

Contents

<i>List of Symbols</i>	page xi
<i>Preface</i>	xv
1 Basic Equations for Long Waves	1
1.1 Approach	1
1.2 Schematization of the Cross Section	2
1.3 Mass Balance	3
1.4 Equations of Motion	5
1.4.1 Euler Equations	6
1.4.2 Flow Resistance	8
1.4.3 Momentum Balance	10
1.5 Summary of the Long-Wave Equations	11
Problems	12
2 Classification and Analysis of Long Waves	13
2.1 Types of Long Waves	13
2.1.1 Translatory Waves	13
2.1.2 Tsunamis	14
2.1.3 Seiches	16
2.1.4 Tides	17
2.1.5 Flood Waves in Rivers	18
2.2 A Condition for the Long-Wave Approximation	19
2.3 Estimation of Terms	21
2.3.1 Advective Acceleration Term	21
2.3.2 Resistance Term	23
2.4 Solution Methods	24
2.4.1 Complete Equations	24
2.4.2 Simplified Equations	25
Problems	26
3 Elementary Wave Equation	27
3.1 Simple Wave	27
3.1.1 Propagation	27
3.1.2 Balance Equations	28
3.2 Elementary Wave Equation	31
3.2.1 Derivation	31

3.2.2	General Solution	32
3.2.3	Total Derivative	33
3.3	Relation between Discharge and Free-Surface Elevation in a Progressive Wave	34
3.4	Solution for Arbitrary Initial Conditions	34
3.5	Boundary Conditions	35
3.6	Periodic Progressive and Standing Waves	37
3.6.1	Infinitely Long Canal	37
3.6.2	Semi-Infinitely Long Canal with a Closed End	39
3.6.3	Closed Basin	39
3.6.4	Semi-Closed Basin Connected to a Reservoir or Tideless Sea	40
3.6.5	Semi-Closed Basin Connected to a Tidal Sea	41
	Problems	42
4	Translatory Waves	45
4.1	Introduction	45
4.2	Low Translatory Waves in Uniform Channels	46
4.3	Propagation in Non-Uniform Canals	48
4.3.1	Rapidly Varying Cross Section	48
4.3.2	Gradually Varying Cross Section	51
4.4	Damping of Translatory Waves	53
4.5	High Translatory Waves	54
4.5.1	Wave Deformation	55
4.5.2	Tidal Bores	57
4.5.3	Bore Propagation	58
4.6	Field Observations	59
4.6.1	Observations in the Twenthekanaal	59
4.6.2	Observations in the Approach Canal to the Lanaye Lock	63
	Problems	64
5	Method of Characteristics	67
5.1	Introduction	67
5.2	Mathematical Formulation	68
5.3	Principle of Application	70
5.3.1	General Procedure	70
5.3.2	Characteristics	71
5.3.3	Boundary Conditions	72
5.3.4	External Forces	75
5.4	Graphical Solution Procedure	76
5.4.1	Initial Value Problem	77
5.4.2	Inclusion of the Boundary Conditions	80
5.5	Simple Wave	83
5.5.1	General Solution	83

5.5.2	Expansion Wave	85
5.5.3	Compression Wave	86
	Problems	88
6	Tidal Basins	91
6.1	Introduction	91
6.2	Mathematical Formulation	92
6.2.1	Motion in the Basin	92
6.2.2	Motion in the Channel	93
6.2.3	Coupled System	96
6.3	Linearization of the Quadratic Resistance	98
6.4	System with Discrete Storage and Resistance	101
6.4.1	Governing Equation	101
6.4.2	Nonhomogeneous Solution	101
6.4.3	Explicit Solution	102
6.5	System with Discrete Storage, Resistance and Inertia	105
6.6	Solution through Complex Algebra	109
6.6.1	Complex Representation	109
6.6.2	Solution	110
	Problems	111
7	Harmonic Wave Propagation	113
7.1	Introduction	113
7.2	Complex Representation of Damped Progressive Harmonic Waves	114
7.3	Formulation and General Solution	116
7.3.1	Formulation	116
7.3.2	General Solution	117
7.3.3	Solution of the Dispersion Equation	118
7.3.4	Solution for the Discharge	119
7.4	Unidirectional Propagation	121
7.4.1	Physical Interpretation	122
7.4.2	Propagation in Compound Channels	124
7.5	Bi-directional Wave Propagation	126
7.5.1	Relation between the Complex Amplitudes at the Ends of a Prismatic Section	126
7.5.2	Response Function of a Semi-Closed Prismatic Basin	129
7.6	Propagation in Non-Uniform Channels	131
7.6.1	Abrupt Channel Transition	131
7.6.2	Exponentially Varying Cross Section	132
7.7	Propagation in Networks	137
7.8	Nonlinear Effects	139
7.8.1	Tidal Wave Deformation	139
7.8.2	Mean Slope of the Free Surface	139
	Problems	141

8	Flood Waves in Rivers	143
8.1	Introduction	143
8.2	Quasi-Steady Approximation	144
8.3	Quasi-Uniform Approximation	145
8.3.1	Formulation and General Solution	146
8.3.2	The High-Water Wave Speed	146
8.3.3	Kinematic Wave Behaviour	147
8.4	Influence of Variable Free-Surface Slope	148
8.4.1	Diffusion Model for Flood Waves	149
8.4.2	Elementary Solution	151
8.4.3	Observations	152
8.5	Discussion	153
	Problems	154
9	Steady Flow	157
9.1	Rapidly Varying Flow	157
9.1.1	Scaling Analysis	157
9.1.2	Flow Patterns	158
9.1.3	Bernoulli Equation	161
9.1.4	Relations between Water Level and Discharge	161
9.1.5	Hydraulic Jump	167
9.2	Gradually Varying Flow	168
9.2.1	Governing Differential Equation	168
9.2.2	Integral Curves	169
9.2.3	Classification of Backwater Curves	171
9.2.4	Boundary Conditions	172
9.2.5	Explicit Representation	172
9.3	Uniform Flow	176
9.3.1	Equilibrium Relations	176
9.3.2	Resistance Relations	177
9.3.3	The Overall Resistance of a Channel	181
9.3.4	Applicability to Unsteady Flow	182
	Problems	182
10	Transport Processes	185
10.1	Introduction	185
10.2	Generic Balance Equation	186
10.3	Molecular Diffusion	187
10.3.1	Fick's Law of Diffusion	188
10.3.2	One-Dimensional Diffusion	188
10.3.3	The Random Walk Model	192
10.3.4	Two-Dimensional Diffusion	194
10.4	Advection and Molecular Diffusion	194
10.5	Turbulent Diffusion	196

10.5.1 Reynolds Averaging	196
10.5.2 Closure Hypothesis	197
10.6 Vertical Diffusion in Free-Surface Flows	198
10.6.1 Turbulence Diffusivity	198
10.6.2 Vertical Distribution of Horizontal Velocity	199
10.7 Horizontal Transport in Free-Surface Flows	200
10.7.1 Introduction	200
10.7.2 Two-Dimensional Horizontal Transport	201
10.7.3 One-Dimensional Horizontal Transport	207
Problems	210
11 Numerical Computation of Solutions	211
11.1 Introduction	211
11.2 Canal-Basin System	212
11.2.1 Model Equations	212
11.2.2 Discretization	213
11.2.3 Semi-implicit Method	213
11.2.4 Some Other Solution Methods	215
11.2.5 Properties of the Semi-implicit Method	216
11.2.6 Python Implementation	218
11.2.7 Verification	220
11.3 Semi-Implicit Method for Long Waves	223
11.3.1 Model Equations	223
11.3.2 Discretization	224
11.3.3 Semi-Implicit Method	225
11.3.4 Some Other Solution Methods	229
11.3.5 Properties of the Semi-Implicit Method	232
11.3.6 Python Implementation	235
11.3.7 Verification	238
11.4 Characteristics-Based Methods	241
11.4.1 Characteristic Equations	241
11.4.2 Space–Time Discretization	242
11.4.3 Forward Time Backward Space Method	243
11.4.4 Some Other Characteristics-Based Methods	247
11.4.5 Properties	250
11.4.6 Python Implementation	252
11.4.7 Verification	254
Problems	256
Appendix A Pressurized Flow in Closed Conduits	259
A.1 Introduction	259
A.2 Governing Equations	260
A.2.1 Constitutive Equations	260
A.2.2 Conservation of Mass	262

A.2.3 Conservation of Momentum	263
A.3 Pressure Waves in Pipelines	263
A.3.1 Characteristic Equations	263
A.3.2 Physical Behaviour	264
A.4 Closure Procedures	265
A.4.1 Abrupt Closure	265
A.4.2 Gradual Closure	266
A.4.3 Influence of Exit Losses and/or Wall Friction	269
A.4.4 Influence of Time Scales	269
Problems	270
Appendix B Summary of Formulas	271
<i>References</i>	279
<i>Author Index</i>	283
<i>Subject Index</i>	285