CONTENTS

Lakes 83
  Types of Lakes 84
  Ecological Zones 84
  Thermal Cycles 85
  Seiches 86
Water Measurement 86
  Overland Flow 87
  River Discharge 87
  Water Storage in Lakes and Reservoirs 90
Flood Events 91
  Flood Frequency 92
  Probable Maximum Precipitation 93
  Probable Maximum Flood 93
  GUEST ESSAY GIS and Flooding by Jake Freier 94
Transport and Deposition 97
  Velocity 98
  Sediment Load 98

CHAPTER 4
GROUNDWATER HYDROLOGY 104
What Is Groundwater? 105
What Is Groundwater Hydrology? 106
The Geology of Groundwater 107
  Sedimentary Rocks 107
  GUEST ESSAY Sinkholes by Carlos Herd 108
  Glaciated Terrain 111
  Alluvial Valleys 113
  Tectonic Activity 113
Groundwater Recharge 114
Aquifers 115
  Aquifer Types 116
  Properties of Aquifers 119
Groundwater Movement 121
  Age of Groundwater 126
  Locating and Mapping Groundwater 127
  Drilling a Groundwater Well 129

CHAPTER 5
WATER QUALITY 137
Water Pollution 137
  Point Source and Nonpoint Source Pollution 139
    Point Source Pollution 139
    Nonpoint Source Pollution 142
Basic Parameters of Water 143
  Temperature 143
  Dissolved Oxygen 144
  pH 144
  Turbidity 146
  Hardness 147
Inorganic Chemicals 147
  Metals 148
  Lead 148
  Arsenic 149
  Minerals 150
  Salt 150
  POLICY ISSUE 150
    Fluoride 152
    Selenium 152
Organic Chemicals 153
  Natural Organic Chemicals 153
  Synthetic Organic Compounds 153
  Pesticides 155
  Nutrients 157
    Nitrogen 157
    Phosphorus 158
  The Nitrogen Cycle 159
    Nitrogen Fixation 160
    Mineralization/Ammonification 160
    Nitrification 160
    Denitrification 161
  The Phosphorus Cycle 161
    Eutrophication 162
Waterborne Diseases 162
  Historical Problems 162
  Microorganisms 164
    Indicator Organisms 164
CHAPTER 6
MUNICIPAL AND IRRIGATION WATER DEVELOPMENT 185

Municipal Water Systems 186
CASE STUDY Los Angeles Department of Water and Power 187
CASE STUDY Lincoln Water System 191
CASE STUDY New York City Department of Environmental Protection 193
GUEST ESSAY Construction of City Tunnel #3 by Eileen M. Schnock 196

Irrigation 202
Historical Perspective 202
The Need for Irrigation 202
Irrigation Techniques 205
Gravity Irrigation 206
Sprinkler Irrigation 210
Drip Irrigation 213

CHAPTER 7
DAMS 217

Dam Basics 217
Purposes of Dams 217
Components of Dams 218
Types of Dams 219
Dam Operations 221

CASE STUDY Hoover Dam and Lake Mead, Nevada/Arizona 223
CASE STUDY Kingsley Dam and Lake McConaughy, Nebraska 227
CASE STUDY Grand Coulee Dam and Franklin D. Roosevelt Lake, Washington State 231

Cost-Benefit Analysis 234
Impacts of Dams 235

GUEST ESSAY Forced Urbanization: The Three Gorges Dam Relocation Process by Colin Flahive 237

Dams and Locks for Navigation 240

GUEST ESSAY Navigation on the Tennessee River by Ted Nelson 242

CHAPTER 8
WATER ALLOCATION LAW 249

Ancient Water Allocation Law 250
Code of Hammurabi 250
Justinian Code 251
Ancient Riparian Doctrine 251

Water Allocation Law: 1200–1799 252
Spanish Water Law 252
First Possession 254
English Common Law: 1200–1799 255
Mill Acts of the Eastern United States 255

Water Allocation Law: 1800–1847 258
Code Napoléon 258
Riparian Doctrine: 1800–1847 258
Tyler v. Wilkinson 259
Local Water Agencies
Municipal Water Departments 338
Historical Overview 339
Water and Sewer Districts 341
Overview 341
EXAMPLE: Highline Water District, Kent, Washington 341
Levee and Flood-Control Districts 342
Historical Overview 342
Levee Districts 342
Flood-Control Districts 345
EXAMPLE: Pima County Regional Flood Control District, Tucson, Arizona 345
Mutual Ditch and Irrigation Companies 346
Historical Overview 346
Regional Water Agencies 348
Overview 348
Irrigation Districts 348
EXAMPLE: Farwell Irrigation District, Farwell, Nebraska 348
Conservancy/Conservation Districts 349
EXAMPLE: Miami Conservancy District, Dayton, Ohio 350
Natural Resources Districts—Nebraska 350
EXAMPLE: Papio-Missouri River Natural Resources District, Omaha, Nebraska 351
Groundwater Management Districts—Kansas 352
EXAMPLE: Northwest Kansas Groundwater Management District No. 4, Colby, Kansas 353
Water Management Districts—Florida 353
State Water Agencies 355
State of Arizona Water Agencies 355
State of Rhode Island Water Agencies 356
Multistate Water Agencies 357
Chesapeake Bay Commission 357
Missouri River Basin Association 357
Water Management in Mexico and Canada 359
Overview 359
GUEST ESSAY Water Management in Mexico by Dr. Alvaro A. Aldama 360

GUEST ESSAY Water Management in Canada: The Inter-Jurisdictional Context by Ralph L. Pentland 366

Careers 371

CHAPTER 11
DRINKING-WATER AND WASTEWATER TREATMENT 374
Historical Perspective on Drinking-Water Treatment 374

GUEST ESSAY Water Desalination in the Middle East: One of the Realistic Options by Dr. Fares M. Howari 380

Federal Protection of Drinking Water in the United States 383
Drinking-Water Treatment Process 384
Protection of Water Quality 384
Intakes for Raw Water 385
CASE STUDY Department of Water Management, City of Chicago, Illinois 386
Pretreatment of Drinking Water 388
Flocculation/Coagulation 388
Filtration 388
CASE STUDY Sewerage and Water Board, City of New Orleans, Louisiana 389
Final Drinking-Water Treatment 390
Distribution System 390
Historical Perspective on Wastewater Treatment 393
Wastewater Treatment Process 396
Primary Treatment 396
Secondary Treatment 397
Tertiary Treatment 398
Nutrient Removal 398
Septic Tanks and Leach Fields 399
Wetlands and Water Treatment 400
# Chapter 12

## Water, Fish, and Wildlife

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Fish and Wildlife Protection</td>
<td>406</td>
</tr>
<tr>
<td>Fish and Wildlife Protection in the 20th Century</td>
<td>407</td>
</tr>
<tr>
<td>Wild and Scenic Rivers Act</td>
<td>408</td>
</tr>
<tr>
<td>National Environmental Policy Act</td>
<td>410</td>
</tr>
<tr>
<td>Endangered Species Act</td>
<td>413</td>
</tr>
<tr>
<td>Wetlands and Wildlife</td>
<td>415</td>
</tr>
</tbody>
</table>

**Case Study**
- Snail Darters and the Little Tennessee River | 421
- Whooping Cranes and the Platte River | 424
- Salmon and the Columbia River | 428

**Guest Essay**
- Careers in Fish and Wildlife Management by Larry Rogstad | 434

# Chapter 13

## The Economics of Water

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>441</td>
</tr>
<tr>
<td>The Value of Water</td>
<td>442</td>
</tr>
<tr>
<td>Water as a Public versus a Private Good</td>
<td>443</td>
</tr>
<tr>
<td>Privatization</td>
<td>444</td>
</tr>
<tr>
<td>Water Affordability</td>
<td>445</td>
</tr>
<tr>
<td>Water Marketing</td>
<td>446</td>
</tr>
<tr>
<td>Surface Water Marketing</td>
<td>446</td>
</tr>
<tr>
<td>Groundwater Marketing</td>
<td>449</td>
</tr>
<tr>
<td>Water Banking</td>
<td>450</td>
</tr>
<tr>
<td>Pollution Fees and Credits</td>
<td>451</td>
</tr>
<tr>
<td>Environmental Values</td>
<td>452</td>
</tr>
</tbody>
</table>

# Chapter 14

## Water Use Conflicts

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reasons for Water Use Conflicts</td>
<td>455</td>
</tr>
<tr>
<td>Texas</td>
<td>457</td>
</tr>
</tbody>
</table>

**Guest Essay**
- Water Planning in Texas by Connie Townsend | 458

Alabama and Florida versus Georgia | 463
Northern and Southern California | 468
Canada | 469
The Middle East | 470
- Religious/Political Background | 471
- Water Resources in the Middle East | 473
  - West Bank Mountain Aquifer | 473
  - Jordan River | 473
  - Tigris and Euphrates Rivers | 475
- Tragedy of the Commons | 477

# Chapter 15

## Emerging Water Issues

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Future Global Water Management Issues</td>
<td>483</td>
</tr>
<tr>
<td>Population</td>
<td>483</td>
</tr>
<tr>
<td>Lack of Wastewater Treatment</td>
<td>483</td>
</tr>
<tr>
<td>Environmental Degradation</td>
<td>484</td>
</tr>
<tr>
<td><strong>Scenario 1:</strong> “Business as Usual”</td>
<td>485</td>
</tr>
</tbody>
</table>

Future Global Water Management Solutions | 486
- Privatization of Water Treatment and Delivery | 486
  - **Scenario 2:** “Technology Saves the Day” | 487
  - Groundwater Recharge | 487
  - Water Conservation | 488
  - Dam Construction | 489
  - **Scenario 3:** “Global Warming Floods the World” | 490

Water Education | 490
- The Watercourse and International Project WET | 490
- Water Education Foundation | 491
- Groundwater Foundation | 491