SOLUTION MANUAL

for

WATER AND WASTEWATER ENGINEERING
Water Supply and Wastewater Removal

By

Nazih K. Shammas and Lawrence K. Wang

John Wiley & Sons, Inc.
Publishers Since 1807

READ IMPORTANT LICENSE INFORMATION

Dear Professor or Other Authorized User:

Jon Wiley & Sons, Inc. ("Wiley") has produced the attached solutions manual or other copyrighted material (the "Supplement") solely for use by professors and other authorized users in the manner provided below. Wiley has established these use limitations in response to concerns raised by professors and other authorized users regarding the pedagogical problems stemming from unlimited distribution of Supplements.

If the attached Supplement was delivered to you by Wiley or its representatives or if you are a professor of a course that has adopted the textbook to which the Supplement relates (the "Course"), then you are an authorized user of the Supplement. As an authorized user, Wiley grants you a non-transferable license to use the Supplement subject to the following conditions. The Supplement is for your personal use only, except that you may post the Supplement (or portions thereof) on a password protected website or otherwise provide the Supplement (or portions thereof) to students of the Course so long as such students are advised that they may not copy or distribute the Supplement to any third party. The Supplement may only be used in connection with Courses for which the related textbook has been adopted. You should take reasonable steps to protect the Supplement from unauthorized use, reproduction, or distribution. Your use of the Supplement indicates your acceptance of the conditions set forth in this Agreement. If you do not accept these conditions, you must return the Supplement unused within 30 days of receipt.

All rights (including without limitation, copyrights, patents and trade secrets) in the Supplement are and will remain the sole and exclusive property of Wiley and/or its licensors. The Supplement is furnished by Wiley on an "as is" basis without any warranties, express or implied. This Agreement will be governed by and construed pursuant to the laws of the State of New York, without regard to such State's conflict of law rules.

We hope that you find the Supplement useful.

Sincerely,
JOHN WILEY & SONS, INC.

Chapter 1
Introduction to Water Systems

Problem 1.1

What is the stream flow in MGD for a catchment area of 80 $mile^2$ where rainfall rate is 45 in. per year and evaporation rate is 20 in. per year?

Solution:

Runoff rate (R)

= rainfall rate – evaporation rate

= (45 – 20) in/year

= 25 in/year

Conversion factors:

1 in/year = 1 in.-$mile^2$/(year-$mile^2$)

= 47,600 gpd/$mile^2$

= 0.0476 MGD/$mile^2$

= 17.378 MG/year/$mile^2$

Stream flow with a runoff rate of 25 in/year

= (25) (17.378 MG/year/$mile^2$) (80 $mile^2$)

= 34800 MG/year

= 95.3 MGD Stream flow

Evaluation:

R = Q/A

Where

R = runoff rate

Q = stream flow or runoff flow in the watershed, MGD

A = watershed, catchment, or drainage area, $mile^2$

Runoff rate, R = (95.3 MGD) / (80 $mile^2$) = 1.19 MGD/$mile^2$, which is **close to 1.0 MGD/$mile^2$** for a typical well-watered watershed in North America

Problem 1.2

A city is served by a raw water reservoir which has a water surface of 5.8 $mile^2$ and an average effective depth of 18 ft. Determine the water storage volume.

Solution:

Conversion factor:

1 ft^3 = 7.48 gal

1 $mile^2$ = 27,878,400 ft^2

Water storage volume

= (5.8 $mile^2$) (27,878,400 $ft^2/mile^2$) (18 ft) (7.48 gal/ft^3)

= 21.8 x 10^9 gal

= **21.8 BG**

Problem 1.3

The population of a city is 400,000, and the average daily per capita water demand is 150 gallons per capita per day (gpcd). Determine the city's average daily water demand.

Solution:

Average daily water demand, Q_{ave} , MGD or gpd

= (population) (average daily per capita water demand)

= (400,000 persons) (150 gpd/person)

= 60,000,000 gpd

= **60 MGD**

Problem 1.4

How many days of draft can a raw water reservoir support for a city of 400,000 people? The reservoir has a water surface of 5.8 $mile^2$ and an average effective depth of 18 ft.

Solution:

Water storage volume calculated from Problem 1.2

$= 21.8 \times 10^9$ gal.

Average daily water demand calculated from Problem 1.3

= 60,000,000 gpd

Reservoir's allowable days of draft

$= (21.8 \times 10^9$ gal) / (60,000,000 gpd)

= **363 days of draft**.

Problem 1.5

What percent of mean annual runoff is to be consumed by a city of 400,000 people in an area with (a) rainfall rate = 45 in/year; (b) evaporation rate = 20 in/year; and (c) watershed catchment or drainage area = 80 mile^2?

Solution:

Average daily water demand for a city of 400,000 people was calculated in Problem 1.3

= 60 MGD

Annual water consumption per square mile

= (average daily water demand) / (drainage area)

= (60 MGD) / (80 mile^2)

= 0.75 MGD/mile^2

= 750,000 gpd/mile^2

Mean annual runoff calculated from Problem 1.1

= 25 in/year

= 435 MG/year/mile^2

= 1,191,780 gpd/mile^2

Percent of mean annual runoff consumed by the city

= (annual water consumption per square mile)/(mean annual runoff)

= (750,000 gpd/mile^2) / (1,191,780 gpd/mile^2)

= 0.63

= **63%**

Problem 1.6

Determine the net yield and water storage volume of a rain water system assuming that (a) the net yield of a rain collection facility approximates two-thirds its gross yield; (b) the mean annual rainfall is 25 in/year; (c) the mean annual evaporation rate is 8 in/year; (d) the rain collection roof area equals to 3,200 ft^2; and (e) water storage volume equals to 50% of annual net yield.

Solution:

The net mean annual rainfall rate

= (25 in – 8 in)/year = 12 in/year

Gross yield per year

= (3,200 ft^2) (17/12 ft) (7.48 gal/ft^3)

= 33,900 gal/year.

Net yield per year

= (2/3) (33,900 gal/year)

= 22,600 gal/year

= 61.9 gpd

Recommended water storage volume

= 0.5 (22,600 gal)

= 11,300 gal

Problem 1.7

Determine the storage volume of a new raw water reservoir in accordance with the following given technical information: (a) city population = 400,000; (b) water consumption = 150 gpcd; (c) watershed or catchment area = 80 $mile^2$; (d) rainfall rate = 45 in/year; (e) evaporation rate = 20 in/year; (f) minimum reservoir volume = 50 % annual net yield, or half of a year's water supply, whichever is greater; (g) 75 % water resources development.

Solution:

Reservoir storage volume based on annual net yield

= (45 in/year - 20 in/year) [(0.0476 MGD /$mile^2$) / (1 in/year)] x (0.75) (80 $mile^2$) (0.5 x 365 d)

= (1.19 MGD/$mile^2$) (0.75) (80 $mile^2$) (0.5 x 365 d)

= 13,030 MG

= 13 billion gal

Reservoir storage volume based on water supply

= (400,000 persons) (150 gpd/person) (0.5) (365 d)

= 60,000,000 gpd (0.5) (365 d)

= 10.95 x 10^9 gal

= 11 billion gal

Select the greater value of 13 billion gal to be the reservoir storage volume.

Problem 1.8

Determine the number of people who can be sustainably supported by a watershed under the following conditions: (a) watershed area = 80 mile^2; (b) annual rainfall rate = 45 in/year; (c) annual evaporation rate = 20 in/year; (d) water resource development = 75 %; (e) raw water reservoir volume to store 50% net annual yield or provide half of a year's water supply, whichever is higher = 13 billion gal; and (f) water consumption rate = 150 gpcd.

Solution:

P = population of a city, which is to be determined.

It is expected that the reservoir will only provide half of a year's water supply = 0.5 x 365 days

$$P\ (150\ \text{gpcd})\ (0.5)\ (365\ \text{d}) = 13{,}000{,}000{,}000\ \text{gal}$$

Population of a city, which can be adequately supported by the watershed, P

$$= (13{,}000{,}000{,}000\ \text{gal}) / [(150\ \text{gpcd})\ (0.5)\ (365\ \text{d})]$$

= **475,000**

Problem 1.9

Determine the number of people that can be adequately supported by a watershed under the following conditions: (a) watershed area = 80 $mile^2$; (b) water supply system with no reservoir for water storage; (c) low-water flow = 0.1 ft^3/s or 64,600 gpd per $mile^2$; and (d) water consumption rate = 150 gpcd.

Solution:

Population that can be sustained

= (80 $mile^2$) (64,600 gpd/$mile^2$) / (150 gpcd)

= **34,500 people**

Problem 1.10

Make a rough estimate of the ground water movement velocity (ft/day) if (a) all the groundwater laterally within 400 ft of the well comes fully within its influence; and (b) the yield of the aquifer is 258 gpm (gallon per minute); and the aquifer through which ground water moves is 25 ft deep.

Solution:

$$Q = (A)\ (V)\ (7.48\ \text{gal/ft}^3)$$

Where

Q = groundwater flow, gpd

A = aquifer cross-sectional area, ft^2

V = groundwater moving velocity, ft/d

Groundwater flow = 258 gpm = 371,520 gpd

$$371{,}520\ \text{gpd} = (25 \times 2 \times 400\ \text{ft}^2)\ (Vg)\ (7.48\ \text{gal/ft}^3)$$

$$\mathbf{V} = (371{,}520) / [(25 \times 2 \times 400)\ (7.48)] = \mathbf{2.48\ ft/d}$$

Problem 1.11

Estimate the surface area (ft^2) of a slow sand filter that is to deliver water to a village of 1000 people assuming that (a) the average daily water demand = 100 gpcd; (b) the slow sand filter's filtration rate is 3 million gallons per acre per day (MGAD); and (c) two slow sand filters are required, each filter is able to treat the full water flow and one of the two filters is a standby unit.

Solution:

$$Q = A\ R$$

Where

Q_s = water flow treated by a slow sand filter, MGD

A = surface area of a slow sand filter, acre

R = filtration rate of a slow sand filter, MGAD

Water flow from a village of 1000 people at 100 gpcd, Q

= (1000 persons) (100 gpcd)

= 100,000 gpd

= 0.1 MGD

Conversion factor: 1 acre = 43,560 ft^2

Surface area of slow sand filter, A

= Q / R

= (0.1 MGD) / (3 MGAD)

= 0.0333 acre

= 0.0333 x 43,560 ft^2

= 1450 ft^2

Select two slow sand filters, each has a surface area of 1450 ft^2. One of the two filters is a standby unit.

Problem 1.12

Estimate roughly the size of a water supply pipe leading to a water distributing reservoir serving a small village of 2000 people assuming that (a) the water consumption rate is 100 gpcd; and (b) water velocity in pipe = 3 ft/s.

Solution:

Average daily water demand, Q_{ave}

= (2000 persons) (100 gpcd)

= 200,000 gpd = = 0.2 MGD

Conversion factor: 1 MGD = 1.547 ft^3/s

Maximum daily water demand, Q_{max}

= 1.5 Q_{ave}

= 1.5 x 0.2 MGD

= 0.3 MGD = 0.464 ft^3/s

$$Q = A\ V$$

Where

Q = selected design flow, ft^3/s

A = cross-sectional area of pipe, ft^2

V = water velocity in the pipe, ft/s

Here, $Q = Q_{max} = 1.5 \times Q_{ave} = 0.464\ ft^3/s$ for designing a conduit leading to a distributing reservoir; V = 3 ft/s

Area of a circular conduit, $A = Q/V$

$= (0.464\ ft^3/s) / (3\ ft/s)$

$= 0.1547\ ft^2$

$A = \pi D^2/4$ where D = diameter of a pipe, ft

$0.1547\ ft^2 = (D^2)(0.785)$

D = 0.444 ft = 5.32 in

Select the nominal size of 6 in. for a circular conduit leading to the distributing reservoir.

Problem 1.13

Determine the diameter of a water main to serve a residential area, assuming (a) an average water demand of 150 gpcd; (b) population = 30,000; (c) fire flow requirement = 500 gpm; and (d) recommended water velocity = 3.5 ft/s.

Solution:

Residential average daily water demand

= (36,000) (150)

= 5,360,000 gpd

= 3,720 gpm

Total water demand = 3,720 + 500 = 4,220 gpm = 3,700/(60 x 7.48) = 9.4 ft^3/s

$$Q = A\ V$$

Where

Q = water flow selected for design, ft^3/s

A = cross-sectional area of a pipe, ft^2

V = water velocity in the pipe, ft/s

Here Q = 9.40 ft^3/s and V = 3.5 fps, then

$$A = Q/V$$

$$= 9.40/3.5$$

$$=2.69\ ft^2.$$

$$A = 2.69 = \pi D^2/4$$

$$D = 1.85\ ft = 22.2\ in.$$

Select the next nominal size of 24 in for the water distribution pipe

Problem 1.14

Roughly, what is the replacement cost of the waterworks of a city of 10,000 people?

Solution:

Assuming a per capita cost of $1,800, the total first cost is 1,800 x 10,000 = $18,000,000

Assuming that 30% of this amount is invested in the collection works, 10% in the purification works, and 60% in the distribution works, the breakdown is as follows:

(a) Collection works, 0.3 x 18,000,000 = $5,400,000

(b) Purification works, 0.10 x 18,000,000 = $1,800,000

(c) Distribution works, 0.60 x 18,000,000 = $10,800,000.

