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Slug Test Application: Using In-Situ Inc. miniTROLL Probe and Aqtesolv Software

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Aquifer tests are expensive, hard to replicate and personnel intensive. You also may need to make accommodations to treat contaminated water and transport water out of the watershed area.

Many hydrologists use Slug Testing for the following reasons:

- Can determine many point source K's (K= hydraulic conductivity)
- Much more simple and quick than aquifer tests
- Useful for small scale studies
- Very good data in low K layers
- Much Less Expensive

The purpose of this application note is to outline a step-by-step method for conducting a standard slug-test on an unconfined/confined aquifer. This outline will cover:

- Field Equipment
- Data Collection Methods
- Software Manipulation and Analysis
- Aquifer Analysis Methods

Field Equipment:

A slug-test implies that you are only conducting an aquifer test at a single-well location. Before you begin a slug-test, you will need the following minimum list of field equipment:

- In-Situ Inc. **miniTROLL** with necessary length **Quick Connect Cable** and **Communication Cable**. See www.in-situ.com for Rental or Purchase information
- A **laptop computer** or **HP iPAQ PDA** for miniTROLL operation.
- **Water level indicator**, such as E-Tape
- **Duct Tape** or water compatible tape

- **Slug or bucket and hose/funnel**. (a slug can consist of a solid object that can slide into a well past the minitroll cable or a volume of water).
- The easiest way to make a solid slug is to get a section of **PVC pipe** that will fit down the monitoring wells, fill it with sand, cap both ends, and put a screw eye on one end.
- **String/cable** for slug.
- **Aqtesolv Software**. See www.aqtesolv.com for purchase information.

Field Set Up:

Once you are in the field, set up at your slug well and:

1. Open the well head and take and record a water level reading with a water level indicator, if the well was not vented to atmospheric pressure, then take a few readings and make sure the level is equilibrated.
2. Make sure the MiniTROLL is screwed all the way onto the MiniTROLL cable and connect the cable end to the communication cable, then connect to your computer or PDA and make sure there is communication with the MiniTROLL.
3. Lower the MiniTROLL down the well and place it below the area where you will insert the slug, but not at the very bottom of the well where it could encounter silt.
4. Fasten the MiniTROLL cable at the top of the well with tape or well dock so it cannot move.
5. Measure the groundwater again with the water level meter to see if the groundwater level has returned to equilibrium after the insertion of the MiniTROLL in the water.



miniTROLL Programming / Win-Situ Operation:

Once the water level in static and you are ready to begin your test, you must program the MiniTROLL with the proper settings to record the data:

1. Connect to your MiniTROLL with your computer/PDA and click on the COM1-9600 connection on the left side of the software window.
2. Once connected, click on the MiniTROLL identification that appears below COM1-9600.
3. All the details of the MiniTROLL should come up on the right hand side of the software window.
4. Click on the edit button, and program the name of the minitroll and proper time.
5. Click on the pressure channel listed on the tree on the left hand side of the software window.
6. All the information on the channel should appear on the right side of the software window, click on edit.
7. Follow the wizard sequence and program the MiniTROLL pressure channel settings, first name the channel if you like (not essential).
8. Choose a display mode, either Level-Surface if you are doing a rising head test, or Level-Top of Casing, if you are doing a falling head test.
9. Enter Depth/Level Conversion where your specific gravity is equal to 1.00.
10. Enter Level Reference equal to 0.00, and click on reference read time with start of test.
11. Click on Tests and find the Add button and click it.
12. Follow the wizard sequence again, and name your test and choose if you want pressure, temperature or both.
13. Choose Log Test
14. Choose an interval at which the log test stops expanding and the test goes linear, that is when the interval of log samples reaches a certain time, it will remain at that interval.
15. Choose Manual Start and finish.
16. Your test is now set up, hit start, and a window will come up asking whether you are ready to start or not.
17. Hit OK, and wait 2-3 seconds before slugging the well.
18. Run your test to conclusion, or hit extract any time you want to look at the data.
19. For data analysis, please open AQTESOLV and follow the import wizard.

Importing Data From In-Situ Data Logger Files

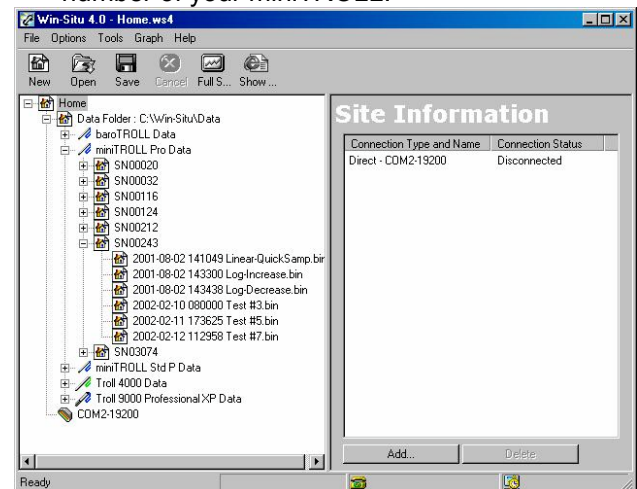
This tutorial describes how to import data from a file recorded by an *In-Situ* data logger. The procedure for importing a file is summarized as follows:

1. Extract the data file from the data logger to the computer/PDA using the Win-Situ software provided by *In-Situ*. You can download the latest version of Win-Situ at the [In-Situ web site](#).
2. If extracted to a PDA, transfer the file to a desktop/laptop PC using Microsoft ActiveSync.
3. Convert the binary (.bin) file created by the data logger to a text (.txt) file
4. Use the **Pumping Test Wizard** or **Slug Test Wizard** in **AQTESOLV for Windows** to enter data for your aquifer test. When prompted for observation (time-displacement) data, launch the **Import Wizard** to import the text file containing the data logger measurements.

Creating a Text File Using the Win-Situ Data Folder

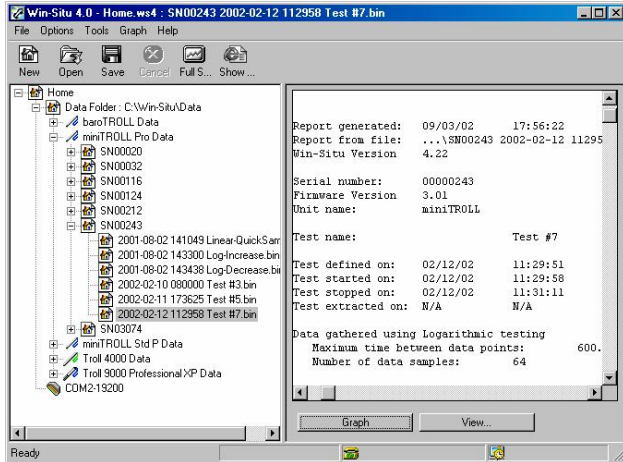
After downloading data from the data logger, you need to convert the binary (.bin) file recorded by the data logger to a text (.txt) file using the data folder in the Win-Situ application.

1. Click the + sign by the data folder to expand the listings. Keep clicking + to expand the device type (e.g., miniTROLL Pro Data) and the serial number of your miniTROLL.

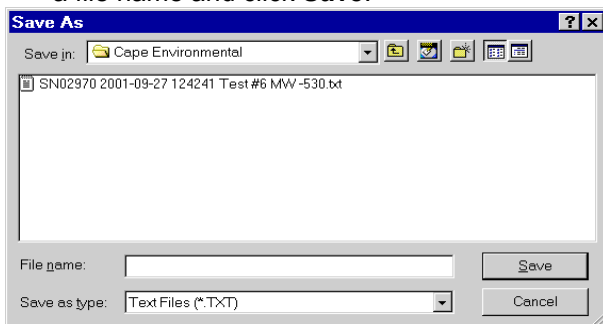




- When you locate the test you want, click on it and it will open in the Win-Situ interface. The measurements recorded by the data logger in the binary file are displayed in text format.

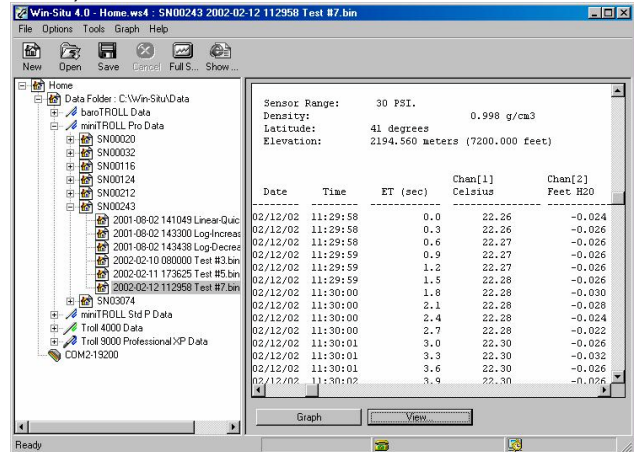


- If you want, select **Options | Preferences** to select units of measurement for displaying the data (e.g., minutes for elapsed time and feet for level or depth). To change the way pressure readings are displayed, click the **View** button, then **Change Channel Settings**, then click **Pressure** to display the pressure readings in raw pressure, depth or level format.
- Choose **File | Save Report** to save the results displayed as a text file. In the **Save as type** box, select the option for Text Files (*.txt). Enter a file name and click **Save**.



- At this point, take a moment to examine the readings displayed. Scroll down until you see a table of measurements. In the example below, the table contains a total of five data columns with elapsed time in column 3, temperature in column 4 and water level in column 5. We will use **AQTESOLV for Windows** to import

elapsed time (column 3) and water level (column 5).



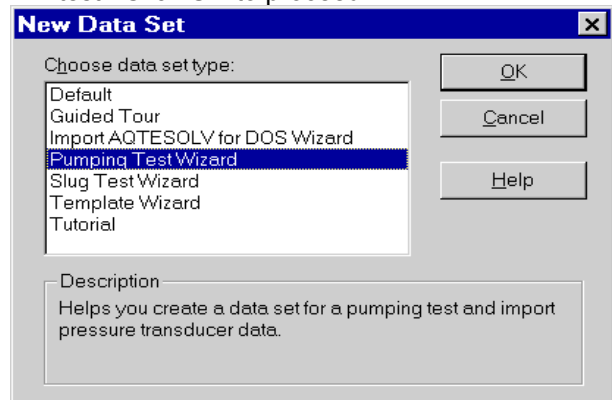
- Choose **File | Exit** to close the Data Manager application.

Importing Data Logger Files into AQTESOLV for Windows

After using Win-Situ to create a text (.txt) file containing the data logger readings, you are ready to enter your aquifer test data into **AQTESOLV for Windows**.

Start the **AQTESOLV for Windows** application (v. 3.0 or higher) and follow the steps below.

- Choose **File | New** and select **Pumping Test Wizard** or **Slug Test Wizard** from the list to create a new data set for a pumping test or slug test. Click **OK** to proceed.





2. Begin the wizard by entering units of measurement as shown and click **Next**.

3. Continue entering data in the wizard until you reach the last step which prompts you for the observation (time-displacement) data for the test. Click **Import** to launch the Import Wizard for importing the observation data from a file.

Obs. No.	Time (min)	Displacement (ft)	Weight
1	0	0	0

4. The **Import Wizard** consists of three simple steps that help you to import data from a file. The import file must have text formatting (not binary) and data values separated by blanks, tabs, commas or quotes. In the first step of the wizard, enter the name of an **Import File**. Click **Next** to continue.

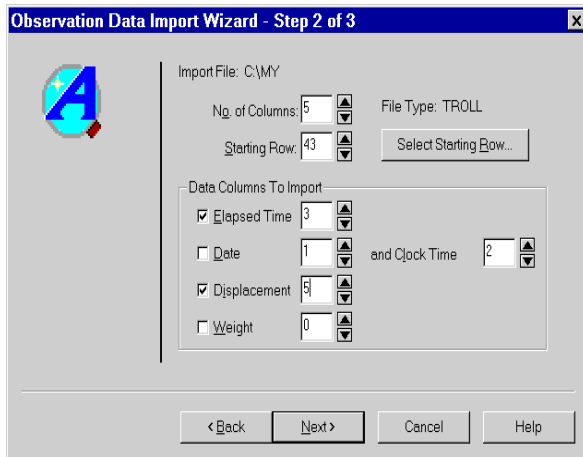
TIPS

- Click **Browse** to locate and select a file to import. After selecting the file, click **View Import File** to view its contents.
- Be default, the imported data overwrite any readings contained in the **AQTESOLV for Windows** data set. Override this behavior by selecting the option to **Append observations from import file to data set**.

5. In the second step of the **Import Wizard**, identify the structure of the import file. Enter the number of data columns and starting row in the file, and the data columns to import. Click **Next** to continue.

TIPS

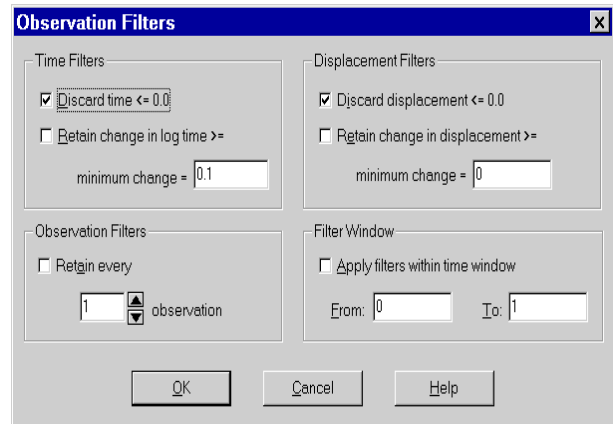
- **AQTESOLV for Windows** automatically scans the import file to identify the **No. of Columns** and **Starting Row** for data contained in the file. Click **Select Starting Row** to modify the number of columns and starting row.
- Enter **Data Columns To Import** that match the structure of your import file. Typically, you will select elapsed time and displacement values to import. The **Import Wizard** also allows you to import time recorded as date and clock time values when an elapsed time column is not available. For example, if your data logger file contains a total of five data columns with elapsed time in column 3 and water-level displacement in column 5, enter the values shown below.
- The **Weight** column is optional; if your file does not contain weights for the readings, **AQTESOLV for Windows** assigns a default value of **1.0** for each reading.



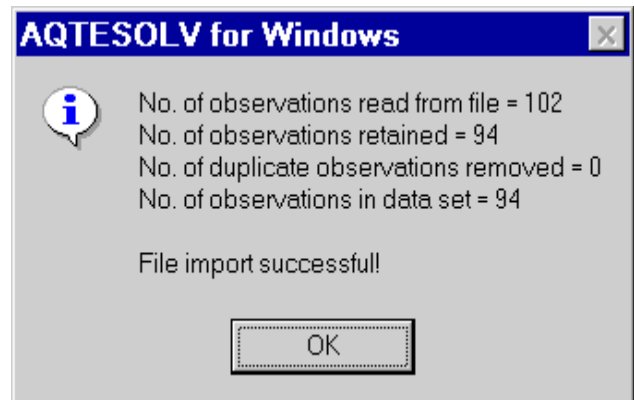
6. In the third step of the **Import Wizard**, select **transformation** and **filter** options to modify the data contained in the import file. Click **Finish** after selecting these options to import the file.

TIPS

- The **Pre-Filter Operations** allow you to perform common transformations on the data. For example, to convert water levels or depths contained in the import file to displacement (drawdown) values, subtract the static water level or depth from all of the readings in the file. You can perform this transformation by selecting the option in **Time Filters** group to subtract a constant from the displacement values and entering the static water level or depth (see example below). Other useful options allow you to multiply time and displacement values by a constant. For example, to convert negative displacements to positive values, check the option for multiplying displacement values and enter a constant of -1.
- Click **Filters** to choose options for filtering data imported from the file. Select **Retain change in log time >= minimum** to retain a fixed number of readings per log cycle time. For example, to retain 10 readings per log cycle, enter a value of 0.1 (=1/10) for this option. Other options allow you to specify a retention interval (e.g., retain every fifth observation), a minimum change in displacement for retaining observations (i.e., discard readings until the change in displacement exceeds the minimum value), and a time window for applying the filters. You can select more than one filter option for your import file.



7. After importing the file, **AQTESOLV for Windows** shows a summary of the data read from the file. Click **OK** to continue.





Examples and Equations

Equations (Fetter)

Fetter, C.W. *Applied Hydrogeology*, Third Edition, Macmillan, NY, 1994.

Cooper - Bredehoeft - Papadopoulos Method – Confined

(Cooper and others, 1967)(Papadopoulos and others, 1973)

- 1) Confined aquifer
 - 2) Fully penetrating well
- Add or remove known volume of water to well rapidly.
 - Initiate head change.
 - Measure head as it returns to equilibrium.

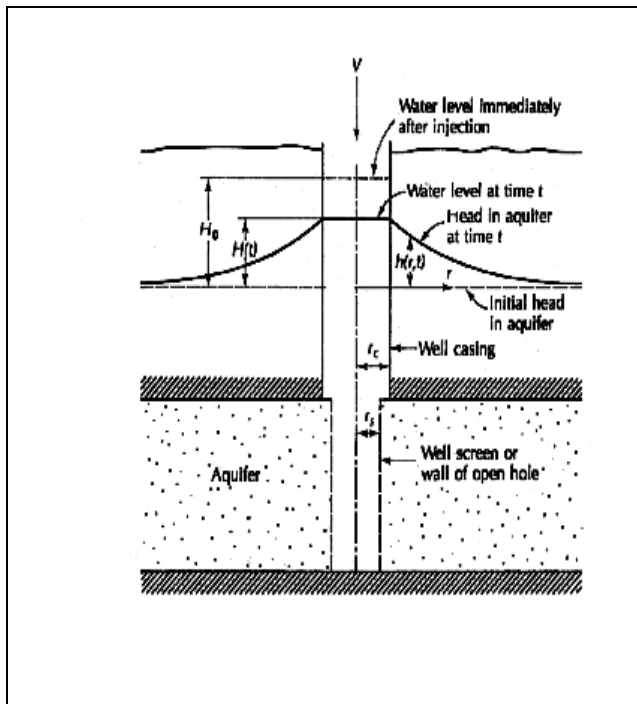


Figure 7.18. Well into which a volume, V, of water is suddenly injected for a slug test of a confined aquifer.

r_c = radius of well casing (ft)
 r_s = radius of well screen (ft)
 H_0 = initial head use (ft)

Method

- 1) Plot ratio of H/H_0 vs time.

- Measure head to head after injection.

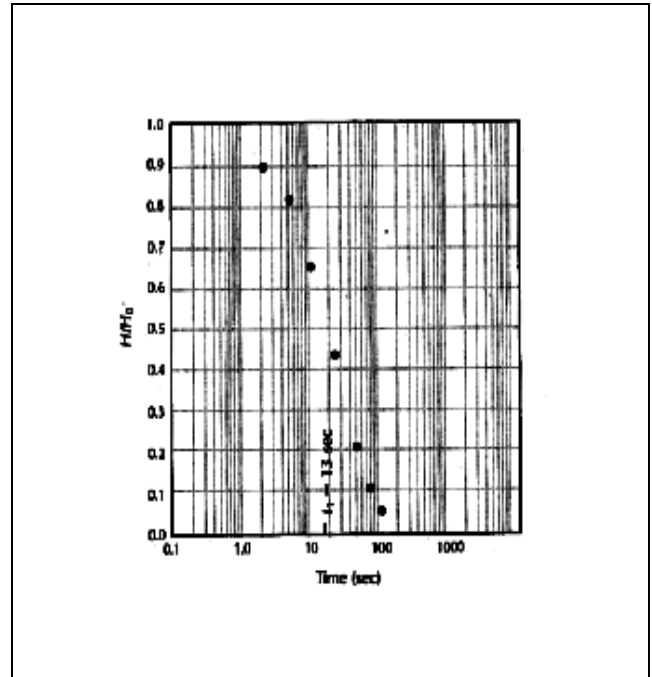


Figure 7.20. Field-data plot of H/H_0 as a function of time for a slug-test analysis.

$$H/H_0 = F(\eta, \mu) - a \text{ function}$$

η - eta

μ - mu

$$\eta = \frac{Tt}{r_c^2}$$

T - transmissivity (ft/s) (cm/s)

t - time (sec)

$$\mu = \frac{r_c^2 S}{r_s^2}$$

r_c - radius casing (ft) (cm)

S - storativity

r_s - radius screen (ft) (cm)

- 2) $F(\eta, \mu)$ type curves for values of this function in appendix.
 Use same scale paper for field data and type curves.
- 3) Place type curves over field data.
 - keep arithmetic axes coincident
 - match to type curve value μ with same curvatures



4) Find time (t_1) value when $\frac{T}{r_c^2} = 1.0$
 read t (seconds) from x axis field data

$$T = \frac{1.0 r_c^2}{t_1}$$

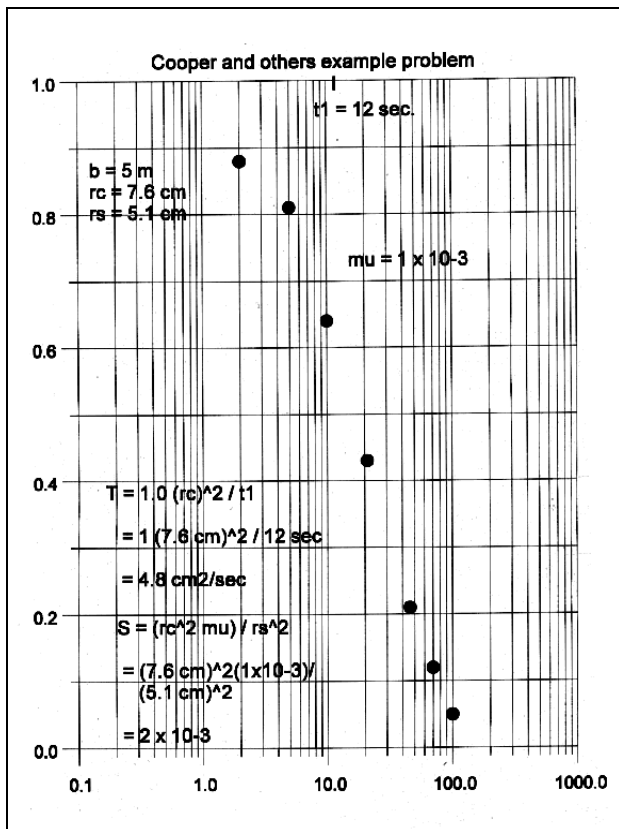
5) Calculate storativity

$$S = \frac{(r_c^2 \mu)}{r_s^2}$$

[Fetter Example p. 246-247 Slug of water is injected.](#)

Time (s)	H (m)	H/H ₀
2	0.37	0.88
5	0.34	0.81
10	0.27	0.64
21	0.18	0.43
46	0.09	0.21
70	0.05	0.12
100	0.02	0.05

Cooper Method



Bouwer & Rice Method

Fetter 7.5.4
 Uses Theim's Equation-

$$Q = \frac{2 \pi T (h_2 - h_1)}{\ln \left(\frac{r_2}{r_1} \right)}$$

$$K = \frac{r_c^2 \ln(R_e/R)}{2L_e} \frac{1}{t} \ln \left(\frac{H_t}{H_0} \right)$$

- r_c - radius of well casing(L)
- R - radius of gravel envelope (L)
- R_e - effective radial distance over which head is dissipated(L)
- L_e - length of screen
- H_0 - drawdown at $t = 0$
- H - drawdown at $t = t$
- t - time since $H = H_0$

Bouwer and Rice established way for getting R_e/R

If $L_w < h$ (saturated thickness) partially penetrating-

$$\ln \frac{R_e}{R} = \left[\frac{1.1}{\ln(L_w/R)} + \frac{A+B \ln[(h-L_w)/R]}{L_e/r_c} \right]^{-1}$$

$$\ln \frac{R_e}{R} = \left[\frac{1.1}{\ln(L_w/R)} + \frac{C}{R} \right]^{-1}$$

A, B, C are dimensionless from curve of Bouwer.

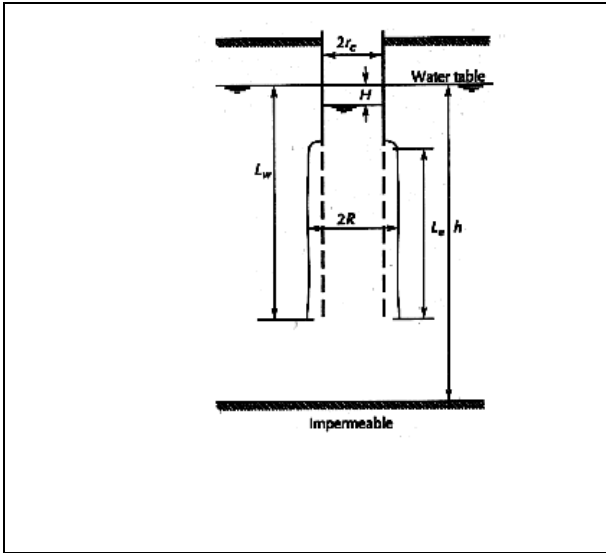
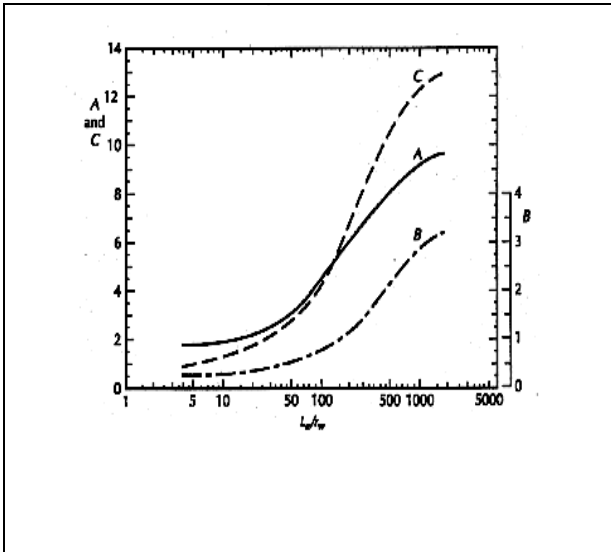
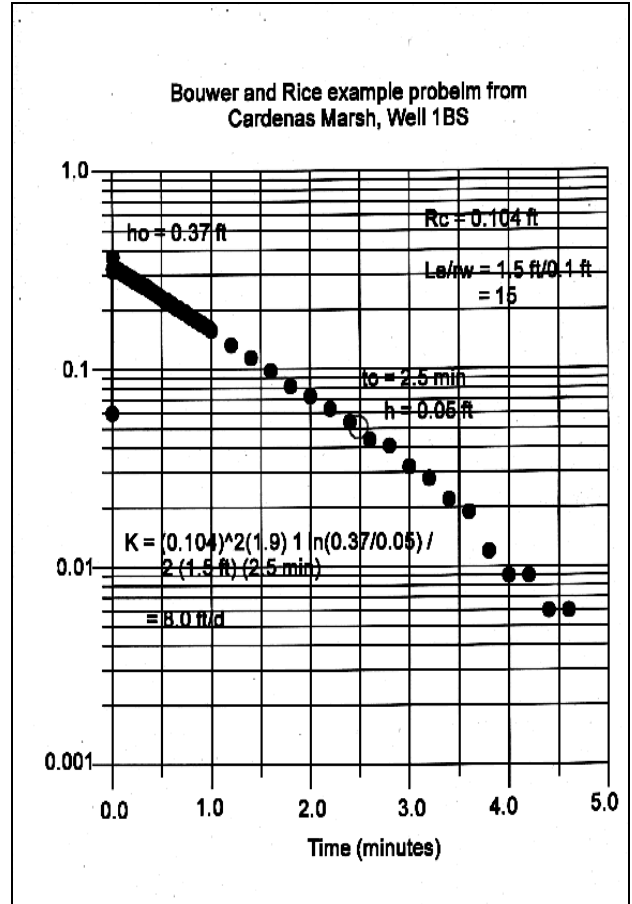


Figure 7.24. Geometry and symbols for a slug test on a partially penetrating screened well in an unconfined aquifer with a gravel pack around the screen



Reference:

Fetter, C.W. *Applied Hydrogeology*, Third Edition, Macmillan, NY, 1994.



Graphical Methods

Methods of Determining Values of Selected Hydraulic Parameters

Method Parameter	Grain size Analysis	Lab permeameter	Slug Test	Pumping Test	Flow Net
K_h	X	X	X	X	X
K_v		X		s	
T	X		X	X	X
S or S_y		X	s	X	
K'		X		X	X

s = some test methods

	Unconfined	Confined	Natural	Anthropogenic	Short-lived	Diurnal	Seasonal	Long term
Ground-water Recharge	X		X				X	
Air trapped during recharge	X		X		X			
ET and plant use	X		X			X		
Bank-storage effects	X		X				X	
Tidal effects	X	X	X			X		
Atmospheric pressure effects	X	X	X			X		
Earthquakes		X	X		X			
G-w pumping	X	X		X				X
Deep-well injection		X		X				X
Artificial recharge	X			X				X
Agricultural irrigation	X			X				X
Geotechnical drainage of mines, ...	X			X				X