sewer Condition Assessment Using Combined Sonar and CCTV Equipment,” APWA International Public Works Congress, NRCC/CPWA Seminar Series: “Innovations in Urban Infrastructure.” Ottawa, Canada	

Technology Summary

Wireless Monitoring Systems

Objective:
Monitor and record data of combined sewer overflows (CSOs) and santitary sewer overflows (SSOs) in conveyance systems and lift stations.

State of Development: Innovative
This technology is currently in use by 25 municipalities in the United States.

Description:
The SSO-33 is a compact recorder that is enclosed in a water-tight case and will monitor and document CSO/SSO events in a conveyance system. Each event is recorded and stamped to show date, time, water level and duration. A wireless communication setup relays recorded data for critical point monitoring. The R-33 is a compact recorder that monitors the intermittent on/off operation of each pump and the flow through a lift station. The total water flow of each recording period is used to document CSOs and SSOs.

Available Cost Information:
Approximate Capital Cost: $2,500 for an individual recorder
Approximate O&M Costs: Minimal
Capital cost is just for the recorder and does not include installation, which is done by the customer.
O&M cost is very low and includes battery replacement or cost of electrical utility.

Vendor Name(s):
Telog Industries, Inc.
830 Canning Parkway
Victor, NY 14564
Phone: 585-742-3000
Fax: 585-742-3006
http://www.telog.com

Practitioner(s):
Massachusetts Water Resource Authority
Charlestown Navy Yard
100 First Avenue
Boston, MA 02129

Key Words for Internet Search:
Monitoring system, sewer pipe, wireless, flow meter system, CSO, SSO

Data Sources:
http://www.telog.com/downloads/Telogers_brochure_ws.pdf
Vendor-supplied information

Technology Summary

Pipe Mechanical/Structural Reliability Analysis	
Objective: Integrated mechanical-electronic system to inspect different kinds of pipes.	State of Development: Embryonic This technology is currently being used in France.
Description: This technology (MAC system) assesses the reliability of the pipe by pipe-soil interactive structural behavior. The mechanical component of the system applies nondestructive loads and measures the displacement while the electronic component analyzes results.	
Available Cost Information: *Approximate Capital Cost:* Unknown *Approximate O&M Costs:* Unknown As of publication date, cost datea was not available for this embryonic technology.	
Vendor Name(s): None	Practitioner(s): None
Key Words for Internet Search: Pipe structure evaluating system, structural reliability analysis, mechanical technologies	
Data Sources: http://www.new-technologies.org/ECT/Civil/pipeeval.htm	

Technology Summary

Smart Sewer Assessment Systems

Objective:
Use an automated system with artificial intelligence to assess cracks and leaks on pipes.

State of Development: Embryonic

Description:
Three different kinds of the technology are available. The KARO system consists of three parts; a mobile control, surveillance station and a mobile robot. The mobile robot has a 3D sensor, and ultra sonic sensor and a microwave sensor for the inspection of pipes. The PIRAT system consists of a laser scanner for a drained pipe and sonar scanner for flooded pipes. The TriScan system consists of a TV-system equipped with a laser distance sensor.

Available Cost Information:
Approximate Capital Cost: Unknown.
Approximate O&M Costs: Unknown
These three systems are still prototypes and are not currently being manufactured. These systems were experimental research and development projects that for one reason or another never got off the ground.

Vendor Name(s):

CSIRO Project Engineer
Locked Bag 9
Preston 3072 Australia
Phone: +61 3 9662-7756
Fax: +61 3 9662-7853
Email: robin.kirkham@csiro.au

Practitioner(s):

None

Key Words for Internet Search:
Emerging construction technology, smart sewer assessment, back-up prevention

Data Sources:
http://www.new-technologies.org/ECT/Civil/smartsew.htm
http://vision.cmit.csiro.au
http://www.optimess.com

Chapter 8

Research Needs

8.1 Introduction

In order to reclassify any technology that is considered to be innovative or embryonic, additional research and field demonstration projects are necessary. This chapter focuses on specific technologies that may have a significant impact on conveyance system construction rehabilitation and management and the relevant research needs in these areas.

8.2 Research Needs

Many of the wastewater collection and conveyance systems in the country were built more than 100 years ago. Maintenance, replacement, and rehabilitation practices during the ensuing period have resulted in a patchwork of technologies in collection systems. In order to adequately preserve the collection system infrastructure, protect the environment, and accommodate growth, new and improved solutions and technologies for wastewater collection systems are necessary.

Emerging and innovative technologies can provide more cost-efficient and effective solutions to the problems associated with deteriorating wastewater collection systems. Research and technical issues can be grouped into three areas: (1) assessment of system integrity; (2) operation, maintenance, and rehabilitation; and (3) new construction.

Assessment of System Integrity

A thorough assessment of system integrity is based on flow monitoring and physical condition assessment elements.

Flow Monitoring

The primary issues related to flow monitoring are accuracy and reliability. Improved accuracy, or an indication of the error of measurement, are areas where research is necessary.

Physical Condition Assessment

A thorough assessment of the physical condition of the collection system is critical to maintain the integrity of the system. An assessment identifies structural features that may require correction and establishes priorities for rehabilitation or replacement. Predicting the likelihood of failure and the associated risk analysis are key elements of the evaluation. The primary research issue associated with physical condition assessment is how to effectively detect and locate defects and failures in the collection system. There is a need to standardize and better define inspection procedures and techniques. Since nearly, all inspection techniques depend on visual observations; interpretation of defect severity is the greatest limitation.

There is a need to further evaluate emerging evaluation technologies to document performance and cost under both controlled-condition testing and field testing for a variety of system characteristics and components. There is also a need to investigate the concept of “intelligent systems” for remote sensing and monitoring the structural integrity.

Current research needs involve the development of predictive tools or performance indicators for measuring degradation of conveyance systems. The intent of this research is to enable municipalities to identify areas for rehabilitation to strategically focus effort in areas most likely to need attention.

Additional research may result in the development of a remote sensing system based on electrochemical impedance techniques and electrochemical polarization decay for monitoring corrosion in underground pipes encased in concrete.

Operation, Maintenance, and Rehabilitation

Fundamental research is needed in these areas:

- Address private ownership issues associated with established rehabilitation and replacement practices in house and service laterals. Since many utilities do not have access or control of these lines, the private ownership issues must be addressed and trenchless technologies that can accommodate bends and line configurations are needed to minimize property disturbance.
- Determine the longevity and performance of rehabilitation methods under the various conditions to provide comparative data on cost effectiveness.
- Evaluate new and improved repair and replacement technologies/methodologies.
- Evaluate approaches to optimize and assess O&M programs.
- Evaluate the performance of sealers (grouts and liners) under various conditions and wastewater chemistry.
- Evaluate alternatives to remove roots and prevent root growth.
- Develop a standardized rating system for sewer system evalaution tools.

Table 8.1 summarizes conveyance system research needs.

Table 8.1 Conveyance System Research Needs

Category	Technology	Focus of Investigation
Large-Diameter Sewers and Deep Tunnels	All rehabilitation techniques	Evaluate longevity and performance of rehabilitation technologies under various conditions.
	All grouts and liners	Evaluate performance of sealers.
	All new and replacement technologies	Identify improved materials and construction techniques.
Small-Diameter Sewers and Laterals	Impact moling	Improve trenchless technologies that can accommodate bends and line configurations.
	CIPP, fold and form, replacement	Evaluate long-term performance of plastic pipe in force mains.
Manholes	Replacement construction	Evaluate approaches to optimize and assess O&M programs.
Conveyance System Management	Sewer maintenance program	Evaluate approaches to optimize and assess O&M programs.
	Regional I/I control program	Develop predictive tools or performance indicators to measure degradation of system.
Capacity Restoration	Root removal and control	Evaluate alternatives to remove roots and prevent root growth.
Conveyance System Assessment	CCTV, digital camera inspection	Standardize and better define inspection procedures and criteria to interpret defect severity.
	Wireless monitoring systems	Improve accuracy or reduction of measurement error in system.
	Smart sewer assessment systems	Investigate “intelligent systems” for remote sensing and monitoring.

New Construction

Improved materials and construction techniques can reduce future deterioration and rehabilitation needs. The relationship between the chemistry of sewage to pipe materials must be thoroughly understood. The use of new materials (resins) and the control of corrosion in metallic and pre-stressed concrete pipes need to be further developed. Improved standards and materials of construction are required. Research needs include:

- Identify new materials for pipe and pipe coatings that control erosion and increase strength.
- Develop sensors that are incorporated into new systems to track deterioration and structural performance over time.
- Evaluate alternative designs for watertight manholes for cost-effectiveness.
- Evaluate long-term performance of plastic pipe materials now in use for force mains.
- Review and evaluate current sewer design and installation practices.
- Evaluate new and improved coupling techniques.
- Determine whether solvent-welded pipe performs better than rubber-gasketed pipe for I/I and root control in house and service laterals.

8.3 Chapter References

Optimizing Operations, Maintenance, and Rehabilitation of sanitary Sewer Collection Systems New England Interstate Water Pollution Control Commission, Lowell, MA 01852 (December 2003)

U.S. EPA. National Risk Management Research Laboratory. *Innovation and Research for Water Infrastructure for the 21st Century*. Summary Report from the EPA Research Planning Workshop, Arlington, VA (20–21 March 2006)

U.S. EPA. Tafuri, A.N. and A. Selvakumar. *Wastewater Collection System Infrastructure Research Needs*. National Risk Management Research Laboratory. EPA/600/JA-02/226 (2002)

Appendix
A

Trade Associations

A.1 Introduction

This chapter lists professional and trade associations that may have significant information and may provide relevant research assistance on conveyance system technologies within their respective areas of expertise.

A.2 Trade Associations

American Concrete Pipe Association
222 W. Las Colinas Blvd, Suite 641, Irving, TX
Phone: 972-506-7216 Web Address: www.concrete-pipe.org

American Underground Contractors Association
4301 N. Fairfax Drive, Suite 360, Arlington, VA
Phone: 703-358-9300 Web Address: www.auca.org

American Society of Civil Engineers (ASCE)
1801 Alexander Bell Drive, Reston, VA
Phone: 800-548-2723 Web Address: www.asce.org

Center for Underground Infrastructure Research and Education
Michigan State University, 230 Farrall Hall, East Lansing, MI 48824
Phone: 517-432-2096 Web Address: www.cuire.org

Ductile Iron Pipe Research Association
245 Riverchase Parkway East, Suite O, Birmingham, AL
Phone: 205-402-8700 Web Address: www.dipra.org

Fiberglass Tank and Pipe Institute
11150 S. Wilcrest Drive, Suite 101, Houston, TX
Phone: 281-568-4100 Web Address: www.fiberglasstankandpipe.com

National Association of Clean Water Agencies
1816 Jefferson Place, NW, Washington, D.C.
Phone: 202-833-2672 Web Address: www.nacwa.org

National Association of Sewer Service Companies
1314 Bedford Ave, Suite 201, Baltimore, MD
Phone: 410-486-3500 Web Address: www.nassco.org

National Clay Pipe Institute
P.O. Box 759, Lake Geneva, WI
Phone: 262-248-9094 Web Address: www.ncpi.org

National Environmental Services Center
P.O. Box 6064, Morgantown, WV
Phone: 304-293-4191 Web Address: www.nesc.wvu.edu

New England Interstate Water Pollution Control Commission
100 Foot of John Street, Lowell, MA 01852
Phone: 978-323-7929 Fax: 978-323-7919
E-mail: mail@neiwpcc.org Web Address: www.neiwpcc.org

North American Society for Trenchless Technology
1655 N. Ft. Meyer Drive, Arlington, VA
Phone: 703-351-5252 Web Address: www.nastt.org

Pipe Rehabilitation Council
423 W. King Street, Suite 350, Chambersburg, PA 17201
Phone: 717-267-1995 Web Address: www.piperehab.org

Trenchless Technology Center
600 W. Arizona, Engineering Annex, P.O. Box 10348, Ruston, LA
Phone: 800-626-8659 Web Address: www.latech.edu/tech/engr/ttc

Uni-Bell PVC Pipe Association
2655 Villa Creek Drive, Suite 155, Dallas, TX 75234
Phone: 450-434-2092 Web Address: www.wwema.org

Water and Wastewater Equipment Manufacturers Associations (WWEMA)
P.O. Box 17402, Washington, D.C.
Phone: 703-444-1777 Web Address: www.wwema.org

Water Environment Federation
601 Wythe Street, Alexandria, VA 22314-1994
Phone: 703-684-2452 http://www.wef.org

Water Environment Research Foundation
635 Slaters Lane, Suite 300, Alexandria, VA 22314
Phone: 703-684-2470 http://www.werf.org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