Solutions Manual

Water Supply and Pollution Control
Eighth Edition

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CHAPTER 1

NO SOLUTIONS REQUIRED

CHAPTER 2

WATER RESOURCES PLANNING AND MANAGEMENT

2.1 The Internet is an excellent source of information on this topic. The level of integrated water resources management varies by state.

2.2 Virtually all of the laws listed in Table 2.1 provide some protection for preventing and controlling water pollution. Information on each law may be found on the Internet. It is also important to note that the EPA only regulates at the Federal level and much of the cleanup and protection is now delegated to states and local governments.

2.3 Point source pollution = Pollution that originates at one location with discrete discharge points. Typical examples include industrial and wastewater treatment facilities. Nonpoint source pollution = Pollution that is usually input into the environment in a dispersed manner. Typical examples include stormwater runoff that contains fertilizers, pesticides, herbicides, oils, grease, bacteria, viruses, and salts.

2.4 Adverse health effects of toxic pollutants are numerous and can include a variety of conditions. Some pollutant-related conditions include asthma, nausea, and various cancers—among many others.

2.5 Agencies that are responsible for water quantity and quality significantly vary by state.

2.6 This is a subjective question and one that has been and will continue to be debated in the water resources community.

2.7 Integrated water resources management is difficult to achieve because it involves both a financial and resources investment over time. It is also important to obtain concensus on this approach from all of the involved stakeholders. This difficulty is perhaps why there are so few examples of true integrated water resources management.

2.8 This question is subjective but the student should research specific examples to support their argument.

CHAPTER 3

THE HYDROLOGIC CYCLE AND NATURAL WATER SOURCES

3.1 The answer to this question will vary by location.

3.2 reservoir area = 3900/640 = 6.1 sq. mi.
annual runoff = (14/12)(190 – 6.1)(640) = 137,704 ac-ft
annual evaporation = (49/12)(3900) = 15,925 ac-ft
draft = $(100 \text{ X } 365 \text{ X } 10^6)/(7.48 \text{ X } 43{,}560)$ = 112,022 ac-ft
precipitation on lake = (40/12)(3900) = 13,000 ac-ft
gain in storage = 137,704 + 13,000 = 150,704
loss in storage = 112,022 + 15,925 = 127,947
net gain in storage = 22,757 ac-ft

3.3 reservoir area = 1700 hec = $17 \text{ X } 10^6$ sq. meters
annual runoff = $0.3(500 \text{ X } 10^6 – 17 \text{ X } 10^6) = 144 \text{ X } 10^6$ sq. meters
annual evaporation = $1.2 \text{ X } 17 \text{ X } 10^6 = 20.4 \text{ X } 10^6$ sq. meters
draft = $4.8 \text{ X } 24 \text{ X } 60 \text{ X } 60 \text{ X } 365 = 151.37 \text{ X } 10^6 \text{ m}^3$
precipitation on lake = $0.97 \text{ X } 17 \text{ X } 10^6 = 16.49 \text{ X} 10^6 \text{ m}^3$
gain in storage = $144 \text{ X } 10^6 +16.49 \text{ X } 10^6 = 160.49\ 10^6$
loss in storage = $151.37 \text{ X } 10^6 + 20.4 \text{ X } 10^6 = 171.77 \text{ X } 10^6$
net loss in storage = $11.28 \text{ X } 10^6 \text{ m}^3$

3.4 To complete a water budget, it is first important to understand how the water budget will be used and what time step will be necessary to successfully model the system. Once the budget is conceptually designed, a variety of online sources can usually be used to collect the data. These sources include—but are not limited to:

- state regulatory agencies
- special water districts
- weather agencies,
- local governments
- geological surveys
- agricultural agencies

Historical data and previous reports can also yield important information on the system. Verification and calibration data should also be considered as part of the data collection effort.

3.5 The solution for this problem will vary based on location.

3.6

Event (n)	Precip (inches)	Tr = n/m	Freq. (% years)
1	33	10	10
2	29	5	20
3	28	3.33	30
4	28	2.5	40
5	27	2	50
6	26	1.67	60
7	22	1.4	70
8	21	1.25	80
9	19	1.1	90
10	18	1	100

n = 10, m = rank, Tr = n/m, Freq = (1/Tr) X 100 Then plot precipitation versus frequency.

3.7

Event (n)	Precip (inches)	Tr = n/m	Freq. (% years)
1	89	10	10
2	75	5	20
3	72	3.33	30
4	70	2.5	40
5	69	2	50
6	66	1.67	60
7	56	1.4	70
8	54	1.25	80
9	48	1.1	90
10	46	1	100

n = 10, m = rank, Tr = n/m, Freq = (1/Tr) X 100 Then plot precipitation versus frequency.

3.8 Once the data is organized in a table (see below), the solution can be found. Note that the cumulative max deficiency is 131.5 mg/mi^2, which occurs in September. The number of months of draft is 131.5/(448/12) = 3.53. Therefore, enough storage is needed to supply the region for about 3.5 months.

Month	Inflow I	Draft O	Cumulative Inflow ΣI	Deficiency $O - I$	Cumulative Deficiency $\Sigma (O - I)$*
Feb	31	37.3	31	6.3	6.3
March	54	37.3	85	-16.7	0
April	90	37.3	175	-52.7	0
May	10	37.3	185	27.3	27.3
June	7	37.3	192	30.3	57.6
July	8	37.3	200	29.3	86.9
Aug	2	37.3	202	35.3	122.2
Sep	28	37.3	230	9.3	131.5
Oct	42	37.3	272	-4.7	126.8
Nov	108	37.3	380	-70.7	56.1
Dec	98	37.3	478	-60.7	0
Jan	22	37.3	500	15.3	15.3
Feb	50	37.3	550	-12.7	2.6

* Only positive values of cumulative deficiency are tabulated.

3.9 S = 128,000/10*100*640 = 0.20

3.10 S = 0.0002 = volume of water pumped divided by the average decline in piezometric head times surface area

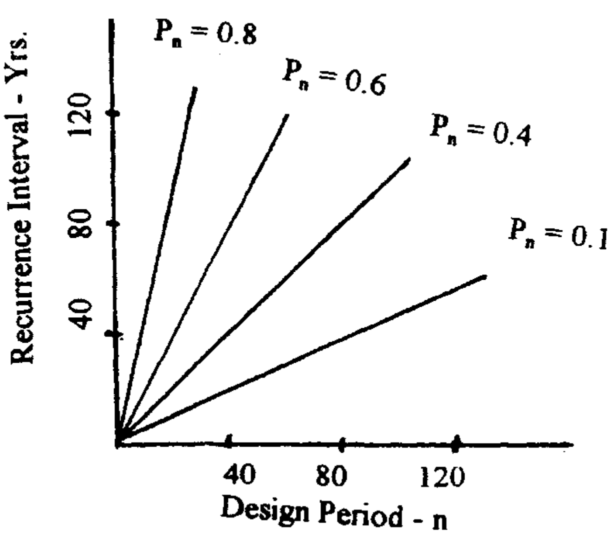
0.0002 = V/(400 X 100)
Noting that there are 640 acres per square mile
V = 0.0002 X 400 X 100 X 640 = 5120 acre-feet

3.11 Draft = (0.726 mgd) X (30 days/mo) = 21.8 mg/month

Month	Inflow *I*	Draft *O*	Deficiency *O - I*	Cumulative Deficiency Σ (*O* – *I*)*
April	97	21.8	-75.2	0
May	136	21.8	-114.2	0
June	59	21.8	37.2	0
July	14	21.8	7.8	7.8
Aug	6	21.8	15.8	23.6
Sep	5	21.8	16.8	40.43
Oct	3	21.8	18.8	59.2
Nov	7	21.8	14.8	74
Dec	19	21.8	2.8	76.8
Jan	13	21.8	8.8	85.6
Feb	74	21.8	-52.2	33.4*
March	96	21.8	-74.2	0
April	37	21.8	-15.2	0
May	63	21.8	-41.2	0
June	49	21.8	-27.2	0

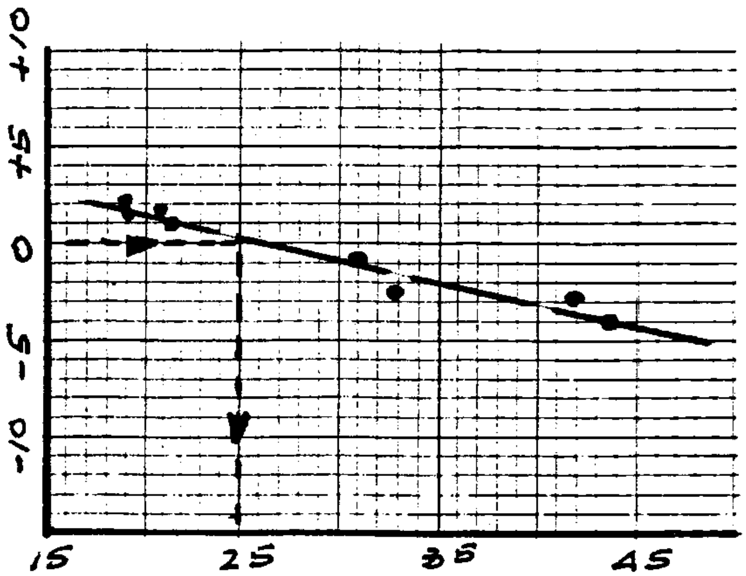
*Maximum storage deficiency is January 85.6 mg/mo/sq. mi.
Storage capacity = 85.6 mg/mo/sq.mi.

3.12 $P_n = (1 - 1/Tr)^n$
$\log P_n = n \operatorname{Log} (1 - 1/Tr)$
$n = \log P_n / \log (1 - 1/Tr)$
A straight line can be defined by this equation and the following probability curves will appear.



3.1320 month flow equals the sum of 12 + 11 + 10 + 12 + … + 6 + 7 + 9 = 169 cfs

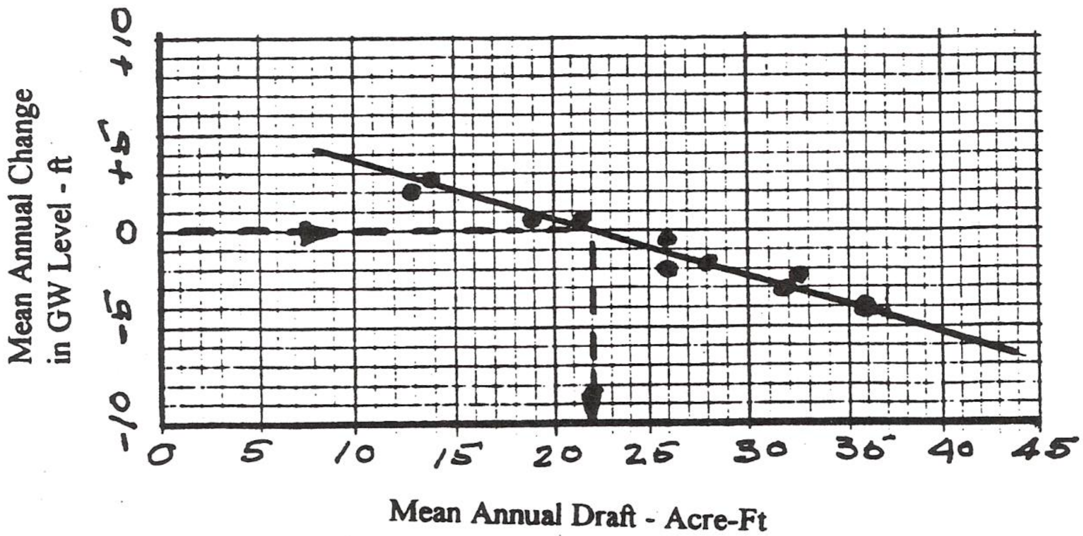
3.14



Draft - 1,000's of Acre-Ft

Safe Yield = 25,000 acre-ft

3.15



Safe Yield = 22,000 acre-ft

3.16 Reservoir capacity = 750 acre-feet
Reservoir yield is the amount of water which can be supplied during a specified time period. Assume the reservoir is to be operated continuously for 1 year without recharge. Also assume that evaporation, seepage, and other losses are zero.
Max continuous yield is 750 acre-ft/year
Or 750 X 43,560 X 0.304 = 917, 846 cubic meters per year
Or 750 X 43,560 X 7.48 X 365 X 24 X 60 = 465 gpm continuously for 1 year

3.17 Constant annual yield = 1500 gpm
Reservoir capacity = ? Time of operation without recharge = 1 yr
Res. Capacity = 1500 X 365 X 24 X 60 X 0.134 X (1/43,560) = 2,425 ac-ft/yr
This storage will provide a yield of 1,500 gpm for one year without any recharge

3.18 mean draft = 100 mgd, catchment area = 150 sq. mi., reservoir area = 4000 acres
rainfall = 38 inches, runoff = 13 inches, evaporation = 49 inches (mean annual)

(a) gain or loss in storage = ?
ΔS = rainfall + runoff – evaporation – draft
rainfall = 38 X 4000 X (1/12) = 12,667 ac-ft
runoff = [(150 X 640) – 4000] X 13 X (1/12) = 99,967 ac-ft
evaporation = 49 X 4000 X (1/12) = 16,333 ac-ft
draft = 100,000,000 X 365 X 0.134 X (43,560) = 112,282 ac-ft
ΔS = 12,667 + 99,667 – 16,333 – 112,282 = -16,281 ac-ft
The net loss in storage is 16, 281 ac-ft

(b) volume of water evaporated = 16,333 ac-ft
given a community of 100,000 people, assume a consumption of 150 gpcd
water demand = 100,000 X 150 X 365 = 5,475 mg/year

volume evaporated = 16,333 X 43,560 X 7.48 = 5,304 mg/year
evaporated water could supply the community with their water needs for 5304/5475 = 0.97 or for about one year

3.19 Use equation 3.29
K = 0.000287
h = 43
m = 8
n = 15
q = 0.000287*8*43/15 = 0.006582
Total Q is therefore 50*0.006582 = 0.325 cfs

3.20 q= 000084*8*22/15 = 0.000986
Q = 0.0007872*35 = 0.0345 m^3/s

3.21 u = $(1.87r^2S_c)/Tt$
= $(1.87 * 1 * 6.4 * 10^{-4})/(6200 * 7.5 * 24 * 60) = 8.58 \times 10^{-10}$
Interpolating, W(u) = 20.3
S = (114.6 * 60,000 * 7.5 * 20.3)/(6,200 * 7.5 * 24 * 60) = 15.6

3.22 $$K_f = \frac{528Q\log(r_2/r_1)}{m(h_2 - h_1)}$$

$$K_f = \frac{528 * 850 * \log(10)}{90 * (10-1)} = 554\frac{gpd}{ft^2}$$

3.23 Equation 3.20 is applicable

$$Q = \frac{K_f(h_2^2 - h_1^2)}{1055\log(r_{2/}/r_1)}$$

$$\log(\frac{r_2}{r_1}) = \log(\frac{235}{100}) = 0.37107$$

$$h_2 = 100 - 21 = 79\,ft$$
$$h_1 = 100 - 22.2 = 77.8\,ft$$

$$Q = \frac{1320(79^2 - 77.8^{2)}}{1055 * 0.37107} = 634.44gpm$$

3.24 Using Equation 3.35, u can be computed

$$u = \frac{1.87*200^2*3*10^{-4}}{3*10^4*12} = 6.23*10^{-5}$$

Referring to Table 3.5 and interpolating, we estimate W(u) to be 9.1. Then using Equation 3.34, the drawdown is found to be:

$$s = \frac{114.6*9.1*300}{3*10^4} = 10.41 ft$$

3.25 (a) Using Equation 3.35, u can be computed as follows:

$$u = \frac{90*90*0.00098}{4*1000*0.0028} = 0.71$$

Then from Table 3.5, W(u) is found to be 0.36. Applying Equation 3.33, the drawdown can be determined

$$s = \frac{0.0038*0.36}{4*\pi*0.0028} 0.039m$$

(c) Follow the procedure used in (a)

$$u = \frac{90*90*0.00098}{4*72000*0.0028} = 0.0098$$

Then from Table 3.5, W(u) is found to be 4.06. Applying Eq. 3.33, the drawdown can be determined

$$s = \frac{0.0038*4.06}{4*\pi*0.000028} = 0.44m$$

3.26 (a) Using Equation 3.31, u can be computed as follows:

$$u = \frac{100*100*0.001}{4*3600*0.0028} = 0.25$$

Then from Table 3.5, the drawdown can be determined,

$$s = \frac{0.004*1.07}{4*\pi*0.0028} = 0.12m$$

(b) Follow the procedure used in (a)

$$u = \frac{100*100*0.001}{4*24*60*60*0.0028} = 0.01$$

Then from Table 3.5, W(u) is found to be 4.04
Applying Equation 3.33, the drawdown can be determined

$$s = \frac{0.004 * 4.04}{4 * \pi * 0.0028} = 0.46m$$

3.27 (a) Using Equation 3.31, u can be computed as follows:

$$u = \frac{150 * 150 * 0.001}{4 * 12 * 60 * 60 * 0.0028} = 0.46$$

Then from Table 3.5, the drawdown can be determined,

$$s = \frac{0.003 * 0.36}{4 * \pi * 0.0028} = 0.05m$$

(b) Follow the procedure used in (a)

$$u = \frac{500 * 500 * 0.001}{4 * 12 * 60 * 60 * 0.0028} = 0.023$$

Then from Table 3.5, W(u) is found to be 3.24
Applying Equation 3.33, the drawdown can be determined

$$s = \frac{0.003 * 3.24}{4 * \pi * 0.0028} = 0.28m$$

3.28 $$Q = \frac{K_f * 2 * \pi * (h_2 - h_1)}{528 * \log_{10}(120/45)} = \frac{600 * 2 * 3.1416 * 100 * 8}{528 * \log_{10}(120/45)} = 13{,}392 \text{ gal/min}$$

3.29 $$K_f = \frac{528 * Q * \log_{10}(r_2 / r_1)}{m(h_2 - h_1)} = \frac{528 * 1200 * \log_{10}(500/75)}{100 * 1.28} = 407.62 \text{ gpd/ft}^2$$

3.30 $$T = \frac{264 * Q}{\Delta h}$$

From a plot of drawdown versus t, drawdown per log cycle is 28.2 – 10.5 = 17.1

$$Q = \frac{T}{264} * 17.1 =$$

Converting T to gal/day/ft
T=5100

$$Q = \frac{5100}{264} * 17.1 = 330 \text{ gpm}$$

3.31 From plot of data, t_0=1.25 minutes = 20.87 x 10^{-3} ft/day, and from plot, D_h 14 feet

$$T = \frac{264*300}{14} = 5657 \text{ gpd/ft}$$

$$S_c = \frac{0.3*T*t_0}{r^2} = \frac{0.3*5657*0.87*10^{-3}}{60^2} = 0.00041$$

3.32 $$u = \frac{1.87*r^2*S_c}{Tt} = 0.00011$$

W(u)=-0.577216-ln(u)

Substituting and solving, using $\log_e$(u)

W(u)=8.537

$$S = \frac{114.6*Q*W(u)}{T} = \frac{114.6*280*8.537}{3.1*10^4} = 8.84 \text{ feet}$$

3.33 Use Equation 3.22

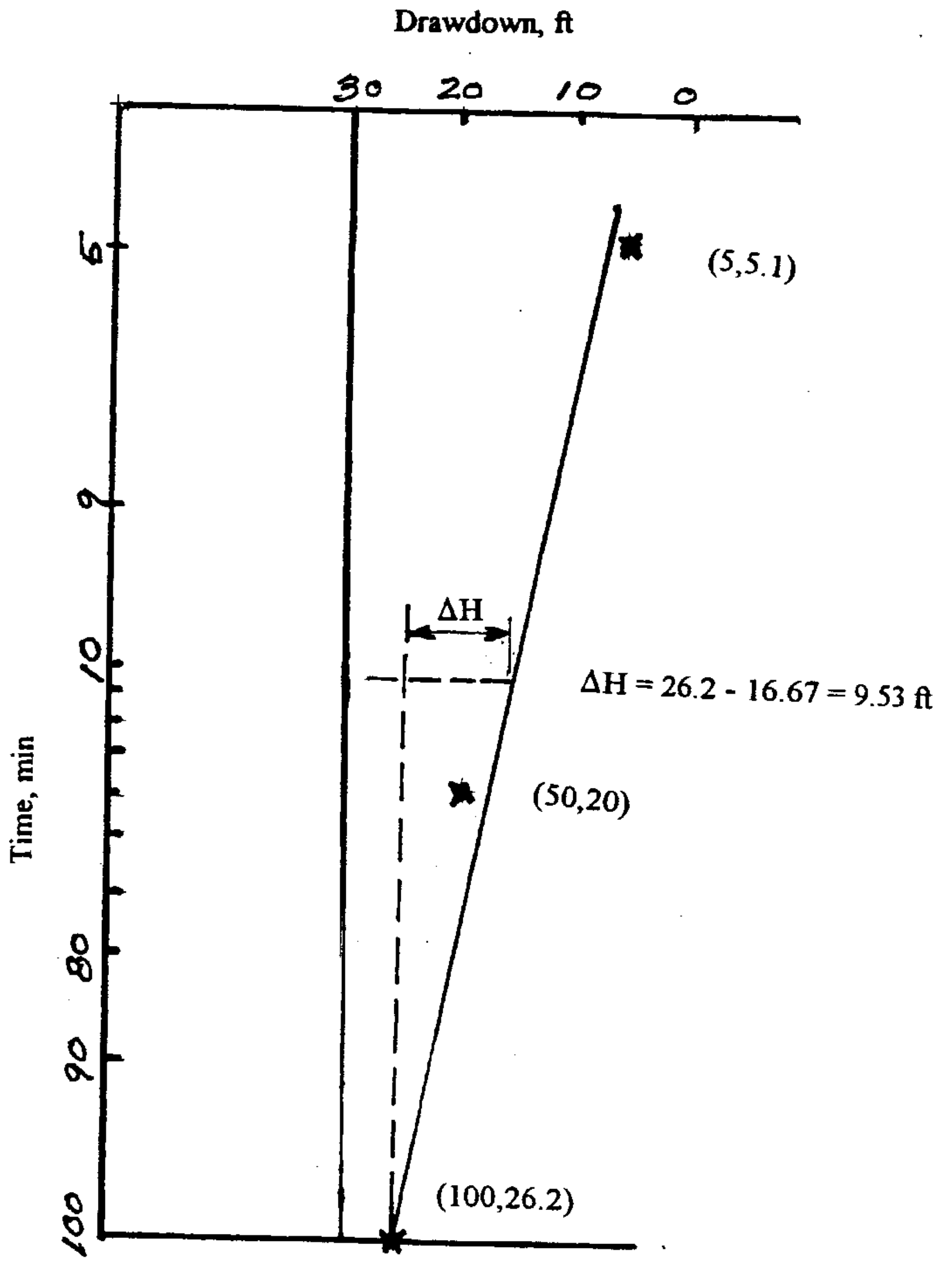
$$\ln(\frac{r_2}{r_1}) = 0.477$$

$$Q = \frac{600*2*\pi*100*9}{528*0.477} = 13{,}468 \text{ gpm}$$

3.34 Use Equation 3.23

$$K_f = \frac{528*1300*\ln(\frac{500}{65})}{130*10.8} = 433.2 \frac{gpd}{ft^2}$$

3.35 Use Equation 3.37 and refer to figure which follows



T=700*7.5 = 5250 gpd/ft
From Fig change in head is 9.53 feet

$$Q = \frac{5250 * 9.53}{264} = 189.5\,\text{gpm}$$

3.36 Use Equation 3.19

$$\log_{10}(\frac{r_2}{r_1}) = 0.41683$$

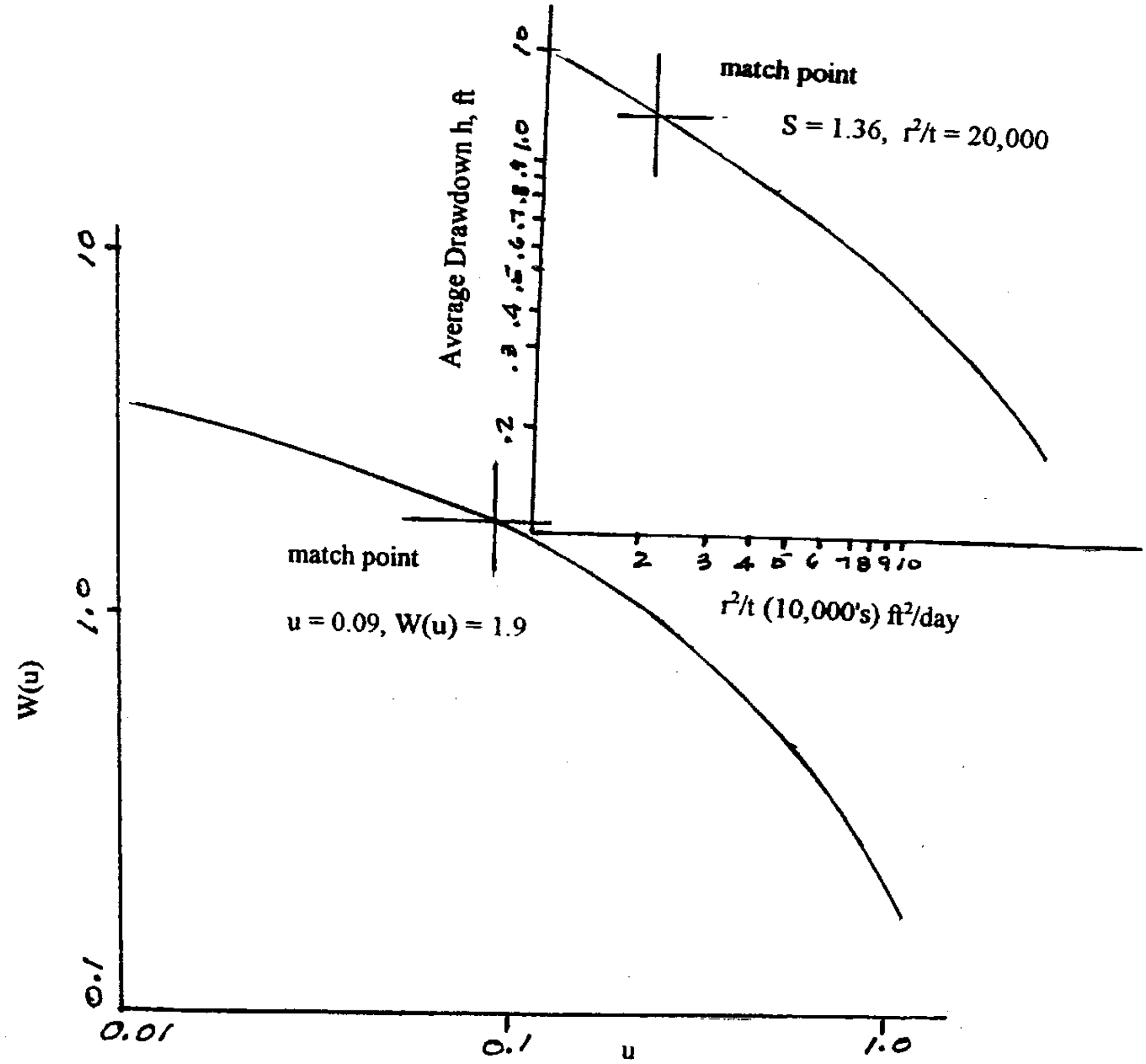
$$Q = \frac{1300*(79.4*79.4 - 77.5*77.5)}{1055*0.41683} = 881 \text{ gpm}$$

3.37 Use Equations 3.34 and 3.35 refer to the following figure determine s and r^2/t from the figure = 1.36 and 20,000

Determine u and W(u) from the figure = 0.09 and 1.9

$$T = \frac{114.6*500*1.9}{1.365} = 80{,}050 \frac{gpd}{ft}$$

$$S_c = \frac{0.09*80050}{1.87*20000} = 0.1926$$



3.38 Use Equation 3.19

$$\frac{50}{66} = \frac{(100^2 - 60^2)}{100^2 - y_1^2}$$

$y_1^2 = 1560$, y_1=39.5

Drawdown is 100-39.5=60.5 feet

3.39 Use Equation 3.23

Log of the ratio = 0.1856

$$K_f = \frac{528 * 700 * 0.1856}{80 * (97 - 95)} = 428.8 \frac{gpd}{ft^2}$$