

TABLE OF CONTENTS

Preface	xiii
1 Introduction to Landform Grading and Revegetation	1
1.1 Form and Function in Nature	1
1.2 Human Impact on Landforms	3
1.3 Historical Development	5
1.4 Objectives and Challenges	10
1.5 References	12
2 Surficial Erosion and Mass Wasting of Slopes	13
2.1 Introduction	13
2.2 Definitions	13
2.2.1 Surficial Erosion	13
2.2.2 Mass Wasting	14
2.2.3 Salient Characteristics and Differences	14
2.3 Nature of Surficial Erosion	15
2.3.1 Agents and Types of Erosion	15
2.3.2 Mechanics of Erosion	16
2.4 Principal Determinants of Erosion	16
2.4.1 Rainfall Erosion	16
2.4.2 Wind Erosion	18
2.5 Types of Water Erosion	18
2.6 Soil Loss Predictions	21
2.6.1 Historical Development	21
2.6.2 Applications of the Universal Soil Loss Equation (USLE)	22
2.6.3 Limitations of USLE	24
2.7 Erosion Control Principles	25
2.8 Nature of Mass Wasting	26
2.8.1 Types of Slope Movement	26
2.8.2 Causes of Slope Failure	27
2.8.3 Indicators of Slope Instability	28
2.9 Slope Stability Predictions	28

iv TABLE OF CONTENTS

- 2.9.1 Approaches to Analysis 28
- 2.9.2 Limit-Equilibrium Analysis 29
- 2.9.3 Shear-Strength Parameters 31
- 2.9.4 Translational Slope Failures 32
- 2.10 Control of Mass Wasting 35
- 2.11 Slope-Stability and Channel-Erosion Thresholds 36
 - 2.11.1 Significance 36
 - 2.11.2 Approaches 36
 - 2.11.3 Slope-Stability Threshold 36
 - 2.11.4 Threshold of Erosion by Saturation Overland Flow 48
 - 2.11.5 Stability Fields and Threshold Boundaries 51
- 2.12 Summary 52
- 2.13 References 54

3 Influence of Vegetation on Hillside Stability

57

- 3.1 Introduction 57
- 3.2 Influence on Surficial Erosion 58
 - 3.2.1 Stabilizing Functions 58
 - 3.2.2 Vegetation Cover Factor 58
 - 3.2.3 Recommended Vegetation 59
- 3.3 Influence on Mass Stability 60
 - 3.3.1 Hydromechanical Effects 60
 - 3.3.2 Beneficial Effects 60
 - 3.3.3 Detrimental Effects 62
- 3.4 Root Morphology and Strength 63
 - 3.4.1 Introduction 63
 - 3.4.2 Depth and Distribution of Root Systems 63
 - 3.4.3 Root Strength 67
- 3.5 Root and Fiber Soil Reinforcement 69
 - 3.5.1 Force-Equilibrium Models 69
 - 3.5.2 In Situ Direct-Shear Tests 69
 - 3.5.3 Stability Analyses 70
- 3.6 Guidelines for Maximizing Benefits of Vegetation 73
 - 3.6.1 General Observations 73
 - 3.6.2 Selection Strategies 73
 - 3.6.3 Placement Strategies 74
 - 3.6.4 Grading and Site Preparation 75
 - 3.6.5 Optimizing Compaction 78
 - 3.6.6 Management Strategies 85
- 3.7 Summary 88
- 3.8 References 89

4	Influence of Topography on Slope Stability and Hydrology	93
4.1	Introduction	93
4.2	Modeling Approaches and Assumptions	94
4.3	Conceptual Modeling	95
4.3.1	General	95
4.3.2	Mass Stability	96
4.3.3	Surficial Erosion	97
4.4	Physical-Mathematical Models	98
4.4.1	General	98
4.4.2	Mass Stability	99
4.4.3	Surficial Erosion	102
4.5	Laboratory and Field Tests	107
4.5.1	General	107
4.5.2	Mass Stability	107
4.5.3	Surficial Erosion	107
4.5.4	Equilibrium Profiles of Natural Slopes	110
4.5.5	Summary	112
4.6	Role of Drainage Networks and Drainage Densities	113
4.6.1	Drainage Density and Zero-Order Watershed	113
4.7	References	117
5	Geomorphic Evolution of Slopes	119
5.1	Introduction	119
5.2	Role of Geologic Processes	120
5.3	Geomorphology	121
5.4	Slope Attributes and Characteristics	121
5.4.1	Classification of Slopes	121
5.4.2	Slope Profiles and Elements	122
5.4.3	Slope Processes	123
5.5	Approaches to Slope Evolution Prediction	124
5.5.1	Traditional approach	124
5.5.2	Morphometric approach	125
5.5.3	Process approach	125
5.5.4	Empirical approach	125
5.6	Anthropogenic Slopes and Landforms	125
5.7	Slope Evolution and Long-Term Stability	126
5.7.1	Evolution and Morphometry of Spoil Mounds	126
5.7.2	Evolution and Morphometry of Natural Slopes	127
5.7.3	Effect of Climate on Hillslope Form	132
5.8	Digital Terrain Models	134

- 5.8.1 Salient Characteristics of Digital Terrain Models 134
- 5.8.2 Example of a Linked, Digital Terrain Model—SIBERIA 136
- 5.8.3 Applications of Digital Terrain Modelling 139
- 5.8.4 Design of Stable Landforms 140
- 5.9 References 143

6 Hillside Grading Fundamentals 146

- 6.1 Introduction 146
- 6.2 Purpose of Grading 146
- 6.3 Grading Considerations 147
 - 6.3.1 Major Stakeholders 147
 - 6.3.2 Selection of Grading Equipment 148
 - 6.3.3 Importance of Subsurface Conditions 151
- 6.4 Elements of Hillside Grading 153
 - 6.4.1 Preparatory Operations 153
 - 6.4.1.1 Clearing and grubbing 153
 - 6.4.1.2 Preapplication of water 153
 - 6.4.1.3 Removal of deleterious materials 154
 - 6.4.2 Special Conditions and Precautions 155
 - 6.4.2.1 Groundwater removal 155
 - 6.4.2.2 Surface drainage control 157
 - 6.4.2.3 Unstable slopes and landslides 158
 - 6.4.2.4 Faults 161
 - 6.4.2.5 Volume changes 161
 - 6.4.2.6 Hard, well-indurated rock 162
- 6.5 Cuts and Fills 163
 - 6.5.1 Cuts and Cut Slopes 166
 - 6.5.1.1 Cut construction 166
 - 6.5.1.2 Selective grading 166
 - 6.5.1.3 Cut slope construction and remediation 166
 - 6.5.2 Fills 171
 - 6.5.2.1 Fill slope construction 171
 - 6.5.2.2 Deep fills 171
 - 6.5.2.3 Fill slope remediation 171
- 6.6 Erosion Control During Grading 173
- 6.7 Economics of Grading 173
- 6.8 References 178

7 Principles of Landform Grading 179

- 7.1 Introduction 179

7.2 The Traditional Method 179

 7.2.1 Conventional Slopes and Their Design Elements 179

 7.2.1.1 Slope plan and profile shape 179

 7.2.1.2 Drainage devices 179

 7.2.2 Building Pads 180

 7.2.3 Landscaping 180

 7.2.4 Historical Use and Observations 181

7.3 The Improved Method 184

 7.3.1 Contour Slopes and Their Design Elements 184

 7.3.1.1 Slope plan and profile shape 184

 7.3.1.2 Drainage devices 184

 7.3.2 Building Pads 184

 7.3.3 Landscaping 185

 7.3.4 Historical Use and General Observations 185

7.4 The Environmentally Responsive New Technique 186

 7.4.1 Landform Slopes and Their Design Elements 186

 7.4.1.1 Slope plan and profile shape 186

 7.4.1.2 Drainage devices 186

 7.4.2 Plateaus and Building Pads 188

 7.4.3 Revegetation Landscaping 189

7.5 Repair and Rejuvenation Techniques for Either Man-Made or Damaged Natural Landscapes 192

 7.5.1 General Observations 192

 7.5.2 Direct Slope Replication 192

 7.5.3 Complete or Partial In Situ Landform Restoration 193

 7.5.4 Creation of New Physiographic Landforms 196

 7.5.5 Slope-Form Restoration via Landform Grading 196

 7.5.6 Landform Restoration after Mass Grading and Filling 198

7.6 Surface Mining Reclamation 199

 7.6.1 Impact of Surface Mining 199

 7.6.2 Importance of Replicating Original Topography and Hydrology 202

 7.6.3 Elements of Critical Concern 203

 7.6.4 Design Alternatives 204

 7.6.4.1 The shape of the footprint 204

 7.6.4.2 The orientation of the footprint 206

 7.6.4.3 Slope profile in cross section 206

 7.6.4.4 The slope in frontal and plan view 207

 7.6.4.5 Revegetation and reforestation 209

viii **TABLE OF CONTENTS**

- 7.7 Summary and Conclusions 210
- 7.8 References 210

8 Essential Design Elements for Slope Forms and Landforms 211

- 8.1 Introduction 211
- 8.2 Natural Landscape Elements 211
 - 8.2.1 Origin of Natural Slope Forms 211
 - 8.2.2 Natural Drainage Forms 213
 - 8.2.3 Natural Vegetation Patterns 213
- 8.3 Basic Slope Forms—“The Architecture of Slopes” 214
 - 8.3.1 General Observations 214
 - 8.3.2 Ridges and Swales—Perpendicular to the Slope Crest 214
 - 8.3.3 Ridges and Swales—Diagonally across the Slope Face 215
 - 8.3.4 Ridges and Swales—Curvilinear across the Slope Face 218
 - 8.3.5 Elbow Shapes across the Slope Face 218
 - 8.3.6 Pyramid- and Cone-Shaped Slope-Face Elements 218
 - 8.3.7 Wishbone Configurations 218
 - 8.3.8 Convex Ridges and Concave-Foot Slopes 220
 - 8.3.9 Compound and Composite Shapes 220
 - 8.3.9.1 Degree of roundness or angularity 222
 - 8.3.9.2 Width 223
 - 8.3.9.3 Height 223
 - 8.3.9.4 Proportion 223
- 8.4 The Rock Element as Part of the Natural Landscape 224
- 8.5 Reference 224

9 Implementation of the Landform Grading Plan 225

- 9.1 Requirements for Successful Implementation 225
- 9.2 Obstacles to Implementation 225
- 9.3 Implementation Strategies 226
 - 9.3.1 Land Planning and Initial Site Design 226
 - 9.3.2 Meetings with Regulatory Agency 226
 - 9.3.3 Allaying Engineering Concerns 227
 - 9.3.4 Geotechnical Engineering 228
 - 9.3.5 Introduction of Concept to Grading Designers 228
- 9.4 Planning and Surveying Requirements 229
 - 9.4.1 Planning Requirements 229
 - 9.4.2 Surveying Requirements 229

9.5	The Grading Phase	231
9.5.1	Retraining of Grading Personnel	231
9.5.2	Ground Preparation	233
9.5.3	Slope Construction	233
9.6	Fill Construction and Compaction Control	233
9.7	Construction of Valley or “Daylight” Fills	233
9.8	Slope-Drainage Devices	234
9.8.1	Terrace Drains	234
9.8.2	Down-Drains	235
9.8.3	Interceptor Drains	236
9.8.4	Toe Drains	237
9.8.5	Hardened Drain Limitations	237
9.9	Revegetation	238
9.9.1	Conventional Landscaping vs. Revegetation	238
9.9.2	Landform Revegetation	238
9.10	The Application of Water on the Slope Face through Irrigation	241
9.10.1	High-Pressure Spray Method	241
9.10.2	Low-Pressure Spray Method	241
9.11	Placement of Rocks and Boulders	241
9.12	Cost Considerations and Analyses	245
9.12.1	Land-Planning Costs	245
9.12.2	Design Engineering Costs	245
9.12.3	Surveying Costs	245
9.12.4	Landscape Architect Costs	247
9.12.5	Construction and Grading Costs	247
10	Public and Regulatory Response to Landform Grading	249
10.1	Introduction	249
10.2	The Development Process	249
10.2.1	Overall Governing Agency or Authority	249
10.2.2	The Land-Planner’s Perspective	249
10.2.3	The Civil Engineer’s Perspective	250
10.2.4	Regulatory Agencies’ Perspectives	250
10.2.5	Owners’ and Developers’ Perspectives	251
10.2.6	Interdisciplinary Team Approaches	251
10.3	Standards and Codes	252
10.3.1	Difficulties with Promulgation	252
10.3.2	“Prescriptive” vs. “Performance” Standards	253
10.4	Project-Approval Benefits of Landform Grading	253
10.5	Agencies that have Adopted or Implemented Landform Grading	254

- 10.6 Future Applications of Landform Grading 262
- 10.7 References 264

11 Landforming Projects—Watershed Restoration and Mining Reclamation 265

- 11.1 Introduction 265
- 11.2 School Girl's Glen 265
 - 11.2.1 Project Type 265
 - 11.2.2 Project Location 266
 - 11.2.3 Client and Project Owner 266
 - 11.2.4 Site Conditions and Problems 266
 - 11.2.5 Repair and Restoration Goals 267
 - 11.2.6 Treatment Considerations 267
 - 11.2.7 Selected Treatments 269
 - 11.2.8 Performance Evaluation 272
 - 11.2.9 References 274
- 11.3 Asaayi Lake Northwest Drainage—Landform Restoration 274
 - 11.3.1 Type of Project 274
 - 11.3.2 Location 274
 - 11.3.3 Client 275
 - 11.3.4 Repair and Restoration Goals 275
 - 11.3.5 Site Conditions and Problems 275
 - 11.3.6 Treatment Considerations 276
 - 11.3.7 Selected Treatment 277
 - 11.3.7.1 Initial design concept 278
 - 11.3.7.2 Final design configuration 279
 - 11.3.8 Performance Evaluation 282
 - 11.3.9 Postscript 285
 - 11.3.10 References 285
- 11.4 Oil Sands Mining Reclamation, Syncrude Canada 286
 - 11.4.1 Project Type 286
 - 11.4.2 Project Location 286
 - 11.4.3 Client 286
 - 11.4.4 Site History 286
 - 11.4.5 Site Conditions and Potential Problems 286
 - 11.4.6 Repair and Restoration Goals 290
 - 11.4.7 Treatment Considerations 290
 - 11.4.8 Selected Demonstrations and Treatments 291
 - 11.4.8.1 Project no. 1—Landform demonstration site no. 1 291
 - 11.4.8.2 Project no. 2—Reconfiguration of an existing tailings dump through landform grading 294

	11.4.8.3	Project no. 3—“Delandform grading”	295
	11.4.9	Performance Evaluation	297
	11.4.10	Postscript	298
12	Landforming Projects—Hillside Developments and Mass-Grading Applications		299
12.1	Introduction		299
12.2	Hollywood Hills Project		299
	12.2.1	Type of Project	299
	12.2.2	Location	299
	12.2.3	Clients	300
	12.2.4	Projects History	300
	12.2.5	Earthwork Disposal and Placement Considerations	301
	12.2.6	Environmental Mitigation Design Considerations	302
	12.2.7	Alternative Grading Studies	303
	12.2.8	Common Design Characteristics of Disposal Fills	303
	12.2.9	Final Design Configurations and Locations	304
		12.2.9.1	Fill F 304
		12.2.9.2	Fill B 310
		12.2.9.3	Fill C 312
		12.2.9.4	Fill A 314
	12.2.10	Post-Construction Evaluation and Observations	319
12.3	Anaheim Hills, California		322
	12.3.1	Type of Project	322
	12.3.2	Location	323
	12.3.3	Clients	323
	12.3.4	Jurisdictional Issues	323
	12.3.5	Site Conditions and Development Constraints	323
	12.3.6	Initial Development Plan—Community Objections	324
	12.3.7	Adopted Plan—Landform Grading Alternative	325
	12.3.8	Highlights and Features of Landform Grading Plan	325
	12.3.9	Performance Evaluation	327
12.4	Talega, California		332
	12.4.1	Type of Project	332
	12.4.2	Location	332
	12.4.3	Client	332
	12.4.4	Jurisdictional Issues	332
	12.4.5	Public and Regulatory Agency Responses	333

xii TABLE OF CONTENTS

12.4.5.1	City of San Clemente’s response	333
12.4.5.2	The County of Orange’s Position	335
12.4.5.3	Final resolution and agreement among stakeholders	335
12.4.6	Highlights and Features of Project	336
12.4.7	Conclusions	339
12.4.6.1	Operational findings	339
12.4.6.2	Economic considerations	339
Appendix		343
Index		347