

Contents

PREFACE

ix

1 AN INTRODUCTION TO THE STUDY OF BEACHES

1

Uses of the Beach 6

The Study of Beaches and Coastal Processes 9

Literature Sources 10

2 THE GEOMORPHOLOGY OF ERODING AND ACCRETING COASTS

16

Coastal Morphology 16

Erosional Coastal Features 16

Accretional Coastal Features 25

Coastal Classifications 38

Summary 42

3 BEACH MORPHOLOGY AND SEDIMENTS

45

General Beach Morphology and Nomenclature 45

Composition of Beach Sediments 48

Beach Sediment Grain Sizes 53

Grain-size Sorting on Beaches 56

Grain Abrasion and Sorting by Shape 62

The Budget of Littoral Sediments	66
Summary	72

4 THE CHANGING LEVEL OF THE SEA 76

Tides—the Heartbeat of the Ocean	77
Mean Sea Level Determined from Tide Gauges	95
Long-term Global Changes in Sea Level	107
Greenhouse Warming and Future Levels of the Sea	115
The Coastal Response	121
Summary	129

5 THE GENERATION OF WAVES AND THEIR MOVEMENT ACROSS THE SEA 137

Periodic Waves	138
Wave Measurements, Analysis, and Data Sources	139
<i>The Measurement of Waves</i>	139
<i>The Analysis of Wave Data</i>	143
<i>Sources of Wave Data</i>	147
Wave Generation and Prediction	151
<i>The Processes of Wave Generation</i>	151
<i>Wave Predictions—the Significant Wave Approach</i>	153
<i>Wave Predictions—the Wave Spectrum Approach</i>	154
Wave Theories	160
<i>Linear Airy Wave Theory</i>	161
<i>Stokes Wave Theory</i>	168
<i>Waves in Shallow Water—Cnoidal and Solitary Wave Theories</i>	172
<i>Limits of Applications</i>	175
Wave Propagation and Transformation	176
<i>Deep-Water Wave Propagation</i>	176
<i>Shoaling Transformations of Waves</i>	183
Wave Refraction and Diffraction	189
Tsunami	196
Summary	199

6 WAVE BREAKING AND SURF-ZONE PROCESSES 208

Wave Breaking in the Nearshore	208
Wave Decay in the Surf Zone	217
Wave Set-up and Set-down	232

Wave Run-up on the Beach Face	238
Infragravity Motions and Edge Waves in the Nearshore	249
Summary	262

7 BEACH PROFILES AND CROSS-SHORE SEDIMENT TRANSPORT 270

The Measurement of Beach Profiles	271
General Beach Morphology and Variations	276
The Slope of the Beach Face at the Shore	285
Berm Formation	290
Longshore Bars and Troughs	292
Profile Changes Due to Storms	302
<i>Observed Profile Responses</i>	302
<i>Eigenfunction Analysis of Profile Variations</i>	307
<i>Prediction of Profile Changes</i>	308
Profile Changes Due to Tides	311
Profile Changes Due to Winds	314
Cross-Shore Sediment Transport and Profile Models	315
Summary	326

8 WAVE-GENERATED CURRENTS IN THE NEARSHORE 336

Rip Currents and the Cell Circulation	338
Longshore Currents Due to Obliquely Breaking Waves	350
Currents Due to Combined Oblique Waves and Longshore Variations in Set-up	364
Wind and Tide Effects on Nearshore Currents	366
Shear Instabilities in Longshore Currents	367
Summary	371

9 THE LONGSHORE TRANSPORT OF SEDIMENTS ON BEACHES 377

The Coastal Response to Engineering Structures	378
The Net and Gross Longshore Sediment Transport	383
Field-measurement Techniques and Results	387
Wave Power Evaluations of Sand-transport Rates	390
Process Models of Sand Transport on Beaches	393

Laboratory Studies of Longshore Sand Transport	395
Transport Dependence on Environmental Factors	397
The Cross-shore Distribution of Longshore Sediment Transport	401
The Modes of Sediment Transport	406
Summary	416

10 SHORELINE PLANFORMS AND MODELS TO SIMULATE THEIR EVOLUTION

424

Wave Patterns and the Equilibrium Shoreline	424
Techniques in Modeling Shorelines	430
Analyses Based on Sediment Continuity Considerations	433
Analytical Solutions of Shoreline Planforms	436
Numerical Models of Shoreline Change	439
Summary	451

11 NEARSHORE MORPHODYNAMICS

456

Rhythmic Shoreline Forms	456
<i>Beach Cusps</i>	458
<i>Rip-current Embayments and Cuspate Shorelines</i>	470
<i>Crescentic Bars</i>	472
<i>Welded and Transverse Bars</i>	478
<i>Large-scale Capes and Erosional Embayments</i>	482
A Morphodynamic Classification of Beach Cycles	486
Summary	493

12 THE PROTECTION OF OUR COASTS

497

No Action—Retreat and Relocation	497
Beach Nourishment—the “Soft” Solution	500
Stabilization Structures—the “Hard” Solution	517
<i>Seawalls and Revetments</i>	517
<i>Groynes and Breakwaters</i>	530
Summary	534

INDEX

541

Preface

There has been a remarkable increase in the scientific and engineering literature dealing with the coastal zone during the 20 years since publication of the first edition of this text. To suggest that the present edition is a “revision” is therefore something of an understatement. In 1976 when the first edition was published, little was known concerning the patterns of wave transformations and dissipation within the surf zone and how these water motions produce cross-shore movements of sediment resulting in beach-profile variations. Profile responses to storms had been documented, but there was little understanding of the underlying causes. By 1976, suggestions had been made that edge waves might be an important form of energy in the nearshore, responsible for the generation of rip currents and for the rearrangement of beach sediments into crescentic bars. At that time, however, no direct measurements had been made of edge waves on ocean beaches to verify that they actually exist outside of the laboratory, and this uncertainty resulted in much debate as to their relevance. This debate has been muted by the clear documentation of the presence of edge waves in the nearshore and that they often contain substantial amounts of energy. We continue to explore their roles in contributing to the transport of sediment in the nearshore and their effects on the beach morphology. These are only a few examples of research advances during the past 20 years, and many others could be cited touching on almost every aspect of beach processes and sedimentation.

In writing this text I was faced with a large volume of literature from scientific and engineering journals and conference proceedings, more than I could satisfactorily summarize in the text while maintaining the total number of pages reasonable and the product readable. Of course, I read many more papers than could be cited and in the end had to select for inclusion only representative publications covering each of the topics. These have tended to be the historic publications (the “first” contribution), those that made significant and lasting contributions, and finally I have tried to cite at least one recent paper that establishes the “state of the art” on the topic and from which the reader can derive an up-to-date list of relevant references. My choices of papers to be summarized were often subjective, so I apologize to the researchers whose important publications have been left out.