CONTENTS

	Preface	xiii
	Acknowledgments	xv
Chapter 1	Wastewater Collection and Pumping:	
•	An Overview	
1-1	Historical Developments	2
	London Sewers	?
	American Sewers	_
	Early Pumping Stations	3
1-2		
	Collection Systems	~
1.2	Pumping Stations	5
1-3	Recent Trends and Developments	n
	Design Materials	
		7
	Alternative Collection Systems Management of Wastewater Collection Systems	•
The second	Storm-Water Management	
1-4		8
	rences	9
Chapter 2	Review of Applied Hydraulics	10
2-1	- · · · · · · · · · · · · · · · · · · ·	10
2-1	Fundamentals of Pipe and Open-Channel Flow Definition of Terms	107
	Laminar Flow Turbulent Flow Pipe and Open-Channel	
	Flow Head Loss Hydraulic Grade Line Energy	
	Grade Line Specific Energy Steady Flow Uniform	
	and Nonuniform Flow Varied Flow	
	Equation of Continuity	13
	Energy Equation	14
	Momentum Equation	16

vi CONTENTS

	2-2	Flow Equations	18
		Flow in Closed Conduits	19
		Poiseuille Equation Darcy-Weisbach Equation	
		Manning Equation Hazen-Williams Equation	
		Comparison of the Darcy-Weisbach, Manning, and	
		Hazen-Williams Equations General Comments on the	
		Use of Pipe-Flow Equations	
		Flow in Open Channels	28
		Pipe Sizes	29
	2-4		30
		Sewers Flowing Full	30
		Sewers Flowing Partly Full	35
	2 5	Hydraulic Elements of Noncircular Sewer Sections	37
	2-5	Minor Losses	38
		Minor Losses in Closed-Conduit Flow	40
		Minor Losses in Open-Channel Flow	42
		Entrance Losses Contractions and Expansions Bends Curves Transitions Exit Losses	
	26		4.4
	2-6	Nonuniform Open-Channel Flow General Equation for Nonuniform Flow	44 44
		Control Sections Critical Depth Drawdown	44
		Backwater Chute Hydraulic Jump	
		Banking on Curves	54
	Disci	ussion Topics and Problems	54
		rences	50
	1010	TOHOUS	
Chapter	r 3	Wastewater Flows and Measurement	60
	3-1	Components of Wastewater	60
	3-2	Wastewater Sources and Flowrates	61
		Sources and Rates of Domestic Wastewater Flows	61
		Residential Districts Commercial Districts	
		Institutional Facilities Recreational Facilities	
		Reduction of Domestic Wastewater Flows	64
		Sources and Rates of Industrial Wastewater Flows	66
		Reduction of Industrial Wastewater Flows	67
		Infiltration/Inflow	67
		Infiltration into Sewers Inflow into Sewers	
		Infiltration Design Allowances for Sewers	
		Variations in Wastewater Flows	71
		Short-Term Variations Seasonal Variations	
		Industrial Variations	
	3-3	Analysis of Wastewater Flowrate Data	72
		Peaking Factors for Wastewater Flows	72
		Peak Infiltration Flows	73
	2 1	Peak Inflow Design Allowance	74
	3-4	Flow Measurement by Direct-Discharge Methods	77
	3-4	Flow Measurement by Direct-Discharge Methods Weirs	
	3-4	Flow Measurement by Direct-Discharge Methods	77

		Venturi Meter	86
		Parshall Flume	88
		Palmer-Bowlus Flume	88
	3-5	Flow Measurement by Velocity-Area Methods	94
	Disc	sussion Topics and Problems	95
		erences	98
Chanta	- 1	Design of Sources	100
Chapte		Design of Sewers	100
	4-1	Types of Collection Systems and Sewers	100
	4-2	Design of Gravity-Flow Sanitary Sewers	103
		Preliminary Investigations	105
		Field Work Preparation of Maps and Profiles	
		Basic Design Considerations	108
		Design Flows Hydraulic Design Equation Sewer Pipe	
		Materials and Sizes Minimum and Maximum Velocities	
		Minimum Slopes Alternative Alignments and Designs	
		Use of Curved Sewers Sewer Appurtenances	
		Sewer Ventilation	
		Design of Sanitary Sewers	114
		Preparation of Contract Drawings and Specifications	124
		Contract Drawings Contract Specifications	
		Acceptance Tests for New Sewers	128
		Water Testing Low-Pressure Air Testing	
	4-3	Design of Gravity-Flow Storm-Water Sewers	132
		Storm-Water Design Flows	134
		Methods of Computation The Rational Method	
		Storm-Water Sewer Pipe Materials and Sizes	135
		Minimum Velocities	136
	4-4	Pressure and Vacuum Sanitary Sewers	140
		Pressure Sewers	142
		Vacuum Sewers	142
	n .	Application of Pressure and Vacuum Sewers	142
		ussion Topics and Problems	145
	Refe	rences	149
Chapte	r 5	Sewer Appurtenances	153
-	5-1	Manholes, Building Connections, and Flushing Devices	153
	J-1	Manholes	153
		Manhole Size Manhole Spacing Transitions and Turns	133
		in Sewer Manholes Manhole Construction Manhole	
		Steps Manhole Frames and Covers Drop Manholes	
		Building Connections	161
		Flushing Devices	162
	5-2	Street Inlets and Catch-Basins	164
		Street Inlets	164
		Types of Inlets Inlet Castings and Assembled Gratings	107
		Hydraulics of Inlets	
		Catch-Basins	167

	5-3	Junctions and Transitions, Depressed Sewers, and Vertical	
		Drops and Energy Dissipators	168
		Junctions and Transitions	168
		Depressed Sewers (Inverted Siphons)	170
		Design Features Design Computations	
		Vertical Drops and Energy Dissipators	176
	5-4	Overflow and Diversion Structures	176
		Side Weirs	177
		Side Weirs—Falling Water Surface Side Weirs—Rising	
		Water Surface Design of Side Weirs	
		Baffled Side Weirs	189
		Transverse Weirs	189
		Leaping Weirs	189
		Relief Siphons	190
	5-5	Regulating Devices	192
		Reverse Taintor Gate	192
		Tipping-Plate Regulator	193
		Hydro-Brake Regulator	193
		Application	195
	5-6	Outlets	195
		cussion Topics and Problems	196
		erences	199
			.,,
Chapte	r 6	Infiltration/Inflow	201
Chapte		Definitions	201
	6-1 6-2		202
	0-2	An Overview of Sewer System Evaluation and Rehabilitation	203
		Elements of EPA Program	203
	()	I/I Analysis in the Future	205
	6-3	I/I Analysis (Phase I)	205
		Basic Steps in I/I Analysis	205
		Determination of Infiltration/Inflow	206
		Cost-Effectiveness Analysis	207
	6-4	Sewer System Evaluation Survey (Phase II)	217
		Basic Steps in Evaluation Survey	217
		Review of Evaluation Survey Methodology	218
		Infiltration Survey Inflow Survey	
		Alternative Survey Method	
		Cost-Effectiveness Analysis	223
	6-5	Sewer System Rehabilitation (Phase III)	223
		I/I Reduction Methods	223
		Sealing Sewer Lining and Replacement	
		Manhole Renovations	
		Removal of Storm Drainage Connections	226
		Removal of I/I Sources from Service Connections	226
		I/I Sources on Private Property	226
		Long-Term Effects of I/I Reduction	226
	6-6	Design Standards for I/I Prevention and Control	227
		Pine Materials Tointing Systems and Appurtenances	227

	Building Sewers	227
	Standards and Inspection Sewer Use Regulations	22.
Dis	cussion Topics and Problems	228
	Ferences	230
		2 11
Chapter 7	Occurrence, Effect, and Control of the	
Chapter /	,	
	Biological Transformations in Sewers	232
7-1	Biological Transformations Occurring During	
	Wastewater Transport	233
	Generation of Hydrogen Sulfide in Sewers	233
	Definition of Terms Soluble Sulfide Equilibrium	
	Process Microbiology Process and Rate of Sulfide	
	Generation Precipitation of Metallic Sulfides Oxidation	
	of Sulfide Emission of Hydrogen Sulfide to the Sewer	
	Atmosphere Sulfide Buildup in Sewers	
	Other Biological Transformations	249
•	Effects of Changes in Wastewater Composition on Treatment	250
	Precipitation of Trace Elements Immediate Oxygen	
	Demand Growth of Filamentous Microorganisms	
7-2		252
	Hydrogen Sulfide Corrosion Process	252
	Cement-Bonded Materials Ferrous Materials	
	Control of Hydrogen Sulfide Corrosion	260
7-3		200
, ,	Other Sewer Gases	261
	Occurrence of Odorous and Other Sewer Gases	261
	Odor Characterization and Measurement Odor Levels	2.(11
	Effect of Sewer Gases	263
	Control of Sewer Gases	264
	Proper Design of Collection Systems Ventilation and	2114
	Air Relief Other Control Methods	
7-4		265
	cussion Topics and Problems	266
	remotes and Problems	267
KEI	EIEILEN	2n /
C1 0	December 1 D C 4	
Chapter 8	Pumps and Pump Systems	269
8-1	Introduction to Pump Analysis	269
	Capacity	270
	Head	270
	Static Suction Head Static Discharge Head	
	Static Head Friction Head Velocity Head	
	Minor Head Loss Total Dynamic Head	
	Pump Efficiency and Power Input	273
	Pump Head-Capacity Curve	273
	System Head-Capacity Curve	274
8-2	Pumps	276
	Classification of Pumps	276

X CONTENTS

		Centrifugal Pumps	276
		Pump Characteristics Radial-Flow Pumps	
		Mixed-Flow Pumps Axial-Flow Pumps	
		Screw Pumps	284
		Other Pumps for Wastewater	286
		Pneumatic Ejectors Bladeless Pumps	
		Air-Lift and Jet Pumps	
		Pumps for Scum, Grit, and Sludge	289
		Torque-Flow Pumps Plunger and Rotary Pumps	
		Pump Construction	289
	8-3	Pump Operating Characteristics	290
		Pump Characteristic Curves	290
		Pump Operating Range	292
		Characteristic Relationships for Centrifugal Pumps	294
		Flow, Head, and Power Coefficients Affinity Laws	
		Specific Speed Changes in Impeller Diameters	
		Cavitation	299
		Cavitation Constant Cavitation at Operating Point	
	8-4		302
	0-4	Electric Motors	302
		Constant- and Multiple-Speed Drives	
		Variable-Speed Drives	
		Internal Combustion Engines	306
		Dual-Fuel Engines Direct and Gear Drives	
	0.5		307
	8-5	Determination of Flowrates	308
			309
		Location of the Pumping Station	309
		Force Mains Powell amount of System Head Connective Curve	310
		Development of System Head-Capacity Curve	311
	8-6		311
		Single-Pump Operation	316
		Multiple-Pump Operation	310
		Parallel Operation Series Operation	337
		cussion Topics and Problems	340
	Refe	erences	3 4 0
~ 1	•	Pour in a Stations	342
Chapte	er y	Pumping Stations	
	9-1	Types of Pumping Stations	342
		Classification of Pumping Stations	343
		General Features of Pumping Stations	344
	9-2	Design of Conventional Pumping Stations	344
		Pumping Station Construction	350
		Wet Wells	350
		Wet-Well Design Considerations Wet-Well Volume	
		Wet-Well Modifications	
		Wet-Well Appurtenances	356
		Bar Racks Comminutors Selection of	
		Screening Devices	
		Soldening Solder	

Dry Wells	357
Pump Settings	358
Suction and Discharge Piping	358
Suction Piping Discharge Piping	550
Pumping Station Instrumentation	361
Automatic Controls Manual Controls Alarms	301
Control Panel Design Flow Measurement	
Selection of Pump Control Points	366
Constant- or Multiple-Speed Pumps Variable-Speed Pumps	300
Electrical Equipment	372
Heating and Ventilation	372
Heating Systems Ventilating Systems	312
Plumbing Systems	271
Pumping Station Drainage	374
9-3 Design of Factory-Assembled Pumping Stations	374
Major Physical Features	375
Materials of Construction	375
Pneumatic-Ejector Station	375
	376
Station Appurtenances Air Compressors	
System Controls	
Wet-Pit Station	378
Dry-Pit Station 9-4 Design of Force Mains	378
O	380
Hydraulic Design of Force Mains	380
Determination of Force Main Size Energy Losses in	
Force Mains Force Main Velocities	
Other Design Considerations	382
Pipe Materials Depth of Cover Anchorage	
Reduction of Outlet Turbulence	
Force Main Appurtenances	387
Blowoffs Air Valves	
9-5 Waterhammer in Wastewater Force Mains	389
Theory of Waterhammer	389
Pressure Wave Velocity Magnitude of Waterhammer	
Pressure Buildup	
Analysis of Waterhammer	392
Waterhammer Control	393
Swing Check Valves Positively Controlled Valves	
Surge-Relief Valves Air and Vacuum Valves	
Other Control Measures	
Discussion Topics and Problems	398
References	399
Appendixes	
A · Conversion Factors	401
B Physical Properties of Water	413
C Minor Losses in Closed Conduits	416

Indexes

Name Index Subject Index