

Solutions Manual

**INTRODUCTION TO HYDROLOGY**

**FIFTH EDITION**

Warren Viessman, Jr.  
University of Florida

Gary L. Lewis  
Consulting Engineer



Pearson Education, Inc.  
Upper Saddle River, New Jersey 07458

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## CHAPTER 1

- 1.1  $100 \times 10^6 \times 0.02 = 2 \times 10^6 \text{ m}^3$   
1 acre-ft = 43,560 cubic feet  
cubic meters  $\times 35.31 =$  cubic feet  
 $(2 \times 10^6 \times 35.31) / 43,560 = 1,612.2$  acre-ft
- 1.2 volume/volume per unit time = time  
 $(500,000 \times 0.3) / (0.5) = 300,000$  sec.  
 $300,000 / 3,600 = 83.3$  hours
- 1.3  $(450 + 500) / 2 - (500 + 530) / 2 =$  avg. inflow - avg. outflow  
the change in storage is thus - 40 cfs  
 $-40 \times 3600 / 43560 = -3.31$ , the change in storage in acre-ft.  
The initial storage is thus depleted by 3.31 ac-ft  
 $3.31 \times 43,560 / 35.31 = 4,083$  cubic meters
- 1.4  $125 / 365 = 0.34$  cm/day = 0.035 cm/day  
 $0.34 / 2.54 = 0.13$  in./day
- 1.5 volume =  $5280 \times 5280 \times 0.5 = 13,939,220$  cubic feet  
 $V/Q =$  time  
 $13,939,220 \times 3600 / 12 = 1,161,600$  sec, or 322.7 hr, or 13.4 days
- 1.6  $ET = P - R$   
 $R = (140 \times 3600 \times 24 \times 365) / (10,000 \times 1000^2) =$   
0.44 m/yr or 44 cm/yr  
 $ET = 105 - 44 = 61$  cm/yr  
This is a crude estimate.
- 1.7 equivalent depth = vol/area  
inflow =  $25 \times 3600 \times 24 \times 365 = 788,400$  cubic feet/yr  
inflow /  $(3650 \times 43560) = 4.96$  ft/yr  
 $E = 100 \times 365 / 3650 = 10.0$  ft/yr  
Hence there is a drop in level of 5.04 ft
- 1.8  $I_{avg} - O_{avg} =$  change in storage per unit time  
 $(20 - 18) \times 3600 = 7,200$  cubic meters  
The storage is thus increased by 7,200 cubic meters  
resulting in a final storage of 27,200 cubic meters

## **CHAPTER 2**

Problems in this chapter are to be developed by the instructor.

## CHAPTER 3

3.1 – 3.4 To be assigned by instructor.

3.5 For the James River rainfall:

<u>Interval in.</u>	<u>f</u>	<u>Σf</u>	<u>P(x)</u>	<u>F(x)</u>
(36-37)	2	2	0.057	0.057
(38-39)	4	6	0.114	0.171
(40-41)	7	13	0.200	0.371
(42-43)	9	22	0.257	0.628
(44-45)	5	27	0.143	0.771
(46-47)	4	31	0.114	0.885
(48-49)	2	33	0.057	0.942
(50-51)	2	35	0.057	0.999 1.000

- a)  $P(\text{MAR} \geq 40) = 1.000 - 0.171 = 0.829 = 82.9\%$   
b)  $P(\text{MAR} \geq 50) = 0.057 = 5.7\%$   
c)  $P(40 \leq \text{MAR} \leq 50) = 0.942 - 0.171 = 0.771 = 77.1\%$

3.6 Using the curve data for a standard normal curve (Table B.1) requires standardization of the limits of the integral,

$$z = \frac{x - \bar{x}}{S} = \frac{8 - 4}{2} = 2$$

From Table B.1, the integral is the area to the right of  $F(z = 2)$ , or  $0.5 - 0.4772 = 0.0228$ .

3.7 For the data given:

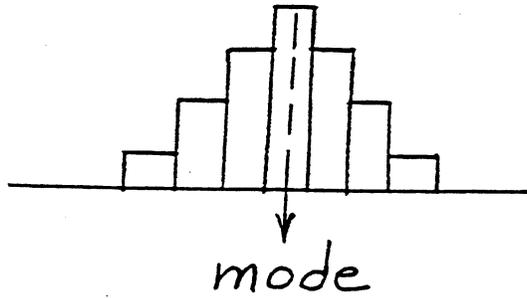
a) The area under the curve must be 1.0 to qualify as a probability density function,

$$A = \int_0^b f(x)dx = \frac{b^3}{8} = 1.0$$

This gives  $b = 2.0$

b) This is the area between 0.0 and 0.5, or  $0.5^3/8 = 0.016$

3.8 The histogram is symmetric, has zero skew, and mean = median = mode.



Sketch for Prob. 3.8

Since area to right of mode is 50%,  $F(\text{mode}) = 50\%$  and  $T = 2$  yr.

3.9 Given  $\bar{x} = 10.3$ ,  $s = 1.1$ ,  $C_v = 0.11$ ,  $n = 20$

$$\text{S.E.}(\bar{x}) = s/\sqrt{n} = 1.1/\sqrt{20} = 0.245$$

$$\text{S.E.}(s) = s/\sqrt{2n} = 1.1/\sqrt{40} = 0.0174$$

$$\text{S.E.}(C_v) = C_v\sqrt{1+2C^2}/\sqrt{2n} = 0.11\sqrt{1+2(0.11)^2}/\sqrt{40} = 0.017$$

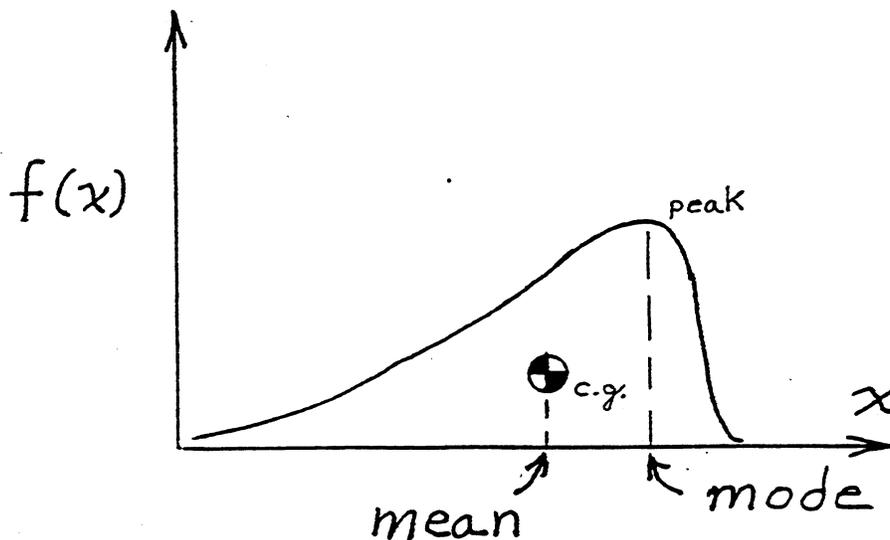
$$95\% \text{ C.L.: } z = \pm 1.96$$

$$\bar{x} \pm 1.96 (\text{S.E.}_{\bar{x}}) = 10.3 \pm 0.48$$

$$= \{10.78 \text{ to } 9.82\}$$

3.10 Because the median divides the area in half, most of the area would be to the right of the median. The distribution is probably skewed right.

3.11 Sketch:



Sketch of p.d.f. for Prob. 3.11

a) Left skewed

b) Negative because Pearson skew = (mean - mode)/s<sub>x</sub>

3.12 For the 30,000 cfs value:

$$T_r = \frac{60 \text{ yrs}}{3 \text{ times}} = \underline{\underline{20 \text{ yrs}}}$$

3.13 Frequency analysis:

a)

<u>m</u> <u>rank</u>	<u>Peak</u> <u>value</u>	<u>m</u> <u>F = 10</u>	<u>T<sub>r</sub> = 1/F</u>
1	1000	.1	10
2	900	.2	5
3	800	.3	3.33
4	700	.4	2.5
5	600	.	.
6	500	.	.
7	400	.	.
8	300	.	.
9	200	.	.
10	100	.	.

By interpolation, 4-yr value is

$$800 + \frac{4 - 3.33}{5 - 3.33} (100)$$

$$= 840 \text{ cfs}$$

b) Using Table B.1,

$$Q_{4\text{-yr}} = \bar{Q} + K s_Q = 550 + .67(300) = 750 \text{ cfs}$$

3.14 For an annual precipitation of 30 in.

a)  $P(x \geq 30) = G(30)$

$$z = (30 - 27.6)/6.06 = 0.396$$

$$F(z) = 0.15392$$

$$G(30) = 0.5 - 0.15392 = 0.346$$

b) Risk in 3 years =  $1 - (1 - G(30))^3$   
 $= 0.720$

c) P(all three years) =  $G(30)^3 = 0.041$

3.15  $P(E_1 \cup E_2) = P(E_1) + P(E_2) - P(E_1 \cap E_2)$

a) If  $E_1$  and  $E_2$  are independent,  $P(E_1|E_2) = P(E_1)$   
and  $P(E_1 \cap E_2) = P(E_1) \times P(E_2)$   
 $P(E_1 \cup E_2) = 0.3 + 0.3 - 0.3 \times 0.3 = 0.51$

b) If dependent, with  $P(E_1|E_2) = 0.1$ ,  
 $P(E_1 \cap E_2) = 0.1 \times 0.3 = 0.03$   
and  $P(E_1 \cup E_2) = 0.3 + 0.3 - 0.03 = 0.57$

3.16  $P(A) = 0.4$ ,  $P(\text{no } A) = P(\bar{A}) = 1 - 0.4 = 0.6$

$P(B) = 0.5$ ,  $P(\text{no } B) = P(\bar{B}) = 1 - 0.5 = 0.5$ ;

A and B independent

a)  $P(A \cap B) = P(A) \times P(B) = 0.4 \times 0.5 = 0.20$

b)  $P(A \cap B) = P(\bar{A}) \times P(\bar{B}) = 0.6 \times 0.5 = 0.30$

3.17  $P(E_1|E_2) = 0.9$ ,  $P(E_2|E_1) = 0.2$ ,  $P(E_1 \cap E_2) = 0.1$

$P(E_1) = P(E_1 \cap E_2) / P(E_2|E_1) = 0.1 / 0.2 = 0.5$

$P(E_2) = P(E_1 \cap E_2) / P(E_1|E_2) = 0.1 / 0.9 = 0.111$

3.18 Two random events that are:

a) Mutually exclusive:

A: Precipitation today exceeds 4 in.

B: Precipitation today does not exceed 3"

b) Dependent:

A: Precipitation today exceeds 4 in.

B: Runoff today exceeds 1 in.

c) Mutually exclusive and dependent:

A: Precipitation today does not exceed 4 in.

B: Runoff today exceeds 6 in.

d) Neither mutually exclusive nor dependent:

A: Today's precipitation exceeds 4 in.

B: Groundwater pumpage this year will exceed 3 acre-feet per acre

3.19  $P(A) = 0.4, P(B) = 0.5$

a)  $P(A \cap B) = P(A) P(B|A) = 0.4(0.5) = 0.20$

b)  $P(\bar{A} \cap \bar{B}) = 0.6(0.5) = 0.30$

c)  $P(\bar{A} \cap \bar{B}) = P(A) P(B) = 0.6(0.5) = 0.30$

3.20 For the given data:

a) Only if  $P(B|A) = P(B)$

Now,  $P(B) = 0.6$

$$P(B|A) = \frac{P(A \text{ and } B)}{P(A)}$$

Since  $P(A \text{ and } B) = 0.2$  and  $P(A) = 0.4$

$$P(B|A) = \frac{0.2}{0.4} = 0.5, \text{ Dependent}$$

b) No, mutually exclusive if  $P(A \text{ and } B) = 0$ , but  $P(A \text{ and } B) = 0.2$

c)  $P(B) = 0.6$

d)  $P(\bar{A}) = 1 - 0.4 = 0.6$

e)  $P(\bar{A} \text{ and } \bar{B}) = P(\bar{B}|\bar{A}) P(\bar{A})$

From data,  $P(\text{both}) = 0.2$

Check:  $P(\bar{A} \text{ and } \bar{B}) = 1 - P(E_1) - P(E_2) - P(E_3)$

Possibles:	Warm Mar	Cold Mar	Warm Mar	Cold Mar
	Apr Flood	Apr Flood	Apr Dry	Apr Dry
	$P = 0.2$	$P = 0.4$	$P = 0.2$	$P = 0.2$

f)  $P(B|A) = 0.5$

g) to make them independent,

$$P(B|A) = P(B)$$

Since  $P(B) = 0.6$

$$P(B|A) = \frac{P(A \text{ and } B)}{P(A)} = \frac{0.2}{0.4} = 0.5$$

Change  $P(B)$  to 0.5, without changing  $P(A \text{ and } B)$

- 3.21 A: Flood  
B: Ice-jam

$$P(A \text{ and } B) = P(A|B)P(B), \text{ thus } P(A \text{ and } B) < P(A|B)$$

$$\text{and } P(A \text{ and } B) < P(A)$$

$$\text{Also } P(A \text{ or } B) = P(A) + P(B) - P(A \text{ and } B)$$

$$\text{Also } P(A) < P(A|B) \text{ because } B < S$$

$$\text{Ranking: Largest} = P(A \text{ or } B)$$

$$\text{Second} = P(A|B)$$

$$\text{Third} = P(A)$$

$$\text{Fourth} = P(A \text{ and } B)$$

- 3.22 For the information given:

a) Both statements say the same thing when  $\underline{n} = \underline{t} = T_r$  years,  
or  $T_r = 1$  yr

b) First:

$$\left(1 - \frac{1}{T}\right)^{t-1} = \left(1 - \frac{1}{3}\right)^{t-1} = \left(\frac{2}{3}\right)^2 = \frac{4}{9} = 0.444$$

Second:  $P$  = Probability annual precipitation value will not be equaled or exceeded in any single year,

$$P = 1 - F_x = 1 - \frac{1}{3} = \frac{2}{3}$$

$$\frac{n!}{r!(n-r)!} P^{n-r} (1-P)^r = \frac{3!}{1!(2)!} \left(\frac{2}{3}\right)^{3-1} \left(1 - \frac{2}{3}\right)^1 = \underline{\underline{4/9}}$$

- 3.23 For risk = 50%,  $R = 0.5 = 1 - (1 - 1/T)^2$

for 2 consecutive yr

Solution gives  $T = 3.41$  yr

For risk = 100%,  $R = 1 = 1 - (1 - 1/T)^2$ ,  $T = 1$  yr

- 3.24 For the temporary cofferdam:

- a)  $P(\text{overtopping in any yr}) = P(F) = 1/T = 1/20 = 0.05$
- b)  $P(\text{non-exceed in yr 1 and non-exceed in yr 2 and exceed in yr 3}) = P(F) \times P(\bar{F}) \times P(\bar{F}) \times P(F) = 0.05 \times 0.95 \times 0.95 \times 0.05 = 0.002275$
- c) Risk =  $1 - (1 - 1/T)^n$   
 $1 - (1 - 1/20)^5 = 0.226$
- d)  $P(\text{non-exceed in 5 consecutive yr}) = (1 - 1/20)^5 = 0.774$

3.25 For  $N = 33$ , median = 17th largest flow.

Defining  $Q$  as the annual peak:

- a)  $P(Q \text{ exceeds median}) = 17/33 = 0.515$
- b)  $T_r = 1/G(Q) = 1/0.515 = 1.94 \text{ yrs.}$
- c)  $G(Q) = 0.515$  in any year.
- d)  $1 - G(Q) = 0.485$
- e)  $P(Q < \text{median in all 10 yrs}) = P(Q \cap Q \cap Q \cap Q \dots) = (0.485)^{10} = 0.00072$
- f)  $P(Q \geq \text{median at least once in 10 years}) = 1 - (1 - G(Q))^{10} = 0.99928$
- g)  $P(Q_1 \text{ and } Q_2 \text{ exceed median}) = P(Q_1) P(Q_2) = G(Q) G(Q) = 0.265$
- h)  $P(Q_1 \text{ exceeds median and } Q_2 \text{ does not}) = G(Q)(1 - G(Q)) = 0.250$

3.26 For the temporary floodwall:

- a)  $P(\text{overtopping in any yr}) = P(F) = 1/T = 1/20 = 0.05$
- b)  $P(\text{non-exceed in 3 consecutive yr}) = (1 - P(F))^3 = P(\bar{F})^3 = 0.95^3 = 0.857$
- c) Risk =  $1 - (1 - 1/T)^N = 1 - (1 - 1/20)^3 = 0.143$
- d)  $P(\text{exceed in 1st yr only or exceed in 2nd yr only or 3rd yr only}) = P(\text{in 1st yr only}) + P(\text{in 2nd yr only}) + P(\text{in 3rd yr only})$   
 $= P(F) \times P(\bar{F}) \times P(\bar{F}) + P(\bar{F}) \times P(F) \times P(\bar{F}) + P(\bar{F}) \times P(\bar{F}) \times P(F)$   
 $= (0.05)(0.95)(0.95) + (0.95)(0.05)(0.95) + (0.95)(0.95)(0.05) = 0.135$
- e)  $P(\text{exceed in 3rd yr exactly}) = P(\bar{F}) \times P(\bar{F}) \times P(F) = (0.95)(0.95)(0.05) = 0.045$

3.27 The owner's acceptance level is:

$$\text{Risk} = 1 - (1 - 1/T_r)^n = 0.25$$

Substitution of  $n = 20$  gives  $T_r = 70$  yrs, thus the wall should be between 8.5 and 10.0 ft, or interpolating, 9.1 ft.

3.28 For Oak Creek:

a) Freq. =  $m/N = 3/60 = 0.05$

b)  $P(F) = \text{freq.} = 0.05$

c)  $T = 1/P(F) = 1/0.05 = 20$  yr

d)  $P(\bar{F}) = 1 - P(F) = 1 - 0.05 = 0.95$

e)  $P(\text{non-exceed in two consecutive yr}) = P(\bar{F}) \times P(\bar{F}) = 0.95 \times 0.95 = 0.9025$

f)  $P(\text{one or more exceed in 20 yr}) = \text{Risk}$   
 $= 1 - (1 - 1/T)^N$   
 $= 1 - (1 - 0.05)^{20} = 0.642$

g)  $P(\text{non-exceed in one yr and exceed in next yr})$   
 $= P(\bar{F}) \times P(F)$   
 $= 0.95 \times 0.05 = 0.0475$

h) Using Binomial Theorem,  $P(3 \text{ occurrences in } 60 \text{ yr})$   
 $= P(x \text{ in } n)$   
 $= [n!/x!(n-x)!] p^x (1-p)^{n-x}$   
 $= [60!/3! 57!](0.05)^3 (0.95)^{57} = 0.230$

i) Same as part f).

3.29 For Anniston, Alabama,

Mean rain = 57.2 in.

Standard deviation = 15.5 in.

100-yr  $X = 57.2 + K(15.5)$

From Appendix B,  $K$  for 0.01 = 2.326,

$$X_{100} = 93.2 \text{ in.}$$

The 1988 depth of 99 inches was the greatest depth of record. It has an apparent recurrence interval of 23 years. If the rain is normally distributed,

$$99 = 57.2 + K_{99}(15.5)$$

$$K_{99} = 2.697$$

The area to the right of 2.697 is .49647, giving a recurrence interval of  $1/.00353 = 283$  years.

3.30  $P(\mu < x < \mu + \sigma) = \text{area from } z = 0 \text{ to } z = 1 = 0.3413 = 34.13\%$

3.31  $P(\mu - 3\sigma \leq X \leq \mu + 3\sigma) = \text{area under standard normal from } -3 \text{ to } +3$

From Appendix C.1:

$$P(\mu - 3\sigma \leq x \leq \mu + 3\sigma) = 2(.4987) = 0.997 \text{ or } = 99.74 \%$$

3.32 For Normal distribution of runoff:

$$x = \bar{x} + zs, \quad s = \sqrt{9} = 3$$

$$11 = 14 + 3z, \quad z = -1.0, \quad F(z) = 0.3413$$

$$P(x \leq 11) = 0.5000 - 0.3413 = 0.1583 \text{ in any yr}$$

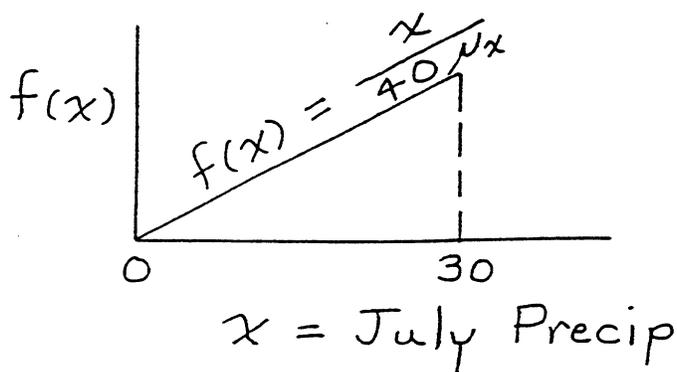
$$P(x \leq 11 \text{ in 3 consecutive yrs}) = 0.1583^3 = 0.004 = 0.4\%$$

3.33 From Table B.1, the standard variate,  $z$ , with area to the right of 0.330 is 0.44 (area left =  $F(z) = 0.5 - 0.33 = 0.17$ ). Thus,

$$\begin{aligned} x &= \bar{x} + zs \\ &= 5 + 0.44(1.0) = 5.44 \end{aligned}$$

3.34 Since  $\mu = 0$ ,  $\sigma = 1$ , then  $\int_{-2}^2 f(z) dz = 2(0.4772) = 0.9544$

3.35 Given:



Prob. 3.35 Definition Sketch

$$\mu_x \approx 30 \text{ in.}$$