in deministry of the second of

Fluvial Processes in River Engineering

Howard H. Chang

San Diego State University

Technische Universität Darmstadt Bibliothek Wasser und Umwelt Petersenstraße 13 D-64287 Darmstadt Telefon 06151 / 163659 Fax 06151 / 163758

Bibliothek des Fachgebletes Hydraulik und Hydrologie

Technische Hochschule Darmstadt D-6100 Darmstadt/Petersenstraße

INV. -Nr. 2350 Gulen 7 12.1.89

A WILEY-INTERSCIENCE PUBLICATION

John Wiley & Sons

New York •

Chichester •

Brisbane

Toronto

Singapore

CONTENTS

PART I		FLUVIAL GEOMORPHOLOGY		
1.	Introduction			
	1.1	The Fluvial System / 3		
	1.2	Variables for Alluvial Rivers / 4		
2.	Over	view of River Morphology	7	
	2.`1	Regime Concept / 7		
	2.2	Channel-Forming Discharge / 8		
	2.3	Longitudinal Stream Profile / 8		
	2.4	River Classifications / 10		
	2.5	Thresholds in River Morphology / 13		
2.6 Hydraulic Geometry / 20				
	2.7	Meander Planform / 24		
	2.8	Geomorphic Analysis of River Channel Responses / 27		
Ref	erence	es for Part I	31	
PA	RT II	FOUNDATIONS OF FLUVIAL PROCESSES	35	
3. Hydraulics of Flow in River Channels			37	
	3.1	Shear-Stress Distribution / 38		
	3.2	Uniform-Flow Formulas / 39		
	3.3	Boundary-Layer Regions / 41		
	3.4	Turbulent Shear Flow in Channels / 43		
	3.5	Fixed-Bed Flow Resistance / 46		
	3.6	Flow Resistance in Gravel-Bed Rivers / 51		
	3.7	Composite Roughness and Side-Wall Corrections / 53		
	3.8	Energy Equation and Water-Surface Profiles / 56		
	3.9	Unsteady Open-Channel Flow / 59		
		References / 67		

ix

4. Physical Properties of Sediment

- 4.1 Size of Sediment Particles / 70
- 4.2 Shape Factor of Sediment Particles / 73
- 4.3 Fall Velocity / 73
- 4.4 Angle of Repose for Sediments / 77 References / 79

5. Scour Criteria and Scour-Related Problems

- 5.1 Critical Shear / 80
- 5.2 Shields Diagram / 82
- 5.3 Other Scour Criteria Based on Shear Stress / 85
- 5.4 Critical Shear on Side Slopes / 85
- 5.5 Permissible Velocity / 88
- 5.6 Distribution of Boundary Shear in Trapezoidal Channels / 90
- 5.7 Boundary Shear in Bends / 92
- 5.8 Design of Stable Channels Subject to Scour But Not to Silt / 93
- 5.9 Local Scour around Bridge Piers / 96
- 5.10 Local Scour around Embankments / 100 References / 103

6. Alluvial Bed Forms and Flow Resistance

- 6.1 Bed Forms / 105
- 6.2 Prediction of Bed Forms / 110
- 6.3 Bed-Form Dimensions / 114
- 6.4 Effect of Water Temperature / 116
- 6.5 Stage–Discharge Predictors for Alluvial Channels / 118 References / 128

7. Sediment Movement in Rivers

- 7.1 Bed-Load Formulas / 133
- 7.2 Turbulent Diffusion and Diffusion Equation / 143
- 7.3 Suspended-Sediment Discharge / 146
- 7.4 Bed-Material Load Formulas / 154
- 7.5 Evaluation of Formulas / 163
- 7.6 Effect of Water Temperature / 166
- 7.7 Effect of Suspended Sediment on Flow Characteristics / 167

105

70

80

131

7.	8	Sediment	Transport	in	Nonuniform	Flow	1	172
••	<u> </u>	~~~	1 milliop of t					

- 7.9 Sediment Sorting / 176
- 7.10 Sampling Fluvial Sediment / 181 References / 185

8. Flow in Curved River Channels

- 8.1 Basic Equations / 190
- 8.2 Transverse Velocity Profiles for Fully Developed Flow / 193
- 8.3 Boundary Shear Stress / 197
- 8.4 Transverse Bed Slope and Grain-Size Distribution / 199
- 8.5 Lateral Bed-Load Transport / 206
- 8.6 Energy Expenditure in Curved Open Channels / 208
- 8.7 Streamwise Variation of Spiral Motion / 212
- 8.8 Computation of Flow through Curved Channels / 216
- 8.9 Transverse Flow and Cross-Stream Flow in River Channels / 220 References / 222

PART III		REGIME RIVERS AND RESPONSES	
9.	9. Analytical Basis for Hydraulic Geometry		227
	9.1	Applicable Physical Relationships / 227 •	
	9.2	Physical Relationships Pertaining to Stable Width / 228	
10.	Desig	n of Stable Alluvial Channels	233
	10.1	Regime Methods for Stable Alluvial Canal Design / 234	
	10.2	Rational Method for Stable Alluvial Canal Design / 241	
	10.3	Design of Stable Alluvial Canals in a System / 250	
	10.4	Maturing of Canals / 253	
	10.5	Hydraulic Geometry of Gravel-Bed Streams / 254	
11.	Analy	tical River Morphology	261
	11.1	Analysis of River Meanders / 262	
	11.2	Power Approach to River Morphology and Thresholds / 271	
	11.3	Channel Geometry, Channel Patterns, and Thresholds / 277	
	11.4	River Channel Changes: Adjustments of Equilibrium / 283	
	11.5	Formation of Alternate Bars / 290	

190

12. Plan	Geometry and Processes of River Meanders	298
12.1	Sine-Generated Curve / 299	
12.2	Meander Path Based on Streamwise Variation of Helical Motion /	300
12.3	Processes Governing Meander Bend Migration / 309	
12.4	On the Cause of River Meandering / 312	
Reference	s for Part III	316
PART IV	MODELING OF RIVER CHANNEL CHANGES	323
13. Math	ematical Model for Erodible Channels	325
13.1	Physical Foundation of Fluvial Process-Response / 326	
13.2	Channel Width Adjustments during Scour and Fill / 327	
13.3	Analytical Basis of the FLUVIAL Model / 330	
13.4	Water Routing / 331	
13.5	Sediment Routing / 333	
13.6	Simulation of Changes in Channel Width / 336	
13.7	Simulation of Changes in Channel-Bed Profile / 338	
13.8	Simulation of Changes Due to Curvature Effect / 339	
13.9	Test and Calibration of Mathematical Model / 340	
14. Com	puter-Aided Study of Alluvial Rivers	342
14.1	General Scour at Bridge Crossings / 342	
14.2	Gradual Breach Morphology / 352	
14.3	Stream Channel Changes Induced by Sand and Gravel Mining /	358
14.4	Tidal Responses of River and Delta System / 364	
14.5	Water and Sediment Routing through a Curved Channel / 371	
14.6	Fluvial Design of River Bank Protection / 377	
14.7	Stream Gaging of Fluvial Sediment / 384	
Reference	es for Part IV	391

			CONTENTS	XIII
PART V		RIVER ENGINEERING		393
15.	River	Training		395
	15.1	Bank Protection / 396		
	15.2	Dikes / 403		
	15.3	Grade-Control Structures / 407		
		References / 411		
AP	PENDI	X: SOME COMMONLY USED TABLES		413
NA	ME IN	IDEX		417
SU	BIECT		423	