Pumping Test Example: Constant Rate (Gridley)

Walton (1962) presented data from a pumping test conducted on July 2, 1953 near Gridley, Illinois. The test well (Well 3) fully penetrated an 18-ft thick sand and gravel aquifer under nonleaky artesian conditions. Pumping continued for eight hours at a constant rate of 220 gallons-per-minute (gpm). Hydraulic response was monitored in an observation well (Well 1) at a distance of 824 ft from the pumped well. Time and drawdown measurements were recorded in minutes and feet, respectively.

This example will introduce you to the following tasks and features in AQTESOLV:

- Creating a new data set with the Pumping Test Wizard
- Importing data with the Observation Data Import Wizard
- Saving a data set
- Inspecting diagnostic plots (radial flow and derivative)
- Estimating aquifer properties using Cooper-Jacob (1946) and Theis (1935) solutions (visual and automatic)
- Predicting future response over time and distance (distance-drawdown and contour plots)

TIP: While following the steps in this example, click **Help** or press **F1** to obtain context sensitive help in the AQTESOLV application.

Create a New Data Set with Pumping Test Wizard

The first step in analyzing data from a pumping test is to create a new AQTESOLV data set. In this example, we will use the Pumping Test Wizard to assist us with data entry.

1. Create a new data set by choosing New from the **File** menu.
2. In the **New Data Set** dialog, select **Pumping Test Wizard** from the list. Click **OK**.
3. Choose **Multiwell test** for the type of pumping test. Click **OK**.
4. The **Pumping Test Wizard** prompts you for data required to analyze a pumping test. Click **Next** to begin the wizard.
5. For units of measurement, choose **ft** for length, **min** for time, **gal/min** for pumping rate and **gal/day/sq. ft** for hydraulic conductivity. Click **Next**.
6. For project information, enter **Gridley, Illinois** for the location and **July 2, 1953** for the test date. Click **Next**.
7. For aquifer data, enter **18** for the aquifer thickness. Enter **1** for the anisotropy ratio (i.e., assume hydraulic conductivity is isotropic). Click **Next**.
8. For pumping well data, enter **Well 3** for the well name. Enter coordinates of X=0 and Y=0. Click **Next**.
9. For pumping well construction, select the option for **vertical, full penetration**. Click **Next**.
10. For pumping well radius data, assume **0.5** for casing radius and **0.5** for well radius. Click **Next**.

11. For pumping rates, enter **0** for time and **220** for rate in the first row of the spreadsheet. Click **Next**.

12. For observation well data, enter **Well 1** for the well name. Enter **824** and **0** for the X and Y coordinates, respectively. Click **Next**.

13. For observation well construction, select the option for **vertical, full penetration**. Click **Next**.

14. For radius data, enter **0.0** for the casing radius to disable delayed observation well response.

15. For observations, click **Import** to launch the Observation Data Import Wizard for importing data from a file.

    We will import a text file consisting of 22 time-drawdown readings arranged in two columns. The first column is elapsed time since the start of the test. The second column contains drawdown measurements.

    > In Step 1 of the wizard, click **Browse**. Select the import file **Gridley.txt** in the AQTESOLV installation folder and click **Open**. Click **Next**.
    >
    > In Step 2 of the wizard, enter **2** for the number of columns, **1** for the starting row in the file, **1** for the column containing elapsed time and **2** for the column containing displacement. Click **Next**.
    >
    > In Step 3 of the wizard, click **Finish**. Inspect the import file summary and click **OK**.
    >
    > Click **Next** to proceed with the **Pumping Test Wizard**.

16. You have completed the **Pumping Test Wizard**. Click **Finish**.

After completing the **Pumping Test Wizard**, AQTESOLV automatically displays an Error Log to let you know if the data set contains any errors. If the **Error Log** identifies any mistakes, choose options from the Edit menu to correct them.

Save Data Set

At this point, it's a good idea to save your work.

Save the data set by choosing Save As from the **File** menu. Choose a folder and enter **Gridley Well No. 1** for the name of the file. Click **Save**. AQTESOLV saves the file with an **.aqt** extension.

Pro Inspect Diagnostic Plots

Before performing curve matching to estimate aquifer properties, you may use diagnostic features in AQTESOLV to evaluate aquifer and flow conditions.

Diagnostic flow plots help you select an appropriate solution method for your pumping test data.

1. Choose Radial Flow from the **View** menu to display a radial flow plot on log-linear axes.

   View Radial Flow Plot

   At late time on this graph, data plotting as a straight line indicate radial flow conditions in an infinite-acting confined aquifer.

Derivative analysis is another useful diagnostic tool for evaluating aquifer conditions.

1. Choose Displacement-Time from the **View** menu to display a plot of the test data. On semi-log axes, this plot is identical to the radial flow plot above.

2. Choose Wells from the **Edit** menu. Select **Well 1** from the list and click **Modify**.

   In the **Symbols** tab, remove the check from **Use data symbols properties** and select **cross** for the derivative symbol.

   In the **Curves** tab, remove the check from **Use type curve properties**. Click **Color** for the derivative curve properties, change the color to **red**, and click **OK**.

   Click **OK** and then **Close**.

3. Select Options from the **View** menu. In the **Plots** tab, check **Derivative curves.** In the **Derivative** tab, select the option for **Bourdet** and enter a differentiation interval of **0.3**. Click **OK**.

   View Derivative Plot

   The form of the derivative plot is characteristic of radial flow in an infinite confined aquifer. At late time, the derivative becomes essentially constant when the data plot as a straight line.

Estimate Aquifer Properties

The radial flow and derivative plots that we have examined for this test confirm the assumption of radial flow in an infinite-acting confined aquifer. To start our analysis, we can use the Cooper-Jacob (1946) solution to obtain preliminary estimates of aquifer properties.

1. Choose Solution from the **Match** menu to select a method for analyzing the data.

2. Remove the check from **Solution is inactive**. Click the **+** next to **Confined Aquifers** to expand the list of available solutions for confined aquifers. Select **Cooper-Jacob (1946)** and click **OK**.

3. Choose Displacement-Time from the **View** menu.

4. Choose Options from the **View** menu. In the **Plots** tab, remove the check from **Derivative curve(s)** and check **Valid time for Cooper-Jacob approximation**. Click **OK**.

   The dashed vertical line shown on the plot is a guide indicating the time when the Cooper-Jacob solution becomes valid. Match the solution to data plotting to the right of the vertical line.

5. Choose Visual from the **Match** menu to perform visual curve matching with the Cooper-Jacob solution.

   > To perform visual matching, move the mouse to a point where you wish to begin drawing a new line with the Cooper-Jacob solution.
   >
   > Click and hold down the left mouse button to anchor the new line at this point.
   >
   > Continue to hold the mouse button down and move the mouse to match a new straight line to your data. As you move the mouse, AQTESOLV draws a straight line between the anchor point and the position of the mouse.
   >
   > Release the left mouse button when you have finished matching a new straight line. AQTESOLV automatically updates the plot legend to reflect changes in parameter values.

6. Repeat the previous step as needed to achieve a satisfactory match.

   View Visual Match With Cooper-Jacob

   Note that very few data points near the end of the test meet the validity criterion (u ≤ 0.01) for the Cooper-Jacob solution. You can change the validity criterion to a less stringent value if desired.

Having completed our preliminary analysis with Cooper-Jacob, let's continue by matching the data with the Theis (1935) solution for a confined aquifer.

1. Choose Solution from the **Match** menu to select a method for analyzing the data.
2. From the list of solutions for **Confined Aquifers**, select **Theis (1935)** and click **OK**.
3. Choose Log Axes from the **View** menu to change the axes to a log-log format.
4. Select Options from the **View** menu. In the **Plots** tab, check **Derivative curves**. Click **OK**.

   The plot displays two curves. The blue curve is the drawdown predicted by the Theis solution (i.e., the trace of the Theis type curve projected on the data plot). The red curve is the derivative curve predicted by the Theis solution.

5. Choose Visual from the **Match** menu to perform visual curve matching with the Theis solution.

   Click and hold the left mouse button down over a point within the plot area.

   Continue to hold the mouse button down and move the mouse to match the curves to the drawdown and derivative data. As you move the type curve, AQTESOLV automatically updates the plot legend to reflect changes in parameter values.

   Release the left mouse button when you have finished matching the curves.

6. Walton (1962) reported values of T = 10,100 gal/day/ft and S = 0.00002 for this test.

   View Visual Match With Theis

7. Choose Automatic from the **Match** menu and click **Estimate** to perform automatic curve matching.

   During the iterative estimation procedure, AQTESOLV displays a progress window and updates the curves displayed on the plot in the background.

8. When estimation has finished, click **OK** and then **Close**. Click **OK** to view the new position of the type curve. The new values of T and S are close to the estimates from visual curve matching.
9. Use residual-time, residual-simulated and normal probability plots to evaluate the fit of the curve by examining residuals. The diagnostics report also presents residual statistics for curve fitting.
10. Choose Save from the **File** menu to save your work.

Prediction

AQTESOLV provides tools for predicting response in the aquifer under future conditions. Using the aquifer properties determined from curve matching analysis, you may forecast drawdown over time or distance.

You may use the **displacement-time plot** to predict drawdown with time for the observation well (s) in your data set.

1. Choose Displacement-time from the **View** menu to display a plot of drawdown versus time.
2. Choose Log-Linear Axes from the **View** menu to display the plot on semi-log axes.
3. Choose Format from the **View** menu and click the **X Axis** tab. Remove the check from **Auto** and enter **10000** for the maximum value. Click **OK**.

Forecast drawdown over distance on a **distance-drawdown plot**.

1. Choose Distance drawdown from the **View** menu to display a plot of drawdown versus distance.
2. Choose Options from the **View** menu and click the **Distance** tab. Enter **43200** min (30 days) for the time used in distance-drawdown calculations. Click **OK**.
3. Choose Format from the **View** menu and click the **Y Axis** tab. Remove the check from **Auto** and enter **50** ft for the maximum value. Click **OK**.
4. If observation wells in your data set do not contain a measurement at the time specified for a distance-drawdown plot, AQTESOLV automatically interpolates/extrapolates a data point for you.

If you have Surfer installed on your computer, you may use the Grid Wizard to generate a **contour plot** of drawdown.

1. Choose Contour from the **View** menu.
2. In Step 1 of the **Grid Wizard**, enter the name of a **Grid file** to store data for the contour plot. Select **X-Y (Plan)** for the grid orientation. Click **Next**.
3. In Step 2 of the **Grid Wizard**, enter **-1000** and **1000** for the minimum and maximum dimensions in the X and Y directions. Enter **51** for the number of grid lines for both directions. For the depths, enter **0** and **18** (i.e., compute the average drawdown over the full thickness of the aquifer). Enter **43200** for the time. Click **Next**.
4. In Step 3 of the **Grid Wizard**, check **Display grid file with Surfer** and select **Contour**. Click **Finish** to display the contour plot with Surfer. Use options in Surfer to customize the appearance of the plot.