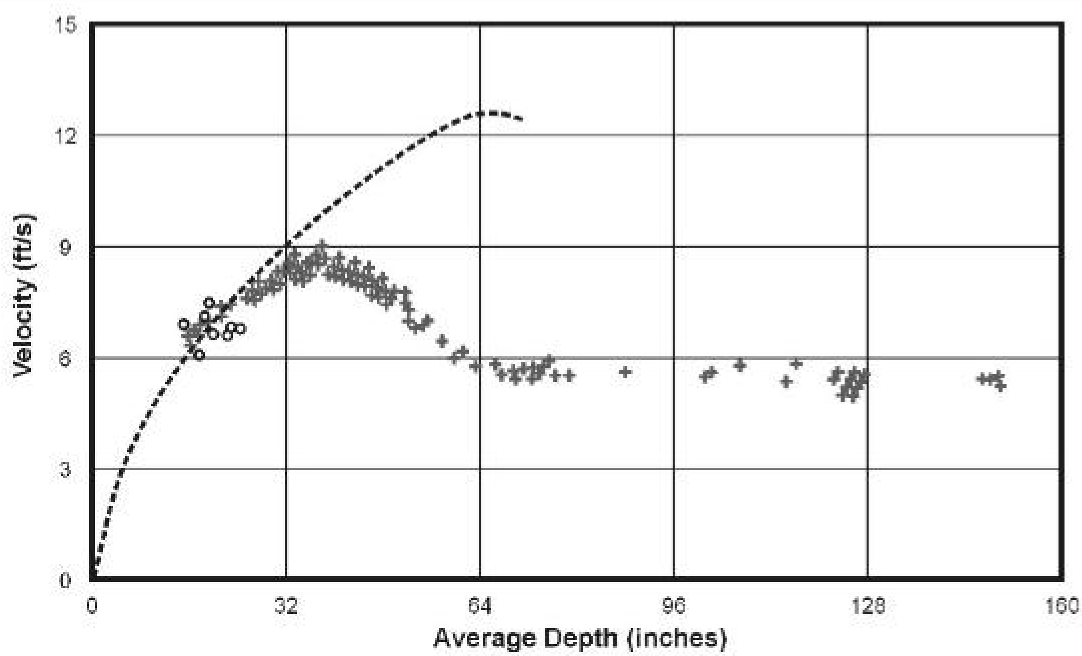
PROTOCOLS FOR IDENTIFYING SANITARY SEWER OVERFLOWS



Upstream SSO

American Society of Civil Engineers
EPA Cooperative Agreement #CX 826097-01-0

June 2000

Protocols for Identifying Sanitary Sewer Overflows

Prepared

by

Black & Veatch Corporation

for

American Society of Civil Engineers

Under

Cooperative Agreement

with

U.S. Environmental Protection Agency
Office of Wastewater Management
Washington, DC

EPA Cooperative Agreement #CX 826097-01-0
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NOTICE

The material in this document has been subject to U.S. Environmental Protection Agency technical and policy review and approved for publication. The views expressed by individual authors, however, are their own and do not necessarily reflect those of the U.S. Environmental Protection Agency.

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Participating wastewater utilities and agencies that provided needed information for this project are listed below. Only those agencies that granted permission to do so are listed by name.

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City of Eugene
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City of Fayetteville, Arkansas
Fayetteville, Arkansas

County of San Diego
Department of Environmental Health
San Diego, CA

Department of Public Works
Fairfax County
Burke, VA

Department of Public Works
City of Columbus
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Overland Park, KS

St. Peters Beach
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Water Works and Sanitary Sewer Board
Montgomery, AL

Executive Summary

The objective of this project was to develop a guidance manual to identify and evaluate existing protocols for identifying Sanitary Sewer Overflows (SSOs), to develop a comprehensive set of protocols for identifying the locations of SSOs, and to disseminate the project findings. This project will benefit public health by helping the operators of municipal sanitary sewer collection systems to reduce the occurrence of SSOs.

An SSO, as defined for this project, is the discharge of untreated sewage from a separate sanitary sewer system, including overflows from structures and basement backups. SSOs often pose significant environmental pollution and health problems. SSOs can pollute receiving surface waters with adverse impacts to aquatic life and drinking water quality. Basement backups create a significant health risk, reduce property values, and cause damage to buildings. Establishment of the National Pollutant Discharge Elimination System (NPDES) was a step toward eliminating SSOs. Nevertheless, SSOs still occur in many systems.

Identification of likely locations of SSOs and evaluation of the causes of SSOs should be a part of a comprehensive preventive maintenance program and a capital expenditures plan. Cities and agencies need established and proven guidance on identifying and evaluating the causes of SSOs. Such guidance should cover both wet weather and dry weather SSOs.

The scope of this project is divided into two phases. This report is the culmination of the work in Phase 1. Phase 2 activities will focus on dissemination of the materials and information developed during Phase 1. The major project tasks are as follows:

Phase 1

Task 1: Literature Search
Task 2: Information Collection
Task 3: Development of a Comprehensive Set of Protocols
Task 4: Development of Guidance Manual
Task 5: Development of Web Page

Phase 2

Task 6: Development of Informational Brochures

Task 7: Dissemination of Informational Material

Many standard techniques for identifying the location of SSOs are described in the literature, including closed circuit television inspection (CCTV), manhole inspection, smoke testing, dyed water testing, and flow and rainfall monitoring analysis. The amount and quality of information available is increasing due to the need for adequate service and changing regulatory requirements.

The data collection effort was extended because of the amount of information requested and inability of the agencies to respond as quickly as desired. Utility personnel who responded to the questionnaire provided a large amount of valuable information despite of their busy schedules. With their help, the data collection effort was successful: twelve agencies returned completed questionnaires which exceeded the project goal of ten responses. The cooperation of the agencies represented by the Technical Advisory Committee (TAC) was invaluable to the completion of this document. The input of the TAC members provided the hands-on experience which is essential in a document such as this. A summary of management actions based on narrative responses from each agency surveyed is presented in Table 1.

The survey was not intended to obtain responses from a representative sample of agencies, but to collect data from agencies known to be leaders and innovators in terms of SSO identification and control. It is obvious from the responses received for this project that much is being done concerning SSO identification and control. This report is not an attempt to portray the survey results as being representative of the general population of utilities, it is simply trying to find out what the agencies with solid SSO control programs are doing and to learn from their insights and experience.

Table 1

SSO Management Activities as Reported by Surveyed Agencies

Category	Activity
Reactive SSO Response	Dispatch Crews
	Clean Area
	Investigate Cause
	Report
	Prepare Work Order
	Stabilize Streambank
	Perform Repair
	Store Flow if Possible
	CCTV
Proactive SSO Measures	Develop Wet Weather Operational Plan
	Upgrade Pumping Stations
	Provide Relief/Equalization
	Reduce I/I
	Conduct Hydraulic Review
	Change System Configuration
	Correct Manhole Channel Geometry
	Conduct Ongoing SSES
	Establish Cleaning and Root Removal Program
	Train Personnel
	Increase Resources
	Improve Record Keeping
	Conduct Hydraulic Modeling
	Inspect Creek Crossings
	Improve Maps
	Conduct Observations During Rainfall
	Track and Investigate SSOs
	Develop Inspection Procedures
	Conduct Survey/Walking/Helicopter Inspection Program
	Create Flood Response Team (Floodbusters)
	Implement GIS/SCADA
	Modify Design Standards
	Implement Oil and Grease Control Program
	Conduct Life-Cycle Costing During Design
	Implement Computerized Maintenance
	Identify Flat Sewers and Problem Configurations

The protocols presented in this report are categorized as follows:

- Hydraulic Protocols
- Maintenance and Inspection Protocols
- Structural Protocols

A summary of the key elements of each protocol is listed in Table 2. A successful SSO control program also requires that administrative needs of the program be met. These needs can include issues such as construction inspection, service lateral installation inspection, demolition inspection, sewer use ordinances, permitting, enforcement, and financing.

These protocols, if used effectively, should assist agencies in identifying and effectively controlling the SSOs.

In addition to this Guidance Manual, several informational brochures will be prepared under Phase 2 of this project and distributed through professional and trade associations.

Table 2

Protocols for Identifying SSOs

Protocol	Element
Hydraulic Capacity	Hydraulic Modeling
	Scattergraphs
	Inventory
	Wastewater Flows
	Rainfall
Maintenance and Inspection	Notification by Customer and/or General Public
	Visual Inspections
	Scheduled Maintenance
	Remote Sensing
	GIS Implementation
	Sanitary Sewer Management Systems
	Flow Monitoring
	Rainfall Monitoring
	Stream Gauging
	Trend Analysis
	Receiving Water Monitoring
	SSES Activities
	New Inspection Technologies
Structural Protocol	Rating Systems
	Inspection Techniques
	Corrosion Monitoring
	Pipe Testing
	Loading Analysis
	Finite Element Stress Analysis

Abbreviations

ADF	average daily flow
ASCE	American Society of Civil Engineers
CCTV	closed circuit television inspection
CIP	Capital Improvements Program
con/mi	connection density per mile
DO	dissolved oxygen
DW/LG	dry weather low ground water
FM	force main
ft/mh	feet of sewer per manhole
Gcd	gallons per capita per day
GIS	Geographic Information System
GW	groundwater
hp	horsepower
I/I	infiltration and inflow
MD	maximum day flow
MD/ADF	maximum daily flow per average daily flow
mh/mi	manhole density per mile
MHOF/mi/yr	manhole overflows per miles per year
mi sewer/sq mi	mile of sewer per square mile
MinM	minimum month
MinM/ADF	minimum monthly flow per average daily flow
MM	maximum month
NPDES	National Pollutant Discharge Elimination System
OSHA	Occupational Safety and Health Association
pf/mi/yr	pipe failures per mile per year
PH	peak hour flow
PS	pumping station
SCADA	Supervisory Control and Data Acquisition
SSES	Sanitary Sewer Evaluation Survey
SSET	Sewer Scanner and Evaluation Technology Surveys
SSMS	Sanitary Sewer Management System
SSO	sanitary sewer overflows
TAC	Technical Advisory Committee
USEPA	United States Environmental Protection Agency
VRG	virtual rain gauge
WEF	Water Environment Federation
WWTP	wastewater treatment plant

1.0 Introduction

1.1 Objective

The objective of this project is to develop a guidance manual accomplish the following:

- Identify and evaluate existing protocols for Sanitary Sewer Overflows (SSOs).
- Develop a comprehensive set of protocols for identifying the location of SSOs.
- Disseminate the study findings.

1.2 Results or Benefits Expected

This project will benefit public health by helping the operators of municipal sanitary wastewater collection systems reduce the occurrence of SSOs.

1.3 Background

An SSO, as defined for this project, is the discharge of untreated sewage from a separate sanitary sewer system, including overflows and basement backups. SSOs may occur as a result of the following causes:

- Heavy rainfall and resulting high infiltration/inflow (I/I).
- Inadequate hydraulic capacity of the collection system.
- System bottlenecks caused by inadequate maintenance, system failures or vandalism.
- Broken or blocked line.
- Overall deterioration of the sewer system.
- Pump failures.
- Poor construction methods or materials.

While many SSOs occur during wet weather as a result of I/I, they can also occur during dry weather. The solution to wet weather SSO problems often involves capital expenditures to reduce I/I maximize and/or expand the capacity of the conveyance and treatment systems. Dry weather SSOs can generally be resolved through operational improvements and increased maintenance.

The occurrence of SSOs can be reduced by the following measures:

- Reducing I/I (public and/or private sectors of the system).
- Increasing the capacity of the treatment facilities.
- Increasing the capacity of the conveyance system.
- Constructing of temporary storage facilities to reduce the peak flow during wet weather conditions.
- Repairing defective pipes.
- Implementing an ongoing sewer system maintenance program.
- Rerouting flows to lines with available capacity.

SSOs often cause significant environmental and public health problems. They can pollute the surface waters; endanger aquatic life; interfere with recreational uses and industry resources; and contaminate drinking water supplies. The National Pollutant Discharge Elimination System (NPDES), developed as part of the Clean Water Act (CWA), was a step toward eliminating SSOs. Nevertheless, SSOs still occur in many systems.

Over the past two decades, agencies in charge of sewer system have made significant efforts to control SSOs by reducing I/I and increasing the capacity of the conveyance systems and treatment facilities. However, many agencies still lack a well-managed, ongoing maintenance program. Proper preventive maintenance practices can greatly reduce SSOs. Identification of the likely SSO locations and evaluation of the causes of SSO units should be a part of a comprehensive preventive maintenance program and capital expenditures plan. Municipalities, sewerage authorities, and other responsible agencies (hereinafter referred to collectively as agencies) need reliable guidance in identifying and evaluating the causes of SSOs. Such guidance material should cover both wet weather and dry weather SSOs.

The following techniques can be used to identify potential locations of SSOs:

- Sewer inspections by closed-circuit television (CCTV) monitoring.
- Analyzing nearby streams and storm drain sewage indicators.
- Flow monitoring and hydraulic modeling.

- Physical inspections, and smoke and dye testing of sewers, including manholes, pumping stations, and private sector sources, and smoke and dye testing.
- Review of customer complaints and/or maintenance records.
- Engineering analysis of structural integrity of the sewer system.

The USEPA has developed two SSO Management Flow Charts, which incorporate the key elements of a sound SSO program, including the protocols for identifying SSOs. Figures 1-1 and 1-2 are charts that can be used by agencies in planning SSO management and in discussions among operators, agencies and with regulators. Figure 1-1 presents a suggested SSO Management Program identifying each decision point and associated activity. Figure 1-2 provides additional details on key elements listed on Figure 1-1. For example, the "Short-Term Remediation with Site-Specific Control Plan to Address..." shown in the upper left corner of Figure 1-1 is expanded on Figure 1-2 to include other subelements. These are helpful guides for implementing an SSO program, which would include the protocols presented in this report.

1.4 Approach

The approach of this project includes two major phases. The first phase, in Year 1, consists of the initial data gathering, literature research, development of this guidance manual, and development of a web page for disseminating materials. The second phase, in Year 2, includes development and dissemination of informational brochures and other material. The approach to the project, as contracted, is described in the following paragraphs.

1.4.1 Phase 1

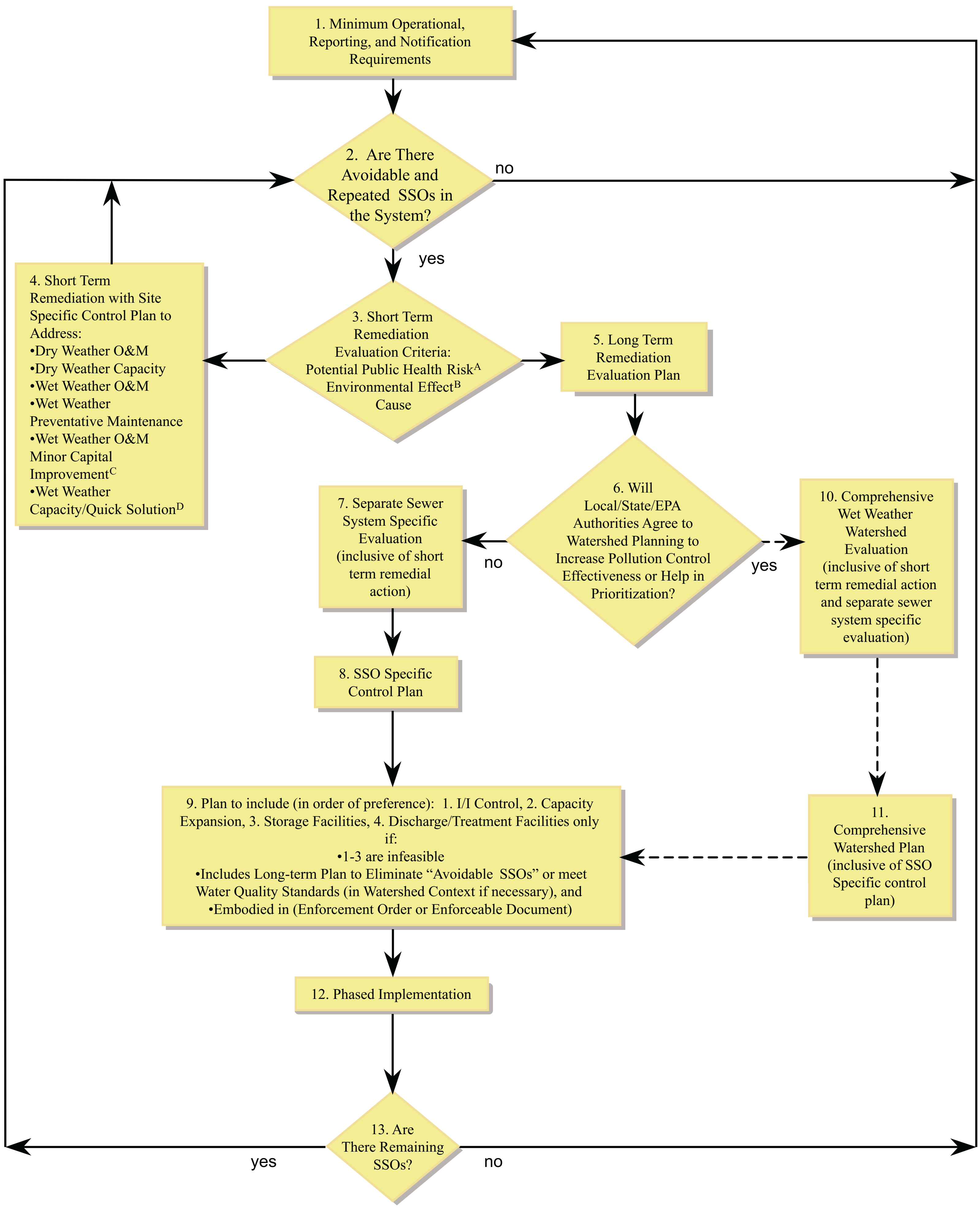
1.1.1.1 Task 1: Literature Search

A literature search was conducted to obtain key articles and other materials related to identification and evaluation of SSOs. The materials gathered were used as a reference to develop this guidance manual.

Before commencing the literature search, a meeting was held at the headquarters of the American Society of Civil Engineers (ASCE) in Reston, Virginia, to discuss the best approach to achieve the project objectives. The participants included representatives of EPA, members of the Technical Advisory Committee, and the project team.

SSO Management Flow Chart
Final Working Draft: 10/12/95

This chart is provided for use by communities in planning SSO management and in discussions among operators, communities, and state and federal regulatory authorities.



A Includes basement backups and SSOs in high public access areas.

B Includes fish or wildlife kills an significant water quality or wetland degradation.

C For example, monitoring equipment upgrades, pumps, computer programs, repair/replacement of broken manholes or pipes.

D For example, known system "bottlenecks," pumps needing replacement, and /or needs for additional staff.

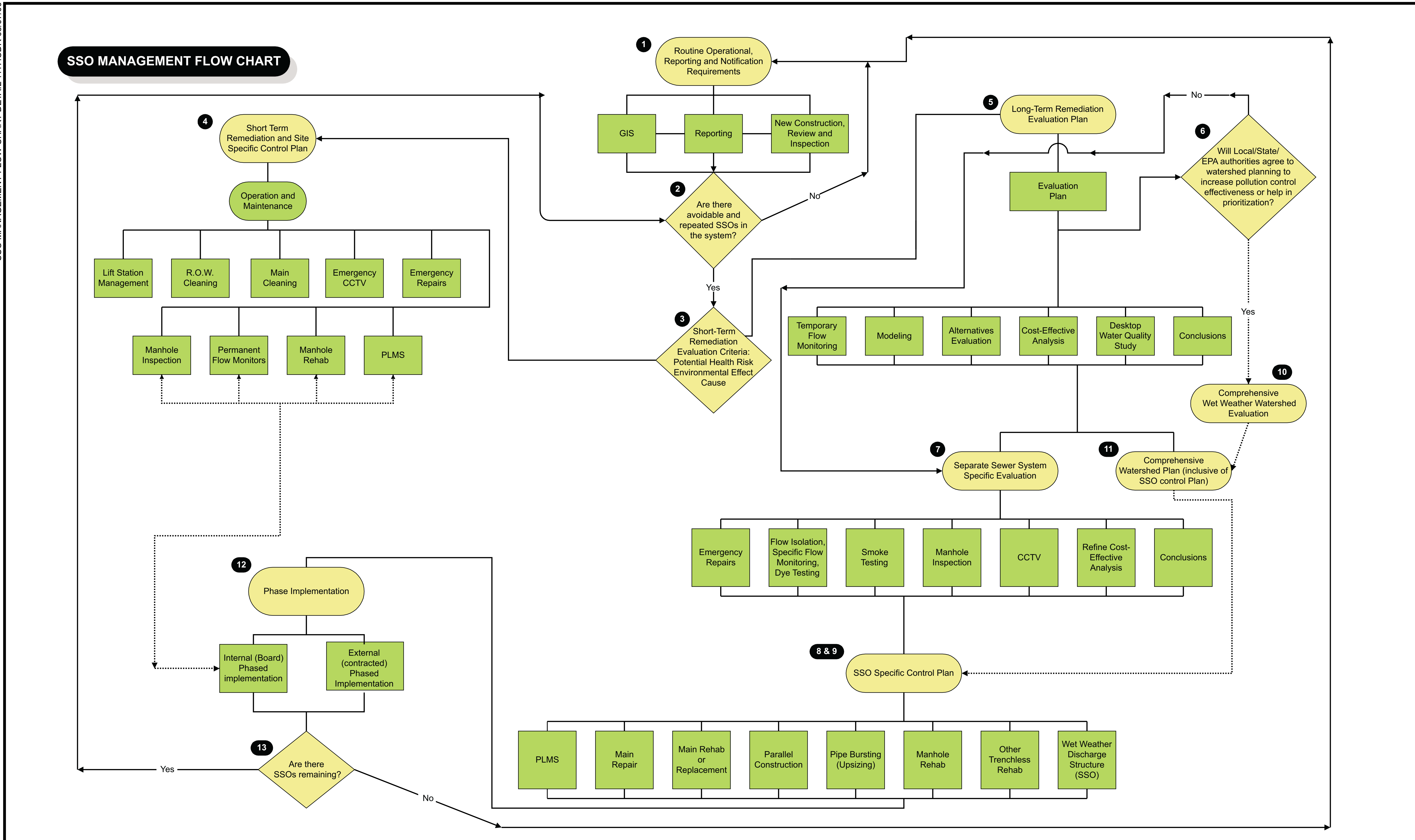
- - - - - → Watershed Planning Track will be addressed by Urban Wet Weather Flows Advisory Committee in consultation with the SSO Subcommittee.

Note: SSO refers to an overflow event, not an SSO structure.

Source: SSO Facility Advisory Committee

SSO Management Flow Chart General

Figure 1-1



Source: Montgomery Water Works and Sanitary Sewer Board

SSO Management Flow Chart Detail

Figure 1-2

1.1.1.2 Task 2: Information Collection

To obtain background information, the goal of this project was to collect data from approximately ten local or regional wastewater agencies regarding the protocols they use to identify and evaluate SSOs. Copies of documents, where available, were reviewed, and telephone interviews were conducted with key staff members of the agencies. Copies of such protocols are included as appendices to this report. In addition, appropriate groups in the U.S. Environmental Protection Agency (USEPA), the Water Environment Federation (WEF), and several consulting firms were contacted for information regarding their experience and expertise with SSO protocols.

A preliminary list of agencies to be interviewed was compiled during the kickoff meeting. A questionnaire was developed to be used as the basis for the telephone interview and to obtain a consistent set of data. The procedures to be used in collecting the information were outlined in the kickoff meeting notes.

1.1.1.3 Task 3: Development of a Comprehensive Set of Protocols

After reviewing the literature and the information supplied by the agencies, a comprehensive set of protocols was developed. Techniques for identifying SSOs, such as CCTV and flow monitoring, are described in detail. The conditions under which each technique may be most effective and the limitations of each technique, are explained.

1.1.1.4 Task 4: Development of Guidance Manual

The material developed in Tasks 1, 2, and 3 was compiled into this guidance manual. The advisory panel was asked to provide input to the development of the outline for the manual and to review the final draft. The manual includes an executive summary, a synopsis of available literature, a list of the protocols studied, and a detailed description of the comprehensive set of protocols.

1.1.1.5 Task 5: Development of Web Page

A web page was established, with links to the web pages of several organizations, including the USEPA and the American Society of Civil Engineers (ASCE). The web page was used during the project to receive input from as many utility operators as possible. As information became available, it was posted on the web at www.bv.com/asce-epa. The advisory panel reviewed all materials before they were posted.

1.1.2 Phase 2

1.1.2.1 Task 6: Development of Informational Brochures

After the development of this guidance manual, up to two informational brochures will be prepared. These brochures will cover topics such as a general overview of SSOs, techniques for identifying SSOs, modeling of SSOs, and case studies.

1.1.2.2 Task 7: Dissemination of Informational Material

In addition to posting material on the web, the informational brochures will be distributed (at no cost to recipients) at relevant ASCE, WEF, and APWA conferences. Target conferences includes the:

- ASCE (National)
- ASCE (Pipeline specialty conference)
- WEF (National)
- WEF (Collection system specialty conference)
- APWA (National)

The availability of the brochures will also be announced in trade journals and newsletters. The guidance manual will be available through ASCE.

At the end of the project, final meeting between members of the project team and the USEPA Project Officer will be held in ASCE headquarters in Reston, Virginia. The purpose of this meeting will be to provide a summary presentation of the project dissemination status and plans, work products, deliverables, results, and recommendations for future work.

2.0 Data Collection

2.1 Introduction

Data collection included literature search, completion by selected agencies; data questionnaire and other contacts and communications.

2.2 Literature Research

A literature search was conducted to gather published information related to SSOs. The following sources were used:

- American Society of Civil Engineers Online Database.
- United States Environmental Protection Agency Website.
- World Wide Web Search Engine Alta Vista.
- Civil Engineering Magazine.
- Water & Environment Technology Magazine.
- Public Works Departments.
- Proceedings of the National Conference on SSOs, April 1995, Washington, DC.
- Proceedings of Water Environment Federation Collection Systems Rehabilitation and O&M Conference, July 1997, Kansas City.
- Proceedings of Water Environment Federation Sewers of the Future Conference, Sept. 1995, Houston, TX.
- Proceedings of Water Environment Federation Collection Systems Operation & Maintenance Conference, June 1993, Tucson, AZ.
- Proceedings of Water Environment Federation's WEFTEC 1993, 1994, 1995, 1996, 1997, and 1998 conferences.
- Proceedings of Water Environment Federation's WEF Conference Advances in Urban Wet Weather Pollution Reduction, July 1998, Cleveland, OH.
- Proceedings of Water Environment Federation's Urban Wet Weather Pollution: Controlling Sewer Overflows and Storm Runoff, June 1996, Quebec City, Canada.
- American Society of Civil Engineers Publication on Urban Drainage Rehabilitation Programs and Techniques, 1994.

- American Society of Civil Engineers MOP No. 87 on Urban Runoff Quality Management, 1998.
- Proceedings of American Society of Civil Engineers Pipeline Conference, Phoenix, AZ, 1994.
- Proceedings American Society of Civil Engineers Conference on Infrastructure Condition Assessment, Boston, 1997.
- United States Environmental Protection Agency Report to Congress, September 1997.
- Association of Metropolitan Sewer Agencies Survey on SSOs (unpublished).

A summary of the literature search is provided in Appendix A.

2.3 Agency Questionnaires

Data and information related to SSOs were obtained through questionnaires and interviews with 12 agencies across the country. The selection was made to gain information from agencies thought to be leaders relative to SSO programs. At the project kick-off meeting, candidate agencies were identified based on the TAC's knowledge and experience. Followup telephone calls to each agency was made to obtain verbal commitment to complete a questionnaire. In addition to the agencies selected at the kick-off meeting, the agencies represented by TAC members agreed to complete questionnaires.

The questionnaires consisted of two parts. The first part consisted of general information about the agency and several quantitative parameters, including the following:

- General Information/Service Area
- Flow Information
- System Characteristics
- SSO Wet Weather and Dry Weather Events
- Frequency of Routine Maintenance
- Inspection Methods and Status
- Ranking of Methods Used to Identify SSO Locations

The second part of the questionnaire consisted of qualitative parameters:

- Grease Problems.
- Design Deficiencies.
- SSOs as a Factor in Sewer Rehabilitation.
- Most Common SSO Related Defects.
- I/I Management Programs.
- Corrosion Control Program.
- Tools for Identifying SSOs.

A copy of the questionnaire is included in Appendix B.

2.4 Data Processing

Data from the questionnaire were entered into a project database and summaries of the data prepared for discussion with the TACs.

3.0 Data Analysis

3.1 Introduction

This chapter presents a summary of the data supplied by the 12 agencies that responded to the questionnaire. A summary of agency information is presented in Table 3-1.

3.2 General Information

Each agency was requested to provide information on, the total miles of sewer, the number of manholes, total number of connections, service area size, population served, and age of the system.

The agencies varied widely with respect to size and other general information. The smallest agency has 726 miles of public sewer lines and serves 130,000 people; the largest has 4,900 miles of public sewer lines and serves a population of 1,484,000.

Manhole density averaged 22.3 manholes per mile of sewer (average manhole spacing of 236 ft) and 88.6 connections per mile of sewer (a service connection approximately every 60 linear feet). The sewer density ranged from 3.0 miles to 20.17 miles of sewer per square mile. The population density ranged from 176 to 469 people per mile of sewer and the majority averaged 282 people.

The survey data showed that most (76.2 percent) of the sewer lines have been installed since 1950, with 37.3 percent having been installed since 1971.

Table 3-1

Summary of Agency Data Collected Protocols for Identifying SSOs

	Item	Count	Average	Maximum	Minimum
I.	**General Information**				
	Manhole Density, mh/mi	10	22.3	29.2	15.9
	Connection Density, conn/mi	11	88.6	227.6	34.9
	Area Density, mi sewer/sq mi	8	10.6	20.2	2.9
	Population Density, persons/mi	11	282.3	468.8	176.4
II.	**Age of Collection System**				
	% Pre 1950	10	23.7	90.0	1.3
	% 1950-70	10	38.9	81.4	9.0
	% 1971-98	10	37.3	63.0	1.0
III.	**Flow Information, mgd**				
	Average Daily Flow, gcd	11	170	297	86
	Maximum Day/Average Daily Flow	8	2.37	4.55	1.61
	Peak Hour/Average Daily Flow	6	3.39	5.12	2.08
	Maximum Month/Average Daily Flow	9	1.39	1.85	1.20
	Minimum Month/Average Daily Flow	9	0.80	0.92	0.68
IV.	**System Characteristics Information**				
	% of System Below Avg Groundwater Table	9	52.2	85.0	0.5
	% of System > 24 in. Dia.	9	10.9	40.0	0.5
	Mile Sewer/Pumping Station	11	84.7	316.7	3.4
	Horse Power/Pumping Station	9	180.1	533.1	47.2
	Miles Force Main/Pumping Station	9	1.2	5.6	0.4
	Number of Equalization Basins (above WWTP)	11	0.9	4.0	0
	Total Volume of Equalization Basins, MG	9	7.9	64.0	0
	% of System Industrial/Commercial	11	17.9	80.0	3.0
V.	**SSO Wet Weather Events**				
	Pipe Failures/100 miles of sewer /yr	9	1.40	8.54	0
	Manhole Overflow/100 miles/yr	11	2.02	7.46	0
	Basement Backups/100 miles/yr	10	4.76	30.28	0
	Pump Station Failures/ 100 miles /yr	10	0.34	1.64	0
	Pump Station Failures/Pump Station/yr	10	0.31	1.63	0
	Other				
VI.	**SSO Dry Weather Occurrences – Last Three Years**				
	Pipe Failures/100 mi/yr	11	0.88	6.03	0
	Manhole Overflows/100 mi/yr	9	2.14	7.46	0
	Basement Backups/100 mi/ yr	9	2.30	17.01	0
	Pumping Station Failures/ 100 mi/yr	9	0.50	2.03	0
VII.	**Routine Maintenance Frequencies**				
	% Cleaned/yr	11	22.6	38.8	6.4
	% Root Treated/yr	11	5.2	34.7	0.0
	Main Stoppages Cleared/100 mi /yr	11	41.4	162.3	0.0
	Service Stoppages Cleared/100 mi /yr	9	104.3	420.0	0.0
	Pumping Station Service/ Pumping Station/ yr	8	141.0	443.5	0.0
	Monitoring Sites/ 100 mi/yr	10	12.0	62.5	0.4
	% Manhole Inspected/ yr	11	15.5	48.5	0.1
	Dye Tests/ 100 mi /yr	10	5.9	30.3	0.8
	% CCTV Inspected/ yr	11	0.4	1.9	0.1

Table 3-1

Summary of Agency Data Collected Protocols for Identifying SSOs

Item	Count	Average	Maximum	Minimum
% Buildings Inspected/ yr	10	0.9	6.8	0

Table 3-1

Summary of Agency Data Collected Protocols for Identifying SSOs

Item	Count	Average	Maximum	Minimum
IX. Ranking of Methods Used to Identify SSOs (1= Used most often or best)				
		Current Sources Rated 1 or 2	Most Effective Rated 1 or 2	Gap %
1. Customer or Other External Sources	12	83.3%	33.3%	-50.0
2. Visual Inspection	12	66.7%	58.3%	-8.3
3. Scheduled Inspections	12	16.7%	41.7%	25.0
4. Collection System Flow Monitoring	12	8.3%	18.2%	9.8
5. Receiving Stream Monitoring	8	0.0%	0.0%	0.0
6. Hydraulic Modeling	11	0.0%	40.0%	40.0
7. SCADA	8	12.5%	30.0%	17.5
8. Other	3	33.3%	0.0%	-33.3
X. Protocols for Identifying SSOs				
		% Yes	% No	
Do you use written protocols?	11	81.8	18.2	
Do you plan to develop protocols?	12	66.7	33.3	
Do you have a grease abatement program?	12	58.3	41.7	
Have you identified SSO design deficiencies?	12	72.7	27.3	
Have you made any design changes for SSOs?	12	72.7	27.3	
Do you give SSOs high priority in rehabilitation program?	12	100.0	0.0	
Do you have SSO requirement in NPDES permit?	12	91.7	8.3	
Do you have an I/I program?	12	100.0	0.0	
Do you have a corrosion control program?	12	63.6	36.4	
Do you use any SSO tools?	12	75.0	25.0	

3.3 Flow Information

Each agency reported its annual average daily flow (ADF) and maximum daily, peak hour, and peak month flows. The ADF rates varied from 86 gcd to 298 gcd, with an average of 171 gcd. The ratio of maximum day to ADF (MD/ADF) ratio as observed at the system WWTP(s) was calculated based on information provided and ranged from 1.61 to 4.55, with an average of 2.37. The ratio of peak hour to ADF (PH/ADF) ranged from 2.08 to 5.12, with an average of 3.39. Maximum month to ADF ratios ranged from 1.20 to 1.85, with an average of 1.39. Minimum month to ADF ratios ranged from 0.68 to 0.92, with an average of 0.80. The wide variation in flow rates demonstrates the impact various infiltration and inflow rates have on peak flows.

3.4 System Characteristics Information

System characteristics data provided by each agency included the percentage of system below the groundwater table, the number of pumping stations, the total pumping horsepower, the length of force mains, the number of equalization basins, and the percentage of system which conveys industrial/commercial flows.

Nine agencies reported the percentage of system below the groundwater table. The average value below was 52 percent, with a range of 0.5 to 85 percent. The portion of the system that consists of pipe larger than 24 inches in diameter averaged 10.9 percent, with a range of 1 to 40 percent.

The number of pump stations the systems reported varied from 10 to 955. The density of pumping stations varied from 3.4 to 84.7 per mile of sewer. The total pump horsepower ranged from 786 to 76,641, with an average of 15,777. The average horsepower per pumping station was 180, with a range of 47 to 533. The force main length per pumping station ranged from 0.36 to 5.56, miles with an average of 1.17.

The number of equalization facilities ranged from zero to 4 with an average of one per agency. The total storage volume ranged from zero to 64 million gallons. The percent of system, which is industrial/commercial, ranged from 3 to 80 percent with an average of 17.9 percent.

3.5 Reported Wet Weather SSOs

System performance data for wet weather SSOs reported for 1996, 1997, and 1998 included SSOs caused by pipe failures, manhole overflows, basement backups, pump station failures, and other causes.

SSOs attributable to pipe during this three-year period ranged from zero to 539, with an average of 78.2 breaks per agency per year. The pipe failure rate ranged from zero to 8.54 pipe failures per 100 miles per year (pf/100mi/yr), with an average of 1.4 pf/100mi/yr.

SSOs that resulted from manhole overflows during the three-year period ranged from zero to 671. The manhole overflow rate ranged from zero to 7.46 per 100 miles per year (MHOF/100mi/yr), with an average of 2.0 MHOF/100mi/yr.

SSOs in the form of basement backups ranged from zero to 1,912. The basement backup rate ranged from zero to 30.3 per 100 miles of sewer per year, with an average of 4.8 basement backups per 100 miles per year.

SSOs caused by pump station failures reported for the three-year period ranged from zero to 136, with an average of 22.4. The failure rate ranged from zero to 1.63 failures per pump station per year, with an average of 0.31.

SSOs due to other performance measures were also reported for 1996, 1997 and 1998. A total of 50 wet weather SSOs for other reasons were reported.

3.6 Reported Dry Weather SSOs

System performance data for dry weather SSOs reported for 1996, 1997, and 1998 included SSO attributable to pipe failures, manhole overflows, basement backups, pump station failures and other causes.

Dry weather SSOs resulting from pipe failures in this three-year period ranged from zero to 500 with, an average of 72.6 breaks per agency per year. The pipe break rate ranged from zero to 6.03 per 100 miles per year (pf/100mi/yr), with an average of 0.88 pf/100mi/yr.

SSOs resulting from dry weather manhole overflows during the three-year period ranged from zero to 671, with zero to 7.46 manhole overflows per 100 miles per year (MHOF/100mi/yr) and an average of 2.1 MHOF/100mi/yr.

SSOs in the form of backups into basements or homes ranged from zero to 2,500. The basement backup rate ranged from zero to 17.0 dry weather backups per 100 miles per year, with an average of 3.0 backups.

Dry weather SSOs attributable to pump station failures ranged from zero to 56, with an average of 13.3. The failure rate ranged from zero to 2.03 failures per pump station per year, with an average of 0.50.

Dry weather SSOs due to other performance measures reported for years 1996, 1997 and 1998 totaled 319.

3.7 Routine Maintenance Data

Each agency was requested to report routine maintenance information for the years 1996, 1997 and 1998. Data reported related to line cleaning, root removal/treatment, main line stoppages cleared, house stoppages cleared, and pumping station inspections performed.

Sewer cleaning was reported by the number of miles cleaned, which was then converted into the percentage of system cleaned per year. On average, 22.6 percent of each system was cleaned per year, with a range of 6.4 to 38.8 percent. Root removal/treatment was also reported. The average root removal/treatment rate was 5.2 percent per year, with a range of zero to 34.7 percent.

Main line stoppages cleared averaged 41.4 stoppages cleared per 100 miles per year, with a range of zero to 162.3 per 100 miles per year. House service stoppages cleared averaged 104 stoppages per 100 miles per year with a range of zero to 420.

Pump station inspections averaged 141 inspections per pump station per year, with a range of zero to 444.

3.8 Inspection Methods and Status

Each agency was requested to report collection system inspection methods used and the status of each for 1996, 1997, and 1998. Data were reported on flow monitoring, manhole inspection, dyed water tests, closed circuit television (CCTV) inspection, and private sector building inspections.

Flow monitoring was reported by the number of monitoring sites installed per year. On average, 12 monitoring sites per 100 miles per year were installed, with a range of zero to 63 sites per 100 miles of sewer per year.

Manhole inspections were reported and converted into the percentage of system manholes inspected per year. The average inspection rate was 15.5 percent per year, with a range of 0.1 to 48.5 percent.

Dyed water tests were reported by the number of tests conducted per year, converted to a rate. On average, 5.9 dye tests per 100 miles of sewer per year were conducted, with a range of 0.8 to 30.3 dye tests per 100 miles of sewer per year.

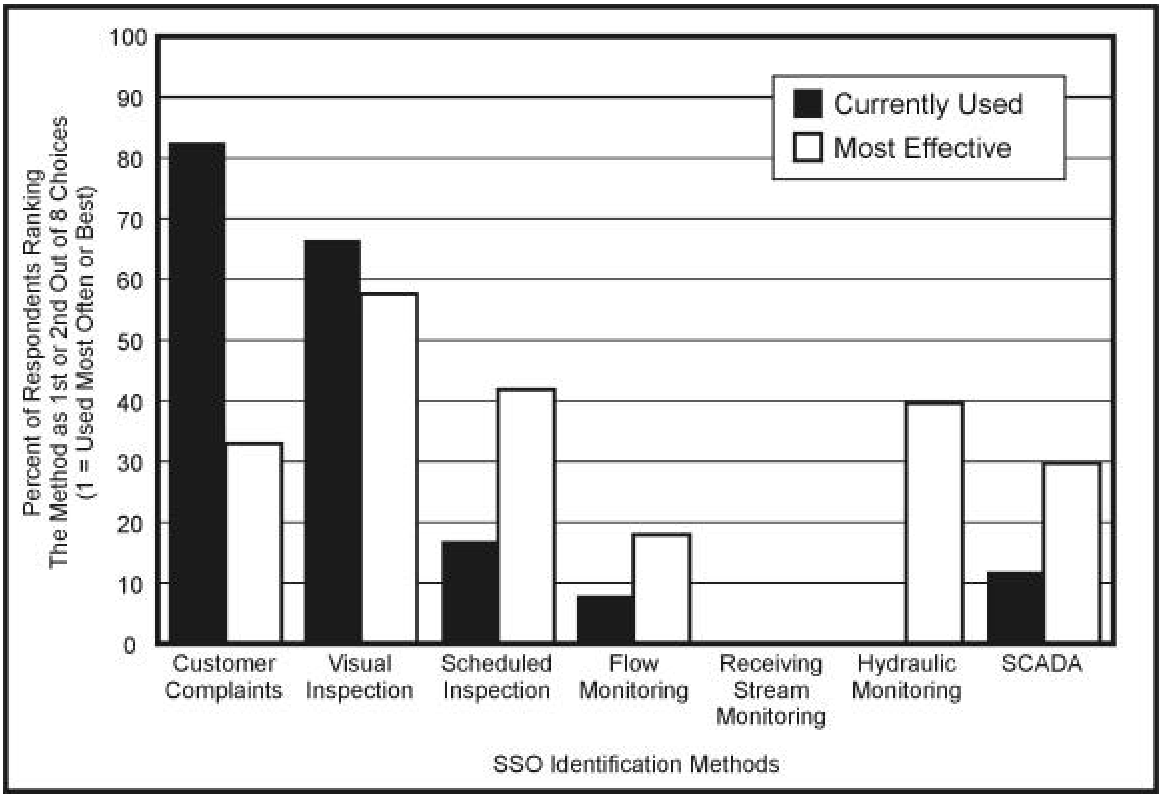
CCTV inspections performed averaged 0.1 to 2 percent of the system per year, with an average of 0.4 percent per year. Private building inspections to locate private sector I/I sources averaged 0.9 percent of the buildings per year, with a range of zero to 6.8 percent per year.

3.9 Ranking of Methods Used to Identify SSOs

Each agency provided information regarding the ranking (from “1” through “8” with “1” being the most often or best) of the use and effectiveness of eight typical ways used to identify SSOs. Methods included customer or other external sources, visual inspection, scheduled inspections, flow monitoring, receiving stream monitoring, hydraulic modeling, SCADA, and other methods indicated by each agency. The responses were summarized with percentages expressed by the number of responses ranked either “1” or “2”.

The data received reveals the methods agencies are actually using and what they believe to be the most effective methods for identifying SSOs. Nearly all (83.3 percent) agencies reported that customer or external sources were used most often in identifying SSOs, yet only 33.3 percent considered this the best (either “1” or “2” ranking) means of identifying SSOs. Visual inspections were often used, and 66.7 percent of the agencies considered this a very effective means of locating SSOs. Scheduled inspections, although considered very effective in identifying SSOs, were used often by only 16.7 percent of the agencies. The results are shown on Figure 3-1

Figure 3-1



SSO Identification Methods Ranking

3.10 Status of Agency Protocols

Each agency was requested to respond to a series of questions regarding its use of written protocols and development of other procedures or programs that would impact on SSO control. The responses were so formatted that a "yes" or "no" response could be provided and the results tabulated.

The responses are summarized in Table 3-1, Section IX, and indicate high awareness of SSOs by the responding agencies. Eighty-two percent of the respondents have written protocols for identifying SSOs; 67 percent plan to develop additional protocols for identifying SSOs; 58 percent have a grease abatement program; 73 percent have identified design deficiencies which can lead to SSOs; 73 percent have modified design standards in an effort to reduce future SSOs; 100 percent give SSO control a high priority in their rehabilitation program; 92 percent have SSO control requirements in their NPDES permit; 100 percent have an I/I program; 64 percent have a corrosion control program; and 75 percent use various "tools" to help control SSOs. This high awareness of SSOs by participating agencies is not surprising, as each agency was selected based on its reputation of being proactive in dealing with SSOs and therefore representing "leading edge" agencies as far a SSO control is concerned.

3.11 Agency Narrative Response Evaluation

The responding agencies provided valuable narrative in response to the survey questions. Following is a brief summary of some of the questions asked, with the most frequent answers:

1. **What is your normal response to the SSO events listed?**
   - Dispatch crew
   - Report to regulatory agency
   - Clean and disinfect
   - Conduct line blockage analysis
   - Conduct a surcharge review for wet weather SSOs
   - Correct manhole geometry

2. **What are your most significant maintenance problems?**
   - Roots
   - Grease
   - Deterioration of older sewers
   - Lack of long-term maintenance program
   - Matching the appropriate cleaning tools and equipment with appropriate cleaning frequency

3. **What maintenance activities do you think are beneficial to preventing dry weather and wet weather SSOs?**
   - SSES Studies
   - Remote alarm testing
   - Effective preventive maintenance program
   - Effective rehabilitation program
   - Exercising lift station equipment

4. What are the limitations for the various methods for finding SSOs?

- Ability to control private sector sources
- Difficulty in identifying appropriate manholes for installing flow meters.
- Manhole inspections are limited by buried manholes that take time to locate
- Out of date maps
- Relying on public for notification of SSOs
- Accuracy of flow monitoring equipment
- Lack of experienced maintenance staff

5. What inspection methods do you think are effective in identifying potential SSO locations?

- CCTV
- Smoke testing
- Flow monitoring
- Dye testing
- Visual observation
- SCADA system connected to a computer model
- Flood response team

6. Do you utilize any written protocols or procedures for identifying or investigating SSOs or potential locations of SSOs?

- SSO mapping
- Wet weather response procedure
- Inspection of high probability SSO lines
- Helicopter over-flights of selected areas

7. Do you have any plans for developing protocols for identifying or investigating SSOs? Do you have any ideas for an effective protocol?

- Implement work order system
- Implement GIS and SCADA
- Develop PM plan and develop contracts for expediting repairs

8. Have you identified any recurring design deficiencies which may be causing SSOs (e.g., flat sewer slopes)?

- Overloaded sewer lines
- Flat line slopes
- Series of 90 degree bends
- Hydraulic restrictions at manholes

9. Have you made any design changes to correct the above problems?

- Working with the engineers in public works that approve private developments
- Constructing relief sewers designed to correct the existing overloaded sewers.
- Revising design standards specify minimum 2 ft./sec. design flow characteristics.

10. What are the most common SSO defects fixed?

- Pipe problems
- Manhole deficiencies
- Remove sewer blockages
- Hydraulic blockages
- Cleaning of grease stoppages
- Root clearing and replacement of broken pipes
- Manholes rehabilitation

11. Do you expect SSO requirements to be added in the future?

- Increase in SSO requirements
- Permitting of collection system
- Reporting of SSO incidents

12. Do you have an I/I management program?

- I/I Program
- Dedicated CIP for collection system improvements

13. Do you have a corrosion control program?

- Relining of pipes and manholes
- Industrial sources control
- Addition of sodium hypochlorite to reduce hydrogen sulfide

Key information from the narratives was extracted and placed in appropriate categories for both reactive and proactive activities as they relate to SSO control. The reactive category provides valuable guidance as to the actions to be considered if an SSO occurs. The proactive category provides valuable guidance for finding SSO locations before they become a problem, preventing SSOs, and constraints for these activities. A summary and analyses of these narratives are presented in Appendix C.

3.11.1 Response to SSOs

SSO occurrences require immediate action by dispatching and cleaning up of the affected area. Actions include clearing the line blockages; CCTV of affected lines; repairing pump stations; housing and disinfecting affected property; diverting flow to tanker trucks, and stabilizing stream banks in cases of washout. Completing the paperwork to document the overflow and reporting the overflow to the state regulatory agency or to the EPA is another important action. Most of the agencies surveyed had a written procedure for maintenance crews to follow.

3.11.2 Maintenance Problems

The most significant maintenance problems the agencies surveyed dealt with included grease, roots, and pump station maintenance. Resources, both personnel and equipment, for cleaning and pump station maintenance were mentioned as a constraint. Lines in backyard easements were noted as significant maintenance problems. The training of maintenance crews was perceived to be a critical factor in the effectiveness of cleaning. Additional training and quality control for maintenance crews could significantly improve the effectiveness of cleaning and thus reduce SSOs. Staff expertise and the human factor were believed to be key to a good maintenance program.

Engineering resources were believed to be key to I/I investigations and to creating and documenting the historical information needed for effective maintenance. Problems mentioned included vandalism and budget constraints.

3.11.3 Activities to Prevent SSOs

The agencies listed cleaning, CCTV, and root removal as very effective maintenance techniques. SSES and I/I studies were seen as providing a basis for development of a sound preventive maintenance program. Planned cleaning, planned inspections, and monitoring of problem areas were noted as being important for SSO control. Remote alarm systems were noted as providing the information needed to prevent or limit the amount of overflow and to prevent a bad situation from getting worse. Regular inspection of creek crossings, regular maintenance of pumping stations, and development of a preventive maintenance program were noted as effective maintenance techniques.

3.11.4 Limitations of SSO Findings Methods

Limitations of finding SSOs included out-of-date maps, reliance solely on public notification of SSOs, lack of a computerized maintenance program, and in accessibility of manholes, and private sector sites to locate I/I. The questionable accuracy of flow meters and correlation of field monitoring flow data with computer hydraulic models were listed as constraints to identifying SSOs. Other limitations included ineffectiveness of CCTV quality during high flows; lack of trained staff and reliable telemetry; and SSOs at “hidden” locations. It was mentioned that field testing is limited in its ability to simulate variable and unpredictable wet weather conditions and to estimate I/I rates through defective pipe and manholes. Other constraints to field testing that were noted include the limited duration of flow studies, conducting inspections under less than ideal conditions, lack of cooperation by the public during private sector inspections, and the weather-dependence and seasonal variability impacts of several key inspection techniques such as smoke testing.

3.11.5 Existing Protocols

Nearly all responding agencies had some form of written procedures for handling SSO situations. Mapping each SSO and having a commitment and procedure for identifying its cause was noted as being an important element of an SSO control program. Implementation of GIS was identified to be an important part of keeping track of SSO locations.

3.11.6 Methods of Identifying Locations of SSOs

Effective ways of locating SSOs include procedures, such as a variety of methods, with a wide range of sophistication and costs. Standard SSES field manhole inspections, flow and rainfall monitoring, CCTV, etc., were mentioned as being effective in locating/predicting SSOs. Visual observations during rainfall, and inspections of stream crossings and alignments were noted. Helicopter flyovers of trunk lines are an effective way of inspecting and identifying potential problems along waterways. Each stream crossing should be documented. Computerized hydraulic modeling combined with field verification was noted as an effective way of locating SSOs. It was noted that agency staff limitations in terms of both time and training could reduce the effectiveness of an in-house model.

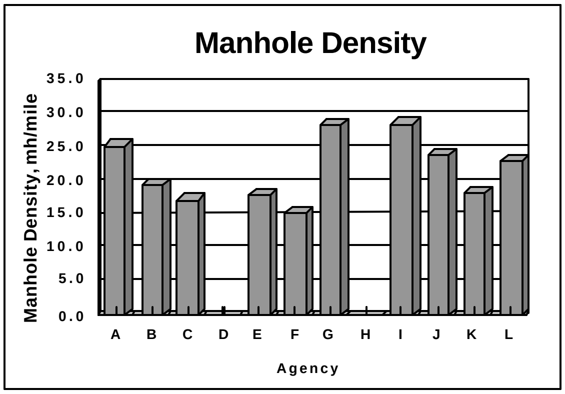
3.11.7 Design Deficiencies

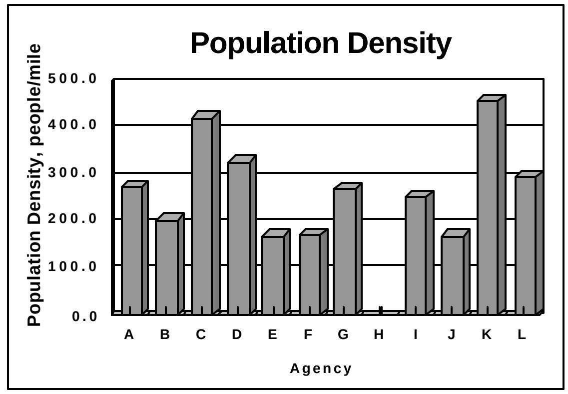
Problems related to the design of sewer systems were also noted. It was suggested that design standards be reviewed and updated, considering design conditions which could cause SSOs. Flat slopes and excessive bends are major factors contributing to SSO problems. Manhole hydraulic conditions were also noted as being very important to proper conveyance of flows. Manhole piping configurations should not create bottlenecks that result in SSOs. Improved design to optimize system configuration was suggested as a needed and worthwhile endeavor. For design, life-cycle costing should be used considering both initial construction costs and the long term operation and maintenance costs of the system.

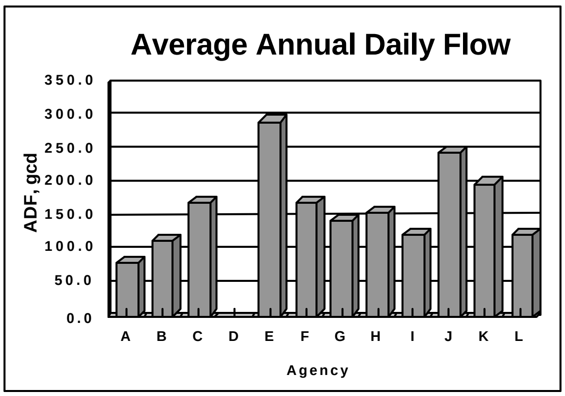
3.12 Graphs of Agency Data

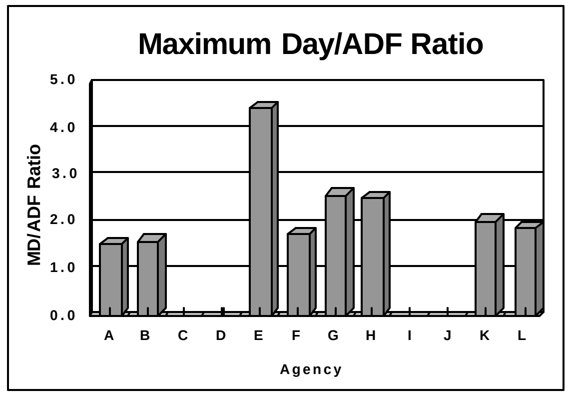
Graphs of various aspects of agency-supplied information are presented on the following pages for reference. Graphs include the following for each agency surveyed:

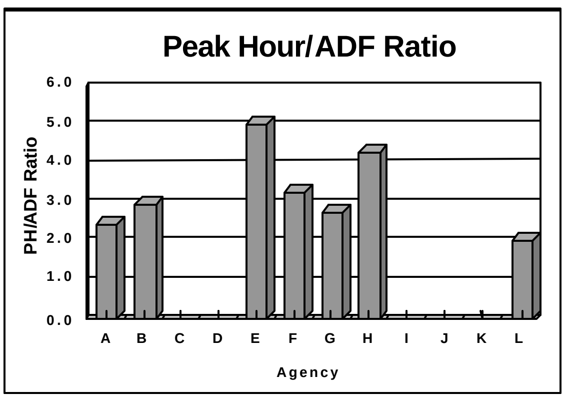
- Manhole density, manholes per mile of sewer
- Population density, population per mile of sewer
- Average annual daily flow, gallons per capita per day
- Maximum day/ADF ratio
- Peak hour/ADF ratio
- Maximum month/ADF ratio
- Minimum month/ADF ratio
- SSOs due to pipe failure (wet and dry weather), SSOs/100 mi/yr
- SSOs due to manhole overflow (wet and dry weather), SSOs/100 mi/yr
- Basement backup rate (wet and dry weather), backup/100 mi/yr
- SSOs due to pump station failure (wet and dry weather), SSO/PS/yr
- System cleaned per year, % system/yr
- Manhole inspection rate, %/year
- Dye test rate, Tests/ 100 mi/yr
- CCTV rate, % system/yr
- Building inspection rate for existing connections, % system/yr

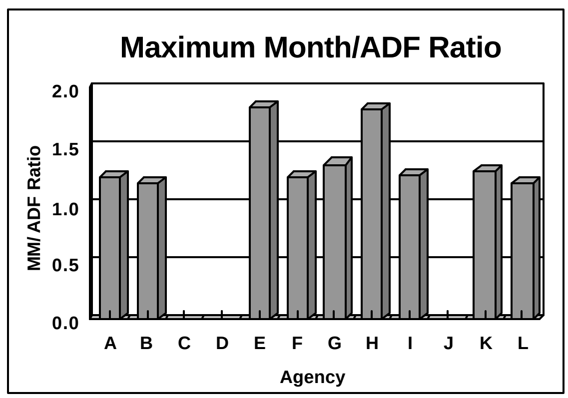

Manhole Density
Manhole Density, mh/mile
35.0 30.0 25.0 20.0 15.0 10.0 5.0 0.0
A B C D E F G H I J K L
Agency

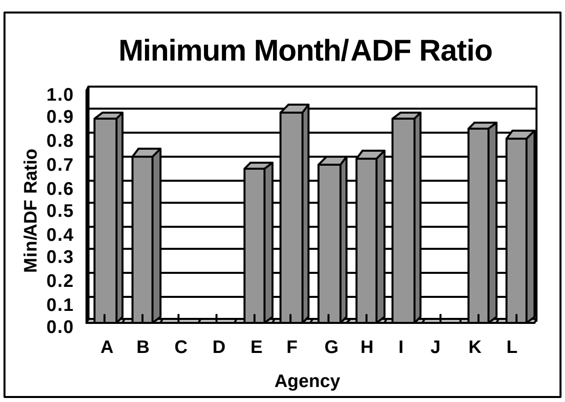

Population Density
Population Density, people/mile
500.0 400.0 300.0 200.0 100.0 0.0
A B C D E F G H I J K L
Agency

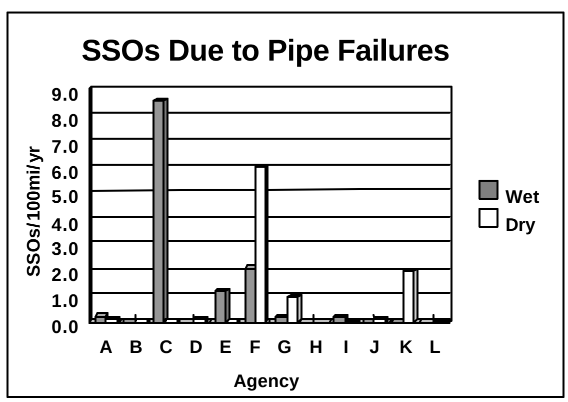

Average Annual Daily Flow
ADF, gcd
350.0 300.0 250.0 200.0 150.0 100.0 50.0 0.0
A B C D E F G H I J K L
Agency

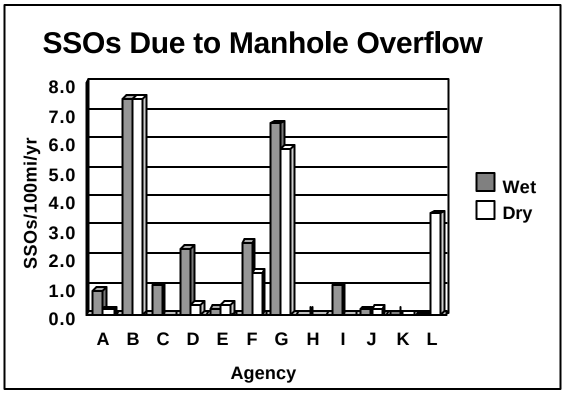

Maximum Day/ADF Ratio
MD/ADF Ratio
5.0 4.0 3.0 2.0 1.0 0.0
A B C D E F G H I J K L
Agency

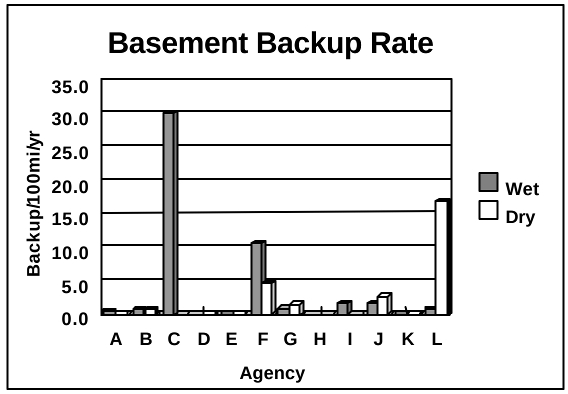

Peak Hour/ADF Ratio
PH/ADF Ratio
6.0 5.0 4.0 3.0 2.0 1.0 0.0
A B C D E F G H I J K L
Agency

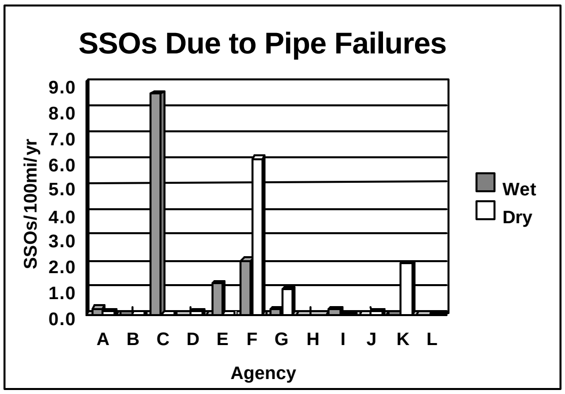

Maximum Month/ADF Ratio
MM/ ADF Ratio
2.0 1.5 1.0 0.5 0.0
A B C D E F G H I J K L
Agency

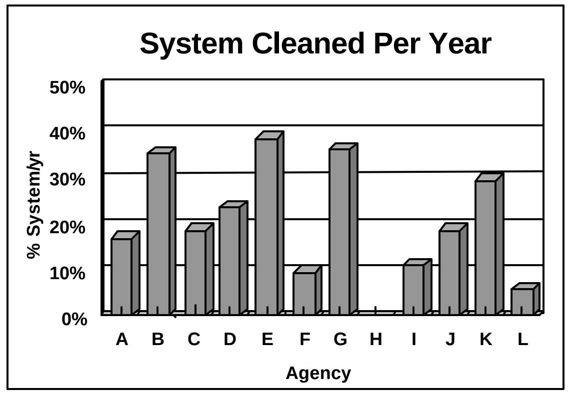

Minimum Month/ADF Ratio
Min/ADF Ratio
1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0.0
A B C D E F G H I J K L
Agency

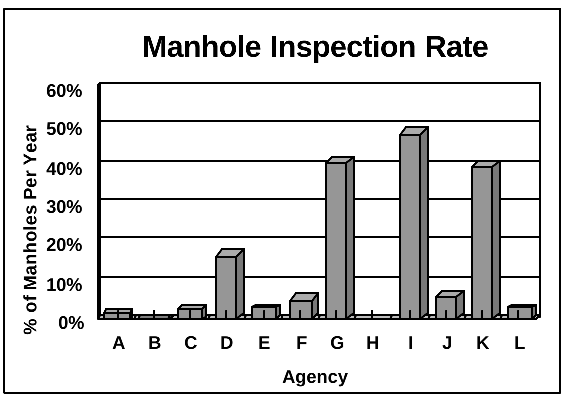

SSOs Due to Pipe Failures
SSOs/100mi/yr
9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0.0
Wet
Dry
A B C D E F G H I J K L
Agency

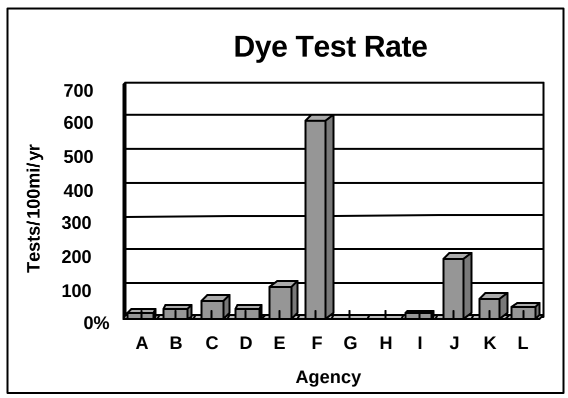

SSOs Due to Manhole Overflow
SSOs/100mi/yr
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
A B C D E F G H I J K L
Agency
Wet
Dry

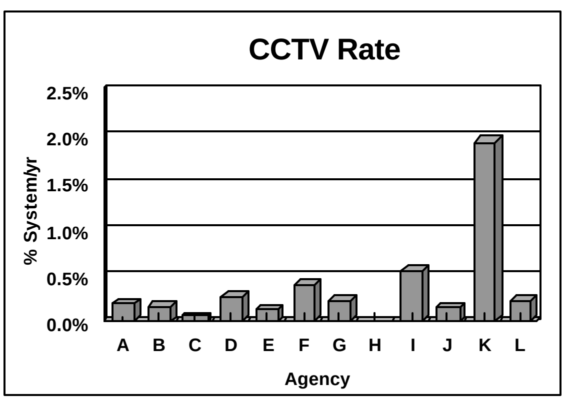

Basement Backup Rate
Backup/100mi/yr
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
A B C D E F G H I J K L
Agency
Wet
Dry

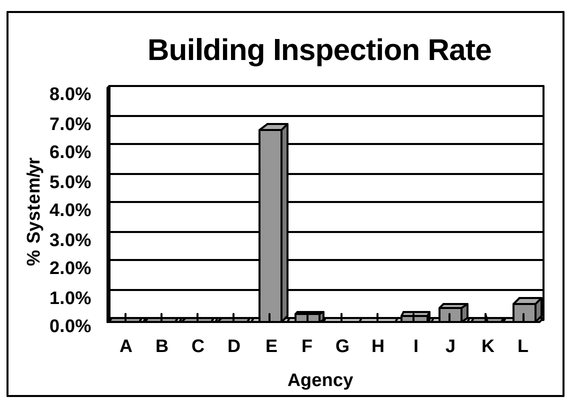

SSOs Due to Pipe Failures
SSOs/100mi/yr
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
A B C D E F G H I J K L
Agency
Wet
Dry


System Cleaned Per Year
% System/yr
50%
40%
30%
20%
10%
0%
A B C D E F G H I J K L
Agency


Manhole Inspection Rate
% of Manholes Per Year
60%
50%
40%
30%
20%
10%
0%
A B C D E F G H I J K L
Agency


Dye Test Rate
Tests/100mi/yr
700
600
500
400
300
200
100
0%
A B C D E F G H I J K L
Agency


CCTV Rate
% System/yr
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
A B C D E F G H I J K L
Agency


Building Inspection Rate
% System/yr
8.0%
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
A B C D E F G H I J K L
Agency

4.0 Hydraulic Protocols

4.1 Objective

The objective of hydraulic analysis protocols is to define the available hydraulic tools which may be used for identifying the potential locations of SSOs in a sanitary sewer system.

4.2 Hydraulic Capacity Related Problems

The profile, size, and internal roughness of the sewer pipe are critical factors that impact the hydraulic capacity of the sewer system. In addition to the hydraulic capacity of the sewer pipe, the hydraulic capacity of interconnecting manholes and transition structures could also be a problem. For example, a 90 degree bend in a manhole may impede the flow of sewage, lead to chronic deposition within the pipe, and result in an SSO during dry or wet weather as a result of blockages or hydraulic conditions which increase the hydraulic grade line. Consideration should be given to conducting a hydraulic analysis on such manholes, based on the shape and size of the manhole channel.

The portions of a sewer system most vulnerable to SSOs, are the low points in the system. For example, a manhole on the bottom of a valley is more likely to surcharge than a manhole on top of a hill. Whenever the hydraulic grade line falls above the rim elevation of a manhole, overflow can be expected.

The size of the sewer line is also critical. An undersized section of the pipe acts as a bottleneck, very similar to a narrow bridge across a wide road, causing backup of flow that may result in an SSO. A sharp decrease in the slope of a line can create a hydraulic jump that would also act as a bottleneck and would reduce the capacity of the line during wet weather. During dry weather, this condition can lead to significant deposition and loss of pipe capacity. An undersized pump station can have the same effect in causing backup of flow upstream.

4.3 Available Techniques

4.3.1 Hydraulic Modeling

The literature review conducted for this project revealed that hydraulic modeling has been used in the past for identifying locations of SSOs. Generally speaking, the hydraulic models can be divided into two groups: steady state models and unsteady state, or dynamic, models. Steady state models are not able to incorporate the effects of overflows on the hydraulic response of the system. Therefore, they cannot predict the location and quantity of overflow. Dynamic models, on the other hand, can predict the locations and flow rates of SSOs. These models have the ability to handle surcharging, backwater, and overflow conditions. They also can route the hydrographs dynamically and predict a time-varying series of flows and water surface elevations throughout the system during a wet weather event.

Walch (41) reports that the Miami-Dade Water and Sewer Authority has developed a "virtual dynamic model" which can be used to predict potential SSOs resulting from peak flow conditions over time. The model combines Geographic Information System (GIS), Supervisory Control and Data Acquisition (SCADA), Oracle™ and MS Access™ databases, NEXRAD Weather for Windows, and Virtual Rain Gauge (VRG). The model uses the XP-SWMM™ software as the dynamic hydraulic model.

Development of a hydraulic model is a very complex and time-consuming process. Hydraulic modeling should be done in conjunction with appropriate field work to verify calibration parameters. However, once the model is calibrated and validation runs are completed, running the model is a relatively straightforward task. The completed model should be updated on a regular basis and comprehensive runs be made on at least an annual basis to assess the impacts of any system changes, including growth. More frequent runs may be performed for areas that are reported to have an SSO problem or to confirm field observations.

The decision to build a hydraulic model for identifying the potential locations of SSOs should be based on the severity and extent of the SSO problem. Hydraulic modeling can be effective in identifying both wet weather and dry weather SSOs.

Hydraulic modeling can be conducted on either the entire system or only on those basins where the potential for SSOs is relatively high. By focusing on the problem basins only, the effort for creating the hydraulic model can be significantly reduced.

1.4.2 Scattergraphs/Flow Monitoring

Another technique cited in the literature refers to the use of "scattergraphs" to identify the location of SSOs. A scattergraph is a two-dimensional plot of velocity versus depth of flow. This technique is discussed in more detail in Section 4.5.

4.4 Methodology for Hydraulic Modeling

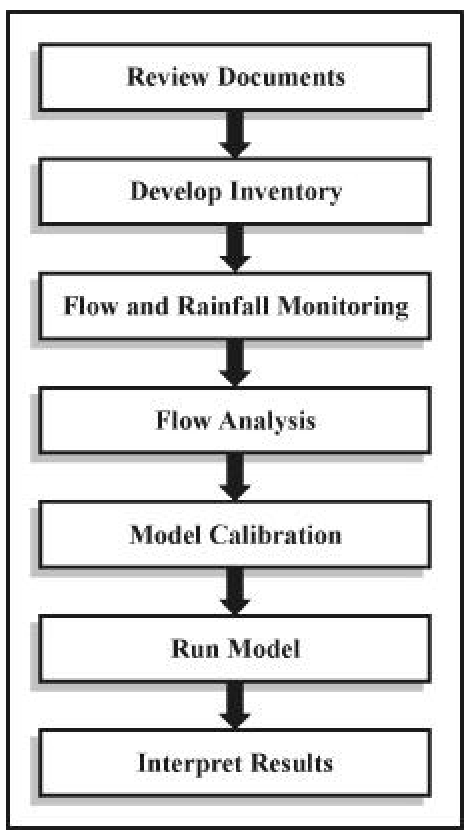
This section provides an overview of the steps necessary to set up and run a model. Figure 4-1 is a schematic flow diagram of the steps involved in hydraulic modeling.

Figure 4-1
Modeling Flow Chart

1.4.3 Review of Documents/Development of Inventory

An inventory of all sewer facilities to be used in the model and how they are interconnected should be prepared. The inventory should include information on gravity sewer pipes, force mains, manholes, pumping stations, siphons, diversions, control structures, and outfalls, and may be based on record documents, field survey work, or a combination of the two. Usually, some field verification will be necessary.

Typically, a "line segment" is defined by an upstream manhole (or node), a down-stream section of pipe, and a downstream manhole (or node). Most models consider manholes and wetwells as "nodes", and pipes, force mains, pumping stations, and control structures as "conduits". The information on each line segment includes pipe size, length, depth, elevation material, and the connecting upstream manhole. The slope of gravity sewers can be calculated from the invert elevation of upstream and downstream manholes and their spacing. Simple, unsteady-state flow type models require equations to estimate flow splits at nodes with two outgoing pipes.



Information on manholes includes the manhole location (coordinates), diameter, invert elevation at inlet and outlet, and rim elevation. Each manhole is treated as a node in the model, and should have a unique identification number.

The information on pumping stations includes, location, number and sizes of pumps, total and firm capacity of the station, size of the wetwell, and inlet and discharge elevations. Firm capacity is defined as the capacity of the pumping station when the largest capacity pump is out of service.

A Sanitary Sewer Management System (SSMS) may be used to facilitate the input of data for the model. This is further discussed in Chapter 5 - Maintenance and Inspection Protocols.

1.4.4 Flow Analysis/Flow Monitoring

Wastewater flows should be estimated and applied to the model at appropriate nodes. Flow hydrographs can be input directly to the model or the flows may be generated by the model based on population density, tributary area, rainfall, and estimated leakage. The wastewater flow consists of three components: the wastes of the community or wastewater production (residential, commercial, and industrial), infiltration, and inflow. Monitored flows during dry weather/low ground water (DW/LG) conditions may include some infiltration, referred to as base infiltration. For this reason, flows monitored during DW/LG conditions are sometimes referred to as average daily dry weather flow (ADDF), or base flow. It should be noted the ADDF is not the same value as the annual average daily flow (ADF), which consists of all flows in the system, including I/I, during a full year. Figure 4-2 is a schematic of flow components. Wastewater production or ADDF can be entered into a model as a diurnal curve. A diurnal curve is the hourly variation of the sewage flow over a 24 hour period. The diurnal curve is constructed by analyzing the results of flow monitoring data. It is obvious that different parts of a system can have different diurnal curves. Many of the existing hydraulic models can handle multiple diurnal curves. A typical diurnal curve is shown on Figure 4-3.

Figure 4-2
Flow Components

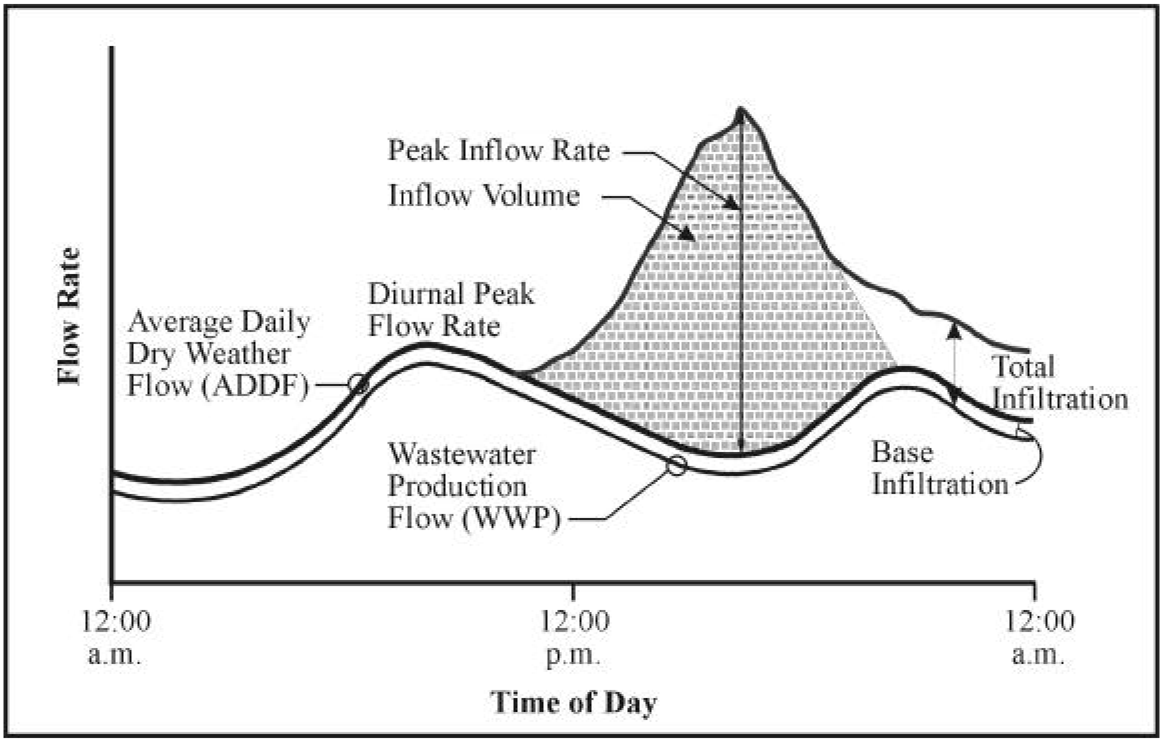
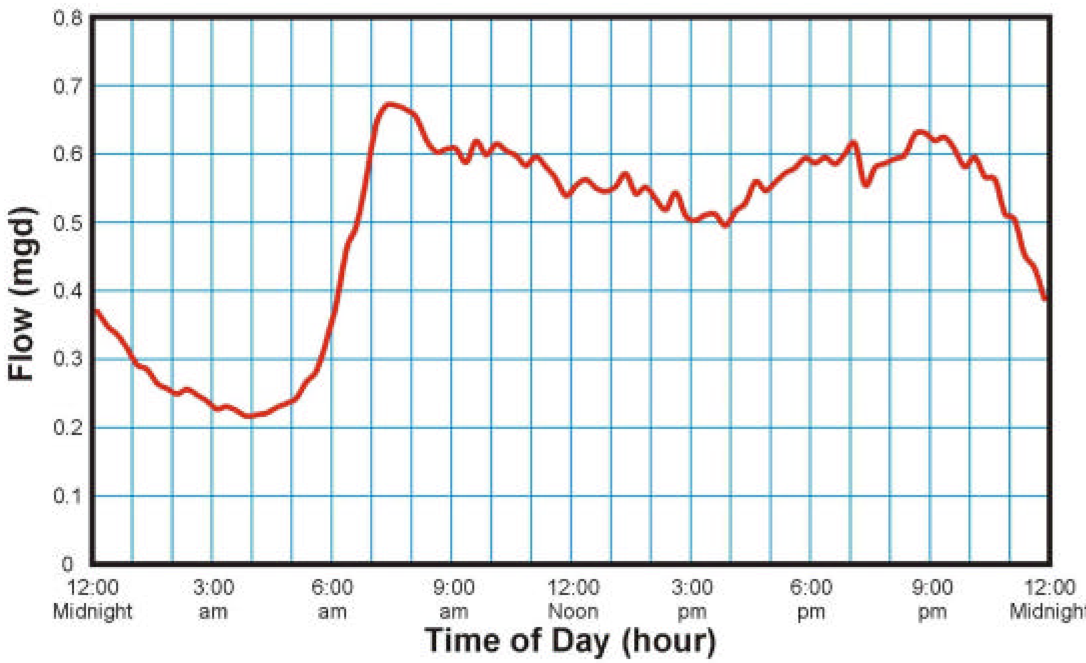

Peak Inflow Rate
Inflow Volume
Flow Rate
Diurnal Peak
Flow Rate
Average Daily
Dry Weather
Flow (ADDF)
Total
Infiltration
Wastewater
Production
Flow (WWP)
Base
Infiltration
12:00
a.m.
12:00
p.m.
12:00
a.m.
Time of Day

Figure 4-3



Diurnal Curve

The second component of wastewater flow is infiltration which is groundwater entering a sewer system through defects. Flow monitoring data can be used to make an estimate of infiltration. Infiltration may increase during wet weather conditions, a phenomenon referred to as rainfall-induced infiltration.

The third component of the wastewater flow is inflow which is extraneous flow entering a sewer system in direct response to rainfall through sources such as manhole covers, the top portion of manhole, indirect and direct storm connections, roof leaders, and basement drains. Inflow for design storm events can be estimated from the analysis of flow monitoring data during several storm events, or from a calibrated model which generates inflow internally to the model. Several techniques have been used to estimate peak inflow rates, including the following:

- Liner and Multiple Regression Techniques
- Ratio Method
- Inflow Coefficient Method

- Dynamic Model Simulation
- "RTK" Method
- Unit Hydrograph

1.4.5 Building the Model

The building of the model results in an input file to be used by the hydraulic model. The file would contain inventory and flow data to be used in modeling. At this stage, the user can specify parts of the system to be modeled. For example, the user may wish to model sewers larger than 30 inches in diameter. The flow data will also be applied at the appropriate nodes and in a proper sequence.

1.4.6 Calibrating the Model

Once the model network inventory is constructed, the model should be calibrated against field data. A simple calibration may consist of making sure that the model accurately predicts the average daily and peak flows at the wastewater treatment plant; however, this type of calibration can result in significant errors between actual and model-generated flows. Preferably, the model should be calibrated using data from a flow and rainfall monitoring network.

1.4.7 Running the Model

Once the model is calibrated, it can be used to analyze the hydraulic response of the system under different conditions, including design storms. The modeling technique is particularly useful in addressing "what if" scenarios and to assess the level of protection being provided by the existing system against SSOs.

1.4.8 Evaluation of Model Output

It is essential that the results of hydraulic model analysis be reviewed by an experienced hydraulic engineer to ensure that the results make sense. Often, an error in the input data causes erroneous results that can be detected only by a person experienced in hydraulic modeling. Graphic presentation of results often helps identify potential problems. In some cases, further analysis of the model output is necessary to arrive at a correct interpretations.

4.4.1 Reporting of Findings

The above steps, the results of the analysis and follow-up evaluations should be documented in a report. The report should provide an overview of the system being analyzed, the methodology used to develop input flows, the type of hydraulic model used, presentation of results and their evaluation, and conclusions. The use of graphs and tables to illustrate the results is greatly encouraged.

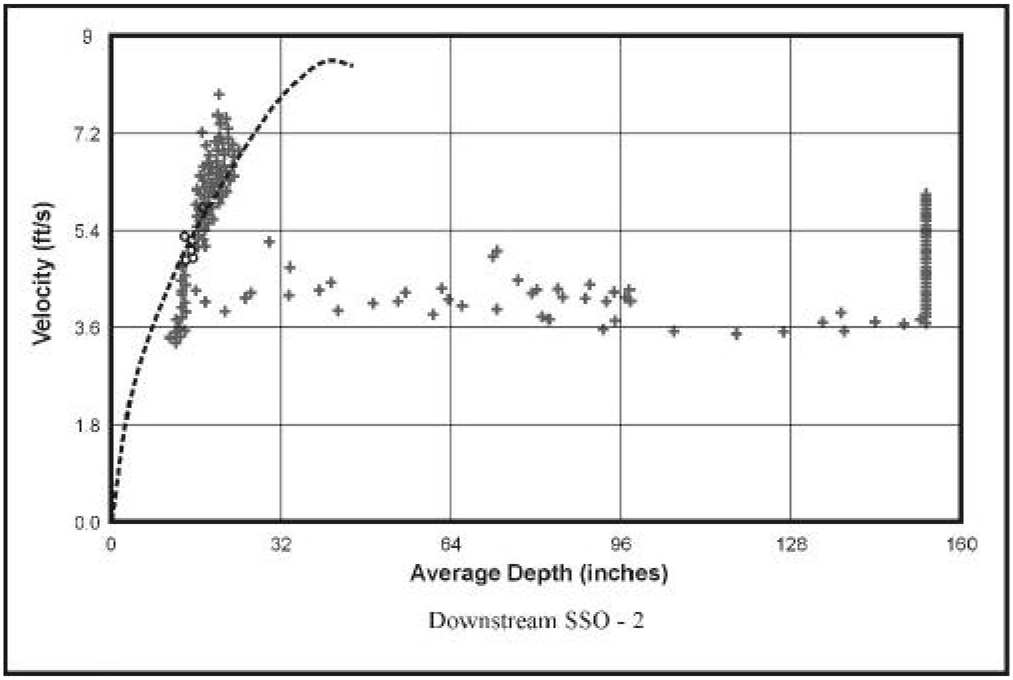
4.5 Scattergraphs

A scattergraph is a two-dimensional plot of velocity versus depth of flow. Depending on the shape of the scattergraph curve, it is possible to determine the potential occurrence of an overflow. The quantity of overflow cannot be determined by scattergraph technique.

Figure 4-4 is an example of a scattergraph indicating the occurrence of an SSO downstream from a monitoring site. While the water level in the downstream manhole rises, the pipe is flowing full with an average velocity of about 3.5 ft/s. When the water level reaches the top of manhole and an SSO occurs, the resistance to flow decreases significantly (since water can easily flow to the environment), causing a sharp increase in velocity, from 3.5 ft/s to 6.0 ft/s. For the duration of the SSO event, the depth of water registered remains relatively steady.

Figure 4-5 is an example of a scattergraph indicating the occurrence of an SSO upstream. When an SSO occurs upstream, the flow depth would remain relatively stable and equal to the depth of the overflowing upstream manhole. The flow also remains steady as the hydraulic gradient remains stable during the occurrence of SSO. Therefore, the steady depth and velocity points are plotted very close together and form a cluster of the data points at high depth. On Figure 4-5, a cluster of points occurs at 128 inches. The velocity is about 6.0 ft/s.

Figure 4-4



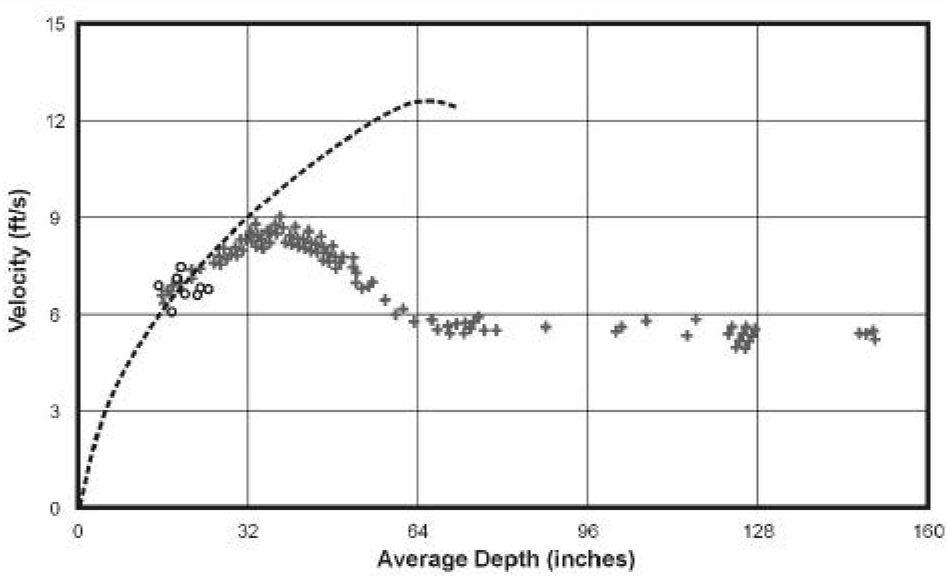
Scattergraph Showing Downstream SSO

Source: ADS Environmental, Inc.

Figure 4-5

Scattergraph Showing SSO Upstream

Source: ADS Environmental, Inc.



Upstream SSO

5.0 Maintenance and Inspection Protocols

5.1 Objective

The objective of the maintenance and inspection protocols is to define the available techniques and procedures which may be performed independently or as part of routine maintenance activities and would help identify the potential location of SSOs in the sanitary sewer system.

5.2 Maintenance Related Problems

Most of the respondents to the questionnaire (Appendix B) identified root intrusion and grease buildup as two major causes of sewer backups. These problems can be averted by regular cleaning of sewer lines. Sewer backups may also be caused by inadequate line slopes and "stairstep" lines where the slope of the line changes to match the topography. Accumulation of sediment at the bottom of lines on relatively flat slope often leads to sewer backup. Short of realigning such lines to increase the slope, the problem can be remedied by regular flushing and cleaning of the line. Other causes of overflows include defects in the sewer lines and manholes which admit excessive infiltration and inflow. Failure of pumping stations as a result power outages or mechanical failures is another common cause of SSOs.

5.3 Available Techniques

Some of the techniques used for inspection of sewer lines can also be used for identifying potential locations of SSOs. Respondents to the questionnaire (Appendix B) indicated that visual inspection after overflows, scheduled maintenance, and reporting by customers were the most commonly used techniques for identifying SSOs. When asked about the most effective technique for identifying the location of SSOs, the respondents listed the following:

- Visual inspection after overflows
- Scheduled maintenance
- Hydraulic modeling
- Remote monitoring

5.3.1 Customer and/or Public Complaint

When a basement backup occurs, it is almost certain that the customer will call the agency to report the backup. The backup may be the result of a stoppage in the main line or in the private lateral. The agency should have a plan to respond to such reports and to resolve the problem if the cause is stoppage in the main line. The issue of reimbursing the customer for the damages caused such backup should also be addressed. If the homeowner's insurance policy covers basement backups, the agency may not need to pay any compensation; otherwise, the agency may have to pay for cleaning the customer's basement and restoring it to its original condition.

When an SSO occurs in an area exposed to view, it is likely that someone will call the sewerage agency and report the incident. The agency should have a plan in place to investigate the reported SSO, find its cause, and take remedial measures to avoid recurrence of the SSO. It is important that the agency inform the person who reported the incident of the outcome of investigation, to encourage future reports.

It would also be helpful for the agencies to develop educational brochures and distribute them to the customers. Such brochures will encourage customers to be vigilant and report SSOs to the agency. If the agency has a web site, the educational materials can also be posted on the web together with an address for reporting SSO incidents via the web page.

5.3.2 Visual Inspections after Overflows

Visual i4nspections can be used to confirm the occurrence of SSOs at suspected locations. The agency should develop a list of such locations and update it periodically. Immediately following a major storm, an inspection team should be sent to investigate these locations. A visual inspection program can be enhanced by encouraging participation of the public through providing opportunities for the public to become part of the solution.

Donovan (23) reports that in Cincinnati, a known SSO location is visited at least once a week, and more frequently if a rain event occurs. A wooden block attached to a string is set in the overflow pipe. If the block has moved, it indicates an SSO has occurred.

5.3.3 Scheduled Maintenance Inspection

Many sewerage agencies perform routine maintenance inspections of their system. While the maintenance crew is performing the inspection, it can also look for signs of SSO. SSOs are most likely to occur at the following locations:

- Pumping Stations
- Manholes
- Stream Crossings
- Cleanouts

A form should be developed for reporting the SSOs identified by the maintenance crews. Once the SSO is reported, the agency should investigate its cause and develop appropriate remedial measures. The incident should also be documented in a database for future reference.

5.3.4 GIS-Based Analysis of Past SSOs

The Geographic Information System (GIS) is designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information. The GIS differs from other database management systems in that it permits spatial operations on the data. For example, GIS can identify the number of SSOs which occur following a specified storm event within a specified geographic location and a specified period.

GIS can answer questions related to location, condition, trends, patterns, and modeling. Listed below are some typical questions that GIS can answer are:

- What exists at a given location?
- Where is the location of an object or outcome with a number of specific characteristics?
- What has changed over a given period?
- What is the spatial distribution of areas with a certain attribute?

Which GIS system can be used to document the location of SSOs, can be superimposed on an existing map of the area. Information about the SSO events should be added in the GIS using colors or symbols to identify SSOs for any given year. Such a map will serve as a snapshot of the locations where SSOs would be concentrated. These locations should be put on a watch list and inspected following each major rainfall.

Once a sufficient number of SSOs are entered into the system, it is possible to perform a number of analyses, for example, to develop a map of potential SSO locations for storm events of different intensities. Such an analysis would help the agency prioritize its efforts in managing SSOs.

Giguere (40) reports that the City of San Diego uses GIS for analyzing SSO data. Every SSO is documented and information such as date, location, cause, and volume of overflow; pipe size and material; and impacts of the overflow on the environment is compiled. The data show that 90 percent of all spills that occur in San Diego during dry weather in are maintenance-related. The data are used to identify “hot spots” and to take appropriate action to avoid the recurrence of SSOs.

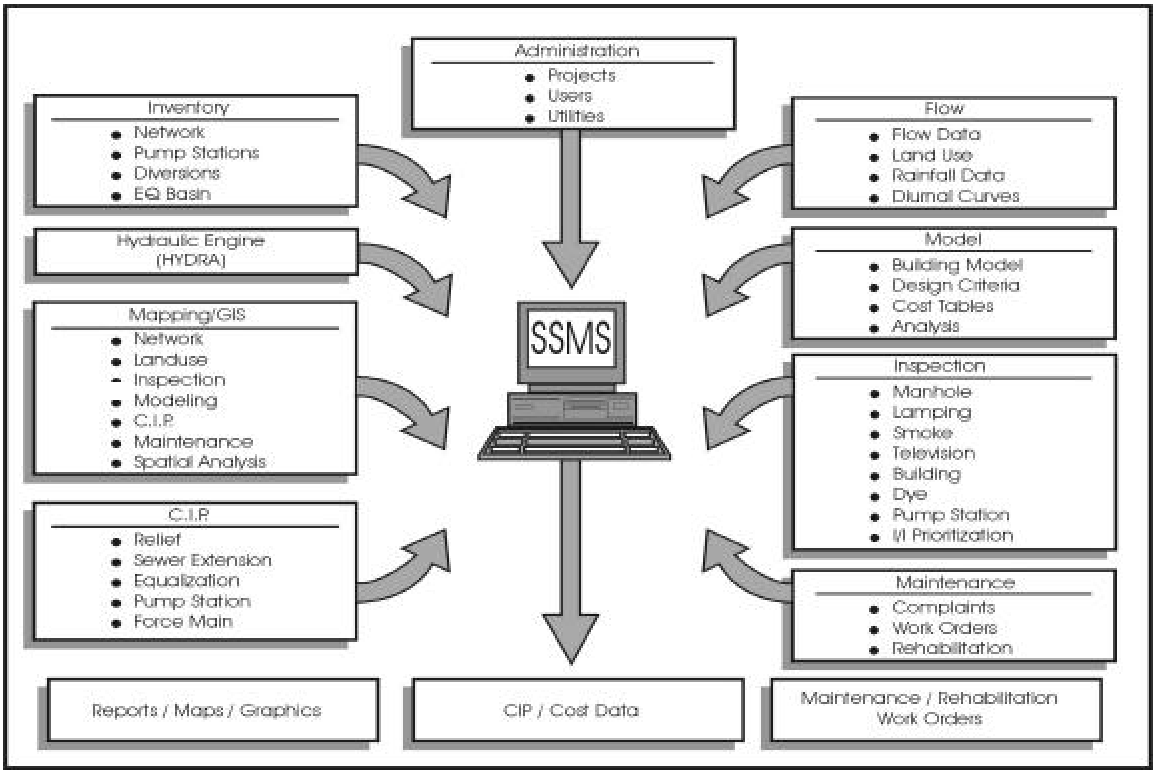
5.3.5 Sanitary Sewer Management Systems

A Sanitary Sewer Management System (SSMS) can be used to store, organize and analyze large quantities of data associated with sewer system operation, maintenance, inspection, modeling and rehabilitation. The SSMS may include the following modules:

- Inventory Module
- Flow Module
- Modeling Module
- Inspection Module
- Maintenance Module
- Rehabilitation (CIP) Module
- Mapping Module

The SSMS may also be linked to a GIS system. Figure 5-1 is a schematic of the SSMS modules. The SSMS can be used to analyze the data and to develop readily usable output such as reports, maps, work orders, and cost information.

Figure 5-1
Sanitary Sewer Management System (SSMS) Schematic



Analysis of the data in the SSMS can reveal many problem areas, trends, and patterns. For example, the database can be searched to develop a list of lines with flat slopes or areas where frequent maintenance is needed.

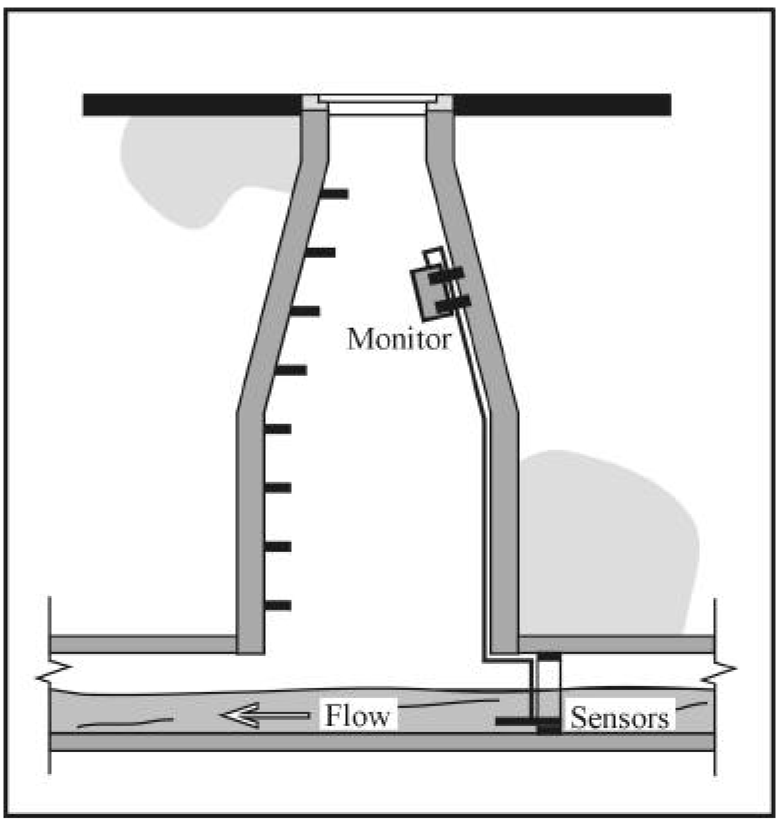
Another application of the SSMS is analysis of historical data. Clemente (16) reported that Dade County reconstructed over 20 years of unscheduled maintenance data to identify occurrence of SSOs. Approximately 26 percent of the 471 overflows were recurrent. Nearly one-half of the overflows occurred during dry weather because of non-capacity related problems.

5.3.6 Flow Monitoring

Flow monitoring at strategic locations may be used to identify potential locations of SSOs. Flow monitors can be installed in open channels and pumping stations to obtain the data necessary for proper system evaluation. In conjunction with flow monitoring, rain gauges should also be installed.

Many open channel temporary flowmeters have both velocity and depth measuring sensors. The instruments are often installed in the upstream reach of the access manhole, as shown on Figure 5-2. These monitoring devices have the capability of storing the data, which can be downloaded to a laptop computer in the field or transferred to the office via a telephone line or SCADA system. Specialized software which help analyze the data is also available.

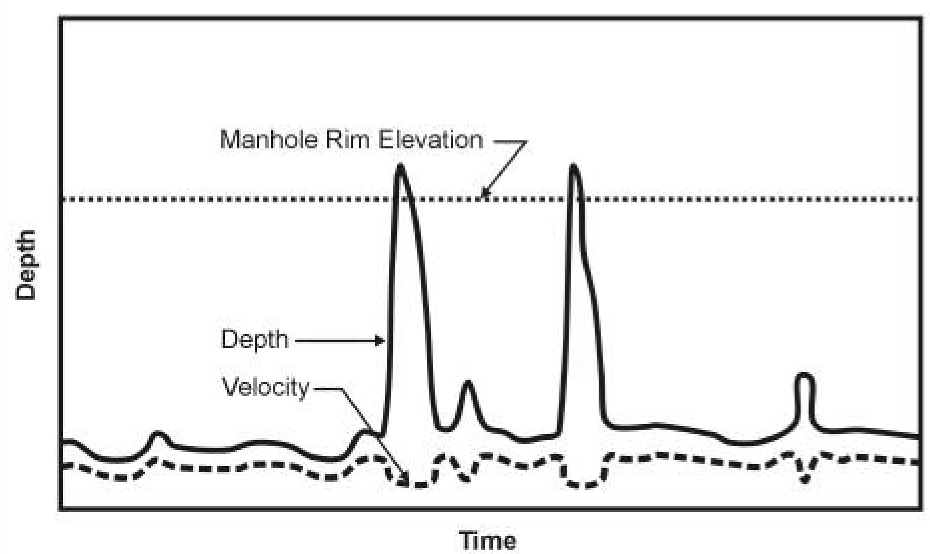
Figure 5-2
Typical Flow Monitor Installation



The flow data can be used to determine the average daily flow, the infiltration rate, and the inflow rate. The rain gauge data can be used to determine the recurrence interval or severity of the storm event (for example, 5-year) that caused the inflow. The flow data will also indicate whether a surcharge occurred during the flow monitoring period. Figure 5-3 is an example of a flow condition with a bottleneck downstream. During a rain event, the depth increases, but velocity decreases. Depth increases until water level rises above the manhole rim, and overflow occurs. The increase in depth is caused by to a bottleneck downstream. A bottleneck has the same throttling effect on sewer flow as a two-lane bridge has on traffic along a six-lane highway.

Once the amount of flow is established, an analysis can be performed to determine the level of protection against surcharging. This is achieved by comparing the capacity of the line with the expected flows for a given storm event. The flow data can also be used for hydraulic modeling calibration.

Figure 5-3
Depth & Velocity Versus Time



Evidence of Surcharge from Depth & Velocity versus Time Diagram

Hayes (31) reports that Sydney, Australia, has installed about 400 permanent monitoring stations in its collection system. The data from these stations are downloaded via dial-up telephone lines. The analysis of the flow data has helped identify the location, frequency, and quantity of SSOs.

5.3.7 Monitoring of Receiving Streams Sewage Indicators

This technique may be used for identifying the locations of dry weather SSOs. Samples from a nearby stream are taken and tested for fecal coliforms. Significant presence of these bacteria would be an indication of sewage leaking from the sewer line into the stream. A study by Gallagher and Brown (9) indicated that fecal coliform counts higher than 100 to 6000 per 100 milliliters were indicative of sewage in the stream. Some agencies have experimented with measuring the concentration of caffeine in the stream water with encouraging results. As part of a recent study, the US Geological Survey (USGS) was able to measure the ability of the Mississippi River to dilute sewage by measuring caffeine concentrations first in domestic sewage and then in the river. The City of Kansas City, Missouri is working with the USGS in monitoring caffeine concentrations in its combined sewer overflows.

5.3.8 Event Notification Systems

Event notification is a process used to predict SSOs by observing prior rainfall data or key upstream flow quantities or depth. This process uses a critical prior or upstream condition to warn of a future or downstream result. For example, the historical data may show that a certain manhole has overflowed every time a nearby rain gauge registered a certain rainfall intensity. This information can be used to predict future SSOs at that manhole by monitoring the rain gauge.

5.3.9 Closed Circuit Television (CCTV) Inspection

CCTV inspection has been widely used for inspection of sewer line interiors. The final of a CCTV inspection is videotape and a field log prepared and narrated by an operator. The success of a CCTV inspection depends largely on the operator's experience. Most CCTV equipment on the market includes color cameras with tilt and pan capabilities.

The videotape provides a visual and audio record of problem areas in the sewer line. Evaluation of the CCTV records will help identify structural problems; locate leaking joints and non-structural cracks, blockages, and dropped joints; and identify areas of root intrusion. Coe (26) reported that during one CCTV inspection, three locations were found where water service lines had been punched through the sewer line.

5.3.10 Sewer Scanner and Evaluation Technology Surveys (SSET)

The SSET is a new pipeline inspection technology developed in Japan. The equipment consists of a scanner, a CCTV, and a three-axis mechanical gyroscope. The mechanics of placing the SSET in the sewer line are similar to those of CCTV inspection. The images produced by SSET are of higher quality than CCTV images. Interpretation of the results is done in the office by an engineer rather than in the field by a technician. This increases the speed of field operations and reduces the cost.

The scanned image is digitized and a color coded computer image is produced. Statistical data on defects can be generated. Since the data are in digitized form, it is possible to develop software programs to automatically interpret the images and to diagnose the defects. Research is underway to develop such diagnostic tools using neural network and fuzzy logic techniques.

5.3.11 Surcharge Level Alarms/Remote Monitoring

These devices can be placed at strategic locations in the manholes and pumping stations. Once the flow reaches a certain elevation, the alarm goes off and sends a signal to a control center via a telephone line or SCADA system. The sewerage agency should have a plan in place to respond immediately to such alarms. In addition to taking appropriate action, the event should also be recorded in a database.

5.3.12 Dye Tracing

Dyed water testing consists of dye tracing or flooding, and is done to locate possible sources of inflow such as area drains or catch basins suspected of being connected to the sewer line, or sources of rainfall-induced infiltration/inflow which indirectly contribute to the flow in the sewer line through the soil and pipe cracks. Dye testing is normally used to complement smoke testing of suspect areas. The downstream manhole is monitored to see if the dye water injected into an outside source such as a downspout has found its way into the sewer system. Color CCTV may also be used for locating problem areas after the dye enters the pipeline through the surrounding soil. Figure 5-4 is a sample form for recording the results of dye water inspection.

5.3.13 Smoke Testing

The purpose of smoke testing is to locate rainfall-dependent I/I sources which could lead to SSOs during a storm events. Public notification is an important and critical element of any smoke testing program. Local fire departments and police departments should be kept informed of the testing on a daily basis. Specific I/I sources detected by smoke testing includes roof, yard, and area drain connections; catch basins; and broken service lines. The testing procedure consists of pumping non-toxic smoke through a manhole into the sewer pipe for distances up to 600 ft. The smoke will surface through open breaks in the pipe connections. All such sources are photographed and documented. An assessment of the quantity of I/I should be made based on the area and type of ground cover of the catch basin. The capacity of the line should be compared with the expected flow to assess the potential of an SSO occurrence. Figure 5-5 is a sample form for recording smoke inspection results.

Smoke testing should not be done when the ground is saturated, when the pipe is flowing full, or during rainy or windy weather.

5.3.14 Aerial Monitoring

Aerial monitoring by helicopter may be used to gain a general understanding of conditions along a sewer line which may lead to an SSO. For example, washout may expose a section of pipe, which would then be at risk of damage and subsequent SSO. The aerial monitoring should be performed in the fall when tree leaves do not obstruct the view. The route can be videotaped and snapshots can be taken of special features. Examples of features which may be observed during such monitoring include manholes with broken or missing covers, and sewer lines exposed by erosion. Following aerial monitoring, a more detailed field inspection may be conducted in problem areas.

Infrared themography may also be used in aerial monitoring. An infrared scanner will be mounted in the helicopter flying over the sewer line. The scanner measures the temperature difference between the soil above the sewer line and the surrounding areas. It can detect voids around the sewer line as well leaking joints.

5.3.15 Monitoring of Grease Buildup

A significant cause of SSOs during dry weather is sewer stoppages resulting from grease buildup. Such stoppages occur most frequently in downtown areas where restaurants are major sources of flow in the sewer system. A list of locations of grease buildup should be developed and these locations should be regularly inspected. Grease buildup can be prevented by enforcing grease ordinances, by effective pretreatment programs, and by promoting public education. The grease accumulations can be removed using the many available cleaning techniques, such as bucket machines with brushes, power rodders, and high velocity jet cleaners. Bioaugmentation, which involves the addition of bacteria cultures to sewers to speed up the breakdown of grease deposits, can also be effective.

Figure 5-4

Example Dyed Water Inspection Form

Dyed

Owner:	Project No.:
Inspection Date/Time: AM/PM	Inspection Crew:
Upstream MH No.:	Subsystem (Monitoring):
Downstream MH No.:	Location/Interceptor:
Sewershed:	Map:
Station:	Sheet:
Plan I.D.:	Segment Length:

Observations

Weather/Ground: 1 Dry
2 Moderate
3 Wet

Source Note / Address	Suffix	Results	Sector	Source Type	Location	Area	Runoff C	Flow
	-							
	-							
	-							
	-							
	-							
	-							

Codes

	Results	Sector	Source Type	Location
1 –	Negative	Public	Service Connection	Paved-Conc.
2 –	Positive	Private	Transition Joint	Paved-Asph.
3 –	Cannot Test		Driveway Drain	Driveway
4 –			Window Well Drain	Sidewalk
5 –			Stairwell Drain	Curb
6 –			Area Drain	Yard-Front
7 –			Down Spout	Yard-Back
8 –			Down Spout Connection	Yard-Side
9 –			Foundation Drain	Non-Paved
10 –			Building Inside	Creek Bottom
11 –			Catch Basin	Field
12 –			Storm Ditch	Golf Course
13 –			Storm Manhole	
14 –			Main Sewer	
15 –			Clean-out	
16 –			MH Frame Seal	

Sketch: (Show Placement of Plugs, Drainage Area, Response Time)

(Not to Scale)

N

Source: Black & Veatch Corporation

Figure 5-5
Example Smoke Testing Form

Smoke

Owner: ______________________ Project No.: ______________________

Inspection Date/Time: ______________ AM/PM Inspection Crew: ______________________

Upstream MH No.: ______________________ Subsystem (Monitoring): ______________________

Downstream MH No.: ______________________ Location/Interceptor: ______________________

Sewershed: ______________________ Map: ______________________

Station: ______________________ Sheet: ______________________

Plan I.D.: ______________________ Segment Length: ______________________

Observations

Weather/Ground: 1 Dry
2 Moderate
3 Wet

Source Note / Address	Suffix	Results	Sector	Source Type	Location	Area	Runoff C	Flow (gpm)

Codes

	Results	Sector	Source Type	Location
1 –	Negative	Public	Service Connection	Paved-Conc.
2 –	Positive	Private	Transition Joint	Paved-Asph.
3 –	Cannot Test		Driveway Drain	Driveway
4 –	+ Dye Tested		Window Well Drain	Sidewalk
5 –	- Dye Tested		Stairwell Drain	Curb
6 –	Suspect		Area Drain	Yard-Front
7 –			Downspout	Yard-Back
8 –			Dwnspt Connection	Yard-Side
9 –			Foundation Drain	Non-Paved
10 –			Building Inside	Creek Bottom
11 –			Catch Basin	Field
12 –			Storm Ditch	Golf Course
13 –			Storm Manhole	
14 –			Main Sewer	
15 –			Cleanout	
16 –			MH Frame Seal	

Sketch: (Show Placement of Blowers, Source Suffix, Drainage Area, Identify Condition)

(Not to Scale)

N

Source: Black & Veatch Corporation

5.3.16 Pump Station Inspection

Pump station failures can lead to significant SSO problems. Such failures can be avoided by regular inspections. The frequency of inspections may vary from once a day to once a month, depending on the size and criticality of the station, and reliance on monitoring by means such as the SCADA system. A sample Pump Station Inspection Form is shown on Figure 5-6.

The sewerage agency should have an emergency response plan in place to respond to pump station failures. Such plan should incorporate the use of generators, pumps, tank trucks, and other equipment.

5.3.17 Manhole Inspection

Manhole interiors are inspected for physical soundness for evidence surcharging such as high water marks on manhole walls. The observed defects should be compiled into a database that will be used to estimate the I/I attributable to each manhole and to establish manhole maintenance and rehabilitation program. An example of a Manhole Inspection Form is shown on Figure 5-7.

Inspection involves a confined space entry into the manhole and observation of all parts of the manhole, cover, frame, chimney, cone, wall, bench, and invert. Improvements in video cameras and other equipment have made it possible to conduct inspections from the ground surface. Inspection results in digitized form can be added to the SSMS. Manholes which are buried, hazardous, or inaccessible, or which cannot be located should be listed accordingly. Each manhole should be photographed and observed defects recorded on the Manhole Inspection Form.

Figure 5-6
Example Pump Station Inspection Form

Pump Station

Owner: ______ Project No.: ______
Inspection Date/Time: ______ AM/PM Inspection Crew: ______
Upstream MH No.: ______ Subsystem (Monitoring): ______
Downstream MH No.: ______ Location/Interceptor: ______
Sewershed: ______ Map: ______
Station: ______ Sheet: ______
Plan I.D.: ______

General

Client Station ID# ______

Constrction Cost ______

General

Station Name: ______
Location: ______
Date of Construction: ______
Rated Capacity (gpm): ______
Force Main Diameter: ______
Force Main Length (ft): ______

Station Type:
1. Pneumatic Ejection
2. Factory Assembled Wet-Pit
3. Factory Assembled Dry-Pit
4. Conventual-Small
5. Conventual-Medium
6. Conventual-Large

Type of Flow Meter:
1. None
2. Magnetic / Doppler
3. Other

System Monitoring:
1. None
2. SCADA

Force Main Material:
1. VCP
2. RCP
3. CMP
4. PVC
5. D/CIP
6. ABS
7. Other

Observations

	Pump 1	Pump 2	Pump 3	Pump 4	Pump 5
Assigned Pump No.:					
Motor No.:					
Manufacturer:					
Horse Power:					
Motor Voltage:					
Motor Amperage:					
Motor Kilowatts:					
Motor Efficiency:					
Motor Speed (RPM):					
Manufacturer Pump No.:					
Pump Rated Capacity (gpm):					
Total Head:					
Flow:					
Impeller Dia.:					
Impeller No.:					

Comment: ______

Source: Black & Veatch Corporation

Figure 5-7

Manhole

Owner: ______ Project No.: ______
Inspection Date/Time: ______ AM/PM Inspection Crew: ______
Manhole No.: ______ Subsystem (Monitoring): ______
Sewershed: ______ Location/Interceptor: ______
Station: ______ Map: ______
Plan I.D.: ______ Sheet: ______

General

Status: 1 Surface Inspected; 2 Internal Inspected; 3 Not Inspected; 4 Not Found; 5 Buried

Location: 1 Paved-Conc.; 2 Paved-Asph.; 3 Driveway; 4 Sidewalk; 5 Curb; 6 Yard-Front; 7 Yard-Back; 8 Yard-Side; 9 Non-Paved; 10 Creek Bottom; 11 Field; 12 Golf Course

Traffic: 1 Two Lane; 2 3-4 Lane; 3 Highway; 4 Parking; 5 Alley; 6 Driveway; 7 Other

Volume/Access: 1 Low/Good; 2 Medium/Fair; 3 High/Poor

Structure Type: 1 Manhole - Offline; 2 Manhole - Offset; 3 Manhole - Open; 4 Manhole - Window; 5 Meter Sta. # ____; 6 Siphon Box; 7 Junction Box; 8 Other

Weather/Ground: 1 Dry; 2; 3 Wet

Cover

Type: 1 Pick; 2 Concealed; 3 Gasketed; 4 Bolted # ____; 5 Vent; 6 Storm

Fit: 1 Good; 2 Tight; 3 Loose; 4 Rocking; 5 None

Condition: 1 Good; 2 No Gasket; 3 No Bolts; 4 Corroded/Pitted; 5 Cracked

No. of Holes: 1 None; 2 Pick (1); 3 Pick (2); 4 3 - 5; 5 6 - 8; 6 > 8

Ponding Depth (in): ______ Grade (+/-) (in): ______
Drainage Area: ____ X ____ = ____ Area (ft²) Cover No./Type: ______

Frame

Size (in): ____ / ____ / ____ / ____
Ck.Opn'G / Depth / Cover Opn'G / Frame Depth

Offset (in): ______

Condition: 1 Good; 2 Minor; 3 Fair; 4 Poor; 5 Deteriorated

Frame Seal

Condition: 1 Good; 2 Minor; 3 Fair; 4 Poor; 5 Deteriorated

Inflow: 1 None; 2 Low; 3 Moderate; 4 Heavy; 5 Severe

Observed Inflow (gpm): ______

Chimney

Depth (in): ______ Min Dia (in): ______

Const: 1 None; 2 Precast; 3 Brick; 4 Block; 5 Poured; 6 Other

Condition: 1 Good; 2 Minor; 3 Fair; 4 Poor; 5 Deteriorated

Inflow: 1 None; 2 Low; 3 Moderate; 4 Heavy; 5 Severe

Observed Inflow (gpm): ______

Cone

Depth (in): ______

Shape: 1 Concentric; 2 Eccentric; 3 Flat Top; 4 Other

Const: 1 None; 2 Precast; 3 Brick; 4 Block; 5 Poured; 6 Other

Condition: 1 Good; 2 Minor; 3 Fair; 4 Poor; 5 Deteriorated

Inflow: 1 None; 2 Low; 3 Moderate; 4 Heavy; 5 Severe

Defect Location: 1 Wall/Cone Joint; 2 Cone Surface; 3 Joint & Cone

Defect Quantity: 1 1; 2 2; 3 3; 4 4; 5 Multiple

Observed Inflow (gpm): ______

Wall

Minimum Dimensions (in): ____ X ____ (Diameter, Width) Bottom Dia (in): ______

Const: 1 None; 2 Precast; 3 Brick; 4 Block; 5 Poured; 6 Other

Condition: 1 Good; 2 Minor; 3 Fair; 4 Poor; 5 Deteriorated

Infiltration: 1 None; 2 Low; 3 Moderate; 4 Heavy; 5 Severe

Defect Location: 1 Wall Joint; 2 Top Half; 3 Bottom Half; 4 Entire Depth; 5 Wall Joint +; 6 Other

Defect Qty.: 1 1; 2 2; 3 3; 4 4; 5 Multiple

Observed Infiltration (gpm): ______

Bench

Const: 1 None; 2 Precast; 3 Brick; 4 Block; 5 Poured; 6 Other

Condition: 1 Good; 2 Minor; 3 Fair; 4 Poor; 5 Deteriorated

Infiltration: 1 None; 2 Low; 3 Moderate; 4 Heavy; 5 Severe

Observed Infiltration (gpm): ______

Channel

Const: 1 None; 2 Precast; 3 Poured; 4 VCP; 5 Plastic; 6 Other

Condition: 1 Good; 2 Minor; 3 Fair; 4 Poor; 5 Deteriorated

Infiltration: 1 None; 2 Low; 3 Moderate; 4 Heavy; 5 Severe

Hydraulics: 1 Good; 2 Minor; 3 Fair; 4 Poor; 5 Deteriorated

Observed Infiltration (gpm): ______

Step

Const: 1 None; 2 Bar; 3 Iron; 4 Plastic; 5 Other

Condition: 1 Good; 2 Minor; 3 Fair; 4 Poor; 5 Deteriorated

Surcharge Evidence (ft): ______
Note 1 (Overflow Yes/No): ______
Note 2: ______

Memo

Memo: ______

Example Manhole Inspection Form

Source: Black & Veatch Corporation

5.3.18 Line Lamping

Line lamping is done in conjunction with manhole inspection by inspecting the interior of the sewer lines connected to the manhole using an artificial light and a mirror. Lamping helps identify pipe defects and provides a basis for selecting sewers for television inspection. An example of a Lamping Inspection Form is on Figure 5-8.

The lamping inspection is done by entering the manhole, and observing the condition of the pipe, flow depth, and deposits or accumulation of debris. The observations should be recorded on the line lamping inspection form.

5.3.19 Building Inspection

Building inspections are conducted to investigate extraneous flow from connections to sump pumps, foundation drains, downspouts, or leaking laterals. Building inspections should include investigation of the causes of basement backups. A sample Building Inspection Form is given on Figure 5-9.

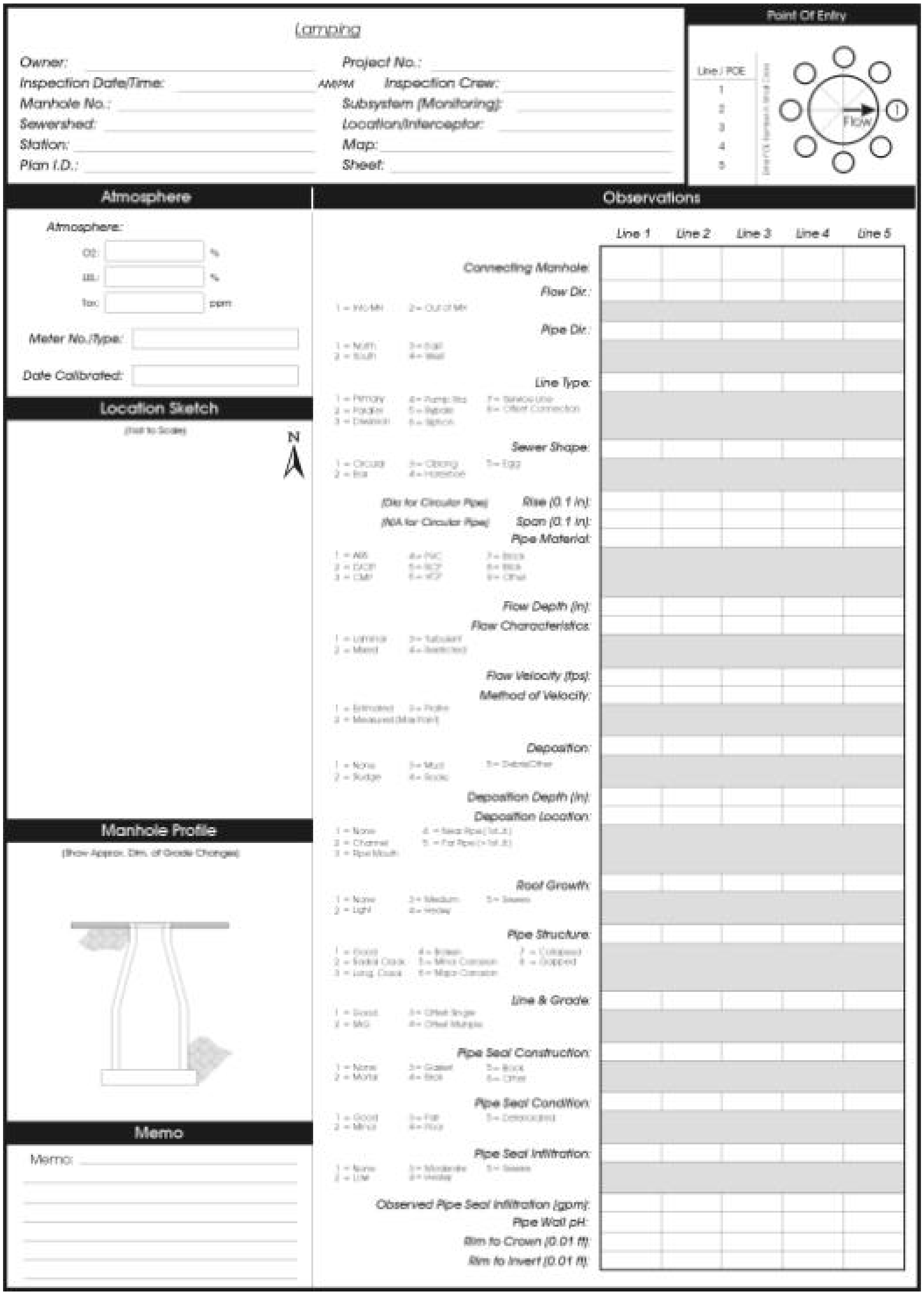
In addition, proper inspection of the service line and service connection to the main sewer during new construction or during demolition is important to reduce any extraneous flows entering the system from buildings.

5.3.20 Ground Penetrating Radar

Ground penetrating radar uses the transmission and reflection properties of an electromagnetic wave passing through the soil to determine soil properties and the depth and extent of subsurface objects. The speed and amplitude of the electromagnetic wave are dependent on the moisture content of the soil. This principle can be used to detect leaking joints in the line and voids around the pipe, which may be caused by soils being washed out. In such locations, the signal will be delayed because the speed of the wave will be reduced, and the amplitude of the wave will be attenuated.

During the survey, the ground penetrating radar device is drawn over the line at a constant speed; there is no need to enter the sewer line. This technique can therefore be used where the sewer is running more than half full and bypass pumping is not possible.

Figure 5-8
Example Lamping Inspection Form



Lamping

Owner:
Project No.:
Inspection Date/Time: AM/PM
Inspection Crew:
Manhole No.:
Subsystem (Monitoring):
Sewershed:
Location/Interceptor:
Station:
Map:
Plan I.D.:
Sheet:

Point Of Entry

Line / POE: 1, 2, 3, 4, 5

Flow

Atmosphere

Atmosphere:
O2: %
LEL: %
Tox: ppm

Meter No./Type:
Date Calibrated:

Location Sketch

N

Manhole Profile

Memo

Memo:

Observations

	Line 1	Line 2	Line 3	Line 4	Line 5
Connecting Manhole:					
Flow Dir.:					
Pipe Dir.:					
Line Type:					
Sewer Shape:					
Rise (0.1 in): (Dia for Circular Pipe)					
Span (0.1 in): (N/A for Circular Pipe)					
Pipe Material:					
Flow Depth (in):					
Flow Characteristics:					
Flow Velocity (fps):					
Method of Velocity:					
Deposition:					
Deposition Depth (in):					
Deposition Location:					
Root Growth:					
Pipe Structure:					
Line & Grade:					
Pipe Seal Construction:					
Pipe Seal Condition:					
Pipe Seal Infiltration:					
Observed Pipe Seal Infiltration (gpm):					
Pipe Wall pH:					
Rim to Crown (0.01 ft):					
Rim to Invert (0.01 ft):					

Source: Black & Veatch Corporation

Figure 5-9

Example Building Inspection Form

Building

Owner: ____________ Project No.: ____________

Inspection Date/Time: ____________ AM/PM Inspection Crew: ____________

Upstream MH No.: ____________ Subsystem (Monitoring): ____________

Sewershed: ____________ Location/Interceptor: ____________

Station: ____________ Map: ____________

Plan I.D.: ____________ Sheet: ____________

Occupant

Address: ____________ Telephone Number: ____________

Occupant Name: ____________ Building Age: ____________

Years in Building: ____________ Number of Occupants: ____________

Building Length: ________ -Width: ________ Number of Units: ____________

Observations

Status of Building: 1 Interview; 2 Interview / Call Back; 3 Interview + Internal / External Inspection; 4 Interview + External Inspection; 5 External Inspection; 6 No One Home; 7 Call Back; 8 Make Appointment; 9 Vacant; 10 Refused

Flooding History: 1 None; 2 Wall/Floor; 3 Sewer Backup; 4 Overland Flow

Building Type: 1 Res/Single; 2 Res/Duplex; 3 Res/Multi.; 4 Apartment; 5 Commercial; 6 Institutional; 7 Industrial; 8 Other

Downspouts: 1 None; 2 Overland; 3 Underground; 4 Underground/OK

Downspout Extensions: 1 None; 2 Short; 3 Medium; 4 Long

Ref. Bldg. Side: 1 1-Side; 2 2-Side; 3 3-Side; 4 4-Side; 5 5-Side

Reference Direction: 1 North; 2 South; 3 East; 4 West

Lot Grading: 1 Good; 2 Flat; 3 Poor

Driveway Drain: 1 No; 2 Yes/Unknown; 3 Yes/Ok; 4 Yes/Sewer

Area Drain: 1 No; 2 Yes/Unknown; 3 Yes/Ok; 4 Yes/Sewer; 5 No/Unknown

Foundation Type: 1 Slab; 2 Crawl; 3 Partial Basement; 4 Basement

Foundation Construction: 1 Poured; 2 Block; 3 Rock; 4 Other

Elevation Service Pipe: 1 Below Floor; 2 Above Floor; 3 Overhead

Floor Drain: 1 None; 2 Sealed Bottom; 3 Open Bottom

Crawl Space Drain: 1 No; 2 Yes

Sanitary Sump: 1 None; 2 Sealed; 3 Unsealed; 4 Can't Open

Sanitary Pump: 1 None; 2 Discharge Sanitary; 3 Discharge Outside; 4 Discharge Unknown

Storm Sump: 1 None; 2 No FND Drains; 3 FND Drains/Sealed; 4 FND Drains/Unsealed

Storm Pump: 1 None; 2 Discharge Sanitary; 3 Discharge Outside; 4 Discharge Unknown; 5 Diverter Valve

Notes

Note: ____________

Source: Black & Veatch Corporation

5.3.21 Soil Moisture and Temperature Monitoring

When the ground is relatively dry, a larger portion of the rainfall will penetrate the soil, which will result in lower inflows. However, as the soil moisture increases, the amount of inflow increases. For this reason, the impact of the next storm will be more severe: while the system did not overflow during the first storm, it will do so during the second storm, although the second storm of smaller intensity than the first. This phenomenon has been observed in Dallas, Texas, and is reported by Sieger (45).

Similarly, when the ground is frozen, the inflow is considerably increased. By monitoring the soil moisture and temperature, it may be possible to develop a measure for assessing the occurrence of SSOs.

5.3.22 Inspections of Stream Crossings and Parallel Lines

Pipes paralleling or crossing streams are often vulnerable to SSOs. If the sewer is buried under the streambed, the scouring action of the stream bed will eventually expose it, causing the pipe to lose its soil support. The pipe segments may move under the water pressure and joints may open, or the pipe may become exposed as a result of bank erosion. Any such openings admit significant amounts of flow, which may exceed the capacity of the sewer pipe. Stream crossings that include inverted siphons often become clogged with accumulations of silt and debris, which may cause an overflow upstream. The foundations of aerial stream crossing piers are also subject to scouring and may lead to foundation failure of the sewer line.

Sewer pipes that cross or parallel streams should be inspected to ensure that they are not broken or cracked. The manholes on each side of the stream should be checked for excess flow, which would indicate a leaking sewer under the stream. Since these sewers are usually in remote areas, they are vulnerable to vandalism and can overflow undetected for long periods. Stream stabilization and sewer relocation would involve long-range planning, design, permitting, and construction, so it is important to identify these problems as early as possible. Additionally, there may be inter-jurisdictional issues to be resolved. For example, while the sewerage agency owns the sewer line and the right-of-way to cross the stream, the stream itself is owned by another entity, with whom the sewerage agency has to negotiate the stream stabilization costs and other matters.

6.0 Structural Protocols

6.1 Objective

The objective of structural protocols is to define available techniques for identifying structurally deficient pipes which may collapse, leading to SSOs.

6.2 Structural Integrity Related Problems

A sewer line's structural integrity can be compromised by several factors, leading to its partial or full collapse and subsequent backup. Such factors include hydrogen sulfide corrosion, excessive external dead or live loads, erosion of soil cover, damage from third party activities, and deterioration of pipe material.

6.3 Evaluation Criteria for Brick Sewers

Brick sewers often fail as a result of loss of mortar by erosion, corrosion, or aging. The cement in the mortar degrades to the point where the mortar can easily be removed from between the bricks. If the deteriorated mortar is washed out by infiltration, vertical deformation as well as longitudinal cracks and gaps in the bricks may lead to a sudden collapse of the brick sewer. Table 6-1 presents a typical checklist for evaluating the structural condition of brick sewers. Each of these items should be given severity rating and a description.

Table 6-1

Brick Sewer Structural Evaluation Criteria

Item	Condition	Description
1	Sags	The pipeline invert drops below the downstream invert.
2	Vertical Deflections/Cracks	A reduction in vertical dimension of the sewer; crack lines visible in the brick and/or mortar; bricks have moved apart from one another; bricks still in place.
3	Missing Bricks	Single bricks, or areas of bricks are missing.
4	Lateral Deflections	Deformed sewer or original cross section of sewer altered.
5	Root Intrusion	Tree or plant roots that have grown into or entered the sewer through brick intersections.
6	Missing Mortar	Mortar between brickwork missing to a degree varying from surface loss to medium or total loss. Bricks still in place.
7	Loose Bricks	A forerunner of missing bricks is displaced bricks, i.e. single bricks, or areas of bricks, have moved from their original position.
8	Protruding Laterals	A service outlet or pipe section that protrudes or extends into the sewer.
9	Soft Mortar	A forerunner of loose or missing brick and sewer shape change, usually caused by corrosion.
10	Depth of Cover	The deeper and larger the sewer, the more critical the defects that could cause a failure become.

6.4 Evaluation Criteria for Concrete and Clay Sewers

The evaluation criteria for the structural condition of concrete and clay sewers are less complex than those for brick sewers. Many concrete (reinforced or unreinforced) and clay sewers continue to function even when in structurally critical condition. Over time, as the problem worsens, the sewer pipe will eventually collapse under the external loading. Table 6-2 lists typical items for evaluation of concrete and clay sewers. Each of these items should be given a severity rating and a description.

Table 6-2

Structural Evaluation Criteria for Concrete and Clay Sewers

Item	Condition	Description
1	Collapsed Pipe	Complete loss of structural integrity of the pipe, most of cross-sectional area lost.
2	Structural Cracking with Deflection	Pipe wall displacement.
3	Slab-out	A large hole in the sewer wall with pieces missing.
4	Structural Cracking without Deflection	Sewer wall cracked but not displaced.
5	Cracked Joints	The spigot and/or bell of a pipe is cracked or broken.
6	Open Joints	Adjacent pipes are longitudinally displaced at the joint.
7	Holes	When a piece of pipe wall or joint is missing.
8	Root Intrusion	Tree or plant roots that have grown into or entered the sewer through an opening in the pipe wall.
9	Protruding Joint Material	When the original joint sealing material is displaced into the sewer from its original location.
10	Corrosion	When the cementitious pipe material shows evidence of deterioration.
11	Pulled Joint	Adjacent pipe joints are deflected beyond allowable tolerances.
12	Protruding Lateral	A service outlet or pipe section that protrudes or extends into the sewer varying in magnitude.
13	Vertical Displacement	The spigot of the pipe has dropped below the normal joint closure.

6.5 Available Techniques

6.5.1 Closed Circuit Television (CCTV) Inspection

Closed circuit television inspection has been widely used for examining the interior of sewer lines. The final product of a CCTV inspection are videotape and a field log prepared and narrated by an operator. The success of a CCTV inspection depends to a large extent on the operator's experience. Most CCTV equipment consists of color cameras with tilt and pan capabilities.

The videotape provides a visual and audio record of problem areas. Evaluation of the CCTV records will help identify structural problems; locate leaking joints and non-structural cracks, blockages, and dropped joints; and identify areas of root intrusion. Coe (26) reported that during one CCTV inspection, three locations were found where water service lines had been punched through the sewer line. Such conditions can compromise the structural integrity of the sewer line. Mehl (49) reported that Columbus, Ohio has reported sewer lines in backyard easements having been punctuated by utility poles and fence posts.

6.5.2 Sewer Scanner and Evaluation Technology Surveys (SSET)

The SSET is a new pipeline inspection technology developed in Japan. The system consists of a scanner, a CCTV, and a three-axis mechanical gyroscope. The mechanics of placing the SSET in the sewer line are similar to those of the CCTV inspection. The images of SSET are of higher quality than CCTV images. The results are read in the office by an engineer rather than in the field by a technician. This increases the speed of field operations and reduces the cost.

The scanned image is digitized and a color coded computer image is produced. Statistical data on defects can be generated. Since the data are in digitized form, it is possible to develop software programs to automatically interpret the images and to diagnose the defects. Research is underway to develop such diagnostic tools using neural network and fuzzy logic techniques.

6.5.3 Man-Entry Inspection

Man-entry inspections may be performed on large diameter sewer lines and tunnels. The inspection should include observing the appearance of the sewer line walls, signs of flow disturbances, extent of corrosion, and the structural condition of the sewer line. Sounding tests may be performed by striking the pipe crown, sidewalls, and invert with a hammer and note whether the sound is dull or solid. Any observed defects should be photographed. The interior surface of the sewer line should be videotaped.

The extent of corrosion should be determined by field measurements of pH, dissolved oxygen, ambient hydrogen sulfide, and dissolved hydrogen sulfide.

When entering the sewer line, safety precautions are of paramount importance and confined space entry procedures specified by OSHA must be followed. If the flow of wastewater cannot be diverted, inspections should be performed at night and during dry weather when wastewater flow is lowest. Ventilation fans should be used to ensure that the crew inside the sewer line has good ventilation. Harnesses must be used for entry and exit structures. Gas detectors, escape capsules, flashlights, emergency air-horns, and life-vests should also be available. The inspection should be conducted by at least two persons, who should be in constant communication with personnel outside the sewer line.

6.5.4 Internal Corrosion Monitoring

Pipe failures caused by corrosion are usually catastrophic, since corrosion results in an unexpected and sudden structural failure of the pipe and its repair involves major construction. SSOs resulting from this type of failure are less frequent than those from other causes, but tend to be more severe in terms of their volume and consequences.

The atmosphere in a sanitary sewer line is conducive to generation of hydrogen sulfide (H_2S), which can cause undesirable odors, can be lethal in high concentrations, and can cause corrosion of unprotected sewer pipes. The area most vulnerable to corrosion is interior pipe wall above the flow line. At points of high turbulence such as drops, manholes, junctions, and other structures, H_2S is released very rapidly and can result in severe corrosion, leading to loss of structural integrity and collapse of the sewer line.

Changes in wastewater characteristics can either accelerate or inhibit the rate of corrosion. In Los Angeles, it was determined that as a result of an industrial pretreatment program which reduced metals concentrations in the wastewater discharge to sewers less sulfide was being precipitated out of the wastewater, and consequently more sulfide became available to migrate into the sewer atmosphere, causing more corrosion. Some pretreatment programs may also promote the growth of sulfide-generating bacteria by removing heavy metals which are toxic to such bacteria.

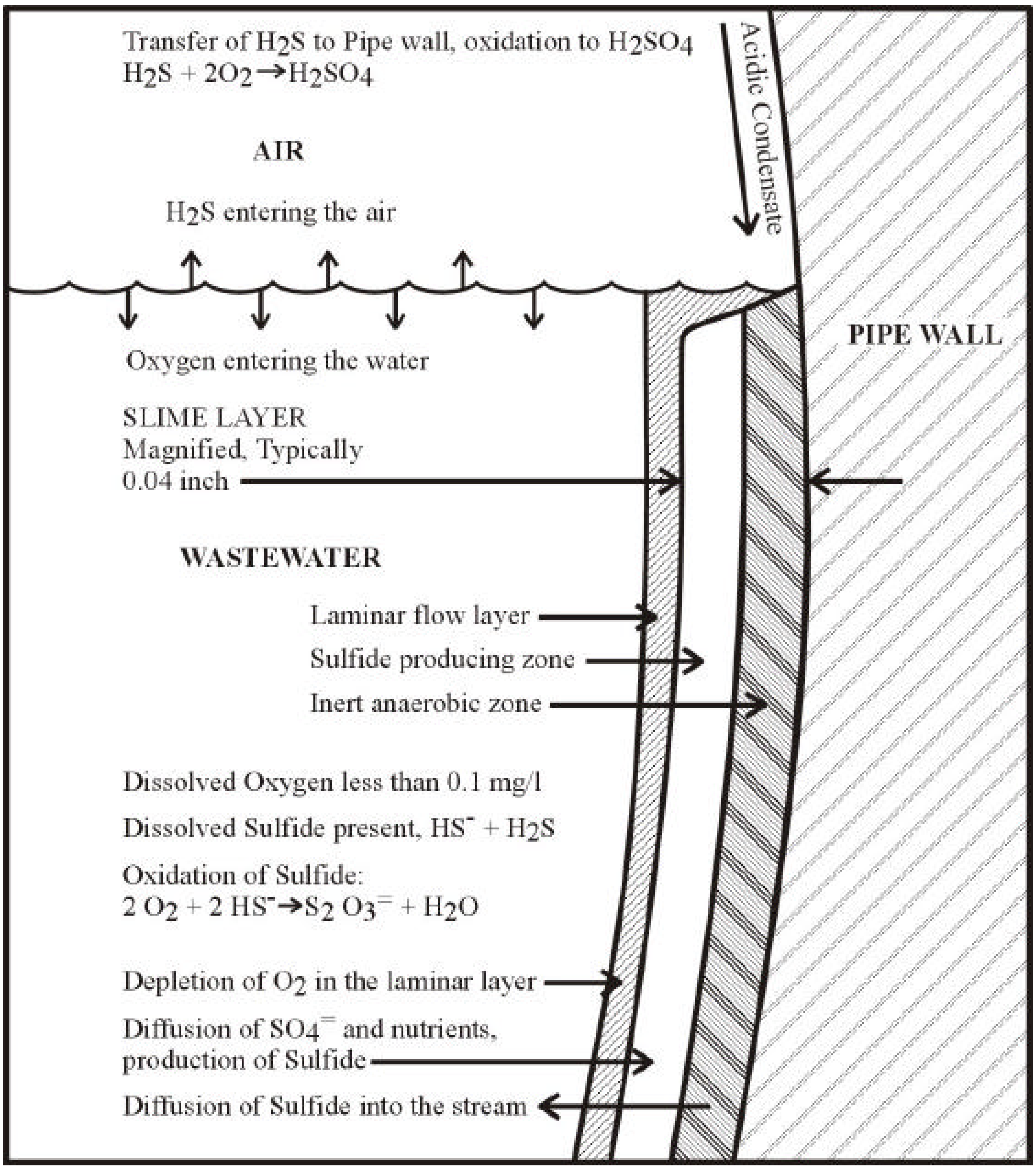
Monitoring of internal corrosion involves field measurement of wastewater constituents such as ambient and dissolved oxygen, ambient and dissolved hydrogen sulfide, pH, and temperature. By analyzing the results of these measurements, the potential corrosivity of the wastewater can be determined. Additional information on the extent of corrosion can be gained by direct measurements of decrease in pipe wall thickness and review of CCTV images.

A discussion of corrosion mechanisms in sewer lines is presented in the following paragraphs to provide a general framework for understanding of the analysis of corrosion data.

6.5.5 Hydrogen Sulfide Monitoring

Sulfide corrosion in sewers is the result of the contact of sulfuric acid (H_2SO_4) with the sewer pipe material. Sulfuric acid is formed when hydrogen sulfide gas in a sewer line that is flowing partially full is oxidized by bacteria on the sewer walls. Figure 6-1 illustrates the sulfide generation process in a sanitary sewer.

Figure 6-1
Processes Occurring in Sewer under Sulfide Buildup Conditions



In this discussion, the term "sulfide" is used as a general term to refer to compounds containing the sulfide ion, S^{-2}, including H_2S (hydrogen sulfide) and HS^- (hydrogen sulfide ion).

Hydrogen sulfide in sewers comes from a variety of sources, but is primarily the result of the bacterial reduction of sulfate ion. Hydrogen sulfide can also be present in discharges from industrial sources or septage.

The relative concentration of H_2S, HS^-, and S^{-2} in wastewater depends on the wastewater pH. In the typical pH range for sewage, sulfide is normally present as H_2S and HS^-. At a wastewater pH of 7, 50 percent of the sulfide concentration is present as H_2S and 50 percent is present as HS^-. At a pH of 6, 90 percent of the sulfide concentration is present as H_2S. At a pH of 5, 99 percent of the sulfide concentration is present as H_2S. As the concentration of H_2S increases, the potential for odor and corrosion increases. As such, as the pH of wastewater is lowered, its potential for creating odor and causing corrosion increases.

The reduction of sulfate to sulfide can occur only in an anaerobic environment and usually occurs in the slime layer along the sewer walls. The thickness of the slime layer depends on the flow velocity in the sewer and the presence of abrasives in the wastewater which may scour the slime layer off the pipe wall. The thickness of the slime layer is typically about 0.04 inches. Sulfate ion, organic food, and nutrients diffuse into the anaerobic layer and the sulfide that is generated diffuses outward.

The rate of sulfide generation has been shown to increase as the temperature and the strength (BOD) of the wastewater increase. An increase in the dissolved oxygen (DO) concentration will reduce the rate of sulfide generation and also increase the rate at which sulfide is oxidized back to sulfate ion, thiosulfate ion, or elemental sulfur.

The sulfides generated in the slime layer, can remain in solution, be precipitated as metallic sulfide compounds, be oxidized, or be released as hydrogen sulfide gas into the sewer headspace. The release of the H_2S gas is the next step in the sulfide corrosion process.

The precipitation of metallic sulfides such as ferrous sulfide is one of the mechanisms by which sulfide concentrations in sewers are reduced and is one of the methods available for actively controlling sulfides in sewers:

$$H_2S + Fe^{++} \rightarrow FeS + H^+$$

It is possible in some instances for the precipitation of metallic sulfide compounds in sewers to adversely affect the downstream wastewater treatment process by removing trace nutrients from the wastewater stream.

Turbulence in the pipeline will act to increase the dissolved oxygen concentration in the wastewater. At the same time, however, the release of hydrogen sulfide to the atmosphere also increases when turbulence is present. This is specially pronounced at drops, manholes, junctions and other structures where there is increased turbulence.

The rate of release of H_2S into the sewer head space increases as the sulfide concentration in the wastewater increases and as the driving force (the relative concentration of hydrogen sulfide in the wastewater compared to the concentration in the atmosphere overhead) increases. As the concentration of H_2S in the atmosphere increases, the rate at which additional gaseous H_2S is released from the wastewater will decrease because the driving force is reduced.

Hydrogen sulfide in the sewer head space is taken up on the damp walls of the sewer. A specific type of bacteria (genus thiobacillus) converts the H_2S to sulfuric acid in an aerobic environment

$$H_2S + 2\,O_2 \xrightarrow{\text{bacteria}} H_2SO_4$$

This reaction requires the presence of moisture and oxygen to proceed. The sulfuric acid that is formed converts calcium carbonate in the unlined concrete pipe to gypsum:

$$\underset{}{H_2SO_4} + \underset{\text{(calcium carbonate)}}{CaCO_3} \rightarrow H_2CO_3 + \underset{\text{(gypsum)}}{CaSO_4}$$

The gypsum forms a pasty mass which has no structural strength and is loosely bonded to the concrete aggregate. The presence of sulfuric acid on the surface of the pipe is evidenced not only by the visible corrosion, but also by low pH measurements at the pipe wall. Low pH at the pipe surface is usually considered indicative of conditions that are conductive to sulfide corrosion, even if corrosion is not yet observed.

6.5.6 Monitoring of External Corrosion

The environment in which the sewer line is installed can affect its long-term performance. The critical factors include pipeline materials, soil type, moisture and free oxygen. Clay pipes are almost inert to the environment and do not corrode. However, the steel reinforcing bars in the concrete pipe can corrode.

Generally, fine-grained soils, such as silt and clay, are more corrosive than coarse-grained soils, such as sand and gravel. If the ground water table is always either above or below the pipe, the potential for corrosion is minimal. However, when the ground water table near the pipe fluctuates, the wetting and drying cycles may result in a high chloride concentration and a supply of free oxygen in the mortar coating on concrete pipe, leading to the breakdown of the passivating film of the steel reinforcing bars in the pipe and accelerating of the corrosion process.

A number of methods are available for monitoring of external corrosion. Some of these methods are listed below:

- Measurement of Acidity of the Environment – The acidity of the soil around the pipe can be determined by measuring the pH of the soil. Various means are available for field checking pH values. If a sample of ground water in the vicinity of the pipeline can be obtained, it can be treated with an indicator solution and the resulting color compared with a color chart to obtain the approximate pH. If a direct water sample cannot be obtained, a sample of the soil may be leached in distilled water and the indicator solution used on the leachate.

- Measurement of the Electrical Resistivity of the Pipeline Environment – High resistivity soils offer resistance to current flow, which minimizes the potential for galvanic corrosion. Resistivity measurements can be made by the 4-pin (Wenner) method. This method gives the average conditions in the immediate area of the test rather than the resistivity of a specific sample of soil, which might have a much higher or lower resistivity than the general average.

- Measurement of Stray Currents – Stray currents from electrical railways, power lines, and other cathodically protected pipelines may be picked up by the sewer pipe and promote corrosion. Recording instruments may be used to measure stray currents. If the stray current is of manmade origin, there will be, in most cases, some sort of repetitive pattern revealed in the data. If the source of stray current is a transit system, the stray current effect will be strongest during periods of heavy travel. If the source of stray current is of another type such as mining operations using DC equipment, there may be readily identifiable load characteristics associated with shift changes.

- Measurements of Potentials between Pipeline and Environment (Potential Survey) – In potential surveys, the electrical potential (voltage) between the buried pipeline and its environment is measured using a voltmeter with the negative terminal connected to the pipeline and the positive terminal connected to a copper sulfate reference electrode in contact with the environment. Potential surveys can provide a general idea of the extent of corrosion, the locations of "hot spots" where corrosion is most severe, and the areas subject to stray current electrolysis.

- Measurement of Electrical Current Flowing on the Pipeline (Line Current Survey) – If corrosion is occurring on a pipeline, there will be current flow to the line at some point and flow from the line at others. Because the pipeline itself has some resistance to the flow of electric current, there will be a voltage drop in the pipe if current is flowing through this resistance. The voltage drops may be determined by instrumentation and measurement techniques. Permanent test stations may be installed for line current surveys.

- Measurement of the Effective Electrical Resistance of the Coating on the Pipeline – Although the same coating specifications may be used throughout the length of a given pipeline, the effective electrical resistance of that coating may vary considerably along the pipe, depending on the type of terrain, construction techniques, average soil resistivity, and quality of pipeline construction work and inspection. To measure the electrical resistance, a current is introduced into the pipe wall, and the voltage and current are measured at several locations. If the pipe is well coated, test locations could be spaced at intervals of more than one mile. The voltage drop between the test locations is used to assess the electrical resistance of the coating.

- Determination of Conditions Suitable for Anaerobic Bacterial Corrosion – Anaerobic corrosion is one manifestation of the effect of soil bacteria. Certain bacteria which exist under anaerobic conditions (absence of oxygen) on the pipeline surface can reduce any sulfates present and consume hydrogen in the process. Consumption of hydrogen at the pipe surface acts to depolarize the metal surfaces in cathodic areas and permits more rapid consumption of the metal by galvanic corrosion cells. The bacteria, do not directly attack the pipes but produce conditions conductive to more rapid attack by existing corrosion cells. The anaerobic potential is measured by a device called "Redox Probe". The potential reduction (called Redox Potential) is a measure of the reducing or oxidizing qualities of the soil. Values below 100 mV are indicative of severe potential of anaerobic corrosion; values above 400 mV indicate minimal anaerobic corrosion potential.

6.5.7 Surface Settlement Monitoring

Excessive vertical deformation of a sewer line can lead to settlement or cracking of the ground surface over the line. By monitoring the ground movements along the centerline of the buried sewer line, it is possible to locate areas of excessive deformation or possible collapse. Movement monitoring monuments may be installed at strategic locations over the line and monitored for settlement or horizontal movement using a level at a regular interval and after major storm events or earthquakes. Other instruments which may be used for settlement monitoring include extensometers and inclinometers.

6.5.8 Ring Sampling and Testing

Ring sampling and testing can provide first hand information about the condition of a sewer line. The ring samples can be used to measure the thickness of the pipe wall; to determine the extent of internal and external corrosion, the remaining wall thickness, the general characteristics of the pipe material, and the condition of the reinforcement; and to assess the structural strength of the pipeline. The ring sample can also be tested to determine the three-edge bearing strength of the pipe. The measured three-edge bearing strength is multiplied by a beding factor to obtain the field carrying capacity of the pipe.

6.5.9 Coupon Sampling and Testing

Coupon sampling and testing can produce information similar to that produced by the ring sampling and testing technique. The advantage of coupon sampling is that it involves only a small area of the pipe which is much easier to repair than the site of a ring sample is taken. However, the three-edge bearing test cannot be done on a coupon sample, and information about internal and external corrosion and minimum wall thickness would be limited to one spot as opposed to the ring sample, where such information would be available for the entire circumference of the pipe.

6.5.10 Structural Loading Analysis

The structural loading analysis can be performed to determine the external loading on the pipe and to compare it with the structural strength of the pipe to determine the factor of safety against failure. The Marston theory may be used to calculate the loads on buried pipes in trench and embankment conditions. The external loadings should include both earth loads and traffic loads. The Marston formula for earth loads on a pipe in a narrow trench is:

$$W = C_d w B_d^2$$

Where w is the unit weight of backfill soil, B_d is the trench width, and C_d is the trench load coefficient. The value of C_d value depends on the type of backfill soil, trench width, and depth of cover.

6.5.11 Finite Element Analysis

A more accurate analysis of external loading can be obtained by performing a finite element analysis of the pipe soil interaction. A finite element program specifically developed for analysis of buried pipelines has been developed by American Concrete Pipe Association. This program, which is referred to in the industry as "SPIDA" (Soil-Pipe Interaction Design and Analysis), can be run on a 486 PC with 3 megabytes of free disk space, and a minimum memory of 640 K. The program can determine the loads, earth pressure distribution and moment, thrust and shear stresses, and the required thickness of the pipe for concrete.

7.0 Closing Remarks

7.1 Closing Remarks

The information presented in this report describes comprehensive methods for identifying SSOs using hydraulic, maintenance and inspection, and structural protocols. The administrative requirements to implement the protocols should not be overlooked. Administrative requirements include sewer use ordinances, permitting, enforcement, and financing. The protocols must be selected based on the individual needs of each agency. In addition to these protocols, information regarding the SSO programs for leading agencies is presented with characteristic and performance data. These data can be useful to other agencies in establishing their own SSO control programs.

This guidance manual completes Phase 1 of the "Protocols for Identifying Sanitary Sewer Overflows ("Protocols") project and provides agencies with information for proactively dealing with SSOs in their systems. Phase 2 of the "Protocols" project includes two tasks for disseminating the information developed herein. As part of Phase 2 tasks, information brochures will be developed and distributed to interested parties, conferences, and organizations. The informational brochures will cover such topics as a general overview of SSOs, techniques for identifying SSOs, modeling of SSOs, and case studies.

By implementing the protocols for identifying SSOs described in this report, agencies can reduce the occurrence and magnitude of SSOs.

Appendix A

Literature Review

ASCE-EPA COOPERATIVE AGREEMENT
PROTOCOLS FOR IDENTIFYING SSOS

LITERATURE SEARCH

The following sources were used for the literature search:

- ASCE Online Database
- EPA Website
- WWW Search Engine Alta Vista
- Civil Engineering Magazine
- Water & Environment Technology Magazine
- Public Works
- Proceedings of the National Conference on SSOs, April 1995, Washington, DC
- Proceedings of WEF Collection Systems Rehabilitation and O&M Conference, July 1997, Kansas City
- Proceedings of WEF Sewers of the Future Conference, Sept. 1995, Houston, TX
- Proceedings of WEF Collection Systems Operation & Maintenance Conference, June 1993, Tucson, AZ
- Proceedings of WEFTEC 93, 94, 95,96,97 and 98
- Proceedings of WEF Conference on Advances in urban Wet Weather Pollution Reduction", July 1998, Cleveland, OH
- Proceedings of WEF Urban Wet Weather Pollution: Controlling Sewer Overflows and Storm Runoff, June 1996, Quebec City, Canada
- ASCE Publication on Urban Drainage Rehabilitation Programs and Techniques, 1994
- ASCE MOP No. 87 on Urban Runoff Quality Management, 1998
- Proceedings of ASCE Pipeline Conference, Phoenix, AZ, 1994
- Proceedings ASCE Conference on Infrastructure Condition Assessment, Boston, 1997
- US EPA Report to Congress, September 1997
- AMSA Survey on SSOs (unpublished)

A summary of the literature search follows. This information will be used in developing the Protocols for identifying SSOs and the Guidance Manual.

1. US EPA, "Final Report, Sanitary Sewer Overflow Workshop," Municipal Technology Branch, Washington DC, August 1995

A workshop on SSOs, which was held in Washington, DC in April 1995, focused on five specific areas: (1) preventive maintenance, (2) peak inflow, (3) rainfall-induced infiltration, (4) laterals, and (5) treatment options for wet weather flow. The workshop participants agreed that almost all-dry weather SSOs can be eliminated and most wet weather SSOs can be significantly reduced. Where wet weather SSOs cannot be eliminated, cost-effective storage and treatment options are available. The workshop participants identified four elements of an effective O&M program: (1) education, (2): program development and implementation, (3) local enforcement, and (4) clearly defined roles for regulators and professional organizations. Participants generally agreed that educating the public about the need for and benefits of preventive maintenance is the most important element.

2. US EPA, "SSOs, What Are They, and How Do We Get Rid of Them?", Office of Wastewater Management, Washington, DC 1996

This document outlines the causes of SSOs as (1) excessive rainfall, (2) inflow and infiltration, (3) sewers and pump stations are undersized, and (4) blockages, broken or cracked pipes, and other equipment or power failures. Blockages is responsible for about 43% of SSOs, infiltration and inflow for 27%, pipe breaks for 12%, power failure for 11%, and insufficient capacity for 7%. SSOs cause health risks and damage to property and environment. SSOs can be reduced by (1) sewer cleaning and maintenance, (2) upsizing or upgrading of sewer system, pumping station, or treatment plants, and (3) constructing wet weather storage and treatment facilities.

3. Weiss, Kevin, and Ben Lesser, "Use of Watershed Concepts to Address Sanitary Sewer Overflows", US EPA Website, May 1996

This paper recommends a watershed-based approach to controlling SSOs. Since urban watersheds are subjected to several pollutant sources, urban municipalities are faced with multiple water pollution control objectives, particularly during wet weather. The municipalities may need to control discharges from sewage treatment plants, sanitary sewer overflows, storm drains, and overflows from combined sewers. Watershed concepts introduced into key SSO areas include monitoring, discharge locations, discharge standards, and operational partnerships. One approach to environmental risk management is to move discharges from high-risk areas to lower risk areas. The shifting emphasis from traditional end-of-pipe water quality monitoring to ambient monitoring and other performance measures applies to SSO programs, too. Ambient monitoring combined with performance measures can provide a more thorough picture of water quality conditions and related health risks. Ambient monitoring can help identify priority water pollution control projects.

4. Ralph G. Petroff, "An Analysis of the Root Cause of SSOs", National Conference on SSOs, April 24-26, 1995, Washington, DC

A database of 8000 surcharging manholes from across the country indicated that over 96% of pipe surcharges are caused by lack of downstream hydraulic capacity. Downstream capacity restriction occurs because depth increases but velocity decreases. This is because of a bottleneck in the system, very much similar to traffic backup behind a narrow bridge on a major highway. The bottleneck can be due to undersized pipe, sags and joint offsets, roots and grease, and debris.

Another cause of SSOs is extreme flow due to I/I. A 1-year storm can generate a 4 to 10 fold peaking factor in small systems.

5. Robert Swarner & Michael Thompson, "Modeling I/I in Separated Sanitary Systems", National Conference on SSOs, April 24-26, 1995, Washington, DC

The paper describes a model used by King County Department of Metropolitan Services to model I/I in separate sanitary sewers in wet weather and dry weather conditions. The model provides the information on how much of the peak flow is the result of inflow and how much is from infiltration.

6. Allan, L. Rae, " Separate Sanitary Sewer Overflows in Illinois", National Conference on SSOs, April 24-26, 1995, Washington, DC

The Illinois Association of Wastewater Agencies conducted a survey of its members. Twenty-four members responded. Some of the highlights of the survey are: 83% had SSOs. 37% had a system for recording SSOs. 30% had an ongoing flow monitoring program. 87% reported SSOs during rainfall events. 83% of overflows occurred in developed areas. 74% reported having an I/I problem. 65% reported that structural defects were a cause of SSOs. 78% reported that age was a factor in SSOs. Maintenance spending was in the range of $1 to $3 per capita. 30% prefer designing for a 10-year storm, while 26% prefer a 25-year storm.

Most overflows occurred in basement. Flat slopes allows formation of hydrogen sulfide which lead to corrosion of the sewer pipe and its eventual failure. I/I and SSES efforts did not help reduce flow to treatment plant. Most I/I is from the private property.

7. Patrick L. Stevens and Heather M. Sands, "SSOs Leave Telltale Signs in Depth-Velocity Scattergraphs", National Conference on SSOs, April 24-26, 1995, Washington, DC

This paper indicates that SSOs can be located both downstream and upstream of a monitoring station by looking at the velocity versus depth diagrams (called Scattergraphs). A vertical line at high depths is indicative of an SSO downstream. A cluster of points at high depth is indicative of an SSO upstream.

8. Thomas C. Davies, "Real-World Hydraulic Modeling for Long Term SSOs Management", National Conference on SSOs, April 24-26,1995, Washington, DC

This paper states that a hydraulic model should be able to identify the location of SSOs; of equal importance, however, is the quantity of flow exiting the system from an SSO. Long term flow monitoring at strategic locations throughout the system, combined with rainfall intensity gauges, provides the best data for accurate modeling and long term control of SSOs. EPA's SWMM model and its EXTRAN module perform the type of analysis required to study backwater conditions. It however can suffer from hydraulic instabilities. Inexperienced users of SWMM often do not know when such instabilities occur. For this reason, SWMM is not recommended. The backwater calculations are imperative for analysis of SSOs. A model is needed which can determine the HGL. The HGL is required to determine the locations of SSOs and the quantity of flow leaving the system through SSOs.

9. Albert E. Gallagher and Scott L. Brown, " Stopping SSOs: Beneficial Maintenance Practices", National Conference on SSOs, April 24-26, 1995, Washington, DC

This paper states that neglect of proper sewer maintenance will result in sanitary sewer overflows. The paper describes the effect of SSOs on water quality. It indicates that fecal coliform of 100 to 6000 counts per 100 milliliters are indicative of sewage in stream water. Another factor is presence of ammonia and BOD.

The paper indicates that grease is a cause in 70% of SSOs, tree roots is involved in 49% of cases, rags is involved in 40% of cases, and sand is involved in 15% of cases.

A comprehensive complaint history database that includes SSO location and cause allows identification of recurring problem geographical areas and contributing factors.

10. Philip M. Hannan, et al, " Line Blockage Assessment Documents Sewer Conditions That Contribute to Overflow", National Conference on SSOs, April 24-26, 1958, Washington, DC

This paper describes a Line Blockage Assessment Program which includes emergency relief, customer contact, follow up cleaning, internal CCTV investigation of the problem sewer section, rehabilitation and preventive maintenance recommendations, and final customer correspondence and response. The objective of the program is to document the cause of the sewer backups and overflows and remedy the identified problems.

The study reports that overflows in WSSC system were due to poor alignment (33%), roots (14%), structural problems (4%), and grease (3%).

11. Timothy W. Kraus & Gordon R. Garner, " Prioritizing SSOs Based on System Impacts and Water Quality", National Conference on SSOs, April 24-26, 1995, Washington, DC

This paper is based on the experience of Louisville and Jefferson County Metropolitan Sewer District. It refers to a monitoring program of the streams to find the impact of discharges. The paper states that dry weather SSOs have an immediate impact on streams, while wet weather flow impact is not readily discernible.

12. Rob Frutchey, et al " Ohio and SSOs: Enforcement, Data Needs, and Implementation", National Conference on SSOs, April 24-26, 1995, Washington, DC

This paper reports on a number of panel discussions organized by the Ohio Water Environment Association SSO Subcommittee. It highlights the need for developing methods to identify the location and type of SSOs. It points out that biological measurements and monitoring should be considered as a tool to determine the effect of SSOs.

13. Art Hamid, " Infiltration Contribution From Private House Laterals and Services", National Conference on SSOs, April 24-26, 1995, Washington, DC

This paper discusses the effect of private sources on SSOs. It describes the City of Berkeley's program to evaluate the condition of the laterals and rehabilitate them.

14. Donna Evanoff Renner, et al, " The Private Sector and SSOs", National Conference on SSOs, April 24-26, 1995, Washington, DC

This paper describes the effect of private sources on SSOs. It reports that about 20% of inflow is generated from private sector sources. It describes several strategies to get the home owners participate in repairing the defects in their laterals. Examples are provided from the City of Tulsa, OK, and the City of Dallas, Texas.

15. Thomas J. Day, " The Use of Sewer Monitoring Information for Operation and Maintenance", National Conference on SSOs, April 24-26, 1995, Washington, DC

This paper is based on the experience of the City of Philadelphia, which has instituted a monitoring program since 1989. The paper discusses cost of monitoring, how to choose instrumentation, deploying a network of monitoring stations at strategic locations identified by studying the maintenance records of the system and interviewing the maintenance workers, identifying the characteristics of the system through monitoring, and implementing proactive maintenance programs.

16. Anthony J. Clemente, et al, " Dade's County Mandated Improvement Program to Reduce SSOs", National Conference on SSOs, April 24-26, 1995, Washington, DC

This paper discusses the efforts of Dade's County to reconstruct over 20 years of unscheduled maintenance records to identify occurrence of SSOs. Approximately 26% of the 471 overflow events were recurrent, most of which were caused by insufficient capacity during wet weather and by pump station system failures. Nearly one-half of the overflows occurred during dry weather because of non-capacity-related problems. Most pipe blockage occurred due to an abundance of buildup grease. An ordinance has been implemented to control discharge of grease and oil from industrial and commercial users. Two-thirds of pipe breaks were due to corrosion and to an overall deterioration of the county's aging infrastructure. The remaining pipe breaks were due to accidents during construction.

17. Alan Hallenbeck, " SSOs: Determining the Appropriate Storm Protection Level", National Conference on SSOs, April 24-26, 1995, Washington, DC

This paper answers questions like what is an SSO? How can an SSO be predicted? What approach or approaches to cost/benefit analysis are appropriate? It presents a diagram of peak inflow versus rainfall intensity. When the peak flow exceeds the pipe capacity when flowing full, surcharging occurs. The paper points out the significance of volume/duration factors of the overflow. The paper illustrates the impact of antecedent soil moisture on the peak inflow. At lower moisture conditions, the peak flow is smaller. The system should be designed for the high soil moisture condition. The inflow is especially very large when the ground is in frozen condition. The paper also points out the impact of a second storm following immediately after the first storm. The second storm is likely to cause an SSO. The paper also presents a knee curve, which shows the cost to prevent a surchargeable occurrence for different storm intensities versus the total present worth. Often there is a break in the curve in the range of 1-year to 10-year.

18. Darin H. Thomas, " Visualizing Your Sanitary Sewer Overflow Status Using Desktop Mapping", National Conference on SSOs, April 24-26, 1995, Washington, DC

This paper describes the use of Desktop Mapping as an inexpensive alternative to GIS. The Desktop Mapping software discussed is MapInfo for Windows. The paper suggests using the TIGER maps (Topologically Integrated Geographic Encoding and Referencing) and adding manhole latitude and longitude by using a hand help GPS equipment (about $800). The sewer lines can be drawn between the manholes. The software can also import/export from AUTOCAD using the DXF (Drawing Transfer) file format.

19. Steve Merrill et al, " Infiltration and Inflow, Infiltration or Inflow- which is the Problem?" National Conference on SSOs, April 24-26, 1995, Washington, DC

This paper presents the results of pilot programs conducted by King County Department of Metropolitan Services to control I/I. It contains cost information for rehabilitation. It also reports on the use of a computer model to simulate the flow in the sewer system resulting from long-term rainfall effects (about six months) accounting for antecedent precipitation. Prior rainfall raises groundwater levels and soaks the trenches resulting in higher flows. The peak flow during long low-intensity events can exceed flows from a much more intense but shorter duration storm.

20. Peter Keefe, " New Approach to SSO Evaluation Yields Surprising Results", National Conference on SSOs, April 24-26, 1995, Washington, DC

This paper advocates an approach based on two questions: How much rain fell on each basin? And how much of this rainfall reached the sewer? The paper states that basins with I/I Coefficient over 40% almost certainly have direct connections to a stream or outside source of water. I/I coefficient of 100% definitely have connections to outside sources of water. I/I coefficient of about 5% have shown a rough correlation with EPA's 5000 gpd/in-diameter per mile rule of thumb for infiltration (often measured the day after the storm). The paper also reports the results of I/I reduction programs at several cities: Athens, TN 62%, Burlington, NC, 50%, Crosby, TX, 92%, Murpheesboro, TN 78%, Fayetteville, AR, 78%, Nashville, TN, 75%, Tallahassee, FL, 95%.

21. Thomas J. Day, " An Assessment of the State-of-the-Art Flow Measurement Techniques for Sanitary Sewers and Overflows", National Conference on SSOs, April 24-26, 1995, Washington, DC

This paper describes the monitoring program developed by the City of Philadelphia Water Department. It describes level measuring devices, velocity and flow measuring devices, alarm generation and reporting systems, and data acquisition systems.

22. John Larson, et al, " Sewer System Operation & Maintenance: A practical Program To Minimize and Mitigate SSOs", National Conference on SSOs, April 24-26, 1995, Washington, DC

This paper describes proactive maintenance and operation procedures to prevent SSOs. The maintenance and operation is part of a comprehensive plan addressing planning issues, design and construction issues, and cost-effectiveness analysis. It also discusses strategies for responding to SSOs.

23. Steven Donovan, " Sanitary Sewer Overflow Removal: The Approach Used by the Metropolitan Sewer District of Greater Cincinnati", National Conference on SSOs, April 24-26, 1995, Washington, DC

This paper reports that in Cincinnati, the known SSOs are visited at a minimum of once a week, and more frequently if a rain event occurs. A wooden block attached to a string is set in the overflow pipe. If the block has moved, it indicates an SSO has occurred. The paper also contains cost information. It shows that $5,000,000 were spent to eliminate 11 SSOs.

24. Jacqueline A. Townsend, et. Al, "The Facility Plan to mitigate SSOs in Charlotte, North Carolina", National Conference on SSOs, April 24-26, 1995, Washington, DC

This paper reports on the use of the EXTRAN block of SWMM to identify bottlenecks. EXTRAN is a dynamic model that allows simulation of an entire storm event, in contrast to a steady-state or static model that models the system for only one point in time. The EXTRAN model was chosen for two primary reasons: 1) its ability to handle surcharging, backwater, and overflow conditions which were common in the trunk sewer, 2)- its ability to route hydrographs dynamically and predict a time-varying series of flows and water surface elevations throughout the system during a wet weather event.

The paper also reports that a "comprehensive approach" to rehabilitation is more effective than the "point repair approach". While the comprehensive approach costs $45 to $55 per ft, it reduces I/I by 60% to 70%. The point repair costs $30 to $45, but only removes 10% to 40% of I/I. The paper summarizes a long-range rehabilitation plan through 2025 which includes relief sewer, equalization basins, and sewer rehabilitation.

25. AMSA, 1994 "SSO Survey Data"

2/3 of respondents to a survey by AMSA indicated that SSOs occurred during wet weather events. The survey also indicated that the volume of SSOs represented a small percentage when compared with total treated wastewater volume. Respondents also felt that sewer system rehabilitation efforts were expensive and met with limited success.

26. Curtis Coe, et. Al, " Sewer Cleaning as a Diagnostic Tool", WEF Collection Systems Rehabilitation and O&M, Kansas City, July 13-16 1997

This paper reports that CCTV can be used to detect defects, which can lead to SSOs. In one case, CCTV inspection revealed a 16-inch boulder in an 18-inch sewer. The CCTV tapes also revealed blockages, dropped joints, cracked and broken pipes, and even three locations where water service lines had been punched through sewer lines. In one instance, it was found that the pipe was 12 inches instead of 18 inches in diameter. In one case, the sewer pipe was found to be on an adverse grade.

27. Patrick L. Stevens, "The Eight Types of Sewer Hydraulics", WEF Collection Systems Rehabilitation and O&M, Kansas City, July 13-16 1997

This paper explains how Scattergraphs can be used to assess the hydraulic performance of a sewer system. Scattergraph is a plot of depth versus velocity. Both bottleneck and SSOs can be detected from scattergarphs. The eight types of hydraulics described in the paper are: 1- normal open channel flow, 2- silt or obstacles, 3- bottlenecks, 4- SSO downstream, 5- SSO upstream, 6- Temporary blockage, 7- CSO or dams, 8- Variable downstream conditions like siphons or pump stations.

28. EPA Region 6, " Water Management Division's Strategy for Wet Weather SSOs"

This document describes the EPA's region 6 strategies to deal with SSOs. The document recommends a three-phase approach. Phase I- Field Activities, Phase II- Construction, Phase III- Monitoring. Phase I includes: A- Characterization, Monitoring and Modeling of the Sanitary System, B- Physical Inspection, C- Smoke Testing, D- Flow Isolation, E- Dye Water testing, F- Cleaning and Televising, G- Evaluation and Final Report.

29. ASCE MOP 87/WEF MOP No. 23, "Urban Runoff Quality Management", 1998

This manual has a section (pages 159,160 and 161) on "leaking sanitary sewer control". It suggests the following approach:

- Identify dry weather infiltration and inflow first
- Locate wet weather overflow and leaking sanitary sewers using conventional source identification techniques, including:
    - Field screening program
    - Fluorometric dye testing
    - Zinc chloride smoke testing
    - CCTV inspection
    - Nessler reagent test kit for ammonia detection, and
    - Citizen hot line for reporting wet weather SSOs

The manual also reports that the City of Stockton, California, Municipal Stormwater Discharge Management Program has a comprehensive program element created to prevent, detect, and eliminate illegal connections to storm sewers.

The manual also reports that the City of Fort Worth, Texas, Drainage Water Pollution Control Program has a program designed for corrective measures using innovative biotoxicity testing.

30. Delleur. J.W., "Sewerage Failure, Diagnosis and Rehabilitation", Paper included in the ASCE publication Urban Drainage Rehabilitation Programs and Techniques, edited by W.A. Macaitis, 1994

This paper classifies the sewerage failures as structural, hydraulic and environmental. SSO's are listed under environmental failures. Diagnostic tools suggested include monitoring, CCTV, man entry observations, infrared scanning, ground penetrating radar, flow monitoring, SWMM model, and water quality monitoring of receiving streams.

The paper reports on the use of automatic samplers which can be programmed in such a way that the time elapsed between consecutive samples is shorter during the rising hydrograph than during the falling or recession part of the hydrograph.

31. Hayes, P.A., "Flow Analysis Used to Diagnose Pipe Capacity and SSO Problems in Sydney, Australia", Proceedings of ASCE Pipeline Conference, Phoenix, AZ, 1994

This paper reports on a project in Sydney where permanent flow monitoring stations were installed at strategic locations at a density of one per 50 kilometers, or about one per 9,000 persons. Overall, 400 stations were installed. The stations were equipped with depth and velocity sensing capability. About half of the stations had also surcharge sensing capabilities.

Dial-up telephone lines were used for telemetry purposes. The flow data is used for calibration of the hydraulic model, identification of area of high I/I, and identification of location, frequency and quantity of SSOs.

32. Abraham, D.M., et al, "Integrating Sensing Technologies for Underground Utility Assessment", Proceedings ASCE Conference on Infrastructure Condition Assessment, Boston, 1997

This paper describes a new innovative technology, Scanner and Evaluation Technology, for internal inspection of sewer lines. It consists of a CCTV, three axes mechanical gyroscope and a scanner. The images are digitized by the scanner and color coded computer printouts are produced to show the defects of the line.

Neural network technology is used to analyze the results. This eliminates the need for viewing the whole length of the scanned images, saving a lot of time in interpreting the results

33. Arbour, Rick, and Ken Kerri, " Collection Systems: Methods for Evaluating and Improving Performance", Report to US EPA by California State University, 1998

This report has a section on identification of inflow sources. The suggested procedure includes flow monitoring, physical survey, internal inspection, and cost-effectiveness analysis. Flow monitoring may be conducted in a subarea for long term monitoring, for mini-basins on a temporary basis, and for a subsystem for instantaneous monitoring. Physical survey include visual inspection of trunk sewer alignment, manhole, stream crossings, and other likely areas of infiltration/inflow. In particular manholes, which are located in high groundwater areas and can be inundated during wet weather or runoff, should be inspected. Smoke testing and dyed water flooding is performed as a part of the physical survey.

34. Moeller, R., et al, "A desktop GIS/Hydraulic Modeling Application for SSO Reduction", Proceedings of WEF Conference on Advances in Urban Wet Weather Pollution Reduction, June 28-July 1, 1998, Cleveland, OH

This paper describes a program initiated by the East Baton Rouge Sewerage Commission (EBROSCO) to reduce SSOs. The program included water quality modeling, flow monitoring, system data collection, and dynamic hydraulic modeling. Hydroworks, a robust dynamic model, was used for this project. The GIS was used to manage and process the data for the model.

35. Agbodo, M.N., and Nelson, R.E., "Real Time Control Modeling for Sewer System Optimization", Proceedings of WEF Conference on Advances in Urban Wet Weather Pollution Reduction, June 28 - July 1, 1998, Cleveland, OH

Real time Control (RTC) enables effective use of the latest technology in sewer system modeling to optimize the performance of existing systems and to design more cost-effective systems. RTC management of sewer systems involves the use of sensors to monitor flows continuously along with telemetry to pass the measurements from sensors to flow regulating appurtenances. The sensors could include rain gages, and flow and level meters. Appurtenances such as penstocks, variable level gates, pumps or weirs could be used to regulate flow through the sewer system.

36. Miles, S.W. et al, "An I/I Analysis and Prediction Method to Help Guide Separate Sanitary Sewer Improvement Programs", Proceedings of WEF Conference on Urban Wet Weather Pollution: Controlling Sewer Overflows and Stormwater Runoff, June 16-19, 1996, Quebec City, Canada

Continuous simulation analysis has been shown to be critical in determining accurate forecasts of the frequencies and volumes of overflows that occur in a sewer system over long periods of time. However, most continuous simulation techniques have used simplified methods of predicting rainfall dependent I/I (RDI/I) responses that do not account for variation in RDI/I response due to antecedent moisture or seasonal groundwater conditions. The RDI/I model presented in this paper provides the ability to simulate continuous responses while accounting for these variations. The influence on modeling results by using this approach for continuous simulation of RDI/I flows as compared to other methods is not fully documented and requires further study.

37. Nelson, R.E., "Risk Analysis for Design of Collection Systems", Proceedings of WEF Conference on Sewers for the Future, September 10-13, 1995, Houston, Texas

This paper proposes a risk-based approach to assess the hydraulic capacity of sewer systems. The risk of flows exceeding system capacity and the cost associated with each level of risk can provide a basis for determining a reasonable level of protection against sanitary sewer overloading.

38. Harris, J.F. and R.H. Wynne, "Diagnosing Future Collection System Problems", Proceedings of WEF Conference on Sewers for the Future, September 10-13, 1995, Houston, Texas

This paper discusses how existing technologies can be utilized for Real Time Control (RTC) network. The benefit of RTC is that the sewer system can be controlled by utilizing immediate and historical rain, flow and modeling data with the objective of maximizing of in-system storage of flow. RTC will allow managers to diagnose and control collection system problems as they occur at a cost that may be a fraction of the cost of existing alternatives. Existing technologies such as flow monitoring, sanitary sewer evaluation surveys (SSES), Geographic Information Systems (GIS), and hydraulic modeling are discussed.

The paper also describes the Event Notification System (ENS) which is a process used to predict CSOs and SSOs by observing prior rainfall data or key upstream flow or depth quantities. This process uses a critical prior or upstream condition to warn of a future or downstream result.

39. Lombardi, C.W., et al, "Technologies Behind the Operation and Maintenance of the Collection Systems Associated with the Boston Harbor Project", Proceedings of WEF Conference on Collection System Operation and Maintenance, June 27-30, 1998, Tucson, AZ

This paper describes an aggressive inspection program implemented by Massachusetts Water Resources Authority (MWRI). The inspection program has three components: internal pipeline inspection, structural inspection (including manholes and diversion chambers), and flow monitoring.

40. Giguere, Paul, et al, "San Diego reduces SSO's by Implementing Focus Control Measures Based on GIS Analysis of Sewer Overflows", Proceedings of WEFTEC 97 Conference, Chicago, IL

This paper presents the City of San Diego's experience in using the GIS for analyzing the SSO data. Every SSO is documented and information such as date of overflows, location, volume of overflow, pipe size and material, cause of overflow, and impact on the environment is compiled. The data shows that 90% of all spills occur during dry weather and are maintenance related. SSOs occur mostly on smaller size sewer lines. The data is used to identify "hot spots" and take appropriate action to eliminate the recurrence of future SSOs.

41. Walch, M.C., et. Al, " SSO Prevention", Water & Environment Technology, February 1998

This article reports that the Miami-Dade Water and Sewer Authority has developed a "Virtual Dynamic Model" (VDM) which can be used to predict potential SSOs resulting from peak flow conditions over time. The model combines Geographic Information System (GIS), Supervisory Control and Data Acquisition (SCADA), Oracle and MS Access databases, and NEXRAD Weather for Windows and Virtual Rain Gage (VRG). The model uses the XP-SWMM software (Storm Water Management Model).

42. Environmental Protection Agency, " 1996 Clean Water Needs Survey (CWNS)", US EPA report to Congress, September 1997

This reports shows about $31.9 billion is needed for rehabilitation of existing and installation of new collection systems $31.9 billion. Although SSO needs are not identified separately in the CWNS, some associated costs to address SSO problems are included in this number. In general, EPA believes that the needs estimates related to SSOs underestimate the total costs associated with preventing SSOs. Therefore, the scale of the SSO problem is currently being addressed by EPA separately from the CWNS. EPA is developing cost estimates for addressing SSOs on a national basis to support the work of the SSO Federal Advisory Committee and other Agency work.

43. Moore. G.T., "Modeling a Sewer to Develop SSO Control", Water & Environment Technology, July 1997

This article reports on the experience of the Metropolitan St. Louis Sewer District (MSD) to control SSOs. MSD developed a computer model, which interfaces with GIS and CAD system. The model was based on watershed boundaries. The model was able to identify watersheds that had critical SSO problems. The computer model can pinpoint such deficiencies as insufficient pipe capacity, flat or adversely sloped pipe, and surcharge conditions due to backwater conditions.

44. Miles, W., et al, "Managing Old Sewers in the New South", Water & Environment Technology, April 1996

This paper describes the improvements made by Charlotte-Mecklenburg Utility Department (CMUD) which included increased storage, sewer rehabilitation, increased gravity sewer and pumping capacity, and knowledge-based preventive maintenance. This approach has reduced SSOs, which stemmed from rapid growth, an aging system, and an average annual rainfall of 43 inches. Results of the program showed that comprehensive rehabilitation of the public system could reduce the rainfall dependent I/I volume by 60% tp 70% and reduce the peak I/I by 40% to 50%. The majority of remaining I/I in the system is believed to be of private origin.

45. Sieger. R.B. and J.E. King, " The Limits of Capacity", Water & Environment Technology, April 1995

This paper presents the experience of Sallas Water Utilities to eliminate SSOs. Dallas used flow monitoring, computer modeling, and Storm Water Management Model (SWMM) to gain an understanding of its system. Flow monitoring included both depth and velocity measurements. Under surcharged conditions, depth measurements become useless, and velocity measurements should be available. The paper also describes a double-peak pattern of storm events. The first rain event raises the groundwater. During storms under 2-year duration, this first peak would not cause overflow if it is precede by a dry period of a few weeks. The second rain event, which normally occurs within a day or two of the first rain, begins with a higher groundwater table and usually causes overflows. Even a small second storm could have the same effect.

46. Gregory, H.N., et al, " New Technologies Help Houston Inspect Its Sewers", Public Works, Feb. 1990

This paper presents Houston's experience with using state-of-the-art handheld and laptop computers, image storage software and hardware, and a unique rules-based expert system to help evaluate the condition of the city's 4,500-mile sewer system. By controlling the type of information submitted and the frequency of reporting, the City has created an early warning system to identify potential problems.

47. Thornhill, Rodney, R. , "Use of GIS-Based SSES to Eliminate SSOs", Public Works, February 1994

The application of GIS technology to the analysis of wastewater collection systems can be used to improve the planning process. Spatial analysis capabilities combined with capacity and sewer defect models can give an engineer a comprehensive understanding of the system behavior. This understanding can be used to make better decisions when solving wet weather wastewater collection system problems. A sewer system evaluation survey (SSES), when combined with a GIS, becomes a powerful tool. This new tool, a geographic sewer evaluation survey (GSES), can be used for sewer system analysis and evaluation.

48. Raab, Charles, Department of Public Works, Kansas City, Missouri.

Per personal conversation.

49. Mehl, Laurie, Department of Public Works, City of Columbus, Ohio.

Per personal conversation.

Appendix B

Questionnaire

Protocols for Identifying SSOs
American Society of Civil Engineers and Black & Veatch
EPA Cooperative Agreement #CX 826097-01-0

The following questionnaire pertains to *separate collection systems only* and should not include data for combined sewers or wastewater treatment facilities. Please answer as many questions as possible. For data which are not available, simply enter An/a.@ Use judgment, if necessary, since exact figures may not always be available. Finally, please indicate the quality of the data where indicated in each section.

Definitions

1. **Sanitary Sewer Overflow.** A sanitary sewer overflow (SSO) is an intentional or unintentional release of flow from a separate sanitary sewer collection system before the headworks of a wastewater treatment facility. SSOs include discharges to waters of the US and, for purposes of this survey, diversions to public or private property (e.g., basement flooding, manhole overflows, etc.). SSOs include leaks from cracked or corroded pipes.

2. **Quality of Data.**

a. Very Good. Data based on operational records or recent studies and is fully documented.

b. Good. Mostly based on operational records and recent studies supplemented by personnel knowledgeable of the data requested.

c. Fair. Based mostly on approximations with some supporting documentation but primarily data provided by memory from personnel knowledgeable of the data requested.

d. A Guess. Written records not available to verify but the best guess representing a what is reasonably thought to be true by a person somewhat knowledgeable of the data requested.

Please FAX or Mail your completed Questionnaire to:

Richard E. (Rick) Nelson, P.E.
Principal Investigator
Black & Veatch
8400 Ward Parkway
Kansas City, MO 64114
Telephone: 913/458-3510
Fax: 913/458-3730
e-mail: nelsonre@bv.com

Thank You

I. General Information

1. City/Agency: ______________________
2. Address: ______________________
3. City/Zip Code: ______________________
4. Telephone No.: ______________________
5. Fax No.: ______________________
6. E-mail: ______________________
7. Completed By/Title: ______________________
8. Date: ______________________

II. Service Area Information

Quality of data for this section: G *Very Good (1)* G *Good (2)* G *Fair (3)* G *A Guess (4)*

1. Data is for: City Wide or Total Regional System G (1) or Individual Drainage Area G (2)
2. Service area name: ______________________
3. Jurisdiction: G Interceptors & Collection System G Interceptors Only G Collection System Only
4. Miles of public sewer: ______________________
5. Number of manholes: ______________________
6. Number of connections: ______________________
7. Area served (sq mi.): ______________________
8. Population served: ______________________
9. Age distribution of collection system construction: ______________________

Percent of System		
Pre 1950	**1950 - 1970**	**1971 - 1998**

III. Flow Information (all values are MGD unless otherwise indicated)

(Select year within last 3 years of data which best represents your system)

Quality of data for this section: G *Very Good (1)* G *Good (2)* G *Fair (3)* G *A Guess* (4)

1. Data is for: City Wide or Total Regional System G (1) or Individual Drainage Area G (2)
2. Year of data: ______________________
3. Average annual daily flow: ______________________
4. Maximum daily flow observed:* ______________________
5. Peak hourly flow observed:* ______________________
6. Maximum month average daily flow: ______________________
7. Minimum month average daily flow: ______________________
8. Percent of system below the average groundwater table: ______________________

*Indicates basis for flows reported (i.e., measured annual, estimated, weather and other related condition upon which estimate was made):

IV. System Characteristic Information

Quality of data for this section: **G** *Very Good (1)* **G** *Good (2)* **G** *Fair (3)* **G** *A Guess* (4)

1. Percent of system greater than 24 inches in diameter:
2. Number of pumping (lift) stations: ______________________________
3. Total installed horsepower of lift stations: ______________________________
4. Total length of force mains, miles: ______________________________
5. Number of equalization basins upstream of WWTP: ______________________________
6. Total volume of equalization basins, mg: ______________________________
7. Percent of system which is industrial/commercial: ______________________________

V. SSO Wet Weather Events

Estimate numbers of storm events that exceeded the capacity of your system and caused SSOs.
Quality of data for this section: **G** *Very Good (1)* **G** *Good (2)* **G** *Fair (3)* **G** *A Guess (4)*

EVENTS[(1)] IN LAST 3 YEARS				
TYPE OF SSO	**APPROX. NUMBER**			**CAUSES**[(2)]
	1998	1997	1996	
1. Pipe Failures				
2. Manhole Overflows				
3. Basement Backups Due to Main Line Problems				
4. Pump Station Failures				
5. Other Types (list):				

(1) Event refers to a storm event which may have caused multiple SSOs.
(2) Possible causes may include broken pipes, high flows, roots, grease deposition, hydraulic restrictions, power outages, surcharge, etc.

What has been your normal response to the SSO events you listed above?

____

____

____

VI. SSO Dry Weather Occurrences

Estimate the number of SSO occurrences during dry weather.

Quality of data for this section: **G** *Very Good (1)* **G** *Good (2)* **G** *Fair (3)* **G** *A Guess (4)*

OCCURRENCES (1) IN LAST 3 YEARS		
TYPE OF SSO	**APPROX. NUMBER**	**CAUSES****
1. Pipe Failures		
2. Manhole Overflows		
3. Basement Backups Due to Main Line Backups		
4. Pump Station Failures		
5. Other Types (list):		
(1) An occurrence is one incident of a pipe failure or other type of dry weather SSO. (2) Possible causes may include broken pipes, roots, grease deposition, hydraulic restrictions, power outages, etc.		

What has been your normal response to the SSO occurrences you listed above?

____

____

____

____

VII. Routine Maintenance Frequencies

Quality of data for this section: **G** *Very Good (1)* **G** *Good (2)* **G** *Fair (3)* **G** *A Guess (4)*

TOTAL COMPLETED EACH YEAR			
ITEM	**1998**	**1997**	**1996**
1. Cleaning, miles of sewer			
2. Root Removal/Treatment, miles of sewer			
3. Main Line Stoppages Cleared, number			
4. House Service Stoppages Cleared, number			
5. Inspections and Services of Lift Stations, number			
Describe Lift Station Inspection Procedure:			

What are your most significant maintenance problems?

What maintenance activities do you think are beneficial to preventing dry weather and wet weather SSOs?

VIII. Inspection Methods Used and Status

Quality of data for this section: **G** *Very Good (1)* **G** *Good (2)* **G** *Fair (3)* **G** *A Guess (4)*

INSPECTIONS CONDUCTED IN LAST 3 YEARS				
INSPECTION METHOD	**UNITS**	**1998**	**1997**	**1996**
1. Flow Monitoring/Capacity Evaluation	Monitoring Sites			
2. Manhole[(1)]	Number of Manholes			
3. Dye Testing	Number of Tests			
4. Television Inspection (internal)	Miles of Sewers Inspected			
5. Private Sector Building Inspection[(2)]	Number of Inspections			

(1) Surface or internal inspections.
(2) Inspections for area drains, downspouts, cleanouts, sump discharges, and other private sector inflow sources into the sewer system.

What are the limitations of the various methods for finding SSOs?

What inspection methods do you think are effective in identifying potential SSO locations?

IX. Ranking of Methods You Use to Identify SSOs or Potential SSO Locations

Rank 1-8 the sources of information you currently use to identify SSOs (where 1 is the most commonly used). Rank 1-8 the sources of information that you believe are most effective in identifying SSOs (where 1 is most effective).

	RANKING	
METHOD	**CURRENT SOURCES (1-8)**	**MOST-EFFECTIVE SOURCES (1-8)**
1. Customer or Other External Source		
2. Visual Inspection by Maintenance Crews after Overflows		
3. Scheduled Inspection (manhole, TV, etc.)		
4. Observe by Flow Collection System Monitoring		
5. Observe by Receiving Stream Monitoring		
6. Predict SSOs by Hydraulic Modeling		
7. SCADA		
8. Other Methods: (list)		

X. Protocols for Identifying SSOs

1. Do you utilize any written protocols or procedures for identifying or investigating SSOs or potential locations of SSOs? If yes, please describe and, if possible, include copy:
____
____
____
____

2. Do you have any plans for developing protocols for identifying or investigating SSOs? Do you have any ideas for an effective protocol? If yes, please describe:
____
____
____
____

3. Do you have a grease abatement/control program? If yes, please describe:

____
____
____
____

4. Have you identified any recurring design deficiencies which may be causing SSOs (e.g., flat sewer slops)? If yes, please describe:

____
____
____
____

Have you made any design changes to correct above problems? If yes, please describe:

____
____
____
____

5. Do you give SSO corrections a high priority in your sewer rehabilitation program? ________

What are the most common SSO defects fixed?

____
____
____
____

6. Do you have SSO-related requirements in your NPDES permit(s)? ______________________

Do you expect SSO requirements to be added in the future? Please describe:

____
____
____
____

7. Do you have an I/I management program? If yes, please describe:

____
____
____
____

8. Do you have a corrosion control program? If yes, please describe:
____
____
____
____

9. Do you use any SSO tools, such as the flow chart developed by FACA SSO Committee; computer maintenance management or simulation models? If yes, please describe:
____
____
____
____

Thank you for your support. Would you like to receive a copy of the final report of this study?

Yes _____________ No, thanks _____________

Appendix C

Agency Responses

Table C1 Agency Responses			
	Reactive	Proactive	
Response	What to Do If An SSO Occurs and Prior to an SSO Event Occurring	How to Find an SSO Location Before it is a Problem	How to Prevent an SSO\ from Occurring
Questionnaire Section V. What is your normal response to the SSO events listed?			
Point repairs/ relining/ additional jet cleaning/ clean up of basements/abandonment of pumps stations as required.	Repair defect/ clean/ clean basement / abandon problem pump station		
Ascertain what can be done immediately and what needs to wait until rainfall lessens or subsides. A report is made to MDNR of events that the City staff is aware of. Work orders prepared by initial investigator for either repair section or cleaning section. Emergencies beyond the wastewater line maintenance's capability are referred to Engineering for an outside emergency contractor.	Prepare report to EPAPrepare work order/Perform emergency repairs		
A crew dispatched to investigate the situation. Minor situations may be resolved by this crew. Major sewer cleaning and cleanup are done by a separate cleaning crew. Note: Primarily dry weather occurrences. Dry and wet weather events are not tracked separately.	Dispatch Crew to investigate		
Clean and disinfect, flush with fresh water, also schedule for cleaning and/or repairs and televised. Excellent result of $186 million investment in AO work.	Clean and disinfect/prepare work order		
Send maintenance personnel to sites. Notify power company. Arrange for back-up generators. Use sewer combination machines to vacuum out and dump liquids. Emergency by-pass as a last resort and notify OR-DEQ.	Dispatch crew to investigate/ arrange for emergency power/ clean/emergency bypass/notify EPA		
The one event was a 50 year storm event. All wet weather facilities (3) capacities were exceeded. (note that only one SSO during a wet weather event occurred in the last three years.			
The plants have a "wet weather" operational plan, which includes the use of flow equalization basins and chorination points to treat any potential raw sewage discharges.			Develop wet weather WWTP operational plan.
Upgrading pump stations to handle higher pressures. Disconnecting "piggy-backing" situations. Increasing size of transmission system. Reducing infiltration/inflow by			Upgrade pumping stations/avoid piggy backing pumping stations/provide relief/ reduce I/I

Table C1 Agency Responses			
	Reactive	Proactive	
Response	What to Do If An SSO Occurs and Prior to an SSO Event Occurring	How to Find an SSO Location Before it is a Problem	How to Prevent an SSO\ from Occurring
approximately 1 mgd per month.			
Manhole overflows - less than 2% of all manhole overflows are wet weather related. Basement Backups - Less than 5% of all basement backups are wet weather related. However, the procedures are similar for both wet and dry investigations. The process begins with the call from the customer. An inspector is dispatched to check the mainline to determine responsibility. If the sewer main stoppage is identified, a crew is dispatched to perform the emergency cleaning of the mainline. A formal process called the "Line Blockage Analysis" then begins a 90 day journey of customer contact internal inspections, sewer evaluations and recommendations for preventing the problem in the future. For wet weather problems, an additional step involves a "surcharge" review that involves all aspects of the collection system impacting the customer; capacity, hydraulic restrictions, and I/I flows. In the last several years, nearly two dozen pipe relocations recommendations have been made to resolve chronic backup conditions aggravated by peak wet weather flows but not solely due to I/I.	Dispatch crew/clean/LBA process		Conduct hydraulic review /make system configuration changes as necessary
These cases include correcting manhole channel geometry that limits capacity substantially less than the corresponding pipe capacity (opposing, matching channel inverts, dominant flows limiting sideline discharge) and local relief of even small diameter pipes where that solution is cheaper than locating and reducing localized I/I conditions.			Correct manhole channel geometry
When warranted, local sewer system evaluation surveys are initiated. I/I rehab, preventative maintenance, and some limited relocation have combined in several locations to resolve problems that are combinations of peak wet weather flow, design restrictions, and blockage issues (roots, grease, and debris).	Conduct SSES/clean/remove blockages		Conduct SSES

Table C1
Agency Responses

Response	Reactive	Proactive	
	What to Do If An SSO Occurs and Prior to an SSO Event Occurring	How to Find an SSO Location Before it is a Problem	How to Prevent an SSO\ from Occurring
Pump Station Failures : All stations have SCADA controls and are visited routinely. These responses to wet weather overflows are most likely to be observed and reported directly by WSSC crews. The extent of clean-up and any chemical stabilization of the discharge is site specific and made by the duty supervisor.	Site specific cleanup		
For pressure sewers: Flow diverted into tanker during line repair for the one pipe failure reported. For the pump, station failure reported the contractor left a valve open during a rehabilitation project. For gravity sewers: immediate response.	Divert flow to tanker truck		
We line maintenance crews respond to the location of the SSO and check the lines for any blockage. The crew then assesses the cause of the SSO and any possible solutions.	Dispatch crew/determine cause		
Investigate 100% of problems reported by customers. Remote alarm system on some locations (flow monitored). Field inspection by SSES.	Investigate all calls/respond to alarms/conduct SSES		Conduct SSES
Questionnaire Section VI. What is your normal response to the SSO events listed?			
Work orders prepared by initial investigator for either Repair Section or Cleaning Section. Report made to MDNR. Verbal in 24 hours written in 15 days. Work beyond Wastewater Line Maintenance referred to Engineering for contract.	Prepare work order/report to EPA		
Clean and disinfect, flush with fresh water, also schedule for cleaning and/or repairs and televised. Excellent result of $186 million investment in AO work.	Clean and disinfect/ prepare work order for cleaning and TV		
Dispatch sewer combination machines to clear blockage, vacuum debris, and pump wet wells.	Clean/pump wet wells		
Regional board notified. Thorough incident review is conducted. Repairs are made as soon as possible. Corrections requiring capital projects are identified and placed into the 5 year plan. (note only one dry weather SSO noted and this was due to a contractor plugged pipe downstream during construction)	Conduct incident review and prepare action plan		

Table C1 Agency Responses			
	Reactive	Proactive	
Response	What to Do If An SSO Occurs and Prior to an SSO Event Occurring	How to Find an SSO Location Before it is a Problem	How to Prevent an SSO\ from Occurring
Assess within on hour & restore normal flow ASAP. If "dig-up" needed.. dig starts same day and continues until completion.	Dispatch crew/perform repairs		
Crew immediately dispatched to solve problem, SSO stopped quickly.	Dispatch crew		
Pipe Failures: The majority of SSO related pipe failures occur at stream crossings. At time of construction, most pipe crossings had 3' cover below the stream invert and were many feet inside the stream bank. Over time, both daily dry weather flow and swollen stream flow has cut the stream invert deeper and eroded the protective cover of the stream banks. Both conditions seek to expose the sewers over time.			
Pipe Failures cont : Most of the pipe failures are small diameter mains crossing streams at remote locations on their way to the trunk. While we have programs for inspection of capital size sewers (15" and greater), these smaller sewers frequently may not have been observed for 5- 10 years at a time. Pipe failures are often reported by hikers or others observing the waste products in downstream locations.			
Pipe Failures cont: Once an identification is made and confirmed by an inspector, a crew is dispatched to initially stop the exfiltration with an emergency repair, typically sleeving the pipe and applying the necessary clamp. The next phase is the restablizations of the eroded stream or bank to properly protect the sewer main again for the long term. This can include gabion baskets or rip rap in addition to the needed soil cover.	Dispatch crew/perform emergency repair /stabilize stream bank		
Manhole Overflows: When a mainline stoppage occurs, the only distinction between a basement backup and a manhole overflow is the elevation of the nearest relief point. A characteristic feature of homes in our service area are basements, due to both the existing topography and			

Table C1 Agency Responses			
	Reactive	Proactive	
Response	What to Do If An SSO Occurs and Prior to an SSO Event Occurring	How to Find an SSO Location Before it is a Problem	How to Prevent an SSO\ from Occurring
typical depth of sewers. Therefore, when a MH overflow occurs, it is more likely to be remote in a right of way area, not typically running down a street.			
Manhole Overflows cont: The initial observation is generally going to be from a customer. the initial response is for an inspector to verify the nature of the problem, dispatch a crew to relieve the mainline stappage and then clean up the remaining solids and paper around the manhole. Lime is applied for some degree of stabilization of the turf area around the manhole.	Dispatch crew/clean/stabilize area around manhole		
Manhole Overflows cont: Experience has shown there are two types of occurrences; the short term "hiccup" and the long term overflow. Frequently, a temporary stoppage will cause a limited overflow and then relive itself. The more serious case is when a hard stoppage is present and the overflow has continued for some days or even weeks. These long term cases are generally more remote and have escaped observations for some time.			
Basement Backups: The prescribed mechanism for studying backups is the previously mentioned Line Blockage Analysis (LBA). This procedure is described in detail in a paper delivered in November at the Virginia Water Environment Association in Richmond, VA	Perform detailed analysis		
Flow diverted into tanker during line repair.	Divert flow to tanker.		
We line maintenance crews clean the sewer lines and conduct television inspection of the lines in question. If repair or rehabilitation is necessary, Engineering/Maintenance Divisions consider options for open cuts vs. trenchless repair.	Clean/TV/conduct repair		
Investigate 100% pf problems reported by customers. TV inspect collection line for corrections. Analyze for problems. Frequently clean problem lines (roots, grease	Dispatch crew/TV/clean		Clean problem lines

Table C1 Agency Responses			
	Reactive	Proactive	
Response	What to Do If An SSO Occurs and Prior to an SSO Event Occurring	How to Find an SSO Location Before it is a Problem	How to Prevent an SSO\ from Occurring
recurrence for example).			
Questionnaire Section VIIa - What Are Your Most Significant Maintenance Problems			
Roots/Grease in mains and laterals			Root removal/cleaning
We need more maintenance work at sanitary pump stations. Sewer lines need more cleaning, both to get rid of debris and remove roots. More inspection needed for I/I sources. More evaluation of sewer lines and more repair of broken sewer lines.			Proper pump station maintenance/cleaning/remover roots and debris/line evaluation.
Our most significant maintenance problems are roots and grease stoppage. Also, deterioration of our older sewers.			Root removal/grease removal/address deterioration in older lines
Power failures bad weather/grease on floats in wet wells/ debris on impellers of pumps.			Address potential power failures/address grease in wet wells/clean pump impellers
Our most significant maintenance problems are first, roots, followed by grease, access into easements, and adjacent other utilities of pipe repair locations.			Root removal/grease removal/improve access/control or address adjacent utility locations.
Pump packing leaking - excessive. Telemetry problems for station monitoring.			Address pump maintenance and improve pump station telemetry reliability
Lack of sufficient resources to do more thorough cleaning and thus reduce blockage and overflows. Lack of a long term and systematic rehab program.			Increase resources. Develop long term system program.
For sewage collection division, grease. For Pump Station Maintenance Division, lack of CMMS and the ability to conveniently track expense, cost effective, equipment reliability and maintenance history.			Develop means to address grease/develop computerized maintenance system to track tasks and costs

Table C1
Agency Responses

Response	Reactive	Proactive	
	What to Do If An SSO Occurs and Prior to an SSO Event Occurring	How to Find an SSO Location Before it is a Problem	How to Prevent an SSO\ from Occurring
Effective cleaning is a significant problem. Matching the right tools and equipment with the appropriate frequency to the problem is a challenge. After the correct recommendation is in place, then field execution becomes paramount. Keeping the equipment in good working order, having all the correct tools in the field (solid blockage cutter and nozzles for jet machines, brushes and corkscrews for rodders) in working order, following correct procedures regardless of site conditions (ie high traffic count roads, rights of ways, etc.) while meeting productivity goals, and removing all the material cleaned from one segment without passing it to the downstream sewer are all daily challenges. Enhancing existing solutions to degrease the pipe walls or more effectively cut or chemically control roots are contenting concerns. Handling combination problems also poses a field challenge (sand and rocks, grease and roots).			Improve cleaning effectiveness/train field personnel in proper use of equipment/conduct proper maintenance of equipment. Properly remove debris while cleaning/improve root and grease control/improve ability to handle other cleaning requirements including rocks and sand

Table C1
Agency Responses

Response	Reactive: What to Do If An SSO Occurs and Prior to an SSO Event Occurring	Proactive: How to Find an SSO Location Before it is a Problem	How to Prevent an SSO\ from Occurring
Maintaining engineering resources for effective I/I investigations is a concern. Consultants are an effective way to address limited personnel and resources for large I/I studies, however, many sewer problem resolutions are assisted by the "corporate memory". What happened before in a collection system under similar circumstances many time is not revealed solely in flow monitoring or TV results but in those records and recollections of previous performance. Devoting some full time resources to collection analysis is critical to resolving the chronic problems that have persisted for years. Getting staff to be knowledgeable in their site and video assessment and consistent in the recommendations is critical, particularly since most of the reviews are performed by non-engineering personnel. Future staffing will be leaner an more divers in the personnel's background. Transferring the tenets of engineering necessary to understand the workings of the collection system to those non-technical staff is an ongoing issue.			Improve engineering resources for I/I investigations/improve record keeping / Improve staff training/
Normal wear on lift station equipment, wet well cleaning. Root, soap and grease in the system.			Improve preventative maintenance of lift station equipment/ improve root, soap, and grease cleaning
Roots, grease, and vandalism.			
Grease and root blockage.			
Questionnaire Section VIIb - What maintenance activities do you think are beneficial to preventing dry weather and wet weather SSOs?			
Routine cleaning of mains (3 years), TV and relining work as required, root treatment			Routine cleaning and TV/root treatment
Evaluation of sewer system by watersheds - conventional SSES or I/I studies. Then a commitment of money for contracts for sewer rehabilitation recommended. Preventative maintenance at pump stations. Checking for all sources of I/I both public and private.			Conduct 'SSES and I/I studies/develop sound preventative maintenance program for pump stations/check for I/I sources in public and private sector
PM sewer cleaning, regular inspections/monitoring			Planned cleaning/ planned

Table C1 Agency Responses			
	Reactive	Proactive	
Response	What to Do If An SSO Occurs and Prior to an SSO Event Occurring	How to Find an SSO Location Before it is a Problem	How to Prevent an SSO\ from Occurring
problem areas.			inspections/ monitor problem areas
Dry weather - qualified service personnel.			
DIG" and "NO-DIG" sewer point repairs, TV inspection, flow monitoring, root and grease removal and control, smoke testing.			Conduct TV, flow monitoring , root and grease removal and control, smoke testing
Remote alarm testing (weekly)			Have remote alarm system
Dry: routine cleaning of sewer mains, repair activity and emergency response to prevent overflows. Wet: modeling of sewer system to identify restrictions and bottlenecks; construction of flow equalization facilitates - in-line and at plant sites.		Conduct system hydraulic modeling	Routine cleaning/conduct hydraulic modeling/construct equalization facilities
Sewer cleaning and a Comprehensive Maintenance schedule which clearly defines maintenance tasks. These tasks need to be tracked by a CMMS so the maintenance problems, which re-occur, can be identified and corrected. Routine maintenance activities identify nor or obvious problems. Predictive maintenance coupled with a good routine maintenance schedule would help prevent and deter failures, which lead to SSO's.			Prepare preventative maintenance plan/predictive maintenance plan
With our dominant dry weather SSO problem, an effective PM program is the most beneficial deterrent to SSOs. Nearly 60% of all recommendations resulting from backup or overflow investigations call for cleaning (also incl. roots and grease).			Prepare preventative maintenance plan /
An effective rehab program, both structural and non-structural (ie chemical grouting for water control), is also necessary to curb deterioration of the sewer leading to peak wet weather flows.			Implement an effective rehab program
Exercising lift station equipment, (ie generators) and alarm system testing. CCTV and visual inspection of the collection system along with scheduled maintenance of known trouble areas.			Exercise lift station equipment and alarm system/prepare preventative maintenance program
Preventative maintenance cleaning, video inspection and main line rehabilitation.			Conduct preventative maintenance program /conduct system

Table C1 Agency Responses			
	Reactive	Proactive	
Response	What to Do If An SSO Occurs and Prior to an SSO Event Occurring	How to Find an SSO Location Before it is a Problem	How to Prevent an SSO\ from Occurring
			rehabilitation
Cleaning lines with line-size root saw followed by nozzle. Frequent cleaning - every 3 to 4 years. Inspection of overflow for cause elimination. Smoke testing. Inspecting creek-crossing annually.		Inspect creek crossings	Inspect creek crossings regularly/perform root removal with correct equipment
Questionnaire Section VIIIa - What are the Limitations For the Various Methods for Finding SSOs?			
Some potential stoppages (SSOs) are found and cleared using TV inspections and manhole inspections		CCTV Inspection/ manhole inspections	
Ability to get private sector sources of I/I identifies. It is difficult to gain access, more difficult in getting sources removed. 2. Flow monitoring - difficulty in getting the right manhole for installing a flow meter. 3. Manhole inspections - hampered by too many buried manholes that take a lot of time to locate and raise to grade.			
Out of date maps, relying on public for notification, lack of computerized maintenance history.			
Flow monitoring: meter accuracy as relates to hydraulic model. TV: difficult during high flows. Smoke test: saturated ground conditions. Experienced and trained personnel.			
Accurate level monitoring data from Level Stations (calibration) and reliable telemetering of data)			
Night or rain-event SSO's are seldom detected unless they are in a visible location.			

Table C1
Agency Responses

Response	Reactive What to Do If An SSO Occurs and Prior to an SSO Event Occurring	Proactive How to Find an SSO Location Before it is a Problem	How to Prevent an SSO\ from Occurring
I don't think "finding" SSOs is quite the problem. The overwhelming majority of our SSOs are dry weather basement backups. I would have to reasonably believe that every one of these occurrences are reported to us by the customer. Next in frequency are dry weather manhole overflows. There has been occasion when one is reported where it is clear this has been ongoing for an extended period of time. This is one of those times when "finding it sooner" could have had a mitigating effect. The same would go for the isolated pipe washout in a remote right of way. The flows associated with both of these instance are generally low. Unless what was exfiltration also allows the stream to flow back into the manhole or the washed out pipe, there is little chance flow monitoring will yield any clue. The number of small diameter sewers not in the streets requiring some type of physical survey is significantly large enough to escape programming inspections on a routine basis.			

Table C1
Agency Responses

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The problems with wet weather backups and overflows are equally as daunting although the quantity is less. The entire premise for our primary tools of investigation, smoke testing, dye testing and building inspection, is they are simulation techniques. Because rainfall is sporadic, sometimes infrequent, often unpredictable and always variable, these techniques are used because they simulate conditions when it is nice, dry, and convenient for the work force. However, simulations are not actual conditions and few techniques can replicate the wet peaks associated with combination events such as thunderstorms with high antecedent groundwater or snowmelt with rainfall. I/I work will always be difficult to get right and the results can often be problematical which are reason why it is not held in the highest esteem by some utilities. Estimating leakage rates and peaking them and locating and correcting both public and private property I/I sources are just some of the frustrations attendant to this work.			
Flow monitoring should continue through several cycles of "wet/dry" periods.			
Manhole inspections of suspect areas must be performed during "wet" periods and especially during rain events for discovery of flooding.			
Side looking cameras provide the best inspection of joints, holes in pipe, and private lateral defects.			Employ proper equipment for inspection during CCTV
Must have cooperation from citizens for private sector inspections.			
Number of staff, expense/resources, some inspection methods are seasonal, limitations on private property inspections for I/I removal.			
Smoke testing has limited access - wet conditions for example. TV inspection too expensive for entire system. Must use all available methods in combination - no simple			

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solution.			
Questionnaire Section VIIIb - What inspection methods do you think are effective in identifying potential SSO locations?			
Additional inspections at force main outfalls, monitoring cleaning of areas with high root growth			Conduct force main outfall inspections/cleaning plan in high root growth areas
Flow monitoring - identify the worst subwatersheds of the entire watershed. Manhole inspections. CCTV inspection of lines.		Conduct flow monitoring program	Conduct flow monitoring/conduct manhole inspections and CCTV
Modeling sewer, past maintenance history, and good maps.		Model sewer/review past maintenance history/develop and review system physical data and maps	Model sewer system/develop good maps
TV; Flow monitoring; smoke testing; dye testing; visual observation			Conduct TV, flow monitoring , smoke testing , dye testing , visual observation
Visual observation during rain events. Modeling of sewer system based on flow data, followed by field verification.		Visual observation during rainfall/system modeling with field verification	Visual observation during rainfall/system modeling with field verification
A well developed SCADA/system modeling that would run data from SCADA through the model.		Implement developed SCADA system connected with model	Implement developed SCADA system connected with model
We maintain approximately 140 permanent monitoring sites and deploys 30 - 60 temporary sites annually (exclusive of any SSES program).		Flow monitoring	
Dealing with potential locations may be more productive for discussion if the reality of work force limitations were to be ignored. Factors that reveal themselves through investigation include:			
Stream crossings: Regardless of the diameter of the pipe, wherever there is a stream crossing, there is the potential in time to erode the soil cover, expose the pipe and create and exfiltration situation. Documenting where all these locations exist and establishing a baseline field inspection		Document all stream crossings /inspect stream crossings regularly	Inspect all stream crossings regularly

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of the condition at a point in time is one method.			
Flow Monitoring: If monitoring is kept to a small scale for I/I purposes as opposed to large scale for capacity analyses, the various DAC and GPDIDM calculations and assessments can be performed which will reveal those systems subject to peak wet weather flows. Doing something about it is another matter.		Conduct flow monitoring	
Track and Investigate Backups and Overflows: The best roads are the ones already traveled. Even if you only reacted to the events after they happen, you'll have the collection systems' manifestation of potential in the actual backup or overflow. Potential realized provides the road signs to how a particular system behaves in wet or dry conditions. Using those signs gleaned from a resulting investigation effectively provides the tools to minimizing their reoccurrence in the future. This is the approach our LBA program takes.	Track and investigate each SSO.	Through tracking and investigating SSOs document and investigate other likely locations where SSOs may occur	
CCTV, visual inspections, and metering.		Conduct CCTV, visual inspections and flow metering.	
Flood response team - A team of engineers and inspectors who investigate chronic problem areas during significant rain events to determine the causes of SSOs. TV inspections/manhole inspections. Surchecks =- We have developed a device to monitor the surcharge levels in manholes. This device is placed in strategic locations in the sewer system. Flow monitoring.		Develop a team of specialists who will track and determine likely causes of SSOs to help locate other potential sites/monitor surcharge levels	
Dye test for cross-connections in conjunction with smoke testing. TV inspection to identify defects, including house laterals, Flow monitoring to isolate inflow sources. Ongoing SSES activities.		Conduct dye testing, smoke testing, TV inspection/conduct flow monitoring/conduct SSES activities	

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Questionnaire Section Xa - Do you utilize any written protocols or procedures for identifying or investigating SSOs or potential locations of SSOs? If yes, please describe and, if possible, include copy:			
Yes, the document included procedures for notification of dispatcher, utility operator telephone numbers, guidance on what needs to be reported, health department numbers, and documentation requirements.	Develop and follow written procedures for handling SSO situations		
We are not using a written protocol for SSOs. We had one for CSOs - It was part of the Nine Minimum Controls.			
Piping ambiguity record field checks, review of old reports, GIS submittals require atlas by atlas review of maps, regular inspection of SSO locations designed into system.			
Dallas monitors and maps each SSO and determines cause and potential for recurrence for a given rain event then this is used as a priority tool to determine capital funding to address SSO.	Map each SSO and determine cause		
Overflow/bypass response procedure - maint. & treatment staff responsibilities/ actions. Triggered by heavy rains, monitor alarm of selected manhole, and/or high wet well alarms at station console.	Develop wet weather response procedure		
Yes, for investigation following SSO			
Yes, our Overflow Prevention Program			
See the enclosed Line Blockage Analysis paper. See also the enclosed description for our trunk walking program, an investigation routine for inspecting capital size sewer manholes (15" and larger) for indications of exposed sewer, leaking manholes, and signs of surcharge in these larger, critical trunk sewers.	Develop procedures for inspections of high probability SSO lines	Implement a trunk walking program	

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While not a protocol, the Commission does routinely employ helicopter overflights of selected trunk lines in late fall or early spring when the leaves are off the trees. There is a surprising amount of detail visible from that elevation. Flying with your sewer maps, a good reference map and a telephoto lens camera has resulted in good documentation of problems to be checked on the ground.		Conduct helicopter overflights of trunk lines and document any problems observed /	
No written protocol, but Trouble Response Inspectors follow standard operating procedures to investigate and respond to SSOs.	Assign responsibility for SSO response		
We have developed a list of "cluster areas", where recurrent backups or SSOs occur. These areas are monitored by a Flood Response Team during significant rain events. These areas are also the focus of SSES work. We have purchased modeling software (Hydroworks) to evaluate these areas and to determine solutions for preventing SSOs.	Create a Flood Response Team (flood busters) for rainfall event inspections	Identify likely locations of SSOs based on historical data/conduct hydraulic modeling	
Yes. We respond to 100 % of customer calls. All confirmed or apparent (visual , debris present) OF's are TV inspected for source. Maintain database & review.	Follow up on each and every customer call/ maintain database of SSOs		
Questionnaire Section Xb - Do you have any plans for developing protocols for identifying or investigating SSOs? Do you have any ideas for an effective protocol? If yes, please describe			
We normally TV mainlines that have stoppages or SSOs.		CCTV	
If there is a requirement for SSOs similar to the NMC that was required for CSOs. If not, we will continue to rely on work order system for Wastewater Line Maintenance.	Implement work order system /		
Review ongoing GIS implementation, SCADA implementation.	Implement GIS and SCADA		
Dallas now experiences less than 25 SSO per year based on current rain and we have capital plan to eliminate in future years.		Conduct hydraulic modeling to identify hot spots	

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Hydraulic modeling effort underway - If "hot spots" are identified, protocols will be developed as required. Continually looking to ensure segregated sanitary sewer.			
Trouble response inspector responds to call. After flow is broken in County line, necessary cleaning work is performed. CCTV of problem line segment is video taped for investigation. Tapes are reviewed against prior historical files.			
We have developed a regular preventative maintenance program, as well as a term and supply CIPP contract to address problem sewer lines. The modeling software and the Flood Response Team are also effective ways of identifying SSOs.	Develop PM plan/develop contracts for expediting repairs	Implement a Flood Response Team to conduct observations during rainfall events/conduct hydraulic modeling.	
Plan outside expert review of procedures, protocols.	Contract out for development of protocols		
Questionnaire Section 10c - Do you have a grease abatement/control program? If yes, please describe:			
No - we have some grease cleaning on specific lines.			Identify lines with grease problems
Our Industrial Waster Control Division handles this as part of their pretreatment program and sampling activities that levy a sewer surcharge fee in addition to the regular commercial and industrial fee.			Implement an industrial control division to sample and help regulate grease discharges into the sewer system
PM locations where grease has been a problem have been referred to Pretreatment, but lack of enforcement ability limits what can be done.			Refer grease locations to pretreatment division
Abatement and control efforts consist of enforcement of local limits on total oil & grease (300 mg/l) and hydrocarbons (100 mg/l) . In addition, regular maintenance on known problem line segments.			Establish local limits on oil and grease discharges/regular maintenance of know problem segments
Source control monitoring.			Monitor sources of grease
Yes, we have grease and oil ordinance. Compliance specialists monitor enforcement and cite violations if necessary.			Implement compliance specialist for grease control

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Yes. The Department of Environmental Resources Management, the County's enforcement authority, tracks grease problems and acts on the sources.			Implement compliance specialist for grease control
Connection permits call for a grease trap depending upon the type of restaurant. In addition, We clean certain chronic grease lines every six months to prevent grease buildup. We have also worked with several major wastewater producers upstream of our New Century Air WWTP to decrease grease using a pretreatment process and adding enzymes.			Require grease traps for restaurants/clean lines with heavy grease often/implement degreasing pretreatment process/add enzymes to the sewer system
Not active but re-starting grease control through enforcement of pre-treatment regulations (maximum concentration limits).			Establish local limits on oil and grease discharges/regular maintenance of know problem segments
Questionnaire Section Xd - Have you identified any recurring design deficiencies which may be causing SSOs (e.g., flat sewer slops)? If yes, please describe:			
Yes, one pump station was responsible for many of our spills, it was recently abandoned.			Upgrade pumping stations as necessary
The most recurring design deficiency in our sewer system is sewer lines being overloaded from a design basis - primarily from developments. Developers not required in the past to see if their proposed flows overload.			Review current design standards and past design standards to determine likely problem areas.
False sewer slopes in flow in pipe greater than 2 cfs. Series of 90 degree bends. Design standards in annexed areas less stringent than current city standards. From sanitary to storm sewers.			Identify flat slopes and bends which may cause problems and investigate solutions and /or monitoring plan
Yes, designing for 2 ft/sec the entire time even when grade would allow a greater grade. Therefore, Dallas has maintained a 3 ft/sec. design velocity as a minimum and use 2 ft/sec as the exception.			Review minimum velocity requirements for design of new sewers.
No recurring deficiencies - some individual spec relaxation, but not all-inclusive. Looking for any cross-connections or overflow points, and tight joints and service taps.			Ensure that design standards for joints and service taps are current /
We have recently completed its Wet Weather Program,			Increase treatment capacity

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which increased the total treatment capacity from 250 mgd to 720 mgd, thereby reducing the number of SSO's drastically.			
Flat sewers are a problem. Lack of capacity. "Gridlock" points in the collection system (ie. inadequate channelization of flow. Failure to design for rainfall events. Sewers are not designed to be leak proof. Sewers are often sized on the basis of expected growth and use but little consideration is given to handling I/I and to the fact that sewer systems function as giant "french drain" systems for large areas ie. they back up inadequate storm drain systems.		Identify flat sewers/identify gridlock points/	Review design standards past and present /
Too many "right angles" in collection system design. Little attention is given to optimizing flow.		Identify excessive system angles.	Improve design of new sewers /
Yes. Areas that have settled sewers - vertical deflective sewers too steep or flat.		Identify flat or steep sewers and monitor /	
The investigations have revealed several recurring problems in our collection system which are exaggerated by elevated flows during wet weather:			
Hydraulic Restrictions: A problem found numerous times in different forms is matching or near matching but opposing inverts in manhole channels. Classic examples include Allsion St which has opposite and opposing 12" flows, on incoming at 4.5%, the opposite at 0.4%. The dominant pipe controls all flow leaving the manhole, slowing the minimum slope sewer to a crawl and increasing grease and deposition problems in the flatter pipe.		Evaluate manhole piping configurations and identify potential problems	
Philadelphia and Cedar Aves. has a drop connection of over 4 vf for the upstream incoming 10" connection and an 8" side connection of 0.5% slope matches inverts with the bottom of the drop. They leave in minimum slope 12" main. The freefall velocity from the drop so dominated the main channel, it were as if a hydraulic plug were inserted in the sideline.		Evaluate manhole hydraulic conditions	

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With the design of a parallel trunk sewer, with the relief sewer at a higher elevation than the existing trunk, the engineers let an existing connection sideline (Highview Terrace) tie into the relief sewer at the same line and grade. Where before it was connected a springline of the existing trunk, the sideline now comes into the bottom third of the nw 48" relief sewer which has a minimum of 15 - 20" of flow in it all times. This means the sideline sewer never drains. Grease and debris chronically builds		Evaluate hydraulics of existing system	Conduct thorough hydraulic evaluation during design
Dorset Ave is a minimum slope sewer discharging to a swift flowing 12" sewer flowing half full most of the day. The channel geometry has nearly matching inverts leading to restrictions of the sideline flow. The examples could go on for a dozen more and there are more in the system waiting to be detected.			
A great graduate student exercise would be to chart and construct a nomgraph to describe the loss of energy and velocity and the resulting deposition potential when traditional "cut and cover" sewer design economics leads to "stairstep" sewer design. This is when steep/flat/steep/flat/ sewer slop patters result with debris accumulating in the minimum slope sewers. Intuitively, more maintenance will be required in those sewers than one, which may have a higher initial cost but balances the flows and slopes....for maximum self cleansing efficiencies. Some refer to this as life cycle costing for sewer design. Purdue University has an NSF grant to pursue a project with some of these characteristics. I can provide a contact if you are interested in pursuing as a reference.		Evaluate system physical configuration and hydraulics /	Optimize sewer design
Not recently. Had common problems in older areas with "dog-leg" - 90 degree bends.		Identify excessive angles.	

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Questionnaire Section Xd - Have you made any design changes to correct above problems? If yes, please describe:			
We are attempting to work with the engineers in public works that approve private developments. Also getting relief sewers designed to correct the existing overloaded sewers.			Relief sewer construction/review and approve private development plans /
Preliminary engineering studies underway will recommend appropriate changes. 4 pump stations were redesigned to minimize overflow occurrences.			Develop improvement plan /
Avoid designing in creek bottoms. Use zero infiltration standards. Improved manhole and lateral connections.			Avoid building sewers in creek bottoms/set tighter infiltration allowances/require improved manhole and lateral connections /
For sewer taps now, require core-drilling and use of invert-tees, hubs, etc. to keep watertight and protect from root intrusion.			Require core - drilling for service connections
Yes. Design standards specify minimum 2 ft./sec. design flow characteristics.			Review design criteria for flow velocity /
Yes. The traditional 0.1 ' change in elevation from inlet to outlet throughout the manhole often is insufficient when there are pipes of varying slope sharing the same manhole at right angles. There has to be recognition of the field reality and designers must compensate. For example, a rule of thumb must be that slow flow discharges to fast flow through grade separation. A slow, minimum slope sewer must be fien the opportunity to freely discharge by being elevated, say 1/2 pipe, at its discharge to .a faster moving flow. If possible, fast flow should not be dropping into slow for fear of further slowing the flat pipe. Drop connection inverts should never match inverts with any sideling. There should always be a half pipe elevation differential for any pipe connections. It's somewhat akin to some traffic design principles relative to margin with the manhole being an unregulated intersection.		Conduct review of manhole piping configuration for possible hydraulic restricted locations /	Review design criteria for pipe drops through manholes

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Life cycle costing should be integrated into sewer design. Cut and cover cannot be the sole basis for pipe design economics.			Conduct life cycle costing during design /
There has been very good success at eliminating the problems once they are identified. However, the problem is that it takes years for collection systems to mature and reach design flow conditions when many of these problems will become apparent. Many times existing topography or site constraints may limit your freedom to employ as much grade separation in the design as desired, but it should be a priority nonetheless.			
Like any engineering problem, the real trick is to properly define the problem. Many resources are expended devising solutions that don't adequately address the problem and sewer work is not different.			
Questionnaire Section Xe - What are the most common SSO defects fixed?			
Pipe problems - point repairs or relining			Repair pipe defects
Sewer manhole deficiencies are number one. Repair or rehabilitation (trenchless technology) of sewer lines. Pumping station rehabilitation and modifications. Building relief sewers.			Repair manhole defects/rehab sewer lines/rehab pumping stations/build relief sewers
Remove sewer blockage, resolve pump station problem, repair sewer lines.			Remove sewer blockage/resolve pumping stations problems/repair sewer lines /
Manhole defects. Line defects.			Repair manholes/repair line defects /
Eliminate cross-connections; install watertight MH lines in ponding areas; pipe re-line and point repair.			Eliminate cross connections/install watertight MH lids in ponding areas/ reline pipes/conduct point repairs
None common now with wet weather improvement program nearing completion.			

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Bottlenecks in the collection system. I/I abatement. Capacity problems. "hydraulic" blockage & design situations.			Remove bottlenecks/remove I/I/address capacity problems/address hydraulic bottlenecks
Grease stoppages cleaning			Remove grease
Those addressed through cleaning.			Conduct proper line cleaning
Pipe defects causing root intrusion leading to backup and SSO			Repair pipe defects with root intrusion
Roots, broken pipes, grease.			Address roots and grease and repair pipes with defects
Manhole rehabilitation. Broken/corroded pipe replacement or rehabilitation.			Conduct manhole rehabilitation/ rehab broken and corroded pipe
Questionnaire Section Xe - Do you expect SSO requirements to be added in the future? Please describe:			
We are hoping to move toward a general "collection systems" permit as opposed to having SSOs tied to a treatment plant.			
Yes, I expect our SSO requirements to be increased. MDNR is going to require us to eliminate all of the constructed sanitary overflows in the future.			
No, Dallas has just completed an administrative order program to eliminate SSO in their system. $186 M invested over nine (9) years.			
Yes. North Carolina is now in the process of implementing separate permitting of Wastewater Collection Systems. There are some SSO abatement requirements in the permits.			
Yes, there is a lot of discussion from both the state and regional level for inclusion of SSO's in the NPDES permit.			
SSO incidents must be reported to Virginia Department of Environmental Quality within five days of occurrence.			

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Yes, It is only a matter of time before our NPDES permits will have SSO-related requirements for all of our facilities. We are currently working to prepare ourselves and our system for these requirements.			