Problem #1

a) A geophysical survey collected a borehole water sample. The concentration of NaCl in the sample was 12,500 ppm. Estimate the density of the borehole liquid.

$$S.G. = \frac{1}{[1-(6.7\times10^{-7})(NaCl_{ppm})]}$$

(Jorgensen, 1991
Assigned reading, Ex #11)

$$NaCl_{ppm} = 12500$$

$$S.G. = \frac{1}{[1-(6.7\times10^{-7})(1.25\times10^{4})]} = 1.01$$

$$\rho_w = S.G.(\rho_{fw}) = (1.01)(1.0) = 1.01\,g/cm^3$$

b) An arid environment receives an average of 20 cm of precipitation per year. If the mean rainfall chloride concentration is 2 mg/L and the mean soil chloride concentration is 2000 mg/L, estimate the average annual net infiltration rate.

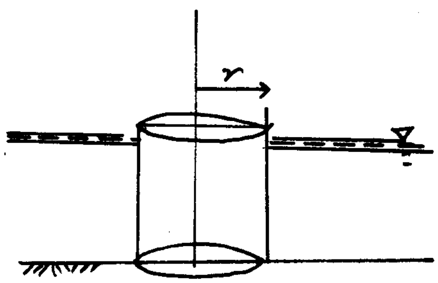
Eqn 4.9.3 (Assigned reading)

$$I_n = (20\,cm/yr)\frac{(2\,mg/L)}{(2000\,mg/L)} = 0.02\,cm/yr = 0.2\,mm/yr$$

Problem #2

Estimate the volume of fresh water in storage beneath an island with a land surface area of 21 km^2 that receives an annual groundwater recharge of 25 cm. The hydraulic conductivity and porosity of the aquifer are 3 m/d and 0.35, respectively. Assume that the density of seawater is 1.025 g/cm^3. How many years of recharge are in storage?

Circular Island



$$Area = \pi r^2 = 21\ km^2$$

$$r = \sqrt{21/\pi} = 2.58\ km$$

$$V_{storage} = \frac{2}{3}\pi n r^3 \sqrt{\frac{W(1+\alpha)}{2K}} \quad \text{(text)}$$

$$\alpha = \frac{\rho_f}{\rho_s - \rho_f} = \frac{1.0}{1.025-1.0} = 40$$

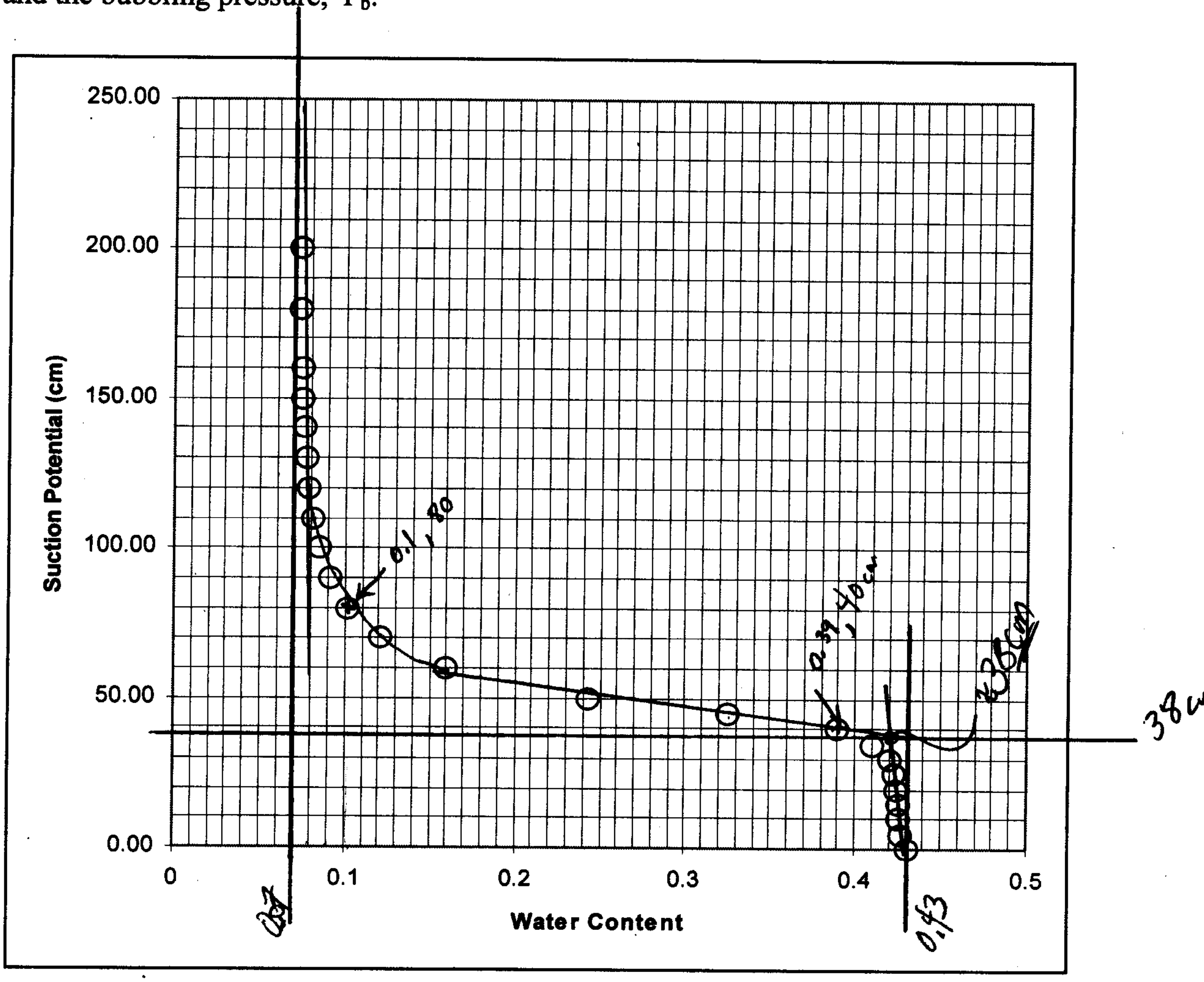
$$V_{storage} = \frac{2}{3}\pi(0.35)(2.58\cdot10^3 m)^3 \sqrt{\frac{\left(\frac{0.25m}{365d}\right)(1+40)}{2(3m/d)}} = \underline{8.61\cdot10^8 m^3}$$

Annual recharge is $(0.25 m/yr)(21 km^2)\left(\frac{1000m}{km}\right)^2 = 5.25\cdot10^6 m^3/yr$

$$\#\text{ years storage} = \frac{V_{storage}}{V_{rech.}/yr} = \frac{8.61\cdot10^8 m^3}{5.25\cdot10^6 m^3/yr} = \underline{160\ yrs}$$

Problem #3

A fine sand soil has the following soil-water characteristic curve. From this curve estimate the soil porosity, *n*, irreducible water content, θ_{wr}, the irreducible saturation, S_{wr}, and the bubbling pressure, Ψ_b.



If you can, also estimate the Brooks and Corey exponent, λ, for this soil.

$\psi_b \approx 38$ cm

$\theta_{wr} \approx$ ~~0.07~~ 0.07

$n \approx 0.43$

$$S_{wr} = \frac{\theta_{wr}}{n} = \frac{0.07}{0.43} = 0.163$$

$$\left(\frac{\psi_b}{\psi}\right)^\lambda = \Theta \quad \text{(Brooks \& Corey Model)}$$

$$\Theta = \frac{\theta - \theta_{wr}}{n - \theta_{wr}}$$

$$(n - \theta_{wr})\left(\frac{38}{80}\right)^\lambda = 0.1 - 0.07 = 0.03 / 0.36 = 0.083$$

$$(n - \theta_{wr})\left(\frac{38}{40}\right)^\lambda = 0.39 - 0.07 = 0.32 / 0.36 = 0.888$$

$0.083 = \left(\frac{38}{80}\right)^\lambda$ Solve for λ; $\lambda = 3.34$

$0.888 = \left(\frac{38}{40}\right)^\lambda$ solve for λ; $\lambda = 2.29$

$\therefore \lambda \approx 2.81$

Problem #4

The following data were obtained from a pumping test where a well was pumped at a rate of 200 gallons per minute. Drawdown was measured in an observation well 250 feet away from the pumped well. The driller's log and test data are listed in Table 1.

Table 1. Drillers Log and Test Data, Problem 4

Depth	Texture	Elapsed Time (minutes)	Drawdown (feet)	* t/r^2
0-23 feet	Glacial till, brown, clayey	0.0	0.00	
23-77 feet	Dolomite, fractured	1.0	0.66	$1.6 \cdot 10^{-5}$
77-182 feet	Shale, black, dense	1.5	0.87	2.4
182-217 feet	Sandstone,well-cemented, coarse	2.0	0.99	3.2
217-221 feet	Shale, gray , limy	2.5	1.11	4.0
		3.0	1.21	4.8
		4.0	1.36	6.4
		5.0	1.49	8.0
		6.0	1.59	9.6
		8.0	1.75	$1.28 \cdot 10^{-4}$
		10.0	1.86	1.6
		12.0	1.97	1.9
		14.0	2.08	2.2
		18.0	2.20	2.88
		24.0	2.36	3.84
		30.0	2.49	4.80
		40.0	2.65	6.4
		50.0	2.78	8.0
		60.0	2.88	9.6
		80.0	3.04	$1.28 \cdot 10^{-3}$
		100.0	3.16	1.6
		120.0	3.28	1.92
		150.0	3.42	2.40
		180.0	3.51	2.88
		210.0	3.61	3.84
		240.0	3.67	

A steel casing was cemented to a depth of 182 feet and the well was screened from 182 feet to its total depth of 221 feet.

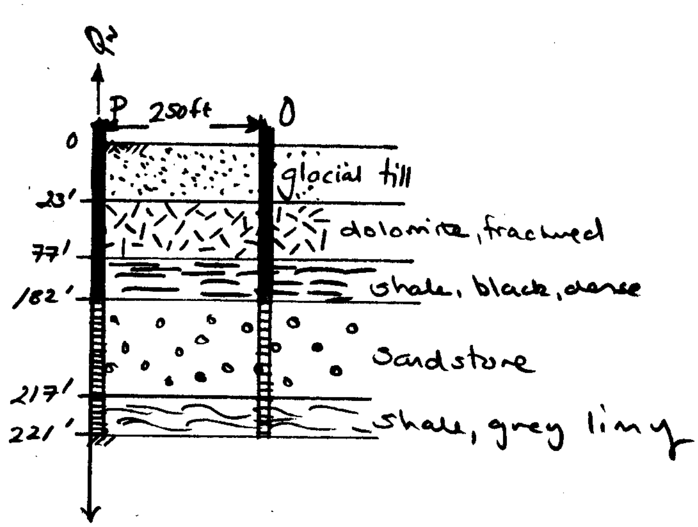
✓a) Draw a schematic diagram of the aquifer system described by the driller's log. Indicate the relative positions of the pumping and observation well.

✓b) Do the data suggest a leaky aquifer? *NO – no change in slope during test*

✓c) Compute the value of storativity and transmissivity for the aquifer system.

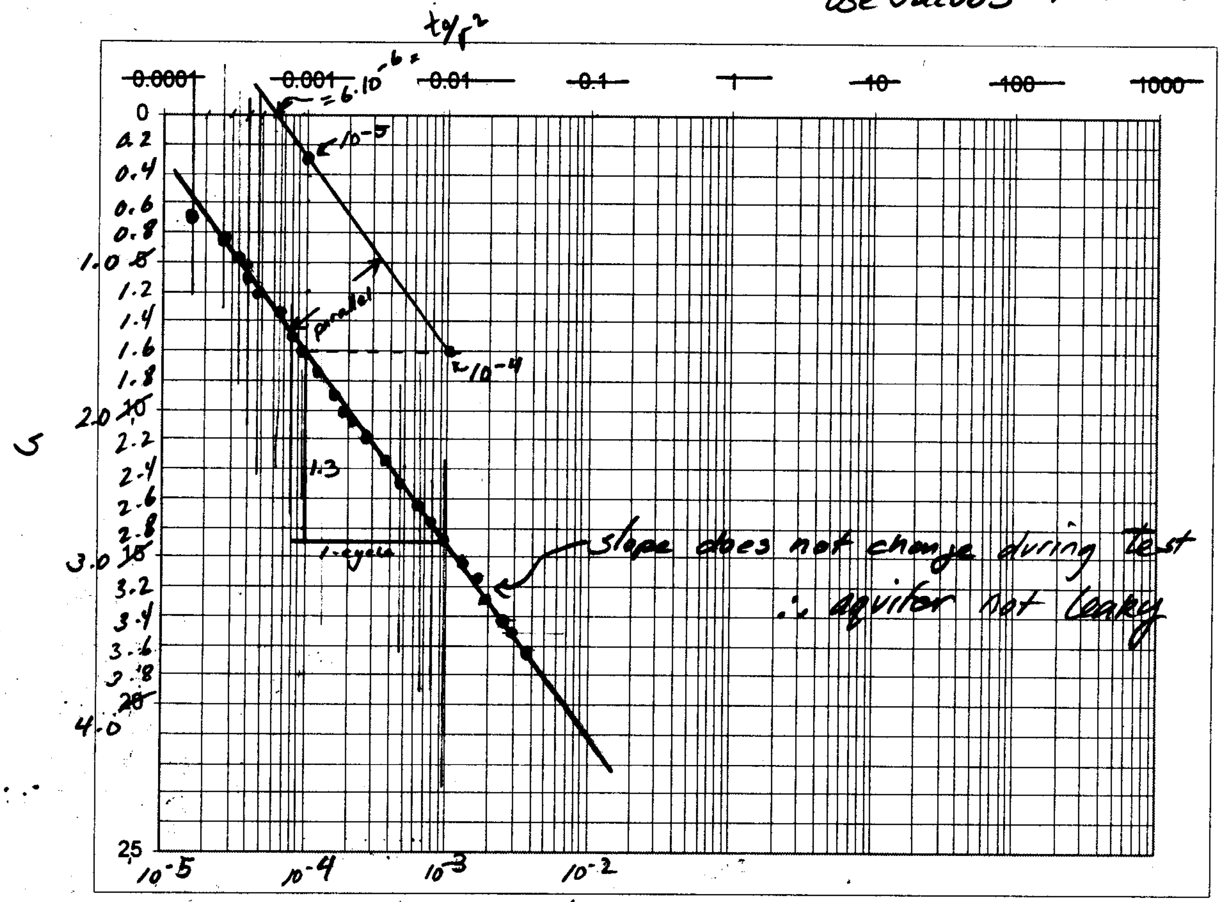
$T = 3.7\ ft^2/min$, $S = 5 \cdot 10^{-5}$

Graph paper is provided on the next page to help in the analysis. You may re-label the scales as needed to fit the problem.



Problem#4 (Continued)

Use Jacob's method



$t_1 = 10^{-4}$

$$\text{Slope} = \frac{1.3\,ft}{10^{-3}-10^{-4}} = \frac{1.3\,ft}{0.001-0.0001} = \frac{1.3}{0.0009} =$$

$$s = \frac{Q}{4\pi T}\ln\left(\frac{2.25T}{S}\cdot\frac{t}{r^2}\right) = \frac{Q}{4\pi T}\ln\left(\frac{2.25T}{S}\right) + \frac{Q}{4\pi T}\ln\left(\frac{t}{r^2}\right)$$

$$\frac{Q}{4\pi T} = \frac{s_2 - s_1}{\ln\left(\frac{t_2}{r^2}\right)-\ln\left(\frac{t_1}{r^2}\right)} = \frac{s_2 - s_1}{\ln\left(\frac{t_2}{t_1}\right)}$$ } if one log cycle this term = 2.303

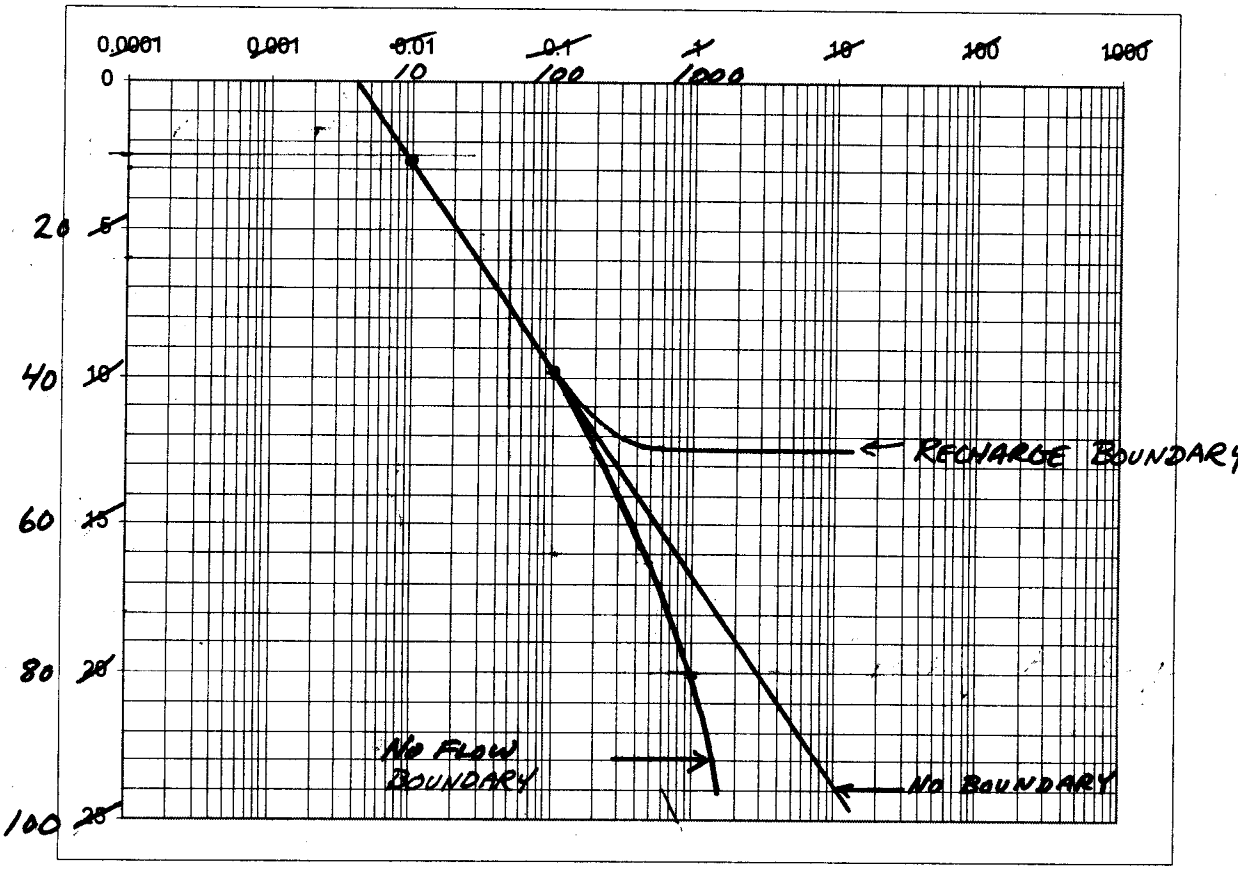
$$T = \frac{Q}{4\pi}\frac{\ln\left(\frac{t_2}{t_1}\right)}{s_2-s_1} = \frac{Q}{4\pi}\frac{2.303}{\Delta s} = \frac{200gpm\,\frac{ft^3}{7.48gal}}{4\pi}\cdot\frac{2.303}{1.3ft} = 3.77 ft^2/min$$

$$S = 2.25T\frac{t_0}{r^2} = 2.25(3.77 ft^2/min)(6\cdot10^{-6}) = 5.08\cdot10^{-5}$$

Problem #5

The effect of hydrologic boundaries is usually evidenced by departures of time drawdown data from theoretical curves. These departures can be analyzed to locate the type of boundaries and their contribution to total flow. Use the graph paper below to display time drawdown curves for the three cases below. Re-label the graph axes as needed.

a) An observation well located 100 feet from a pumped well in a confined aquifer. The pumped well is operated at a rate of 200 gpm, T=2000 gpd/ft, and S=0.001.
b) Same as above except the observation well is between the pumping well and a recharge boundary located 500 feet from the pumping well.
c) Same as above except the boundary is a no-flow boundary.
d) Compare and contrast the behavior of the three cases – explain how one can infer if boundary effects may be present in a given set of data.



Use Jacob's formula $s = \frac{Q}{4\pi T} \ln\left(\frac{2.25T}{S}\frac{t}{r^2}\right)$

Problem 5 (Continued)

real well 100 ft from obs well

t	s
10	13.1
50	31.5
100	39.4
500	57.8
1000	65.8

image well 900 feet from obs well

t	s
10	-37
50	-18
100	-10.9
500	7.5
1000	15.5

(–) means effect not arrived yet

t	s_1	s_2	s_3
10	13	13	13
50	31.5	31.5	31.5
100	39.5	39.5	39.5
500	57.5	50	65
1000	65.5	50	81

Recharge boundary – drawdown approaches some "constant" value during test, departure from ideal behavior identifies distance to image well & thus boundary

No flow boundary – drawdown rate increases with time, departure from ideal identifies distance to image well & thus boundary

10/28/01

Problem #6 The following multiple choice questions relate to practical aspects of engineering – have fun!

When designing a small water supply system, a good materials supplier for pump and motors is

(a) W.L. Grainger Co. (general light industrial supply)
b) Ben Meadows Co. (forestry & sampling equipment)
c) Home Depot Inc. (residential homebuilding)
d) Worldwide Pants Inc. (① clothing ② David Letterman's production company)

A good first reference to find suppliers of various services (equipment rental, drilling suppliers, etc.) is

a) The local branch of American Society of Civil Engineers.
(b) The phone book.
c) A web search engine.
d) The grey haired guy/gal in the cube over by the photocopy machine who has been with the company forever.

(all answers are "correct")

During a dewatering project field inspection a citizen approaches you and tells you that you are drilling on their (not your client's) land. Where do you go to find out if the person is correct?

a) Your company's general counsel.
b) You immediately contract for a survey
(c) The county courthouse to get the plat map and a copy of the metes and bounds.
d) The county sheriff.

Usually you can determine if on-line from plat map; if not sure then survey

You are going to make a field inspection during a project and collect samples. The most important piece of field equipment is

a) Bolt cutters
b) Cellular telephone
c) Toilet paper
d) First aid kit
e) Ice chest
f) Map
g) Raingear

Explain your choice. – Depends on your priorities – all correct; First aid kit contains bandages that can be used as 'toilet paper.' I always take bolt cutters. A map is useful to figure out where to go. – if you are sampling, you are likely to have already visited the site.