Table of Contents

Introduction xv

PART 1. 3D MODELS 1

Chapter 1. Non-Linear Waves With REFLUX 3D 3
Philippe SERGENT

1.1. Context 3
1.1.1. System of equations to be solved 4
1.1.2. h-s method 5
1.1.3. Linear dispersion 7
1.1.4.Vertical profiles 9
1.1.5. Linear shoaling 10
1.1.6. Non-linear analysis 12
1.2. Data required for implementation 13
1.3. Specific numerical methods 14
1.3.1. Variational formulation 14
1.3.2. Lax-Wendroff scheme 14
1.3.3. TVD scheme with slope limiter 16
1.4. Modeling options 17
1.4.1. Wave breaking 17
1.4.2. Treatment of the moving boundary 18
1.4.3. Treatment of an open boundary 19
1.4.4. Generation of the incident wave 20
1.5. Results output by the code, and operation 21
1.5.1. Distortion of a wave by a trapezoidal bar 21
1.5.2. Breaking 22
1.5.3. Migration of an undersea sandbar 23
1.6. Examples of models 25
1.7. Bibliography 25

Chapter 2. Current Modeling with TELEMAC3D 29
Jacques CHORDA and Marie-Madeleine MAUBOURGUET

2.1. TELEMAC3D: 3D hydrodynamics at a free surface 29
2.2. Equations used in TELEMAC3D 30
2.3. Choices of 3D mesh 31
2.4. Specific features 31
2.5. Simple transition from TELEMAC2D to TELEMAC3D 32
2.6. Application example 32
2.7. Bibliography 34

Chapter 3. Atmospheric Modeling 35
Jean PAILLEUX

3.1. The rise of modeling as a tool in meteorology 35
3.2. Operational weather forecasting models 36
3.3. Towards kilometer-scale numerical forecasting – the AROME model 40
3.3.1. Other applications of atmospherical modeling 41
3.4. Bibliography 43

Chapter 4. Groundwater Flow Modeling in Porous Media Using MARTHE 45
Dominique THIÉRY

4.1. Application area 45
4.2. References 46
4.3. Technical features 47
4.3.1. Classic hydrodynamics 47
4.3.2. Hydrodispersive transport 47
4.3.3. Unsaturated zone, density, temperature 47
4.3.4. Automatic initialization, optimization 48
4.3.5. Specialized uses 48
4.3.6. Gridding 48
4.3.7. Flow calculation 49
4.3.8. Transport calculation 49
4.3.9. Geochemical interactions 49
4.4. Structure of the code 49
4.5. WinMarthe preprocessor 51
4.5.1. Preparation and visualization of data 51
4.5.2. Plan view and vertical cross-sections using the WinMarthe preprocessor 51
4.5.3. WinMarthe preprocessor: exporting to MAPINFO 53
4.5.4. Alluvial groundwater modeling under an industrial site 54

4.5.5. Modeling using an irregular mesh and an embedded sub-mesh . . . 54
4.6. Simulation of the migration of a pollution plume . . . 54
4.6.1. Infiltration of a pollutant across the unsaturated zone and subsequent migration within the water table . . . 54
4.7. Complex hydrogeological configurations . . . 56
4.7.1. Density effects – coupled hydraulic and thermal simulation . . . 57
4.8. Biphasic simulation of saline intrusion . . . 59
4.9. Infiltration of imiscible TCE (tetracholoethylene) into heterogenous sand initially saturated with water . . . 60
4.10. Biphasic simulation of water injected at four points into an aquifier initially saturated with oil . . . 60
4.11. Biphasic simulation of methane storage in an aquifer . . . 60

PART 2. 2D MODELS . . . 63

Chapter 5. Meteorology and Hydrology . . . 65
Florence HABETS

5.1. Bibliography . . . 69

Chapter 6. Hydrological Modeling with MARINE . . . 71
Marie-Madeleine MAUBOURGUET

6.1. General description of MARINE . . . 71
6.1.1. Pre-processing . . . 72
6.1.2. Runoff calculation . . . 72
6.1.3. Transport of water from the river to its outflow . . . 72
6.2. Description of pre-processing . . . 72
6.2.1. Required data . . . 72
6.2.2. Determination of slopes and their directions . . . 73
6.2.3. Handling of accumulation . . . 73
6.2.4. Changing the resolution of the DEM . . . 73
6.3. Description of the hydrological module . . . 73
6.3.1. Production function . . . 73
6.3.2. Transfer function for runoff water from grid sites to the river or to drains . . . 75
6.3.3. Transfer function for water into drains . . . 76
6.3.4. Transfer function for subsurface water . . . 77
6.4. Description of river transport . . . 78
6.5. Application examples . . . 78
6.5.1. Data . . . 79
6.5.2. Pre-processed data . . . 79
6.5.3. Flood hydrographs at the outlet (Anduze) . . . 80
6.6. Bibliography . . . 80

Chapter 7. Distributed Hydrological Modeling – the ATHYS Platform 83
Christophe BOUVIER, Anne CRESPY, Agnès L'AOUR-DUFOUR, François Noël CRES, François DESCLAUX and Arthur MARCHANDISE

7.1. General description of ATHYS 83
7.2. Pre-processing phase 84
7.2.1. Input data 84
7.2.2. Data pre-processing 86
7.3. Description hydrological models 86
7.4. Description of post-processing 92
7.5. Applications 93
7.5.1. Example 1: impact of spatial distribution of rainfall on flood surge calculations 93
7.5.2. Example 2: impact of spatial soil variation on flood calculations 94
7.5.3. Example 3: impact of flood control dams on flood simulations 97
7.5.4. Example 4: flood modeling in streets of urban areas 97
7.6. Conclusions and future directions 99
7.7. Bibliography 100

Chapter 8. Operational Applications of the LARSIM Model for Flood Forecasting 101
Norbert DEMUTH

8.1. The problem 101
8.2. Structure of the LARSIM model 101
8.3. Operational mode – summary 102
8.4. Quality control and validation of input data 103
8.5. Spatial interpolation of rainfall data 105
8.6. Launching a forecasting simulation 105
8.7. Analysis of results, and experiments performed by the flood prediction services 105
8.8. Bibliography 107

Chapter 9. Real-Time Runoff – Infiltration Models: TOPMODEL 109
Georges-Marie SAULNIER

9.1. Introduction 109
9.2. TOPMODEL philosophy 110
9.3. Advantages of TOPMODEL 113
9.4. Forcing and predicted variables in TOPMODEL 113
9.5. Analytical basis 116
9.6. Bibliography 117

Chapter 10. Currents with TELEMAC2D 119
Marie-Madeleine MAUBOURGUET and Jacques CHORDA

10.1. TELEMAC2D: hydrodynamics and the environment 119
10.2. The TELEMAC system 120
10.3. Original features and customizable code 121
10.4. TELEMAC as a training tool for hydraulic engineers 122
10.4.1. Modeling a fluviarium 122
10.4.2. Study of the Carcans lake 125
10.5. Bibliography 126

Chapter 11. 2D Model of Sediment Transport with RUBAR 20TS 129
André PAQUIER

11.1. Description of the 2D RUBAR 20TS model 129
11.1.1. Numerical computation 132
11.1.2. Example simulation : sedimentation in the Zardezas dam . . . 133
11.1.2.1. Specifying inflow 133
11.1.3. Model implementation 134
11.1.4. Results obtained for the period 1975–1986 136
11.2. Bibliography 138

Chapter 12. NAVMER: Ship Trajectory Simulator. 139
Yann HOLLOCOU

12.1. The simulator 139
12.2. Simulations of a passenger vessel on the Seine 140
12.3. Sixth crossing on the Seine 141
12.4. Le Havre Port 2000: navigability of outer reaches 145
12.5. Port of Nice 146
12.6. Outlook 153

PART 3. 1D MODELS 155

Chapter 13. Waves Using VAG 157
Philippe SERGENT

13.1. Context 157
13.1.1. Curvature of wave orthogonals 157
13.1.2. Flux conservation between two orthogonals 160
13.1.3. Data required for implementation 161
13.1.4. Specific numerical methods 162
13.2. Results from the operational code 162
13.3. Examples of models 163
13.4. Bibliography 163

Chapter 14. Real Time Discharge-Discharge Models with SOPHIE . . . 165
Marie-Pierre NÉRARD

14.1. Discharge-discharge relationships . . . 166
14.1.1. Linear relationships – LRs . . . 166
14.1.1.1. Autoregressive models . . . 167
14.1.1.2. Field of application . . . 167
14.1.1.3. Comments . . . 167
14.1.2. Power laws – PLs . . . 167
14.1.2.1. Brief description . . . 167
14.1.2.2. Field of application . . . 168
14.1.2.3. Comments . . . 168
14.1.3. Transient values or multiple linear relationships – TV . . . 168
14.1.3.1. Brief description . . . 168
14.1.3.2. Field of application . . . 168
14.1.3.3. Comments . . . 169
14.1.4. Bachet's method – BM . . . 169
14.1.4.1. Brief description . . . 169
14.1.4.2. Field of application . . . 169
14.1.5. Formalized intuitive forecasting – FIF . . . 170
14.1.5.1. Brief description . . . 170
14.1.5.2. Field of application . . . 170
14.2. Rainfall-runoff models . . . 170
14.2.1. Fabret type rainfall-runoff model with fixed *b* – PQ . . . 170
14.2.1.1. Brief description . . . 170
14.2.1.2. Field of application . . . 170
14.2.1.3. Comments . . . 171
14.2.2. Fabret type rainfall-discharge model with variable *b* – PQb . . . 171
14.2.2.1. Brief description . . . 171
14.2.2.2. Field of application . . . 171
14.2.2.3. Comments . . . 171
14.2.3. GR3H rainfall-discharge model . . . 171
14.2.3.1. Brief description . . . 171
14.2.3.2. Field of application . . . 171
14.2.3.3. Comments . . . 171
14.3. Other models . . . 172
14.3.1. Multimodel processes . . . 172
14.3.1.1. Brief description . . . 172
14.3.1.2. Field of application . . . 172
14.3.1.3. Comments . . . 172
14.3.2. "Multi-agent" auto-adaptive model – MA . . . 173
14.3.2.1. Brief description . . . 173
14.3.2.2. Field of application . . . 173
14.3.2.3. Comments . . . 173

14.4. Which model to use? 174
14.4.1. When collection dominates: at the heads of catchment areas 174
14.4.2. When propagation dominates 174

Chapter 15. 1D Flow Models: Comparing MASCARET and RUBAR 3 177
André PAQUIER, Patrick CHASSÉ, Nicole GOUTAL and Amélie BESNARD

15.1. Analysis of Saint-Venant equations for transcritical flows 177
15.1.1. Classical form of equations 177
15.1.1.1. Modeling a compound channel 179
15.1.2. Conservative form of the 1D system of Saint-Venant equations 181
15.1.2.1. Formulation using Riemann invariants 182
15.1.2.2. Hydraulic jumps 183
15.2. Numerical solution of sub-critical and super-critical regimes for the 1D Saint-Venant equations: examples of the RUBAR 3 and MASCARET computer codes 184
15.2.1. The problem to be solved 184
15.2.2. RUBAR 3 and MASCARET computer codes 184
15.2.2.1. Boundary conditions 187
15.2.2.2. Treatment of singularities 188
15.2.3. Characteristics of RUBAR 3 190
15.2.4. Characteristics of MASCARET 193
15.2.4.1. Involvement of transcritical kernel 193
15.2.4.2. Confluence modeling 193
15.3. Example calculation: propagation of the dam-break wave for the Malpasset barrage 194
15.3.1. The event, and available observations 195
15.3.2. Simulation output from the MASCARET and RUBAR 3 codes 196
15.4. Bibliography 198

Chapter 16. 1D Compartment Flow Models 201
Jean-Baptiste FAURE and André PAQUIER

16.1. Context 201
16.2. Modeling options 202
16.2.1. Modeling engineering works 202
16.3. Data required for implementation 203
16.4. Specific numerical methods 205
16.5. Code output and analysis 206
16.6. Examples of models 206

Chapter 17. CANOE: an Urban Hydrology Software Package 209
Bernard CHOCAT

17.1. Origin 209
17.2. General description 209
17.3. Structural data management (project) 211
17.4. Management of structure catalog (transport) 212
17.5. Management of hydrometric data (rainfall) 213
17.6. Hydrological and hydraulic simulation 213
17.6.1. Calculations for waste water and infiltration water 213
17.6.2. Rainfall-runoff transformation 214
17.6.3. Hydraulic modeling 214
17.7. Water quality simulation 215
17.8. Project assistant 216
17.9. CANOE-GIS 217
17.10. Examples of pre-and post-processing workflows 217

Chapter 18. Water Quality with ProSe 219
Patrick GOBLET and Stéphanie EVEN

18.1. Hydrodynamic model 219
18.2. Transport model 220
18.3. Sediment exchange 220
18.4. Biochemical model 222
18.5. Bibliography 224

Chapter 19. Substance Transport 227
Jean-Baptiste FAURE

19.1. Context 227
19.2. Modeling options 228
19.3. Data required for implementation 229
19.3.1. 2D planar models 230
19.3.2. 3D models 230
19.4. Specific numerical methods 230
19.4.1. Example numerical scheme 231
19.5. Results from the code, and analysis of results 232
19.5.1. Examples of models 232
19.6. Bibliography 232

Chapter 20. 1D Sediment Transport with RUBARBE and TSAR 233
André PAQUIER

20.1. RUBARBE code 233
20.2. Sediment description for the river bed 235
20.3. Method of solution 236
20.4. Sedimentary balance within a mesh cell 236

20.5. Shear stress calculation 238
20.5.1. Mechanisms for cross-section deformation 239
20.6. The TSAR code 240
20.7. Bibliography 243

Chapter 21. An Integrated Simulation Platform – PamHyr 245
Jean-Baptiste FAURE

21.1. Overview 245
21.2. Key features of a hydraulic modeling environment (HME) 246
21.3. PamHyr: an example HME 247
21.4. Bibliography 251

List of Authors 253

Index 257

General Index of Authors 259

Summaries of Other Volumes in the Series 261