# Brief Contents

## Part 1

### Foundations of Environmental Geology

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Philosophy and Fundamental Concepts</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Earth Materials and Processes</td>
<td>24</td>
</tr>
<tr>
<td>3</td>
<td>Soils and Environment</td>
<td>56</td>
</tr>
</tbody>
</table>

## Part 2

### Hazardous Earth Processes

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Natural Hazards: An Overview</td>
<td>86</td>
</tr>
<tr>
<td>5</td>
<td>Rivers and Flooding</td>
<td>98</td>
</tr>
<tr>
<td>6</td>
<td>Landslides and Related Phenomena</td>
<td>132</td>
</tr>
<tr>
<td>7</td>
<td>Earthquakes and Related Phenomena</td>
<td>161</td>
</tr>
<tr>
<td>8</td>
<td>Volcanic Activity</td>
<td>205</td>
</tr>
<tr>
<td>9</td>
<td>Coastal Hazards</td>
<td>232</td>
</tr>
</tbody>
</table>

## Part 3

### Human Interaction with the Environment

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Water: Process, Supply, and Use</td>
<td>260</td>
</tr>
</tbody>
</table>

## Part 4

### Minerals, Energy, and Environment

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Water Pollution and Treatment</td>
<td>291</td>
</tr>
<tr>
<td>12</td>
<td>Waste Management</td>
<td>317</td>
</tr>
<tr>
<td>13</td>
<td>The Geologic Aspects of Environmental Health</td>
<td>342</td>
</tr>
</tbody>
</table>

## Part 5

### Global Change, Land Use, and Decision Making

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>Mineral Resources and Environment</td>
<td>374</td>
</tr>
<tr>
<td>15</td>
<td>Energy and Environment</td>
<td>400</td>
</tr>
<tr>
<td>16</td>
<td>Global Change and Earth System Science</td>
<td>446</td>
</tr>
<tr>
<td>17</td>
<td>Air Pollution</td>
<td>472</td>
</tr>
<tr>
<td>18</td>
<td>Landscape Evaluation and Land Use</td>
<td>493</td>
</tr>
</tbody>
</table>
## Contents

### Preface

- 

### PART 1

#### Foundations of Environmental Geology

- **CHAPTER 1**
  - Philosophy and Fundamental Concepts

  1. Introduction to Environmental Geology
  2. How Geologists Work: The Scientific Method
  3. Culture and Environmental Awareness
  4. Environmental Ethics
  5. The Environmental Crisis
    - *A Closer Look* The Land Ethic and the American Experience
  6. Fundamental Concepts of Environmental Science
    - Concept One: Population Growth
    - *Case History* Aral Sea
    - Concept Two: Sustainability
    - Concept Three: Systems
      - *A Closer Look* The Gaia Hypothesis
    - Concept Four: Limitation of Resources
    - Concept Five: Uniformitarianism
      - *A Closer Look* The Gaia Hypothesis
    - Concept Six: Hazardous Earth Processes
    - Concept Seven: Geology as a Basic Environmental Science
    - Concept Eight: Our Obligation to the Future
      - *A Closer Look* Geology and Ecosystems

- **CHAPTER 2**
  - Earth Materials and Processes

  1. The Geologic Cycle
    - The Tectonic Cycle
    - The Rock Cycle
    - The Hydrologic Cycle
    - Biogeochemical Cycles
  2. Rocks

- **CHAPTER 3**
  - Soils and Environment

  1. Introduction to Soils
  2. Soil Profiles
    - Soil Horizons
    - Soil Color
    - Soil Texture
    - Soil Structure
    - Relative Profile Development
    - Soil Chronosequences
  3. Soil Fertility
  4. Water in Soil
  5. Soil Classification
    - Soil Taxonomy
    - Engineering Classification of Soils
  6. Engineering Properties of Soils
    - *Putting Some Numbers On* Properties of Soil
  7. Rates of Soil Erosion
  8. Sediment Pollution
    - *A Closer Look* Universal Soil Loss Equation
    - *Case History* Reduction of Sediment Pollution, Maryland
  9. Land Use and Environmental Problems of Soils
    - Urbanization
    - Off-Road Vehicles
  10. Soil Pollution
  11. Desertification
  12. Soil Surveys and Land-Use Planning
    - *Case History* Desertification of the San Joaquin Valley

### Additional Notes

- *A Closer Look* 
  - Minerals
  - The Strength of Rocks
  - Stress and Strain
  - Types of Rocks
  - *Case History* Baldwin Hills Dam
  - *Case History* St. Francis Dam
  - *Case History* Hubbard Glacier

- Surficial Processes: Ice and Wind
  - Ice
  - *Case History* St. Francis Dam
  - *Case History* Hubbard Glacier

- Rates of Soil Erosion
- Sediment Pollution
- *A Closer Look* Universal Soil Loss Equation
- *Case History* Reduction of Sediment Pollution, Maryland
- Land Use and Environmental Problems of Soils
  - Urbanization
  - Off-Road Vehicles
- Soil Pollution
  - Desertification
- Soil Surveys and Land-Use Planning
  - *Case History* Desertification of the San Joaquin Valley
Faults and Fault Movement 162

A Closer Look  Intraplate Earthquakes at New Madrid 163

A Closer Look  The Northridge Earthquake and Buried Faults 166

Seismic Waves and Ground Shaking 168

Comparing Earthquakes 172 / The Earthquake Cycle 175

A Closer Look  Moment Magnitude 176

Earthquakes Caused by Human Activity 179

Effects of Earthquakes 180

Shaking and Ground Rupture 182 / Liquefaction 182

Landslides 183 / Fires 183 / Tsunamis 183

Regional Changes in Land Elevation 184

Earthquake Risk and Earthquake Prediction 184

Estimation of Seismic Risk 184 / Conditional Probabilities for Future Earthquakes 185

Short-Term Prediction 187 / Toward Earthquake Prediction 189

A Closer Look  Twelve Centuries of Earthquakes on the San Andreas Fault in Southern California 190

The Response to Earthquake Hazards 190

Earthquake Hazard-Reduction Programs 190

Earthquakes and Critical Facilities 191

Adjustments to Earthquake Activity 192

Earthquake Warning Systems 193 / Perception of the Earthquake Hazard 195

Putting Some Numbers On  Earthquake Hazard Evaluation 196

Chapter 8

Volcanic Activity 205

Introduction to Volcanic Hazards 205

Volcanism and Volcanoes 206

Volcano Types 206 / Volcano Origins 210

Volcanic Features 211 / Caldera Eruptions 211

Volcanic Hazards 213

Lava Flows 213

A Closer Look  The Long Valley Caldera 214

Pyroclastic Hazards 216 / Poisonous Gases 216

Case History  Controlling a Lava Flow in Iceland 217

Debris Flows and Mudflows 218

Some Case Histories 219

Mt. Unzen, Japan 219 / Nevado del Ruiz 219

Mt. Pinatubo 220 / Mount St. Helens 221

Case History  Surviving to Tell the Tale 224

Prediction of Volcanic Activity 225

Seismic Activity 226 / Geophysical Monitoring 226

Topographic Monitoring 226 / Monitoring of Volcanic Gases 226 / Geologic History 227

Progress in Prediction of Eruptions 227 / Volcanic Alert or Warning 228

Adjustment to and Perception of the Volcanic Hazard 224

Chapter 9

Coastal Hazards 232

Introduction to Coastal Hazards 232

Tropical Cyclones 233

Tidal Floods 236

Coastal Processes 236

Waves 236

Case History  The Thames Barrier 237

Beach Form and Beach Processes 238

Littoral Cells, Beach Budget, and Wave Climate 240

Coastal Erosion 241

Erosion Factors 241 / Seafill Erosion 242

Putting Some Numbers On  A Beach Budget 244

Coastal Hazards and Engineering Structures 246

Seawalls 246 / Groins 246 / Breakwaters and Jetties 246 / Beach Nourishment 247

Case History  Galveston and Seabright 249

Human Activity and Coastal Erosion: Some Examples 250

The Atlantic Coast 250 / The Gulf Coast 252

The Great Lakes 252

Perception of and Adjustment to Coastal Hazards 248

Perception of Coastal Erosion 253 / Adjustment to Coastal Hazards 253

A Closer Look  E-Lines and E-Zones 255

The Cape Hatteras Lighthouse Controversy 256

Part 3

Human Interaction with the Environment 259

Chapter 10

Water: Process, Supply, and Use 260

Water: A Brief Global Perspective 261

Water as a Unique Liquid 262
Contents

Surface Runoff and Sediment Yield 263
- Factors Affecting Runoff 264 / Runoff Paths 266
- Sediment Yield 266

Groundwater 267
- Aquifers 269 / Groundwater Movement 270
- Interactions Between Surface Water and Groundwater 270
  - Putting Some Numbers On  Groundwater Flow 272
- Perceptions About Groundwater 272

Water Supply 273
- The Water Budget 273 / The Groundwater Supply 274 / Desalination 275

Water Use 275
- Movement of Water to People 277 / Trends in Water Use 279 / Water Conservation 280

Water Management 281
- The Future of Water Management 281 / A Managed River: The Colorado 281

Dams, Reservoirs, and Canals 284
- Dams and Reservoirs 284 / Canals 285

Water and Ecosystems 285
- Case History  The Grand Canyon 286
- A Closer Look  Wetlands 288

CHAPTER 11
Water Pollution and Treatment 291

An Overview of Water Pollution 292

Selected Water Pollutants 293
- Oxygen-Demanding Waste 293 / Pathogenic Organisms 293 / Nutrients 294 / Oil 294
  - Case History  Exxon Valdez 296
- Toxic Substances 296 / Sediments 297
- Thermal Pollution 297

Surface-Water Pollution and Treatment 297
- Point Sources of Surface-Water Pollution 298
- Nonpoint Sources of Surface-Water Pollution 298
- Reduction of Surface-Water Pollution 298
  - A Closer Look  Acid Mine Drainage 299

Groundwater Pollution and Treatment 299
- Case History  Cleaning Up the Hudson 300
- Comparison of Groundwater and Surface-Water Pollution 300 / Exchanges Between Groundwater and Its Surroundings 301 / Salt Water Intrusion 301

- Case History  The Threatened Groundwater of Long Island 302

Water Quality Standards 305

Wastewater Treatment 305
- Septic-Tank Sewage Disposal 306 / Wastewater Treatment Plants 308 / Wastewater Renovation 309
- Wastewater Treatment as Resource Recovery 309

Water Law and Federal Legislation 310
- Surface Water Law 311 / Groundwater Law 311
- Case History  Mono Lake and the Public Trust Doctrine 312
- Federal Water Legislation 314

CHAPTER 12
Waste Management 317

Concepts of Waste Management: An Overview 317
- Earlier Views 318
  - Case History  The Fresh Kills Landfill 319
- Modern Trends: Integrated Waste Management 320

Materials Management 320

Solid-Waste Disposal 320
- On-site Disposal 321 / Composting 321
- Incineration 321 / Open Dumps 322
- Sanitary Landfills 322

Hazardous Waste Management 325
- Case History  Love Canal 326
- Responsible Management 327 / Secure Landfill 328
- Land Application 330 / Surface Impoundment 330
- Deep-well Disposal 330 / Incineration of Hazardous Chemical Waste 332 / Alternatives to Land Disposal 333

Radioactive Waste Management 334
- Disposal of Low-level Radioactive Wastes 334
- Disposal of High-level Radioactive Wastes 336

Ocean Dumping 338
- Ocean Dumping and Pollution 338 / Ocean Dumping: The Conflict 339

CHAPTER 13
The Geologic Aspects of Environmental Health 342

Introduction to Environmental Health 343
- Environmentally Transmitted Infectious Diseases 343
- Cultural Factors 343 / Climatic Factors 344
Contents ix

Some Geologic Factors of Environmental Health 344
Natural Abundances of Elements 345
Concentration and Dispersion of Chemical Substances 345
• A Closer Look Nitrogen and People 349

Trace Elements and Health 349
Dose Dependency and Effective Dose 349
Imbalances of Selected Trace Elements 351
Human Use and Imbalances of Trace Elements 354

Chronic Disease and Geologic Environment 354
Heart Disease and the Geochemical Environment 354
• Case History Mining and Toxic Trace Elements 355
Cancer and the Geochemical Environment 356
• Case History Heart Disease in Georgia 357
• A Closer Look Asbestos 358

Radioactivity and Radon Gas 359
The Nature of Radioactivity 359 / Radiation Units 360 / The Health Danger from Radioactive Radiation 361 / Radon Gas 362

Risk Assessment in Toxicology 368

PART 4

Minerals, Energy, and Environment 373

CHAPTER 14

Mineral Resources and Environment 374

Minerals and Human Use 374
Resources and Reserves 375 / Availability and Use of Mineral Resources 376

Geology of Mineral Resources 379
Local Concentrations of Metals 379
Igneous Processes 381
• A Closer Look Plate Tectonics and Minerals 382
Metamorphic Processes 385 / Sedimentary Processes 386 / Biological Processes 388
Weathering Processes 389 / Minerals from the Sea 390

Environmental Impact of Mineral Development 392
Impact of Mineral Exploration and Testing 392
Impact of Mineral Extraction and Processing 392
Minimizing the Impact of Mineral Development 394
The Impact of Mineral Development: Summary and Conclusions 395

Recycling of Mineral Resources 395
• Case History Homestake Mine, South Dakota 395
Recycling Scrap Metal 396 / Urban Ore 396

PART 5

Global Change, Land Use, and Decision Making 445

CHAPTER 16

Global Change and Earth System Science 446

Global Change and Earth System Science: An Overview 446
Tools for Studying Global Change 448
The Geologic Record 448 / Real-Time Monitoring 449 / Mathematical Models 449
Earth's Atmosphere and Energy Balance 450
The Atmosphere 450 / Solar Radiation and Earth's Energy Balance 451
Atmospheric Carbon Dioxide and Global Warming 453
   The Greenhouse Effect 453 / Changes in Greenhouse Gases 454
Global Temperature Change: Evidence for a Warming Trend 456
   Role of Particulates in the Atmosphere 457
   ▶ A Closer Look Causes of Climatic Change 460
   Potential Effects of Global Warming 463 / Strategies for Reducing the Impact of Global Warming 464
Ozone Depletion 465
   Ozone Formation and the Ozone Layer 465
   Removal of Stratospheric Ozone 466
   Environmental Effects of Ozone Depletion 467
   Management Issues Related to Ozone Depletion 467
Coupling of Global-Change Processes 467
   ▶ A Closer Look Role of Stratospheric Clouds in Antarctic Ozone Depletion 468

CHAPTER 17
Air Pollution 472

Introduction to Air Pollution 472
Pollution of the Atmosphere 473
   General Effects of Air Pollution 473
   ▶ Case History The London Smog Crisis of 1952 474
   Sources of Air Pollution 475 / Air Pollutants 475
Urban Air Pollution 479
   Influence of Meteorology and Topography 479
   Potential for Urban Air Pollution 480 / The Urban Microclimate 480 / Smog Production 482
   The Future of Air Pollution in Urban Areas 483
Indoor Air Pollution 484
Control of Air Pollution 484
   Control of Particulates 486 / Control of Automobile Pollution 486 / Control of Sulfur Dioxide 486
   Air Quality Standards 488 / The Cost of Controls 490

CHAPTER 18
Landscape Evaluation and Land Use 493

Landscape Evaluation, Land Use, and the Earth Scientist 493
Environmental Geology Mapping 494
   Interpretive Environmental Geology Maps 494
   Environmental Resource Units (ERUs) 495
   The Geographic Information System 495
Site Selection 499
   Role of the Earth Scientist in Site Selection 499
   Methods of Site Selection 499 / Site Evaluation for Engineering Purposes 500
Environmental Impact Analysis 502
   Environmental Impact Statements 502 / State Environmental Impact Legislation 503 / Negative and Mitigated Negative Declarations 503
   Methodology and Achievements of Environmental Impact Analysis 504
Case Histories: Uses of Environmental Impact Analysis 504
   Cape Hatteras National Seashore 504 / The San Joaquin Valley 506
Land Use and Planning 511
   Scenic Resources 511 / Sequential Land Use 511
   Land-Use Planning 512 / Comprehensive Planning 512
   ▶ Case History Butchart Gardens 514
   Land Management 514 / Emergency Planning 515
Environmental Law 515
   The Process of Law 515 / Some Legal Case Histories 516 / Environmental Legislation 518
   Land-Use Planning and Law 519

Appendix A: World Wide Web: An Introductory Statement 523
Appendix B: Maps and Related Topics 527
Glossary 535
Index 551