



INTERNATIONAL
EDITION



Water-Resources Engineering

THIRD EDITION

David A. Chin

ALWAYS LEARNING

PEARSON

WATER-RESOURCES ENGINEERING

Third Edition

David A. Chin

**International Edition contributions by
Asis Mazumdar**

Pankaj Kumar Roy

PEARSON

Boston Columbus Indianapolis New York San Francisco Upper Saddle River
Amsterdam Cape Town Dubai London Madrid Milan Munich Paris Montreal Toronto
Delhi Mexico City Sao Paulo Sydney Hong Kong Seoul Singapore Taipei Tokyo

Water-Resources Engineering

Table of Contents

Cover

Contents

Preface

1 Introduction

1.1 Water-Resources Engineering

1.2 The Hydrologic Cycle

1.3 Design of Water-Resource Systems

1.3.1 Water-Control Systems

1.3.2 Water-Use Systems

1.3.3 Supporting Federal Agencies in the United States

Problem

2 Fundamentals of Flow in Closed Conduits

2.1 Introduction

2.2 Single Pipelines

2.2.1 Steady-State Continuity Equation

2.2.2 Steady-State Momentum Equation

2.2.3 Steady-State Energy Equation

2.2.3.1 Energy and hydraulic grade lines

2.2.3.2 Velocity profile

2.2.3.3 Head losses in transitions and fittings

2.2.3.4 Head losses in noncircular conduits

2.2.3.5 Empirical friction-loss formulae

2.2.4 Water Hammer

2.3 Pipe Networks

2.3.1 Nodal Method

2.3.2 Loop Method

2.3.3 Application of Computer Programs

2.4 Pumps

Table of Contents

2.4.1 Affinity Laws

2.4.2 Pump Selection

2.4.2.1 Commercially available pumps

2.4.2.2 System characteristics

2.4.2.3 Limits on pump location

2.4.3 Multiple-Pump Systems

2.4.4 Variable-Speed Pumps

Problems

3 Design of Water-Distribution Systems

3.1 Introduction

3.2 Water Demand

3.2.1 Per-Capita Forecast Model

3.2.1.1 Estimation of per-capita demand

3.2.1.2 Estimation of population

3.2.2 Temporal Variations in Water Demand

3.2.3 Fire Demand

3.2.4 Design Flows

3.3 Components of Water-Distribution Systems

3.3.1 Pipelines

3.3.1.1 Minimum size

3.3.1.2 Service lines

3.3.1.3 Pipe materials

3.3.2 Pumps

3.3.3 Valves

3.3.4 Meters

3.3.5 Fire Hydrants

3.3.6 Water-Storage Reservoirs

3.4 Performance Criteria for Water-Distribution Systems

3.4.1 Service Pressures

3.4.2 Allowable Velocities

3.4.3 Water Quality

3.4.4 Network Analysis

3.5 Building Water-Supply Systems

3.5.1 Specification of Design Flows

Table of Contents

3.5.2 Specification of Minimum Pressures

3.5.3 Determination of Pipe Diameters

Problems

4 Fundamentals of Flow in Open Channels

4.1 Introduction

4.2 Basic Principles

4.2.1 Steady-State Continuity Equation

4.2.2 Steady-State Momentum Equation

4.2.2.1 DarcyWeisbach equation

4.2.2.2 Manning equation

4.2.2.3 Other equations

4.2.2.4 Velocity distribution

4.2.3 Steady-State Energy Equation

4.2.3.1 Energy grade line

4.2.3.2 Specific energy

4.3 Water-Surface Profiles

4.3.1 Profile Equation

4.3.2 Classification of Water-Surface Profiles

4.3.3 Hydraulic Jump

4.3.4 Computation of Water-Surface Profiles

4.3.4.1 Direct-integration method

4.3.4.2 Direct-step method

4.3.4.3 Standard-step method

4.3.4.4 Practical considerations

4.3.4.5 Profiles across bridges

Problems

5 Design of Drainage Channels

5.1 Introduction

5.2 Basic Principles

5.2.1 Best Hydraulic Section

5.2.2 Boundary Shear Stress

5.2.3 Cohesive versus Noncohesive Materials

5.2.4 Bends

5.2.5 Channel Slopes

Table of Contents

5.2.6 Freeboard

5.3 Design of Channels with Rigid Linings

5.4 Design of Channels with Flexible Linings

5.4.1 General Design Procedure

5.4.2 Vegetative Linings and Bare Soil

5.4.3 RECP Linings

5.4.4 Riprap, Cobble, and Gravel Linings

5.4.5 Gabions

5.5 Composite Linings

Problems

6 Design of Sanitary Sewers

6.1 Introduction

6.2 Quantity of Wastewater

6.2.1 Residential Sources

6.2.2 Nonresidential Sources

6.2.3 Inflow and Infiltration (I/I)

6.2.4 Peaking Factors

6.3 Hydraulics of Sewers

6.3.1 Manning Equation with Constant n

6.3.2 Manning Equation with Variable n

6.3.3 Self-Cleansing

6.3.4 Scour Prevention

6.3.5 Design Computations for Diameter and Slope

6.3.6 Hydraulics of Manholes

6.4 System Design Criteria

6.4.1 System Layout

6.4.2 Pipe Material

6.4.3 Depth of Sanitary Sewer

6.4.4 Diameter and Slope of Pipes

6.4.5 Hydraulic Criteria

6.4.6 Manholes

6.4.7 Pump Stations

6.4.8 Force Mains

Table of Contents

6.4.9 Hydrogen-Sulfide Control

6.4.10 Combined Sewers

6.5 Design Computations

6.5.1 Design Aids

6.5.1.1 Mannings n

6.5.1.2 Minimum slope for self-cleansing

6.5.2 Procedure for System Design

Problems

7 Design of Hydraulic Structures

7.1 Introduction

7.2 Culverts

7.2.1 Hydraulics

7.2.1.1 Submerged entrances

7.2.1.2 Unsubmerged entrances

7.2.2 Design Constraints

7.2.3 Sizing Calculations

7.2.3.1 Fixed-headwater method

7.2.3.2 Fixed-flow method

7.2.3.3 Minimum-performance method

7.2.4 Roadway Overtopping

7.2.5 Riprap/Outlet Protection

7.3 Gates

7.3.1 Free Discharge

7.3.2 Submerged Discharge

7.3.3 Empirical Equations

7.4 Weirs

7.4.1 Sharp-Crested Weirs

7.4.1.1 Rectangular weirs

7.4.1.2 V-notchweirs

7.4.1.3 Compound weirs

7.4.1.4 Other types of sharp-crested weirs

7.4.2 Broad-Crested Weirs

7.4.2.1 Rectangular weirs

7.4.2.2 Compound weirs

7.4.2.3 Gabionweirs

Table of Contents

7.5 Spillways

7.5.1 Uncontrolled Spillways

7.5.2 Controlled (Gated) Spillways

7.5.2.1 Gates seated on the spillway crest

7.5.2.2 Gates seated downstream of the spillway crest

7.6 Stilling Basins

7.6.1 Type Selection

7.6.2 Design Procedure

7.7 Dams and Reservoirs

7.7.1 Types of Dams

7.7.2 Reservoir Storage

7.7.2.1 Sediment accumulation

7.7.2.2 Determination of storage requirements

7.7.3 Hydropower

7.7.3.1 Turbines

7.7.3.2 Turbine performance

7.7.3.3 Feasibility of hydropower

Problems

8 Probability and Statistics in Water-Resources Engineering

8.1 Introduction

8.2 Probability Distributions

8.2.1 Discrete Probability Distributions

8.2.2 Continuous Probability Distributions

8.2.3 Mathematical Expectation and Moments

8.2.4 Return Period

8.2.5 Common Probability Functions

8.2.5.1 Binomial distribution

8.2.5.2 Geometric distribution

8.2.5.3 Poisson distribution

8.2.5.4 Exponential distribution

8.2.5.5 Gamma/Pearson Type III distribution

8.2.5.6 Normal distribution

8.2.5.7 Log-normal distribution

8.2.5.8 Uniform distribution

8.2.5.9 Extreme-value distributions

Table of Contents

8.2.5.10 Chi-square distribution

8.3 Analysis of Hydrologic Data

8.3.1 Estimation of Population Distribution

8.3.1.1 Probability distribution of observed data

8.3.1.2 Hypothesis tests

8.3.1.3 Model selection criteria

8.3.2 Estimation of Population Parameters

8.3.2.1 Method of moments

8.3.2.2 Maximum-likelihood method

8.3.2.3 Method of L-moments

8.3.3 Frequency Analysis

8.3.3.1 Normal distribution

8.3.3.2 Log-normal distribution

8.3.3.3 Gamma/Pearson Type III distribution

8.3.3.4 Log-Pearson Type III distribution

8.3.3.5 Extreme-value Type I distribution

8.3.3.6 General extreme-value (GEV) distribution

8.4 Uncertainty Analysis

Problems

9 Fundamentals of Surface-Water Hydrology I: Rainfall and Abstractions

9.1 Introduction

9.2 Rainfall

9.2.1 Measurement of Rainfall

9.2.2 Statistics of Rainfall Data

9.2.2.1 Rainfall statistics in the United States

9.2.2.2 Secondary estimation of IDF curves

9.2.3 Spatial Averaging and Interpolation of Rainfall

9.2.4 Design Rainfall

9.2.4.1 Return period

9.2.4.2 Rainfall duration

9.2.4.3 Rainfall depth

9.2.4.4 Temporal distribution

9.2.4.5 Spatial distribution

9.2.5 Extreme Rainfall

9.2.5.1 Rational estimation method

9.2.5.2 Statistical estimation method

Table of Contents

9.2.5.3 World-record precipitation amounts

9.2.5.4 Probable maximum storm

9.3 Rainfall Abstractions

9.3.1 Interception

9.3.2 Depression Storage

9.3.3 Infiltration

9.3.3.1 The infiltration process

9.3.3.2 Horton model

9.3.3.3 GreenAmpt model

9.3.3.4 NRCS curve-number model

9.3.3.5 Comparison of infiltration models

9.3.4 Rainfall Excess on Composite Areas

9.4 Baseflow

Problems

10 Fundamentals of Surface-Water Hydrology II: Runoff

10.1 Introduction

10.2 Mechanisms of Surface Runoff

10.3 Time of Concentration

10.3.1 Overland Flow

10.3.1.1 Kinematic-wave equation

10.3.1.2 NRCS method

10.3.1.3 Kirpich equation

10.3.1.4 Izzard equation

10.3.1.5 Kerby equation

10.3.2 Channel Flow

10.3.3 Accuracy of Estimates

10.4 Peak-Runoff Models

10.4.1 The Rational Method

10.4.2 NRCS-TR55 Method

10.5 Continuous-Runoff Models

10.5.1 Unit-Hydrograph Theory

10.5.2 Instantaneous Unit Hydrograph

10.5.3 Unit-Hydrograph Models

10.5.3.1 Snyder unit-hydrograph model

10.5.3.2 NRCS dimensionless unit hydrograph

Table of Contents

10.5.3.3 Accuracy of unit-hydrograph models

10.5.4 Time-Area Models

10.5.5 Kinematic-Wave Model

10.5.6 Nonlinear-Reservoir Model

10.5.7 Santa Barbara Urban Hydrograph Model

10.5.8 Extreme Runoff Events

10.6 Routing Models

10.6.1 Hydrologic Routing

10.6.1.1 Modified Puls method

10.6.1.2 Muskingum method

10.6.2 Hydraulic Routing

10.7 Water-Quality Models

10.7.1 Event-Mean Concentrations

10.7.2 Regression Equations

10.7.2.1 USGS model

10.7.2.2 EPA model

Problems

11 Design of Stormwater-Collection Systems

11.1 Introduction

11.2 Street Gutters

11.3 Inlets

11.3.1 CurbInlets

11.3.2 Grate Inlets

11.3.3 Combination Inlets

11.3.4 Slotted Inlets

11.4 Roadside and Median Channels

11.5 Storm Sewers

11.5.1 Calculation of Design Flow Rates

11.5.2 Pipe Sizing and Selection

11.5.3 Manholes

11.5.4 Determination of Impervious Area

11.5.5 System-Design Computations

11.5.6 Other Design Considerations

Problems

Table of Contents

12 Design of Stormwater-Management Systems

12.1 Introduction

12.2 Performance Goals

12.2.1 Quantity Control

12.2.2 Quality Control

12.3 Design of Stormwater Control Measures

12.3.1 Storage Impoundments

12.3.1.1 DetentionbasinsDesignparameters

12.3.1.2 Wet detention basins

12.3.1.3 Dry detention basins

12.3.1.4 Design of outlet structures

12.3.1.5 Design for flood control

12.3.2 Infiltration Basins

12.3.3 Swales

12.3.3.1 Retention swales

12.3.3.2 Biofiltration swales

12.3.4 Vegetated Filter Strips

12.3.5 Bioretention Systems

12.3.6 Exfiltration Trenches

12.3.6.1 General design guidelines

12.3.6.2 Design for flood control

12.3.6.3 Design for water-quality control

12.3.7 Subsurface Exfiltration Galleries

12.4 Selection of SCMs for Water-Quality Control

12.4.1 Nonstructural SCMs

12.4.2 Structural SCMs

12.4.3 Other Considerations

12.5 Major Drainage System

Problems

13 Estimation of Evapotranspiration

13.1 Introduction

13.2 PenmanMonteith Equation

13.2.1 Aerodynamic Resistance

13.2.2 Surface Resistance

Table of Contents

13.2.3 Net Radiation

13.2.3.1 Shortwave radiation

13.2.3.2 Longwave radiation

13.2.4 Soil Heat Flux

13.2.5 Latent Heat of Vaporization

13.2.6 Psychrometric Constant

13.2.7 Saturation Vapor Pressure

13.2.8 Vapor-Pressure Gradient

13.2.9 Actual Vapor Pressure

13.2.10 Air Density

13.3 Application of the PM Equation

13.4 Potential Evapotranspiration

13.5 Reference Evapotranspiration

13.5.1 FAO56-PenmanMonteith Method

13.5.2 ASCE PenmanMonteith Method

13.5.3 Evaporation Pans

13.5.4 Empirical Methods

13.6 Actual Evapotranspiration

13.6.1 Index-of-Dryness Method

13.6.2 Crop-Coefficient Method

13.6.3 Remote Sensing

13.7 Selection of ETE estimation Method

Problems

14 Fundamentals of Groundwater Hydrology I: Governing Equations

14.1 Introduction

14.2 Darcys Law

14.2.1 Hydraulic Conductivity

14.2.1.1 Empirical formulae

14.2.1.2 Classification

14.2.1.3 Anisotropic properties

14.2.1.4 Stochastic properties

14.3 General Flow Equation

14.4 Two-Dimensional Approximations

Table of Contents

14.4.1 Unconfined Aquifers

14.4.2 Confined Aquifers

14.5 Flow in the Unsaturated Zone

Problems

15 Fundamentals of Groundwater Hydrology II: Applications

15.1 Introduction

15.2 Steady-State Solutions

15.2.1 Unconfined Flow Between Two Reservoirs

15.2.2 Well in a Confined Aquifer

15.2.3 Well in an Unconfined Aquifer

15.2.4 Well in a Leaky Confined Aquifer

15.2.5 Well in an Unconfined Aquifer with Recharge

15.2.6 Partially Penetrating Wells

15.3 Unsteady-State Solutions

15.3.1 Well in a Confined Aquifer

15.3.2 Well in an Unconfined Aquifer

15.3.3 Well in a Leaky Confined Aquifer

15.3.4 Other Solutions

15.4 Principle of Superposition

15.4.1 Multiple Wells

15.4.2 Well in Uniform Flow

15.5 Method of Images

15.5.1 Constant-Head Boundary

15.5.2 Impermeable Boundary

15.5.3 Other Applications

15.6 Saltwater Intrusion

Problems

16 Design of Groundwater Systems

16.1 Introduction

16.2 Design of Wellfields

16.3 Wellhead Protection

16.3.1 Delineation of Wellhead Protection Areas

16.3.2 Time-of-Travel Approach

Table of Contents

16.4 Design and Construction of Water-Supply Wells

16.4.1 Types of Wells

16.4.2 Design of Well Components

16.4.2.1 Casing

16.4.2.2 Screenintake

16.4.2.3 Gravel pack

16.4.2.4 Pump

16.4.2.5 Other considerations

16.4.3 Performance Assessment

16.4.4 Well Drilling

16.5 Design of Aquifer Pumping Tests

16.5.1 Pumping Well

16.5.2 Observation Wells

16.5.3 Field Procedures

16.6 Design of Slug Tests

16.7 Design of Exfiltration Trenches

16.8 Seepage Meters

Problems

17 Water-Resources Planning

17.1 Introduction

17.2 Planning Process

17.3 Economic Feasibility

17.3.1 Compound-Interest Factors

17.3.1.1 Single-payment factors

17.3.1.2 Uniform-series factors

17.3.1.3 Arithmetic-gradient factors

17.3.1.4 Geometric-gradient factors

17.3.2 Evaluating Alternatives

17.3.2.1 Present-worth analysis

17.3.2.2 Annual-worth analysis

17.3.2.3 Rate-of-return analysis

17.3.2.4 Benefitcost analysis

Problems

A: Units and Conversion Factors

Table of Contents

A.1 Units

A.2 Conversion Factors

B: Fluid Properties

B.1 Water

B.2 Organic Compounds Found in Water

B.3 Air at Standard Atmospheric Pressure

C: Statistical Tables

C.1 Areas Under Standard Normal Curve

C.2 Frequency Factors for Pearson Type III Distribution

C.3 Critical Values of the Chi-Square Distribution

C.4 Critical Values for the Kolmogorov-Smirnov Test Statistic

D: Special Functions

D.1 Error Function

D.2 Bessel Functions

D.2.1 Definition

D.2.2 Evaluation of Bessel Functions

D.2.2.1 Bessel function of the first kind of order n

D.2.2.2 Bessel function of the second kind of order n

D.2.2.3 Modified Bessel function of the first kind of order n

D.2.2.4 Modified Bessel function of the second kind of order n

D.2.2.5 Tabulated values of useful Bessel functions

D.3 Gamma Function

D.4 Exponential Integral

E: Pipe Specifications

E.1 PVC Pipe

E.2 Ductile-Iron Pipe

E.3 Concrete Pipe

E.4 Physical Properties of Common Pipe Materials

F: Unified Soil Classification System

F.1 Definition of Soil Groups

F.2 Terminology

Bibliography

Table of Contents

Index