

G476/576 Hydrology Lab Exercise
Well Hydraulics/Aquifer Testing

ANSWER KEY

PART I. Use the AQTESOLV Aquifer Testing Software on the following problems.

(Hint: make sure all units are similar in dimension prior to running AQTESOLV. Remember 1 cu. Ft = 7.48 Gal) (i.e. make sure all distance units are same: Ft, M, Cm, etc; all time units are same: Min, Sec, Day; etc.)

For each AQTESOLV problem in Part 1, complete the following:

1. Save your project files to your I:\drive in the "aqtest" folder... or some other folder you create.

Problem 1	Prob1.aqt
Problem 2	Prob2.aqt
Problem 3	Prob3.aqt
Problem 4	Prob4.aqt

2. Print out a hard copy of all your graphs and calculated aquifer parameters. Remember to put your name on them and make them look fancy.

Problem 1.

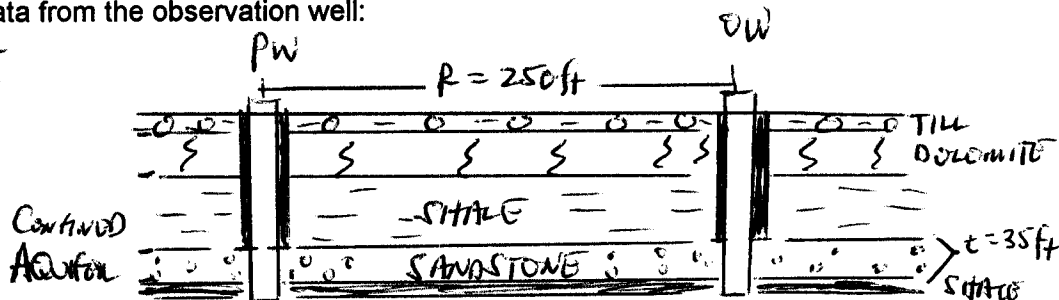
The following data are from a pumping test where a well was pumped at a rate of 200 Gal/Min. Drawdown as shown below was measured in an observation well 250 feet away from the pumping well. The geologists log of the well is:

0-23 Ft	Glacial Till, clayey
23-77 Ft	Dolomite, fractured
77-182 Ft	Shale, black, dense
182-217 Ft	Sandstone, coarse
217-221 Ft	Shale, gray, limey

A steel well casing was cemented/grouted to a depth of 182 feet and the well was extended as an open boring past that point. Assume the well is fully penetrating and no external leakage is occurring.

The following is the drawdown data from the observation well:

Elapsed Time (Min)	OBS. WELL Drawdown (Ft)
1	0.66
1.5	0.87
2	0.99
2.5	1.11
3	1.21
4	1.36
5	1.49
6	1.59
8	1.75
10	1.86
12	1.97
14	2.08
18	2.2
24	2.36
30	2.49



$$Q = \left(200 \frac{\text{GAL}}{\text{MIN}} \right) \left(\frac{1 \text{ FT}^3}{7.48 \text{ GAL}} \right) = 26.7 \frac{\text{FT}^3}{\text{MIN}}$$

40	2.65
50	2.78
60	2.88
80	3.04
100	3.16
120	3.28
150	3.42
180	3.51
210	3.61
240	3.67

Preliminary Questions Before You Do the Calculations:

A. What are the aquifer conditions and which aquifer test solving routine is most applicable?

1. Is the aquifer confined or unconfined? **CONFINED**
2. What rock unit(s) make up the aquifer? **SANDSTONE**
3. What is the saturated thickness of the aquifer? **217 ft - 182 ft = 35 ft**
4. Assume that the pumping system is not at equilibrium, wells are fully penetrating, and no leakage is occurring; which aquifer test solving method is the most applicable in this situation?

Theis (1935) or Cooper-Jacob (1946)

Using AQTESOLV:

B. Plot the time-drawdown data on a 3 x 5 cycle log-log plot of time (min; x-axis) vs. drawdown (ft; y-axis). Use the Theis-type curve method to find:

1. Aquifer transmissivity in sq. Ft/min $T = 0.1393 \text{ ft}^2/\text{min}$
 2. Aquifer transmissivity in sq. Ft/day $T = 200.5 \text{ ft}^2/\text{day}$
 3. Aquifer storativity $S = 1.44 \times 10^{-6}$
 4. Aquifer hydraulic conductivity in Ft/min (remember $T=Kb$) $K = \frac{T}{b} = \frac{0.1429 \text{ ft}^2/\text{min}}{35 \text{ ft}} = 0.0041 \text{ ft}/\text{min}$
- Handwritten calculations:
 $T = 0.1429 \text{ ft}^2/\text{min}$
 $T = (0.1429 \text{ ft}^2/\text{min}) \left(\frac{60 \text{ min}}{1 \text{ hr}} \right) \left(\frac{24 \text{ hr}}{1 \text{ day}} \right) = 205.8 \frac{\text{ft}^2}{\text{DAY}}$
 $S = 1.74 \times 10^{-6}$
 $K = 0.004 \text{ ft}/\text{min}$

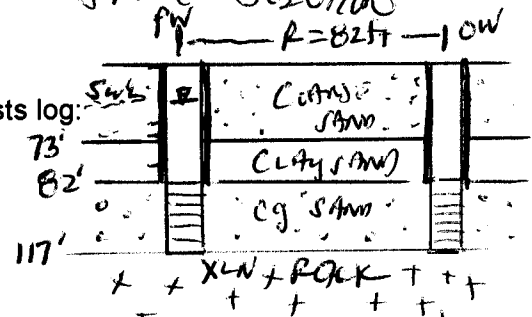
C. Use the Cooper-Jacob (straight-line) method. Replot the data on a 4-cycle semi-log plot with drawdown on the arithmetic scale of the y axis and time on the log scale of the x-axis. Determine the following:

1. Aquifer transmissivity in sq. Ft/min $T = 0.1429 \text{ ft}^2/\text{min}$
2. Aquifer transmissivity in sq. Ft/day $T = 205.8 \text{ ft}^2/\text{day}$
3. Aquifer storativity 1.733×10^{-6}
4. Aquifer hydraulic conductivity in Ft/min (remember $T=Kb$) $K = 0.0041 \text{ ft}/\text{min}$
5. What is the percent difference in calculation of the hydraulic parameters between the Theis method and the Cooper-Jacob method? **0% Difference - SAME SOLUTION**

Problem 2

A test well was drilled to a total depth of 117 feet with the following geologists log:

0-73 Ft	Coarse sand
73-82 Ft	Clayey sand
82-117 Ft	Coarse Sand
117 Ft	Crystalline Bedrock, Dense, Impermeable



A pumping well was installed with steel casing cemented to a depth of 82 Ft. The well was screened from 82 to 117 Ft. The static water level rose in the well to a depth of 55 Feet below the surface. During a pumping test, the well was pumped at a rate of 560 gallons per minute. Drawdown was measured in an observation well that was also screened from 82 to 117 Ft, and was located 82 feet away from the pumping well. The following time-drawdown data were collected from the observation well.

$R = 82 \frac{\text{ft}}{2}$

$Q_p = \left(560 \frac{\text{GAL}}{\text{min}} \right) \left(\frac{1 \text{ FT}^3}{7.48 \text{ GAL}} \right) = 74.9 \frac{\text{FT}^3}{\text{min}}$

Elapsed Time (Min)	Drawdown (Ft)
1	0.9
2	2.15
3	3.05
4	3.64
5	4.07
6	4.52
7	4.74
8	5.02
9	5.21
10	5.53
15	5.72
20	5.97
30	6.12
40	6.2
50	6.25
60	6.27
90	6.29
120	6.29

Preliminary Questions:

A. What are the aquifer conditions and which aquifer test solving routine is most applicable?

1. Is the aquifer confined or unconfined? *CONFINED / ARTESIAN*

A. How does the SWL compare to the depth to the top of the aquifer?

82 - 55 = 27 ft → SWL IS 27 ft ABOVE TOP OF AQUIFER

2. What sediment unit(s) make up the aquifer? *CLAYEY SAND*

3. What is the saturated thickness of the aquifer? *117 ft - 82 ft = 35 ft*

4. Assume that the pumping system is not at equilibrium, wells are fully penetrating, and leakage IS occurring.

A. Which sediment unit is acting as the leaky aquitard in this case? *CLAYEY SAND*

B. What is the thickness of the leaky aquitard? *82 ft - 73 ft = 9 ft*

Using AQTESOLV:

B. Plot the time-drawdown data on a 3 x 5 cycle log-log plot of time (min; x-axis) vs. drawdown (ft; y-axis). Use the ~~Hantush~~ leaky confined aquifer routine to solve the following (assume a scenario in which there is NO storage of groundwater in the aquitard)

Note: at the Hantush menu window, select "starting guesses" and assume an r/B ratio of 0.6026

1. Aquifer transmissivity in sq. Ft/min

2. Aquifer transmissivity in sq. Ft/day

3. Aquifer storativity

4. Aquifer hydraulic conductivity in Ft/min (remember T=Kb)

$$T = 0.01973 \text{ ft}^2/\text{min}$$

$$T = (0.01973 \text{ ft}^2/\text{min}) \left(\frac{60 \text{ min}}{\text{hr}} \right) \left(\frac{24 \text{ hr}}{\text{day}} \right) = 28.4 \frac{\text{ft}^2}{\text{DAY}}$$

$$S = 1.11 \times 10^{-5}$$

5. Determine the vertical hydraulic conductivity of the confining unit (i.e. the leakage rate through the confining unit) in Ft/Min

Use the following equation:

$$K = \frac{T}{b} = \frac{0.01973 \text{ ft}^2/\text{min}}{35 \text{ ft}} = 5.6 \times 10^{-4} \frac{\text{ft}}{\text{min}}$$

$$K' = \frac{T b' (r/B)^2}{r^2} = \frac{(0.01973 \frac{\text{ft}^2}{\text{min}})(9 \text{ ft})(0.6026)^2}{(82 \text{ ft})^2}$$

$$K' = (Tb'(r/B)(r/B))/(r^2)$$

$$K' = \frac{0.0645}{6724} = 9.6 \times 10^{-6} \text{ ft/min}$$

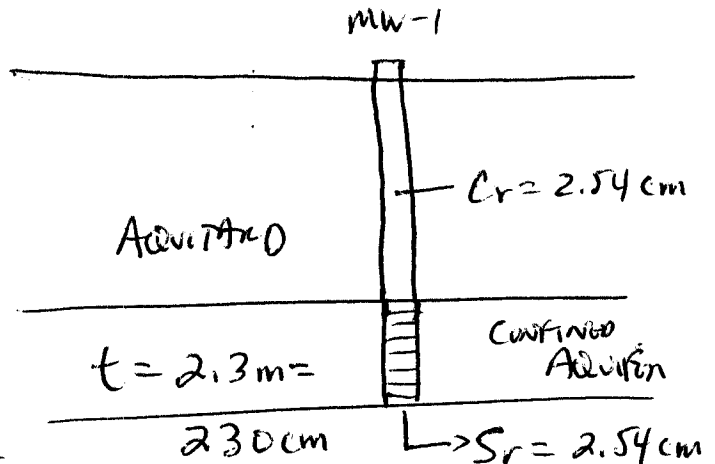
~~$$K' = 0.00079 \text{ ft/min} = 7.86 \times 10^{-4} \text{ ft/min}$$~~

where K' = vertical hydraulic conductivity of leaky aquitard, T = transmissivity of confined aquifer, b' = thickness of the leaky aquitard, r/B = the Hantush well function = 0.6026, r^2r = the square of the distance of the observation well from the pumping well.

Problem 3.

A slug test was made with a piezometer that had a casing radius of 2.54 cm and a screen radius of 2.54 cm. A slug of 4000 cu. cm of water was injected, raising the water level in the piezometer by 197.3 cm. The well completely penetrated a confined aquifer that was 2.3 m thick. The decline in head with time was recorded as the well began recovery. The data is as follows:

Elapsed Time (Min)	Head (Ft) (cm)
1	185.4
2	178.6
3	173.6
5	167.7
7	158.8
10	147
13	140
17	129.2
22	118.4
32	99.6
53	74
84	51.3
119	35.5
170	23.3
245	15.2
400	8.7
800	4.3



SLUG TEST
 INITIAL DISPLACEMENT = 197.3 cm
 CASING RADIUS = 2.54 cm
 WELL BORE RADIUS = 2.54 cm
 SATURATED THICKNESS = 230 cm
 SCREEN LENGTH = 230 cm
 GRAVEL PACK POROSITY = 0.30
 ANISOTROPY = 1
 WARM COLUMN = 1

A. What are the aquifer conditions and which aquifer test solving routine is most applicable?

- Cooper et al. SL
1. Is the aquifer confined or unconfined? **CONFINED**
 2. What is the saturated thickness of the aquifer? **230 cm**
 3. Why is there no data regarding the distance of the pumping well from the observation well?
IT'S A SINGLE-Well SLUG TEST!!

Using AQTESOLV:

B. Plot the head recovery data on a semi-log plot of time (min; logarithmic x-axis) vs. H/H_0 (arithmetic, y-axis). Enter the data as is using AQTESOLV Dataset Manager, it will compute the H/H_0 values automatically. Use the Cooper et al. slug test solver method (Cooper, Bredehoeft and Papadopoulos) to determine the following:

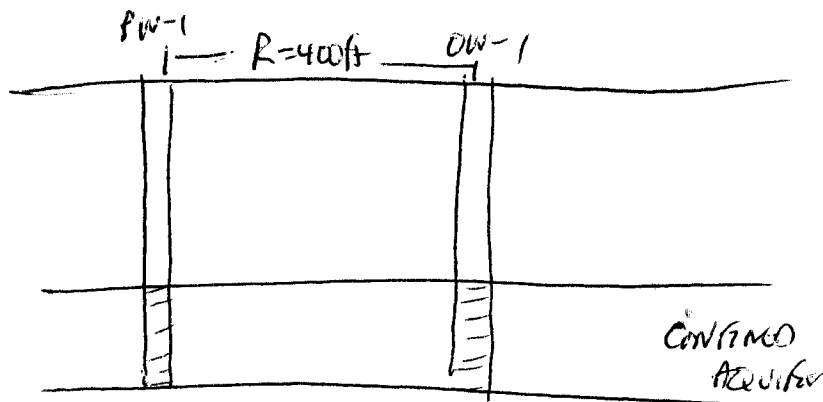
1. Aquifer transmissivity in sq. Cm/sec $T = 0.1613 \text{ cm}^2/\text{min} \left(\frac{60 \text{ min}}{60 \text{ sec}} \right) = 2.7 \times 10^{-3} \text{ cm}^2/\text{sec}$
 2. Aquifer transmissivity in sq. Ft/day $T = 0.25 \text{ FT}^2/\text{DAY}$
 3. Aquifer storativity $S = 0.01149$
 4. Aquifer hydraulic conductivity in cm/min (remember $T = Kb$)
 $K = \frac{T}{b} = \frac{0.1613 \text{ cm}^2/\text{min}}{230 \text{ cm}} = 7.0 \times 10^{-4} \text{ cm}/\text{min}$
- $T = \frac{(0.1613 \text{ cm}^2/\text{min}) \left(\frac{60 \text{ min}}{\text{hr}} \right) \left(\frac{24 \text{ hr}}{\text{day}} \right)}{\left(\frac{1 \text{ FT}^2}{926 \text{ cm}^2} \right)} = 0.25 \text{ FT}^2/\text{DAY}$

Problem 4

A pump test is conducted in a confined aquifer. Full penetration the wells are assumed. The pumping rate at the pumping well is 500 gallons/minute. The observation well is located 400 Ft away. The following is the time-drawdown data for the observation well:

Time Elapsed (Min)	Drawdown (Ft)
1	0.16
1.5	0.27
2	0.38
2.5	0.46
3	0.53
4	0.67
5	0.77
6	0.87
8	0.99
10	1.12
12	1.21
14	1.3
18	1.43
24	1.58
30	1.7
40	1.88
50	2
60	2.11
80	2.24
100	2.38
120	2.49
150	2.62
180	2.72
210	2.81
240	2.88

$$Q_p = \frac{500 \text{ gpc}}{\text{min}} \left(\frac{1 \text{ ft}^3}{7.48 \text{ gpc}} \right) = 66.8 \frac{\text{ft}^3}{\text{min}}$$



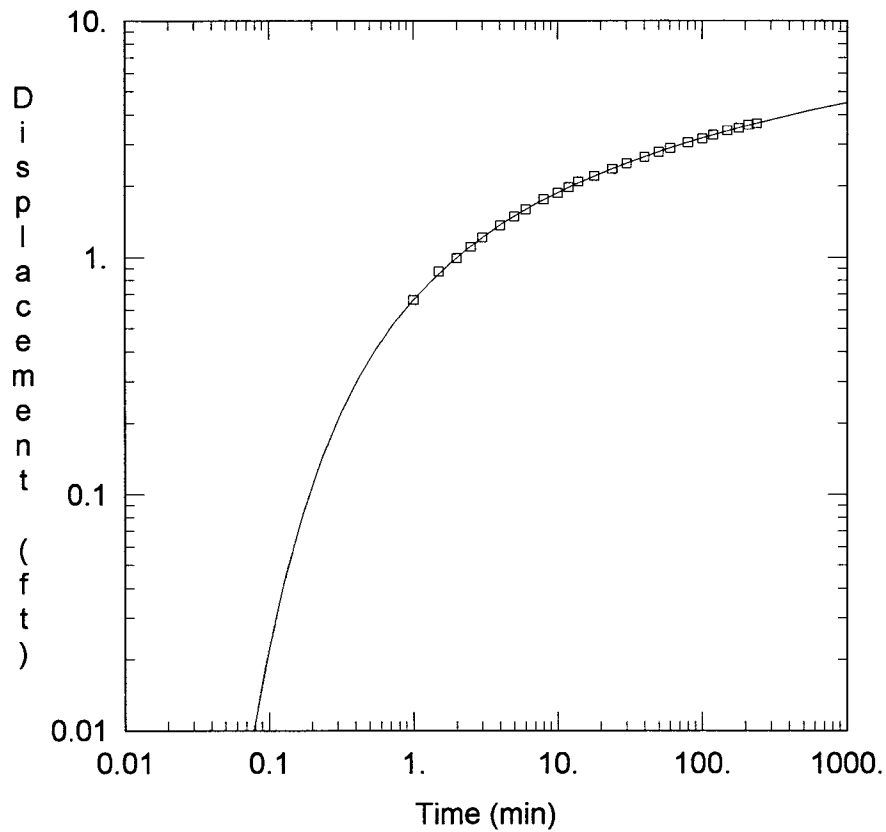
A. Using the Cooper-Jacob method determine the transmissivity and storativity of the aquifer. Complete a semi-log plot of the data with drawdown (arithmetic, y-axis) vs. time (logarithmic, x-axis).

1. Transmissivity in sq. Ft/min $T = 0.1536 \text{ Ft}^2/\text{min}$
2. Transmissivity in sq. m/day $T = 20.6 \text{ m}^2/\text{day}$ ←
3. Storativity $S = 2.23 \times 10^{-6}$
4. Assume the aquifer is 10 Ft thick, what is hydraulic conductivity in Ft/Min?

A. Hydraulic conductivity in cm/sec? $T = kb; K = \frac{T}{b} = \frac{0.1536 \text{ Ft}^2/\text{min}}{10 \text{ Ft}} = 0.015 \frac{\text{Ft}}{\text{min}}$

$$K = \left(0.015 \frac{\text{Ft}}{\text{min}} \right) \left(\frac{1 \text{ min}}{60 \text{ sec}} \right) \left(\frac{30.48 \text{ cm}}{\text{Ft}} \right) = 7.62 \times 10^{-3} \text{ cm/sec}$$

$$T = 0.1536 \left(\frac{\text{Ft}^2}{\text{min}} \right) \left(\frac{60 \text{ min}}{\text{hr}} \right) \left(\frac{24 \text{ hr}}{\text{day}} \right) \left(\frac{1 \text{ m}^2}{10.76 \text{ Ft}^2} \right) = 20.6 \frac{\text{m}^2}{\text{day}}$$



HYDRO PROBLEM NO. 1 - CONFINED AQUIFER

Data Set: C:\WOU\HYDRO\AQTESO~1\HWPROB1.AQT
 Date: 03/13/01 Time: 16:22:47

PROJECT INFORMATION

Company: Western Oregon University
 Client: Dr. Taylor
 Project: HW Prob. No. 1
 Test Location: Monmouth, OR
 Test Well: PW-1
 Test Date: 3/10/01

SOLUTION

Aquifer Model: Confined
 Solution Method: Theis
 $T = 0.1393 \text{ ft}^2/\text{min}$
 $S = 1.935\text{E-}06$

AQUIFER DATA

Saturated Thickness: 35. ft

Anisotropy Ratio (K_z/K_r): 1.

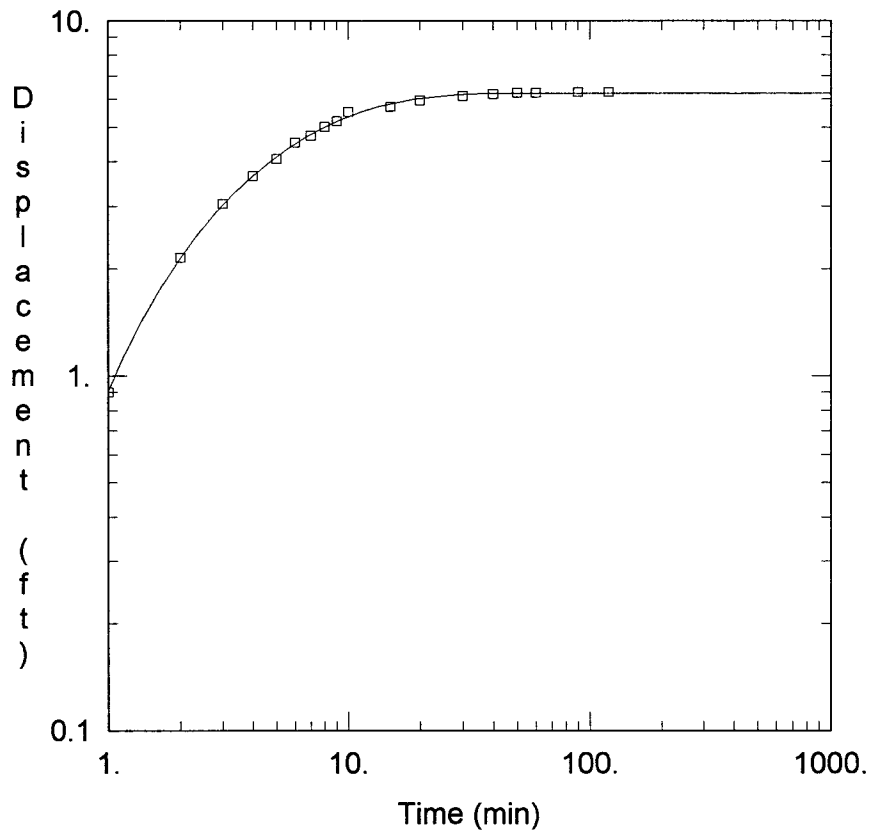
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW 1	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
□ OW 1	250	0



G476 HYDROLOGY AQTESOLV HW PROB. NO. 2

Data Set: C:\WOU\HYDROAQTESO~1\HWPROB2.AQT

Date: 03/13/01

Time: 16:23:05

PROJECT INFORMATION

Company: Western Oregon University

Client: Dr. Taylor

Project: HW Prob. 2

Test Location: Monmouth, Oregon

Test Well: PW-1

Test Date: 03/10/01

SOLUTION

Aquifer Model: Leaky

Solution Method: Hantush-Jacob

T = 0.01973 ft²/min

S = 1.11E-05

r/B = 0.6027

AQUIFER DATA

Saturated Thickness: 35. ft

Anisotropy Ratio (Kz/Kr): 1.

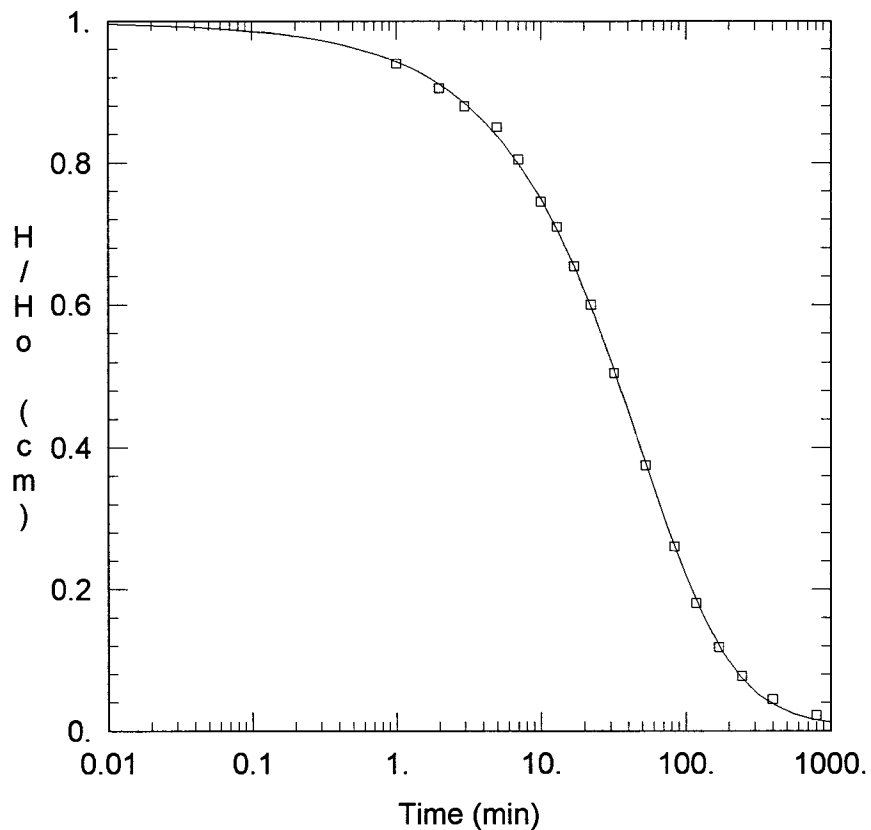
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW 1	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
□ OW 1	82	0



G476 HYDROLOGY AQTESOLV HW PROB. 3

Data Set: C:\WOU\HYDROAQTESO~1\HWPROB3.AQT
 Date: 03/13/01 Time: 16:23:15

PROJECT INFORMATION

Company: Western Oregon University
 Client: Dr. Steve Taylor
 Project: HW-3
 Test Location: Monmouth, OR
 Test Well: MW-1
 Test Date: 03/10/01

SOLUTION

Aquifer Model: Confined
 Solution Method: Cooper-Bredehoeft-Papadopoulos
 $T = 0.1613 \text{ cm}^2/\text{min}$
 $S = 0.01149$

AQUIFER DATA

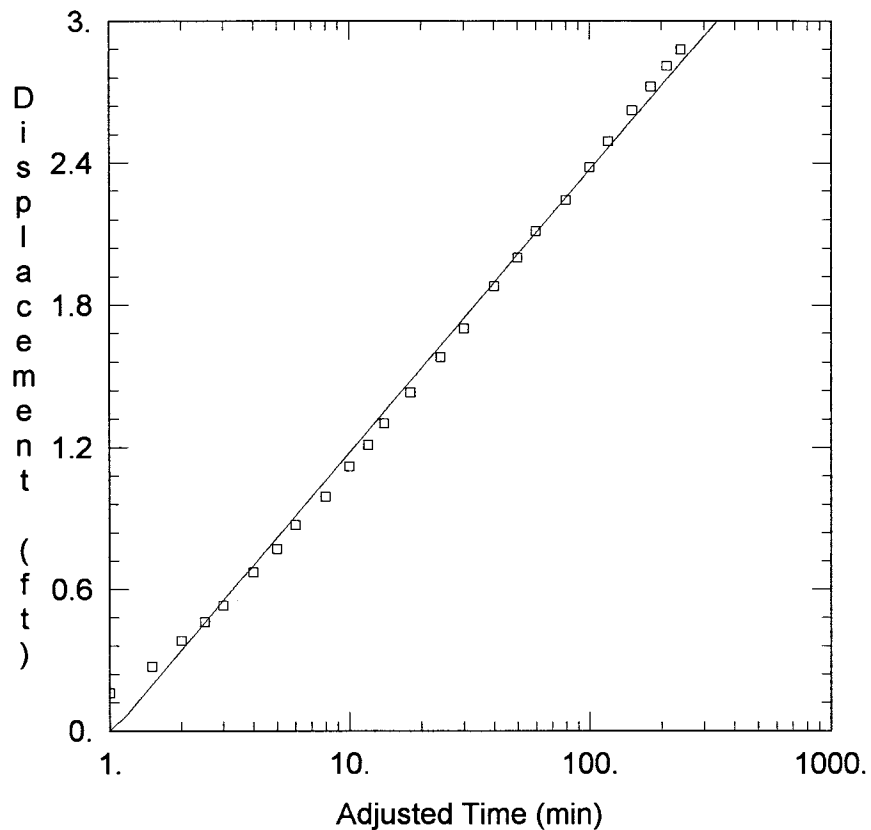
Saturated Thickness: 230. cm

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 197.3 cm
 Casing Radius: 2.54 cm
 Screen Length: 230. cm

Water Column Height: 1. cm
 Wellbore Radius: 2.54 cm
 Gravel Pack Porosity: 0.3



G476 AQTESOLV HW PROB. 4

Data Set: C:\WOU\HYDRO\AQTESO~1\HWPROB4.AQT
 Date: 03/13/01 Time: 16:23:25

PROJECT INFORMATION

Company: Western Oregon University
 Client: Dr. Steve Taylor
 Project: HW-4
 Test Location: Monmouth, Oregon
 Test Well: PW-1
 Test Date: 03/10/01

SOLUTION

Aquifer Model: Confined
 Solution Method: Cooper-Jacob
 $T = 0.1536 \text{ ft}^2/\text{min}$
 $S = 2.233\text{E-}06$

AQUIFER DATA

Saturated Thickness: 1. ft

Anisotropy Ratio (K_z/K_r): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW 1	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
□ OW 1	400	0

**G476 / G576 Supporting Documentation on the Use of Aqtesolv
(As Applied to the Well Hydraulics / Aquifer Testing Homework)**

Example Steps for Using Aqtesolv for Problem 1 of the Homework Set

Start Aqtesolv

File - New - error log opens as window (leave this open for helpful dialogue)

Edit

units: length = ft time = min

title: ... give the project a title (e.g. "Homework 1")

Project Info: give some information as you see fit

Aquifer Data

 saturated thickness = 35

 hydraulic conductivity = 1

Pumping Well

 Edit

 x = 0

 y = 0

 check fully penetrating

 depth to top of screen = 182

 depth to bottom of screen = 217

 well bore / radius = default

Observation Well

 Edit

 x = 250

 y = 0

 check fully penetrating

 depth to screen top = 182

 depth to screen bottom = 217

 test type... check pumping test

Edit - Observation Well - Edit (add drawdown data to list)

View - Displacement/Time Plot

View - Semi-Log Axes

View-Report - ..double check the data and information

View-Displacement Time

Solution

 Confined - Theis (1935).. for Part A of problem

 Match-Parameters-Choose Default

 Match-Iterations-Choose Default

 Match-Automatic-Start (will auto-fit the curve and calculate T and S)

 Match-Visual ... try a manual / visual match to see how it compares (refer to notes below)

 Print your results / report for the Theis solution

Solution

confined - Cooper Jacob (1946)
match parameters - default
match iterations - choose default
match-automatic-start
match-visual-... see how this method compares
Print your results / report for the Cooper Jacob solution

Tips for Automatic Curve Matching / Hydraulic Properties Solution Routines

Choose Automatic... from the Match menu to use automatic curve matching to estimate the values of hydraulic parameters. This procedure automatically adjusts the values of hydraulic properties to achieve the best statistical match between the solution (i.e., type curve) and the test data.

The automatic curve matching feature provided by AQTESOLV for Windows uses a nonlinear least squares estimation procedure to match a type curve or straight-line solution to your data. The procedure iteratively minimizes the "residuals" or errors between the computed and the observed drawdown or displacement.

Starting Estimation

Click the Start button to begin the procedure of automatically matching a solution to your data. During automatic estimation, the dialog box displays a residual sum of squares (RSS) convergence criterion and the values of the estimated parameters which indicates the progress of the automatic curve matching.

Aborting Estimation

To halt estimation before any of the termination criteria are met, click the Abort button. Viewing residual plots and diagnostic statistics requires that you allow the automatic estimation procedure to terminate normally; if you halt estimation prematurely, you will not be able to view residual plots or diagnostic statistics.

Tips

- I n general, automatic curve matching performs more efficiently with good starting guesses for the hydraulic properties in an aquifer model. One way to ensure good initial guesses is to perform visual curve matching prior to initiating automatic estimation. For solutions involving three or more parameters, it is a good idea to perform visual estimation prior to automatic curve matching.

Tips for Visual Curve Matching / Hydraulic Properties Solution Routines

Choose Visual from the Match menu to invoke visual curve matching feature provided by AQTESOLV for Windows. By selecting this option, you can interactively match a type curve or straight line to your data. The Visual option is only available if you are viewing a displacement vs. time or composite plot in the active window.

AQTESOLV for Windows lets you perform visual estimation of aquifer properties by using a mouse to move a type curve (or straight line) on the screen. The procedure for visually matching type curves and straight lines

slightly different.

Matching Type Curves

1. After choosing the Visual option, click and hold the left mouse button down within the plot axes.
2. Move the mouse to match the type curve to your data. As you move the type curve, AQTESOLV for Windows automatically updates the plot legend to reflect changes in parameter values.
3. Release the left mouse button when you have finished matching the type curve.

Matching Straight Lines

1. After choosing the Visual option, move the mouse to a point located on the new straight line you wish to match to your data. Click and hold the left mouse button down to anchor the new straight line at this point.
2. Move the mouse to match a new straight line to you data. As you move the mouse, AQTESOLV for Windows drags a straight line between the anchor point and the position of the mouse.
3. Release the left mouse button when you have finished matching a new straight line. AQTESOLV for Windows automatically updates the plot legend to reflect changes in parameter values.