

Table of Contents

Chapter 1

Understanding Wastewater Collection System Problems and Needs

1.1 Purpose of a Wastewater Collection System	2
1.2 Problems	2
1.3 O&M Programs	4
1.3.1 Types of Maintenance	5
1.3.2 Benefits of Effective O&M Programs	6
1.3.2.1 Asset Management	7
1.3.2.2 Service to Customers	7
1.3.2.3 Regulatory Compliance	8
1.3.2.4 Public Health and Safety	8
1.3.2.5 Environmental Protection	9
1.3.2.6 Cost-Effective Use of Agency Resources	9
1.4 Performance Indicators	9
1.5 Additional Resources	11
Chapter Review	13

Chapter 2

Researching Trends in Collection System Performance

2.1 Literature Review	16
2.2 Site Visits and Interviews	17
2.3 Developing the Survey	17
2.3.1 Identifying O&M Categories	17
2.3.2 Identifying Significant Activities or Events	17

2.3.3 Defining Metrics	18
2.3.4 Refining Survey Questions	18
2.3.5 Arranging Data in a Matrix	18
2.3.6 Reviewing Performance Indicators	18

2.4 Survey Matrix 19

2.4.1 Sewer Maintenance (Stoppages and Overflows)	19
2.4.2 Pump Station and Force Main Maintenance	19
2.4.3 Emergency Response (Sewers and Pump Stations)	21
2.4.4 Planning, Scheduling, and Work Order Control	22
2.4.5 Level of Service Provided to Users	23
2.4.6 Control of Infiltration/Inflow and SSOs	23
2.4.7 Equipment	25
2.4.8 Finance	25
2.4.9 Personnel	26
2.4.10 Safety	27
2.4.11 Regulatory Compliance	27

Chapter Review 28

Chapter 3

Developing Benchmark Data

3.1 Profile of 1998 Survey Respondents	30
3.1.1 Population Served, System Size, and Major System Components	31
3.1.2 Flow Characteristics and Precipitation	31
3.1.3 Local Conditions Affecting Design, Construction, and Inspection	31
3.1.3.1 Precipitation	32
3.1.3.2 Terrain	33
3.1.3.3 Soils	33
3.1.3.4 Temperature	33
3.1.3.5 Groundwater	33
3.1.3.6 Geology	33

- 3.1.3.7 Corrosion 34
- 3.1.3.8 Odors 34
- 3.1.3.9 Grease 34
- 3.1.3.10 Roots 34
- 3.1.4 Age, Size, and Pipe Materials 35
- 3.2 Operation and Maintenance Data 36**
- 3.2.1 Inspection and Cleaning Data 36
 - 3.2.1.1 Visual Inspection 36
 - 3.2.1.2 Closed-Circuit Television Inspection 37
 - 3.2.1.3 Cleaning Crew Size and Equipment 37
- 3.2.2 Stoppages and SSOs 37
- 3.2.3 Proactive Repairs, Rehabilitation, and Replacement 38
- 3.2.4 Pump Stations 40
 - 3.2.4.1 Inspection 41
 - 3.2.4.2 Redundancy, Capacity, and Backup Power 42
 - 3.2.4.3 Calibration, Flow Monitoring, and Running Time Meters 42
 - 3.2.4.4 Electrical and Mechanical Maintenance 42
 - 3.2.4.5 Pump Station Failures 44
- 3.2.5 Force Mains 44
- 3.2.6 Air, Vacuum, and Air/Vacuum Relief Valves 45
- 3.2.7 Staff Utilization 45
- 3.3 Financial Data 47**
- 3.3.1 Revenue 47
- 3.3.2 Current Value of Collection System Assets 47
- 3.3.3 Operation and Maintenance Costs 49
- 3.3.4 Repair, Replacement, and Rehabilitation Costs 49
- 3.4 Training and Certification 50**
- 3.5 Safety 51**
- 3.6 Level of Service 52**
- 3.7 Regulatory Compliance 53**
- 3.8 O&M Policies and Procedures 53**

- 3.9 Information Management 54**
- 3.10 Additional Resources 54**
- Chapter Review 55**

Chapter 4 Developing, Analyzing, and Interpreting O&M Performance Indicators

- 4.1 Introduction 58**
- 4.2 Identifying and Using Appropriate Performance Indicators 59**
- 4.3 Benchmarking Process 60**
 - 4.3.1 Collecting Current Data 60
 - 4.3.2 Selecting Comparable Agencies 60
 - 4.3.3 Comparing Performance Data with Other Agencies 61
 - 4.3.4 Applying the Benchmarking Process 64
- 4.4 Setting Target Performance Levels 67**
- 4.5 Making Changes to Enhance Performance 67**
- 4.6 Analyzing and Interpreting Data 69**
- 4.7 Recommendations 69**
- 4.8 Additional Resources 70**
- Chapter Review 71**

Chapter 5 Improving Collection System Performance

- 5.1 Systematic Maintenance Programs 74**
- 5.2 Physical Inspection 74**
- 5.3 Solving Problems 77**

5.4	Cleaning	78
5.4.1	Methods	80
5.4.1.1	Hydraulic Cleaning	80
5.4.1.2	Mechanical Cleaning	81
5.4.1.3	Chemical Cleaning	83
5.4.1.4	Summary	84
5.5	Pump Station and Force Main O&M Program	86
5.5.1	Inspection	86
5.5.2	Electrical/Mechanical Preventive Maintenance	87
5.5.3	Emergency Response	88
5.6	Controlling Infiltration/Inflow Sources	89
5.6.1	Investigating Infiltration/Inflow Sources	90
5.6.1.1	Sewer System Evaluation Survey	92
5.6.1.2	Flow Monitoring	93
5.6.1.3	Physical Survey	93
5.6.1.4	Internal Pipe Inspection	94
5.6.2	Reducing or Eliminating Infiltration/Inflow Sources	95
5.6.3	Protecting the System from Infiltration/Inflow Sources	95
5.7	Underground Repair	96
5.7.1	Connections	97
5.7.2	Main Line Sewer	97
5.7.3	Selecting a Rehabilitation Method	98
5.7.3.1	Nonstructural Repairs	98
5.7.3.2	Structural Repairs	99
5.7.3.3	Selecting Structural Rehabilitation/Reconstruction Methods	102
5.7.3.4	Preparing the Scope of Work	102
5.7.4	Prioritizing Pipe Rehabilitation Backlogs	103
5.8	Emergency Response	104
5.8.1	Emergency Management and Response Plans	105
5.9	Data Management	107
5.10	Additional Resources	108
Chapter Review		109

Chapter 6

Case Histories and Benchmarking Surveys

6.1	Introduction	112
6.2	Summary of Case Histories	112
6.2.1	Sacramento County	113
6.2.2	Central Contra Costa Sanitary District	115
6.2.3	City of Bloomington	117
6.2.4	Denver Metro Wastewater Reclamation District	127
6.2.4.1	Planner Performance Report	128
6.2.4.2	Overtime and Work Backlog Report	129
6.2.4.3	Maintenance Performance Report	130
6.2.4.4	Open Work Order Report	130
6.2.4.5	Equipment Maintenance History Tracking	131
6.2.5	County Sanitation Districts of Orange County	131
6.2.6	Union Sanitary District	133
6.3	Benchmarking Surveys	140
6.4	Performance Indicator Categories	146
6.5	Additional Resources	147
Chapter Review		148

Chapter 7

How Has Performance Improved?

7.1	Comparing Performance Data	150
7.2	Performance Survey Objectives	151
7.3	Data Collection Procedures	151
7.4	Survey Data Analysis	152
7.4.1	Explanations and Trends	153
7.4.2	Identifying Factors for Improvement	168
7.5	Factors Influencing Changes in System Performance	170

7.5.1 Discussion of Most Influential Factors 171
7.5.2 Regulatory Compliance and Enforcement 171
 7.5.2.1 Adopting CMOM 172
7.5.3 New Technologies 173
7.5.4 Staff 173
7.5.5 O&M Business Practices 174
7.5.6 Replacement, Rehabilitation, and Capital Improvement Plan 174
7.5.7 Training and Certification 175
7.5.8 Attitudes and Public Education 175
7.5.9 Remaining Factors 175

7.6 Characteristics of High-Performing Agencies 176

7.6.1 Leadership 176
7.6.2 Financial 176
7.6.3 Operation and Maintenance Programs 176
7.6.4 Performance Indicators 177
7.6.5 Technology 177

7.6.6 Training 177
7.6.7 Community Support 178

7.7 Additional Resources 178

Chapter Review 179

Appendix A

Literature Review

Appendix B

Data Collection Forms

Appendix C

Benchmarking Worksheets

Answer Key 219

Glossary 221

Index 225

A

Acceptance, collection systems, 4
 Acceptance test, 158
 Access
 poor or no physical access as a design-related problem, 32
 requiring easement, 31
 Accidents, 177
 Accountability, 58
 Additional Resources, 11–12, 54, 108, 147
 Administrative orders, 8
 Agency averages and standard deviations, 152–153
 Agency characteristics, 176–178
 Agency responsibility, 2
 Aging of system, 170, 171, 175
 Air relief valves, 21, 31, 45
 Air testing, 75
 Air/vacuum relief valves, 21, 30, 45
 Analysis of survey data, 69, 152–170
 Annual O&M cost
 per capita, 64, 153, 160, 162–163
 per mile of sewer, 65, 153, 163, 164
 Annual rate for residential users, 65, 153, 164, 165, 168, 169
 Annual stoppage caused SSO, trend, 151
 Applied Science and Technology Index, 16
 As-builts, 74
 Assessment, condition, 158
 Asset management, 7, 25, 156, 158, 170, 171, 177
 Assets, collection system, 47–48
 Attitudes of community, management, and policy makers, 170, 171, 175
 Availability of facilities and equipment, 6
 Average annual rate for residential users, 65, 153, 164, 165, 168, 169
 Averages, survey data, 152–170

B

Backfill, 33
 Backup power, pump stations, 42
 Backups, 3, 23, 75
 Bags, cleaning, 81
 Balanced scorecard, 177
 Balls, cleaning, 81
 Bedding, 33
 Benchmark data
 additional resources, 54
 age, size, and pipe materials, 35
 certification, 50–51
 compliance, regulatory, 53
 corrosion, 34

finance, 47–50
 flow characteristics, 31–32
 geology, 32, 33
 grease, 34
 groundwater, 33
 information management, 54
 level of service, 52
 local conditions affecting design, construction, and inspection, 31–34
 major system components, 31
 odors, 34
 O&M policies and procedures, 53–54
 operation and maintenance data, 36–46
 population served, 32
 precipitation, 32–33
 profile of 1998 survey respondents, 30–35
 regulatory compliance, 53
 roots, 34
 safety, 51–52
 soils, 33
 system components, 31
 system size, 31
 temperature, 32, 33
 terrain, 32, 33
 training, 50–51
 Benchmarking
 performance indicators, 10, 59
 process, 60–67
 surveys, 140–145
 worksheets, 209–218
 Bloomington (Minnesota), City of, 117–126
 Bonds, 176
 Breaks, force mains, 44
 Bucket machines, 83
 Budget
 performance indicators, 59
 process, 25
 system performance, 170, 171, 175
 Bursting, pipe, 100, 102
 Business practices, 156, 162, 170, 171, 172, 174, 176
 Bypasses, 2

C

Cable machines, 83
 Calibration, pump stations, 42, 43
 Capacity, collection system, 2
 Capacity Assurance, Management, Operation, and Maintenance (CMOM), 162, 172–173, 175
 Capacity redundancy, 42

Capita, annual O&M cost per, 64, 153, 160, 162
 Capital costs, funding, 176
 Capital improvement plan (CIP), 4, 38, 50, 59, 67, 75, 170, 174–176
 Case histories, 112–140
 Categories of performance indicators, 146–147
 CCTV (closed-circuit television)
 inspection, 37, 75, 172
 percent inspected, 63, 153, 156–158, 169, 170
 Central Contra Costa Sanitary District (CCCS), 115–117
 Certification, 26, 50–51, 170, 171, 175, 177
 Changes to enhance performance, 67–69
 Characteristics of agencies, 176–178
 Charlotte-Mecklenberg Utilities Department, 3, 142
 Chemical cleaning methods, 84
 Cholera, 2
 CIP (capital improvement plan), 4, 38, 59, 67, 170, 171, 174–176
 CIPP (cured-in-place pipe), 98, 100, 101
 City of Bloomington, Minnesota, 117–126
 City of Portland, Oregon, 3
 Claims, 23
 Cleaned, percent of system, 63, 153, 158–160
 Cleaning
 costs, 50
 equipment, 25
 frequency, 79–80
 schedule, 156
 sewers, 36, 80–86
 Clean Water Act (CWA), 8, 172
 Closed-circuit television (CCTV) inspection, 37, 75, 182
 CMMs (computerized maintenance management systems), 76, 177
 CMOM (Capacity Assurance, Management, Operation, and Maintenance), 162, 172–173, 175
 Collection of data, 61
 Collection system performance indicators, 152
 Collection system performance standards, 152
 Communication, 178
 Community support, 178
 Compaction, 33
 Comparing agencies, 61–64
 Comparing performance data, 150–151
 Complaints, 23, 52
 Complaints per 100,000 population, 66, 153, 164, 166
 Compliance, regulatory, 8, 27, 53, 171–173, 176
 Components
 core, program, 17
 system, 32
 Computerized maintenance management systems (CMMs), 76, 177
 Computerized management program, 177, 184
 Condition assessment, 158
 Condition of system, 6
 Confined spaces, 168
 Connections, 30
 Consent agreements, 8
 Construction, collection systems, 4
 Contracted services, 25
 Controlling infiltration/inflow sources, 89–96
 Conventional point repair, 100
 Core components, program, 17

Corrective maintenance, 5, 166, 176
 Corrosion, 34
 Cost-effective use of resources, 9, 178, 183
 Costs
 claims, 23, 52
 cleaning, 50
 inspection, 50
 O&M, 49–50
 regulatory fines, 53
 rehabilitation, 49
 repair, 49–50
 replacement, 50
 safety, 27
 service, 7
 County Sanitation Districts of Orange County, 131–133
 Crews
 inspection, pump stations, 41
 performance, 26
 size, 37
 Criticality, pump stations, 41
 Criticality of pump failure, 89
 Cryptosporidiosis, 2, 8
Cryptosporidium, 8
 Cured-in-place pipe (CIPP), 98, 100, 101
 Customer service, 7–8
 CWA (Clean Water Act), 172

D

Data collection
 forms, 200–206
 performance survey, 151
 procedures, 151–152
 Data management, 107–108, 162, 170, 171, 174
 Debris, 78, 82, 83
 Defects
 nonstructural, 97
 rehabilitation, 98–103
 repairs, 98–103
 structural, 78, 99
 Denver Metro Wastewater Reclamation District, 127–131
 Design, collection systems, 5, 31–34, 74
 Design life, 6
 Deterioration, 170, 171, 175
 Developing, analyzing, and interpreting performance, 58–70
 Disease-causing organisms, 8
 Diseases transmitted, 2
 Drop manhole, 33
 Dry weather capacity, pump stations, 42, 44
 Dyed water flooding, 76, 94
 Dye testing, 22

E

Easement required for access, 31
 Economies of scale, 164
 Effectiveness of sewer cleaning methods, 86
 Efficiency of managing O&M resources, 170, 171
 Electrical maintenance, pump stations, 43, 87–88

Emergency maintenance, 5, 176
 Emergency response, 21, 38, 44, 88–89, 104–107
 Emergency stoppages, 86
 Enforcement, regulatory, 170–173
 Enterprise basis, 176
 Environmental Periodicals Bibliography, 16
 Environmental protection, 9
 Equipment, cleaning, 25
 Examples, performance indicators, 61–64
 Explanations, survey data, 153–168
 Extraordinary emergencies, 5

F

Factors influencing performance, 170–175
 Failure
 air, vacuum, and air/vacuum relief valves, 45
 criticality of pump, 89
 force mains, 44–45
 pump stations, 44
 Failure analysis, 158
 Fats, oils, and greases (FOG) programs, 156, 160, 174
 Fee-for-service basis, 176
 Finance
 asset management, 25
 assets, 47–49
 budget process, 25
 cleaning, 49, 50
 contracted services, 25
 difficulties, 47
 information, 47–49
 inspection, 49, 50
 O&M, 25, 49–50
 personnel, 25
 rates, 47
 rehabilitation, 49–50
 repairs, 49–50
 replacement, 49–50
 revenue, 47
 spot repairs, 50
 value, 48
 Financial management strategies, 176
 Fines, regulatory, 27, 53
 Flow characteristics, 31–32
 Flow monitoring
 effective O&M business practices, 176–177
 pump stations, 42, 43
 sewers, 92–93
 Flow velocity, 79
 FOG (fats, oils, and greases) programs, 156, 160, 174
 Fold-and-formed lining, 98, 101
 Force mains
 age, 35
 breaks, 44–45
 corrosion, 34
 failures, 44–45
 inspection, 44
 maintenance, 19–20
 material, 35

 monitoring, 44
 O&M program, 86–89
 size, 35
 Frequency
 cleaning, 79
 inspections, pump stations, 41, 43

G

Geographic Information System (GIS), 177
 Geology, 32, 33
Giardia, 8
 Giardiasis, 2, 9
 GIS (Geographic Information System), 177
 Global positioning satellite (GPS), 173
 Gravity systems
 age, 35
 corrosion, 34
 inspections, 23, 24
 material, 35
 planning and scheduling, 22–23
 size, 35
 work order control, 22–23
 Grease, 34, 78, 83, 84
 Greater Houston Wastewater Program Survey, 144–145
 Grit, 85, 86
 Groundwater, 32, 33

H

Hazard awareness, 167
 Health of the public, 8–9
 Health warnings, 23, 52
 Hepatitis, 2
 High-performing agencies
 community support, 178
 financial, 176
 leadership, 176
 operation and maintenance programs, 176–177
 performance indicators, 177
 technology, 177
 training, 177
 High-velocity cleaners, 80–81
 Hot spot, 156
 House service lines, responsibilities, 30
 Houston Program Survey, 144–145
 Hydraulic capacity, 170
 Hydraulic cleaning methods, 80–81
 Hydraulic continuity, 100, 101
 Hydrogen sulfide
 corrosion, 34
 odors, 34

I

Improving collection system performance
 cleaning, 78–86
 controlling infiltration/inflow sources, 89–96

Improving collection system performance (*Continued*)

- data management, 107–108
- emergency response, 104–107
- force mains, O&M program, 86–89
- infiltration, 89–96
- inflow, 89–96
- management, data, 107–108
- performance indicators, 59
- physical inspection, 74–77
- pump stations, O&M program, 86–89
- references, 108
- repair, underground, 96–104
- response, emergency, 104–107
- solving problems, 77–78
- underground repair, 96–104

Indicators, performance

See Performance indicators

Infiltration/inflow (I/I), 23, 24, 89–96, 170, 174

Information management, 54, 170, 171, 174

Injuries, frequency, 27

Injuries, lost time, 51, 52, 66, 165, 167, 177

Inspection

- air, vacuum, and air/vacuum relief valves, 45, 46
 - CCTV, 37, 63, 75, 157, 158, 172, 182
 - collection systems, 5, 21, 23, 34
 - costs, 50
 - crews, pump stations, 41
 - force mains, 44–45, 86–87
 - gravity systems, 22
 - internal pipe, 94–95
 - pump stations, 41, 86–87
 - relief valves, 45
 - staff per 10 pump stations, 64, 153, 160, 161
 - system, 85
- Internal pipe inspection, 94–95
- Interpreting data, 69
- Interviews and site visits, 17
- Investment, 6
- ISO environmental standards, 177

J

Joint sealing, 98–99

K

Kites, cleaning, 80

L

- Lateral Sealing System (LSS), 97
- Leadership, 176
- Level of service, 7, 17, 23, 153, 154, 162, 170, 171, 176, 178
 - categories, 23, 52–53
 - performance indicators, 58, 59, 61
- Life cycle costs, 156
- Lines of best fit, 152
- Lining, 101

Literature review (Appendix A), 182–197

Local conditions affecting design, construction, and inspection, 31–34

Lost time injuries, 51, 52, 66, 165–167, 177

M

Main line rehabilitation, 40

Main line repairs, 39

Main line stoppage caused SSO, trend, 150

Maintenance

- access structures, 30
- air relief valves, 21
- computerized maintenance management systems (CMMSS), 76, 177
- electrical and mechanical, 43
- force mains, 19–21
- programs, 182
- pump station, 19–21
- sewer, 17
- tasks, 166
- types, 5–6
- vacuum relief valves, 21

Major system components, 31

Management

- assets, 7
- data, 107–108, 162, 170, 171, 174
- information, 54, 170, 171, 174
- O&M resources, 170, 171, 174

Mandrel testing, 75

Manhole rehabilitation, 40

Manholes, 31

Matrix, survey, 19–27

Mechanical cleaning methods, 81–83

Mechanical maintenance, pump stations, 43, 86

Monitoring

- flows
 - effective O&M business practices, 174
 - pump stations, 42–43
 - sewers, 92–93
- force mains, 44
- pump stations, 42, 43

Monthly stoppage caused SSO, trend, 150

N

National Conference on Sanitary Sewer Overflows, 3

National Pollutant Discharge Elimination System (NPDES), 8, 172, 173

Needs of collection system, 9

New technologies, 173

Nonstructural defects, 97

NPDES (National Pollutant Discharge Elimination System), 8, 172, 173

O

O&M

See Operation and maintenance (O&M)

Objectives, performance survey, 151

- Odors, 34, 86
 - Operation and maintenance (O&M)
 - benefits, 6
 - budget, 25
 - business practices, 156, 162, 170, 171, 172, 174, 176
 - cost per capita, 64, 153, 160, 162
 - cost per mile of sewer, 65, 153, 163
 - costs, 49–50
 - data
 - breaks, main line, 39
 - cleaning, 36
 - closed-circuit television (CCTV) inspection, 37
 - crew size, cleaning, 37
 - emergency response, 38
 - equipment, 37
 - inspection, 36
 - main line rehabilitation, 40
 - main line repairs, 39
 - manhole inspection, 36
 - manhole rehabilitation, 40
 - proactive repairs, rehabilitation, and replacement, 38–40
 - rehabilitation, 38–40
 - repairs, 38–40
 - replacement, 38–40
 - spot repairs, 39
 - SSOs, 37–38
 - stoppages, 37–38
 - visual inspection, 36
 - expenditures, 25
 - performance indicators
 - See Performance indicators
 - performance standards, 10
 - policies and procedures, 53
 - programs
 - acceptance, 4
 - administrative orders, 8
 - asset management, 7
 - availability of facilities and equipment, 6
 - benchmarking, 10
 - benefits, O&M, 6
 - benefits, preventive maintenance, 5
 - capital improvement plan (CIP), 4
 - characteristics, 176
 - compliance regulatory, 8
 - condition of system, 6
 - consent agreements, 8
 - construction, 4
 - core components, 17
 - corrective maintenance, 5
 - cost-effective use of resources, 9
 - cost of service, 7
 - customer service, 7–8
 - data and information, 6
 - design, 4
 - design life, 6
 - disease-causing organisms, 8
 - emergency maintenance, 5
 - environmental protection, 9
 - essential elements, 4
 - health of the public, 8–9
 - inspection, 4
 - investment, 6
 - level of service, 7
 - maintenance, types, 5
 - management of assets, 7
 - performance indicators, 7, 9–11
 - problems, 2
 - public health and safety, 8–9
 - regulatory compliance, 8
 - reliability, 6
 - scheduled maintenance, 5
 - startup, 4
 - system performance, 6
 - training, 9
 - Operator training, 167
 - Orange County Sanitation Districts, 131–133
 - Outreach, public, 175
 - Overflows, 19, 77, 173
- ## P
- Parachutes, cleaning, 81
 - Percent of system cleaned annually, 63, 153, 158, 159
 - Percent of system inspected annually by CCTV, 63, 153, 156–158, 169, 170
 - Performance, system
 - aging of system, 170, 171, 175
 - attitudes of community, management, and policy makers, 170, 171, 175
 - budget, 170, 171, 175
 - business practices, 156, 162, 170, 171, 172, 174, 176
 - capital improvement plan (CIP), 170, 171, 174, 176
 - certification, 170, 171, 175
 - compliance, 170, 171, 176
 - deterioration of system, 170, 171, 175
 - enforcement, 170, 171
 - factors, 170–175
 - new technologies, 173
 - O&M business practices, 156, 162, 170, 171, 172, 174, 176
 - population served, 170, 171, 175
 - public education, 170, 171, 175
 - regulatory compliance/enforcement, 170, 171, 172, 176
 - rehabilitation, 170, 171, 174, 176
 - repair, 176
 - replacement, 170, 171, 174, 176
 - size of system, 170, 171, 175
 - staff, 173
 - technologies, 173
 - training, 170, 171, 175
 - Performance data, comparing, 150
 - Performance deterioration, 170
 - Performance goal, 2
 - Performance indicators
 - accountability, 58
 - analyzing data, 69
 - annual O&M cost per capita, 64, 153, 160, 162
 - annual O&M cost per mile of sewer, 65, 153, 163, 164
 - annual rate for residential users, 65, 153, 164, 165, 168, 169

- Performance indicators (*Continued*)
 - benchmarking, 10, 58
 - benchmarking process, 60–67
 - budget, 59
 - capital improvement plan (CIP), 59
 - categories, 146–147
 - changes to enhance performance, 67
 - characteristics of high-performing agencies, 177
 - CIP (capital improvement plan), 59
 - collection of data, 60
 - comparing agencies, 60
 - complaints per 100,000 population, 66, 153, 164, 166
 - cost, 58
 - data collection, 151
 - developing, analyzing, and interpreting, 57–70
 - enhancing performance, 67
 - examples, 61–64
 - improving performance, 58
 - inspection staff per 10 pump stations, 64, 153, 160, 161
 - interpreting data, 69
 - level of service, 58, 59, 61
 - lost time injuries, 66, 153, 165–167
 - O&M cost per capita, 64, 153, 160, 162
 - O&M cost per mile of sewer, 65, 153, 163, 164
 - O&M programs, 7, 9–11
 - percent of system cleaned annually, 63, 153, 158, 159
 - percent of system inspected annually by CCTV, 63, 153, 156–158, 169, 170
 - production indicators, 59
 - production rates, 58
 - rate for residential users, 65, 153, 164, 165, 168, 169
 - recommendations, 69
 - SSOs per 100 miles of gravity sewer, 61, 153, 154, 169, 170
 - stakeholders meetings, 58
 - stoppages per 100 miles of gravity sewer, 62, 153, 154, 155
 - target performance levels, 67
 - trends, 11, 59, 61
 - using, 59
- Performance standards, 152
- Performance survey, data collection procedures, 151
- Personnel
 - certification, 26
 - crew performance, 26
 - finance, 25
 - training, 26
- Physical inspection, 74–77
- Physical survey, 93–94
- Pipe bursting, 100, 102
- Pipe inspection, 94
- Pipes, corrosion, 34
- Planning and scheduling
 - gravity systems, 22
 - pump stations, 22
- PLC (programmable logic controller) controls, 173
- Policies and procedures, O&M, 53
- Policymakers, 175
- Polio, 2
- Population served, 31, 170, 171, 175
- Portland (Oregon), City of, 3
- Power, backup, pump stations, 42
- Precipitation, 31, 32–33
- Predictive maintenance, 5, 87, 160, 176
- Pretreatment inspector, 174
- Preventive maintenance, 5, 87–88, 160, 176
- Priority codes, 103
- Proactive maintenance, 4, 75, 79, 88, 176
- Proactive repairs, rehabilitation, and replacement, 38
- Problems, collection systems, 2
- Production indicators, 59
- Production rates, 58
- Professional organizations, 177
- Profile of 1998 survey respondents
 - air relief valves, 30
 - air/vacuum relief valves, 30
 - area, 30
 - components, system, 31
 - connections, 30
 - force mains, 30
 - gravity sewer length, 30
 - length, gravity sewer, 30
 - maintenance access structures, 30
 - major system components, 31
 - manholes, 31
 - population served, 31
 - pump stations, 30
 - siphons, 30
 - system components, 31
 - system size, 31
 - vacuum relief valves, 30
- Program, safety, 27
- Protruding tap, 78, 97
- Public advisory council, 175
- Public education, 170, 171, 175
- Public health warnings, 23, 52
- Public outreach, 175
- Pump stations
 - age, 35
 - backup power, 42
 - calibration, 42, 43
 - capacity redundancy, 42
 - crews, inspection, 41
 - criticality, 40
 - dry weather capacity, 42
 - electrical maintenance, 43
 - emergency response, 21, 44
 - failures, 44
 - flow monitoring, 42, 43
 - frequency, inspections, 41
 - inspection, 41
 - inspection crews, 41
 - maintenance, electrical and mechanical, 42
 - maintenance programs, 19–20, 176
 - mechanical maintenance, 42
 - O&M program, 86–89
 - power, backup, 42
 - redundancy, capacity, 42
 - running time meters, 42
 - SCADA systems, 41

- staff, electrical and mechanical, 42
- tasks performed, inspection, 41
- wet weather capacity, 42

Purpose

- collection systems, 2
- O&M programs, 4

R

Rates

- level of service categories, 23
- residential users, 65, 153, 164, 165, 168, 169

Reactive maintenance, 5

Recommendations, performance indicators, 69

Record drawings, 74

Recordkeeping, 173

Redundancy, capacity, 42

Regulatory compliance/enforcement, 8, 27, 53, 170, 171, 172, 176

Rehabilitation

- considerations, 97
- costs, 49
- defects, 98–104
- inflow/infiltration, 24
- manhole, 40
- methods, 98
- sewers, 38, 40
- SSOs, 24
- system performance, 170, 171, 174, 176

Reliability, 6

Repairs

- costs, 49
- defects, 98–104
- inflow/infiltration, 24
- sewers, 38, 39
- SSOs, 24
- system performance, 176
- underground, 96–104

Replacement

- sewers, 38
- system performance, 170, 171, 174, 176

Researching trends in collection system performance, 15–27

Residential user rates, 65, 153, 164, 165, 169

Response, emergency, 21, 38, 44, 88–89, 104–107

Responsibility for repairs, 2, 30

Revenue, 47

Review of literature, 16, 181–197

Rodders, 81–82

Root cause failure analysis, 78

Roots, 34, 78, 85, 86

Running time meters, pump stations, 42, 43

S

Sacramento Area Sewer District (SASD), 150

Sacramento County, 113–115

Safety

- cost, 27
- hazards, 168

- injuries, 27, 51

- lost time, 51–52

- program, 27, 51–52, 167, 177

- public, 8

Sand, 78, 85, 86

Sanitary Sewer Overflow Federal Advisory Committee, 3

Sanitary sewer overflows (SSOs), 3, 23, 24, 37–38

SASD (Sacramento Area Sewer District), 150

Satellite collection systems, 173

SCADA (supervisory control and data acquisition) systems, 41, 86, 88, 160, 177

Scheduled maintenance, 5

Scooters, cleaning, 81

Scorecard, balanced, 177

Service, level of, 7, 17, 23, 153, 154, 162, 170, 171, 176, 178

- categories, 23, 52–53

Service area, 170, 171

Sewer cleaning methods, effectiveness of, 86

Sewer maintenance, 19

Sewers, emergency response, 21

Sewer System Evaluation Surveys (SSESs), 49, 92

Silt, 78

Siphons, 30, 32

Site visits and interviews, 17

Size of system, 31, 170, 171, 175

Sliplining, 102

Smoke testing, 24, 75, 93

Soils

- benchmark data, 32, 33

- corrosive, 33

Solving collection system problems, 77–78

Spot repairs, 39, 50

SSESs (Sewer System Evaluation Surveys), 49, 92

SSO reporting, 171

SSOs (sanitary sewer overflows), 3, 23, 24, 37–38

SSOs per 100 miles of gravity sewer, 61, 153, 154, 169, 170

Staff

- electrical and mechanical, 42

- inspection, 64, 153, 160, 161

- system performance, 173

- utilization, 45–46

Stakeholders meetings, 58

Standards, collection system performance, 152

Startup, collection systems, 4

Stoppages, 3, 19, 37, 38, 77, 85, 86

Stoppages per 100 miles of gravity sewer, 62, 153, 154, 155

Strategic plans, 177

Structural defects, 78, 97

Supervisory control and data acquisition (SCADA) systems, 41, 86, 88, 160, 177

Surcharging, 77

Survey respondents, profile

- See Profile of 1998 survey respondents

Surveys

- data analysis, 152–170

- development, 17

- forms, 151

- matrix, 19–27

- physical, 93–94

Sydney Water, Australia, performance indicators, 146–147

System components, 31
 System inspection, 85
 System performance
 aging of system, 170, 171, 175
 attitudes of community, management, and policy makers, 170, 171, 175
 budget, 170, 171, 175
 business practices, 156, 162, 170, 171, 172, 174, 176
 capital improvement plan (CIP), 170, 171, 174, 176
 certification, 170, 171, 175
 compliance, 170, 171, 176
 deterioration of system, 170, 171, 175
 enforcement, 170, 171
 factors influencing, 170–175
 new technologies, 173
 O&M business practices, 156, 162, 170, 171, 172, 174, 176
 O&M programs, 6
 population served, 170, 171, 175
 public education, 170, 171, 175
 regulatory compliance/enforcement, 170, 171, 172, 176
 rehabilitation, 170, 171, 174, 176
 repair, 176
 replacement, 170, 171, 174, 176
 size of system, 170, 171, 175
 staff, 173
 technologies, 173
 training, 170, 171, 175

T

Tap, protruding, 78, 97
 Tap cutting, 99
 Target levels of performance, 67
 Tasks performed, pump station inspection, 41
 Technology
 high-performing agencies, 177
 system performance, 173
 Temperature, 32, 33
 Terrain, 32, 33
 Testing
 air, 75
 dye, 24, 76
 mandrel, 75
 smoke, 24, 75
 vacuum, 75, 173
 Tetanus, 2
 Third party notice, 172
 Tracking, 11
 Training, 9, 26, 50–51, 167, 170, 171, 175, 177
 Trench fatalities, 168
 Trenchless point repair, 99

Trends
 main line stoppage caused SSO, 150
 performance indicators, 11, 59, 61
 survey data, 152–170
 Tuberculosis, 2
 Turbulence as a design-related problem, 32
 Types of maintenance, 5
 Typhoid, 2

U

Underground repair, 96–104
 Union Sanitary District (USD), 133–134
 Using performance indicators, 59
 Utilization, staff, 45–46

V

Vacuum relief valves, 21, 30, 45
 Vacuum testing, 75, 173
 Value, collection system, 47
 Velocity of flow, 79
 Violations, regulatory, 27, 53
 Visual inspection, 36, 75, 76

W

Washington Suburban Sanitary Commission (WSSC), 3
 Wastewater collection systems
 agency responsibility, 2
 backups, 3
 benchmarking, 10
 bypasses, 2
 capacity, 2
 diseases transmitted, 2
 needs, 9
 operation and maintenance (O&M) program, 3, 4
 performance goal, 2
 performance indicators, 9
 problems, 2
 purpose, 2
 sanitary sewer overflows (SSOs), 3
 stoppages, 3
 Water Environment Federation's Annual Literature Review, 16
 Weil's disease, 2
 Wet weather capacity
 limitations, 160
 pump stations, 42
 Work order control
 gravity systems, 22
 pump stations, 22
 Worksheets, benchmarking, 209–218