

How To Prepare for Your Aquifer Test

By Dennis Nelson

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Those in the business of supplying drinking water are finding their jobs a lot more complicated lately. Issues of water quantity and quality seem to occur on a daily basis. You are often asked to make recommendations or reach conclusions regarding an issue without having benefit of the really critical information necessary to do so. From a water quality standpoint, there may be concern as to whether or not the contaminant from a particular spill or release is going to reach the well.

Another common issue concerns land use and community development. Someone wants to locate a particular activity at a specific site in your community. You are asked, "Is this going to affect our drinking water?" Neither one of these important issues can be adequately addressed unless the groundwater system that supplies the community's drinking water is better understood. You need to know what area of the community is directly over that part of the aquifer that supplies the well(s).

To determine where in the aquifer your drinking water is coming from, data is needed on the aquifer's characteristics, particularly related to the aquifer's ability to transmit groundwater (its permeability or hydraulic conductivity) and the direction that groundwater is moving (the hydraulic gradient). We will address the hydraulic gradient in a later PIPELINE issue; here we want to talk about how to determine the aquifer's hydraulic conductivity. The principle tool used by hydrogeologists to obtain this information is the aquifer test.

What is an aquifer test?

An aquifer test consists of a carefully planned interval of pumping and water level monitoring. We use the term "aquifer test" instead of "pump test" for two reasons. First of all, the objective is not just to test the pump; rather it is to better characterize the aquifer. Secondly, an aquifer test is a multi-phase effort that includes a number of steps in addition to just pumping the well.

(Dennis Nelson is groundwater coordinator of the Drinking Water Section)

For the purpose of obtaining aquifer characteristics, the aquifer test normally consists of a period of constant rate pumping at a sufficient rate and for a long enough interval to involve a representative portion of the aquifer. Generally this means pumping the well at normal operating levels for a period of 24 to 72 hours.

The drop in the water levels (called the drawdown) in the production well and in nearby monitoring wells as a function of time are monitored throughout the test. The drawdown-time data is critical to the proper determination of aquifer properties. Therefore, the monitoring is done according to a rigorous schedule in order to ensure that the data obtained is useful.

How are aquifer test results used?

There is a direct relationship between the aquifer's characteristics and the amount of drawdown relative to both the time since pumping began and the distance a monitoring well is from the production well. For example, if we know the aquifer's transmissivity (equal to the hydraulic conductivity x the aquifer's thickness) and storativity (the amount of water the aquifer releases), we can predict what the drawdown will be for a given pump rate after a certain time and at a certain distance from the well. There are equations that allow us to make those predictions depending on the type of aquifer and the hydrogeologic setting.

It follows, then, that we can use those same equations in reverse to calculate transmissivity and storativity if we know the drawdown, time and distance. Generally, the solutions are graphical; that is, we plot the data and compare the graph to theoretical solutions. There are many different types of solutions, depending on the hydrogeologic setting.

How do we design aquifer tests?

Aquifer tests can be expensive and time consuming. Therefore, it is important that the data be collected in a manner that will yield useful results in terms of aquifer characteristics. We recommend that you consult with a professional early on in the planning of the aquifer test so that the data collected will meet your needs and expectations. The Drinking Water Program will provide technical assistance and advice to help get you started.

Importantly, there is no "off-the-shelf" aquifer test plan that is available. Critical questions of what pump rate, what test duration, what additional wells should be involved and at what distance, what hydrogeologic boundaries may affect the results, and what corrections need to be applied to the drawdown data, all need to be addressed on a site by site basis. As discussed above, there are several solution methods that are applied to aquifer test results depending on the hydrogeologic setting and well construction characteristics. For the solutions to be valid, certain criteria must be met with regard to how the test is performed. Clearly these criteria have to be identified prior to running the test itself.

Your consultant will likely prepare a conceptual model of the hydrogeologic setting based on well reports and other data available. From this information, a simulation of the aquifer test can be run prior to the actual test in order to identify potential problems and critical data to be collected. This allows the consultant to design the test to fit your specific setting and helps to ensure that the data collected will in fact represent your part of the aquifer and groundwater flow system.

What are some of the common mistakes?

- a. Inadequate planning. The most common mistake is not planning the test adequately beforehand. As a result the data is only marginally useful and any use of it is open to some question.
- b. Too short of test. We often see pump test data that is of limited duration, i.e. 1 to 4 hours. This data may be useful to evaluate the specific capacity of the well or to monitor the groundwater resource regionally, but is generally inadequate to define aquifer characteristics. The purpose of the test is to obtain representative values for those parameters that influence groundwater movement in the aquifer. The longer the duration of the test, the larger volume of aquifer involved and, therefore, the more representative is the data. Another issue here is the potential impact of hydrogeologic boundaries. These boundaries, e.g. streams, geologic contacts, groundwater divides, etc. may significantly affect groundwater flow in the area. Their presence can be recognized in a longer test, but may be completely missed in a test of limited duration
- c. Inadequate recovery. As has already been discussed, the important data that is collected is the amount of drawdown as a function of time in the given well. If the pump has been on just prior to the test and the water level in the well has not fully recovered, i.e. returned to its prepumping level, the drawdown recorded subsequently will not accurately reflect the pumping conditions during the test. As a result, the aquifer characteristics determined will be in error. The well should be idle for a minimum of 16 hours prior to the aquifer test.
- d. Inadequate corrections to drawdown. A number of factors other than pumping can influence the water level in the well during the test. These include long-term changes in the aquifer due to regional pumping or recharge effects, changes in barometric pressure (especially for confined aquifers), changes in surface water stage (especially for unconfined aquifers) and interference from nearby pumping wells. If these features are identified and monitored before and during the test, corrections can be made to the data.
- e. Poor monitoring practices. We have seen aquifer test data in which the water levels have been measured too infrequently or too imprecisely. Careful monitoring is critical to the utility of the data. We provide recommendations for frequency of monitoring water levels below.
With respect to field measurements, it is recommended that the pump rate be monitored on a two hour basis and the rate be maintained within 10 percent of its starting value. Significant variations in the pump rate pose large problems in interpreting the data.
Water level measurements should be determined to the nearest 0.01 feet. Tapes marked in tenths/hundredths of feet should be used as opposed to inches/feet. Time determinations should be

made to the nearest minute, and if more than one observer is involved, the measurements should be synchronous to within one percent of the time since pumping began.

- f. Improper conveyance of pumped water. The water brought to the surface during the pump test must be piped sufficiently far away from the production and monitoring wells so that it will not seep back into the ground and artificially recharge the aquifer in the vicinity of the well. This is particularly important for aquifer tests involving unconfined aquifers.

How do we collect the data?

Below we list OHD's current recommendations regarding the collection of data during the aquifer test's prepumping, pumping and recovery phases. These recommendations reflect discussions with staff at the Water Resources Department and review of literature pertaining to aquifer tests. It should be noted that these are general recommendations only, modifications may be necessary as dictated by the conceptual model and simulation results.

- 1- Duration. The pumping phase should be at a constant rate for a minimum of 24 hours for a confined aquifer and 72 hours for an unconfined aquifer.
- 2- Pump Rate. The pump rate should be a normal operating levels, but care must be taken to avoid the possibility of excessive drawdown, i.e. lowering the water level to the perforations or screens, during the test. It may be necessary to calculate the safe yield of the well and set the constant rate at 75% of that value.
- 3- Observation Wells. If other wells, e.g. domestic or irrigation, open to the same aquifer as the test well, are available in the vicinity, e.g. within 1000 feet, they should be identified as possible observation (monitoring) wells. The use of observation wells greatly enhances the ability to obtain representative data during the test. The conceptual model and simulation will provide information as to which wells can be used as a function of their depth and distance. If these observation wells are screened over different portions of the aquifer, corrections to the drawdown will probably be necessary. If the aquifer being evaluated is confined, it may be useful to select an observation well completed within the overlying unconfined aquifer to determine if there is any leakage from the overlying aquifer into the confined system.
- 4- Stream Stage. If there is a stream near the well being tested, and the conceptual model or simulation suggests a potential connection, it may be useful to periodically monitor the stage (depth and width) of that stream during the test.
- 5- Pre-pumping phase. The well to be tested should remain idle for at least 16 hours prior to the test. During that time, water level measurements should be made at 16, 12, 3, 2 and 1 hours prior to initiating pumping. Within the hour immediately proceeding pumping, water level measurements should be taken at 20 minute intervals. The purpose of this exercise is to establish any long-term trends in water level changes that may be occurring. Barometric measurements of atmospheric pressure (inches of mercury) should be made as well. Confined aquifers may show significant responses; e.g. 0.5 to 1 foot, to large changes (e.g. 1 inch of mercury) in atmospheric pressure. These measurements will allow for appropriate corrections to be applied to the drawdown data.
- 6- Pumping Phase. After initiation of the pumping, drawdown measurements in the production and observation wells should be made according to the schedule below. The most critical period of measurements are within the first 100 minutes, when the water levels are changing rapidly.

Time After Pumping Started	Time Intervals
0 -1 minute	(As frequent as practical)
10 minutes	1 minute
10 -100 minutes	10 minutes
100 - 300 minutes	30 minutes
300 - 1000 minutes	1 hour
1000 - 5000 minutes	4 hours
5000 - end	1 day

- 7- Recovery Phase. Water level measurements made during the recovery of those water levels after the pump has been shut down should be taken at the same frequency as the drawdown measurements during the pumping phase. As in the drawdown phase, the most important information is obtained during the first 100 minutes. Measurements should continue for the same duration as in the pumping phase, or until the water levels have reached 95% recovery.
- 8- Measurement Devices. Water level and flow rate measurement methods should be in accordance to Water Resource Department requirements (see "Pump Test Requirements for Ground Water Right Holders" distributed by the Department).

Who can perform aquifer tests?

Qualified individuals should perform aquifer tests. Registered geologists, engineering geologists or professional engineers, providing they have hydrogeological experience should perform the conceptual model/simulation phase. The actual test itself can be conducted by experienced individuals in the above professional groups as well as licensed well drillers and certified water rights examiners.

Where can I get more information on aquifer test?

There are many standard texts that address aquifer tests. Among the most useful are:

Groundwater and Wells, Driscoll, F.G., 1986, Johnson Division. [Excellent discussion of test procedures and methods of analysis.]

Groundwater Pumping Tests: Design and Analysis, Walton, W.C., 1987, Lewis Publishers, Inc. [Comes with a disk containing a number of BASIC programs that help in both the design of the test and the analysis of the data.]

Why do aquifer tests?

As indicated at the start of this article, the data derived from a carefully planned aquifer test can be utilized to identify the critical portion of the aquifer that supplies water to your well. With this information, you become a better water manager in that you will be able to contribute in an informed way regarding changes that may be occurring in and around your community and how those changes will impact the community's water supply.

From the perspective of groundwater protection, the aquifer test data is absolutely fundamental to developing a wellhead protection plan for your community because it is the basis for delineation of the wellhead protection area. The aquifer test data is the first step in developing an integrated plan for the use of your community's resources.