Contents

Preface vii

Acknowledgment ix

1. Introduction 1

2. Wind Waves 3

2.1 Introduction . . . 3
2.2 Wave generation, propagation and dissipation . . . 4
2.3 Spectral description . . . 5
2.4 Wave conditions . . . 8
2.5 Wave modeling . . . 9
2.6 Governing equations . . . 10
2.6.1 Wave action balance . . . 10
2.6.2 Wave energy balance . . . 12
2.6.3 Roller energy balance . . . 15
2.7 Propagation of wave groups . . . 16
2.8 Wave propagation over complex bathymetry . . . 18
2.9 Wave blocking . . . 18

3. Currents 23

3.1 Introduction . . . 23
3.2 Governing equations . . . 23
3.2.1 3D Shallow water equations . . . 23
3.2.2 Depth-averaged shallow water equations . . . 27
3.2.3 Stokes drift . . . 28
3.2.4 Wave forcing . . . 28
3.2.5 Bottom shear stress . . . 33
3.2.6 Turbulent eddy viscosity . . . 36
3.3 Tidal currents . . . 37

3.3.1 Open coasts . . . 37
3.3.2 Propagation into estuaries . . . 42
3.3.3 Resonance . . . 43
3.3.4 Funnelling effect . . . 44
3.3.5 Short, wide basins . . . 45
3.3.6 Tidal currents around structures . . . 46
3.3.7 Flow patterns around a realistic inlet . . . 48
3.3.8 Current pattern across a trench . . . 49
3.4 Wind-driven longshore current and set-up on an alongshore uniform coast . . . 51
3.4.1 Wind-driven longshore current . . . 51
3.4.2 Wind-driven set-up . . . 53
3.5 Wave-driven longshore current and set-up on an uniform coast . . . 53
3.5.1 Wave-driven longshore current . . . 53
3.5.2 Wave-driven set-up . . . 54
3.5.3 Numerical evaluation . . . 55
3.5.4 Shear instabilities . . . 58
3.6 Wave-group driven motions . . . 62
3.6.1 Introduction . . . 62
3.6.2 Wave group induced bound long waves . . . 63
3.6.3 Leaky waves and trapped waves . . . 66
3.6.4 Edge wave resonance . . . 69
3.6.5 Very Low Frequency motions . . . 72
3.7 Vertical structure of the current . . . 74
3.7.1 Tide (or slope) driven current profile . . . 74
3.7.2 Wind-driven current profile . . . 76
3.7.3 Wind driven longshore current profile . . . 78
3.7.4 Wind-driven cross-shore current profile . . . 79
3.7.5 Wave driven current profile . . . 81
3.8 3D Wave-driven currents on a non-uniform coast . . . 84

4. Sediment transport 89

4.1 Introduction . . . 89
4.2 Suspended transport . . . 90
4.2.1 3D Advection-diffusion equation for sediment . . . 90
4.2.2 2DH Advection-diffusion equation for sediment . . . 92
4.3 Bed load and total load transport formulations . . . 94
4.3.1 Current-only situation . . . 94
4.3.2 Waves plus current . . . 95
4.4 Wave-driven transport . . . 97
4.4.1 Wave skewness and asymmetry . . . 97
4.4.2 Lagrangian drift . . . 103

4.4.3 Streaming . . . 103
4.4.4 Wave group induced bound long waves . . . 104
4.5 Return flow . . . 107
4.5.1 Breaker delay . . . 109
4.6 Rip circulation cells . . . 109

5. Morphological Processes 111

5.1 Introduction . . . 111
5.2 Some principles . . . 111
5.2.1 Propagation of bed forms . . . 111
5.2.2 Equilibrium depth . . . 113
5.3 Open coasts . . . 115
5.3.1 Cross-shore profile behavior . . . 115
5.3.2 Bed-slope related transport . . . 117
5.3.3 Dune erosion and overwash . . . 120
5.3.4 Rip channel dynamics . . . 122
5.3.5 Plan shape evolution . . . 125
5.4 Tidal inlets and Estuaries . . . 133
5.4.1 Ebb and flood tidal delta formation . . . 133
5.4.2 Equilibrium relations . . . 135
5.4.3 Discussion . . . 142

6. Modeling Approaches 145

6.1 Coastal profile, coastline and area models . . . 145
6.2 Scales of application . . . 146
6.2.1 Coastal profile models . . . 146
6.2.2 Coastline models . . . 147
6.2.3 Coastal area models . . . 147
6.3 Input schematisation . . . 150
6.3.1 Input parameters . . . 150
6.3.2 General principle of schematisation . . . 151
6.3.3 Tidal schematisation . . . 152
6.3.4 Schematisation of wind/wave climate . . . 159

7. Coastal Profile Models 169

7.1 Introduction . . . 169
7.1.1 Principles and Approach . . . 169
7.1.2 Profile modeling . . . 170
7.2 Short-term event modeling . . . 173
7.3 Long-term evolution of barred profiles . . . 175
7.3.1 Including longshore transport gradients . . . 176
7.4 Nourishments . . . 176

8. Coastline Models 179
8.1 Principles . . . 179
8.2 Existing models . . . 179
8.3 A simple Matlab version . . . 180
8.3.1 Profile model to generate S-phi curves . . . 181
8.3.2 Coastline computation . . . 181
8.3.3 The basic version based on S-phi curves . . . 181
8.3.4 Including large-scale variations in wave climate . . . 182
8.3.5 Representing small-scale features . . . 184
8.4 Case study of IJmuiden, the Netherlands . . . 184

9. Coastal Area Models 187
9.1 Introduction . . . 187
9.2 Wave drivers . . . 188
9.2.1 Wave-averaged . . . 188
9.2.2 Short wave averaged . . . 189
9.2.3 Short wave resolving . . . 189
9.3 2DH, Q3D and 3D . . . 190
9.3.1 Flow model . . . 190
9.3.2 Sediment transport . . . 190
9.3.3 Bottom . . . 191
9.4 Grids and numerical aspects . . . 192
9.4.1 Overview of model components in some morphodynamic model systems . . . 193
9.5 Boundary conditions for coastal area models . . . 193
9.5.1 Flow model . . . 193
9.5.2 Waves . . . 199
9.5.3 Sediment transport . . . 200
9.5.4 Bed level . . . 200
9.6 Modeling strategies for wave-current interaction . . . 200
9.7 Strategies for morphodynamic updating . . . 204
9.7.1 Tide-averaging approach . . . 205
9.7.2 Continuity correction . . . 207
9.7.3 RAM approach . . . 208
9.7.4 Online approach with morphological factor . . . 209
9.7.5 Tide-averaged approach vs. morphological factor . . . 211
9.7.6 Parallel online approach . . . 213
9.7.7 Efficiency of the methods . . . 214
9.8 Strategies for longer-term simulations . . . 215
9.8.1 Beach profile extension . . . 215
9.8.2 Representation of subgrid features . . . 217
9.8.3 Representation of dredging . . . 217

9.8.4 Beach nourishments 217

10. Case Studies 219

10.1 Toy models of small coastal problems 219
10.1.1 Introduction 219
10.1.2 Model setup 219
10.1.3 Wave height patterns 221
10.1.4 Current patterns 222
10.1.5 Effect on bathymetry 223
10.1.6 Relative erosion/sedimentation patterns 224
10.1.7 Discussion 224
10.2 Long-term modeling of tidal inlets, estuaries and deltas 225
10.2.1 Introduction 225
10.2.2 How far can upscaling lead us? 225
10.2.3 Necessary model improvements for long-term modeling . . 226
10.2.4 How much of the morphology of an estuary is forced by its boundaries? 227
10.2.5 Effect of sediment sorting 230
10.2.6 Some sample simulations 232
10.3 Dune erosion 235
10.4 Overwash 237
10.5 Sand bars and rip channels 239

11. Modeling Procedure 245

11.1 Introduction 245
11.2 Data collection and analysis 245
11.2.1 Bathymetry data 245
11.2.2 Wave and wind data 245
11.2.3 Tidal data 246
11.2.4 Longshore current data 246
11.2.5 Sediment transport data 246
11.3 Conceptual model 246
11.4 Setting up modeling strategy 246
11.5 Setting up model grid and bathymetry 247
11.5.1 Flow and morphology grid 247
11.5.2 Wave grids 247
11.5.3 Bathymetry 247
11.6 Boundary conditions 247
11.6.1 Wave schematisation 247
11.6.2 Representative tide. 248
11.6.3 Sediment transport 248
11.6.4 Bottom change 248

11.7 Calibration . . . 248
11.8 Validation . . . 248
11.9 Preparing scenarios . . . 249
11.10 Defining output . . . 251
11.11 Running and postprocessing . . . 251
11.12 Interpretation . . . 252
11.13 Reporting . . . 252
11.14 Archiving . . . 253

12. Modeling Philosophy 255

12.1 Virtual reality or realistic analogue? . . . 255
12.2 Process-based or data-driven? . . . 257
12.3 Top-down or bottom-up? . . . 257
12.4 More physics, better model? . . . 258
12.5 How to judge model skill? . . . 258
12.6 Absolute vs. relative skill . . . 259

Bibliography 261