

# Chapter 10 - Aquifer Testing

## Introduction

A key area of interest for individual well owners and regulators alike is how much water a particular aquifer or well can produce. The most common and dependable way of establishing this is by pumping a well and measuring its response. This procedure is known as a pump test or aquifer test.

A typical aquifer test involves pumping a well at a constant rate for a certain period of time. The change in aquifer level at the pumped well, and in neighbouring wells is measured. From these measurements the aquifer or well hydraulic properties can be evaluated.

It will usually be obvious during the drilling process if a well will provide the volumes required for a domestic supply, without the need to carry out an aquifer test. However where larger volumes are required at certain times of the year, such as for frost protection, crop irrigation or town supply, it may not be as clear-cut. In this case detailed seasonal test information may be needed to select the most efficient pump type and to prove reliable flows exist.

The most frequently conducted tests are those carried out by drilling contractors following the successful completion of a new well (Fig. 10.1). These tests generally involve pumping the well for several hours to test the well's capacity. The test results can also be used to assess the value of the aquifer hydraulic properties of transmissivity and storativity. Knowledge of these wider aquifer parameters allows the performance of a well to be forecast into the future.

Where detailed information is needed, a more comprehensive test is carried out. These tests can last anywhere from 1 to 30 days and involve many wells, some at large distances from the pumped well. They normally involve pumping the well at a constant rate.

Over the years, numerous tests have been carried out by the MDC or its predecessors, and private well owners



Figure 10.1: A very large surface mounted pump being used to test the Bar test well (1733) during a 72 hour test in 1987



Figure 10.2: Peter Davidson manually dipping the depth to the water table during a pump test - 1987

for a variety of purposes. During the 1980s and 1990s, the focus of MDC testing was to measure the hydraulic properties of lesser understood aquifers, mostly in the Southern Valleys Catchments (Fig. 10.2).

Historically the MDC has been involved in some way either in a general role, by providing water level or flow measuring equipment, but this is less common in recent times. With the expansion of irrigated vineyard into areas where there are competing demands for groundwater, aquifer testing is increasingly required to quantify interference effects between wells. These are commissioned by private concerns and supervised by consultants rather than regulators.

## Purpose of aquifer testing

The key aim of a test is to determine whether there is sufficient groundwater available for the proposed use. The most important information that is collected as part of an aquifer test is the depth to groundwater and how that varies in response to pumping the well of interest, and how well water levels vary seasonally.

The most important index of well behaviour is the difference between the water level at rest and the pumping level, which is called the drawdown. Larger drawdowns are associated with higher pumping rates or lower producing wells or aquifers (Fig. 10.3).

The higher yielding an aquifer or well, the smaller the drawdown for a given flow rate and the faster water levels will recover once pumping stops. Generally drawdown increases the longer pumping continues and is greatest in the pumped well and reduces with distance (Fig. 10.4).

For an individual well owner, testing the productivity or efficiency of their well will be of prime importance. For MDC the wider characteristics of how transmissive it is and how much groundwater it stores, would be the focus for regional scale water management. The storage of an aquifer can only be calculated if there

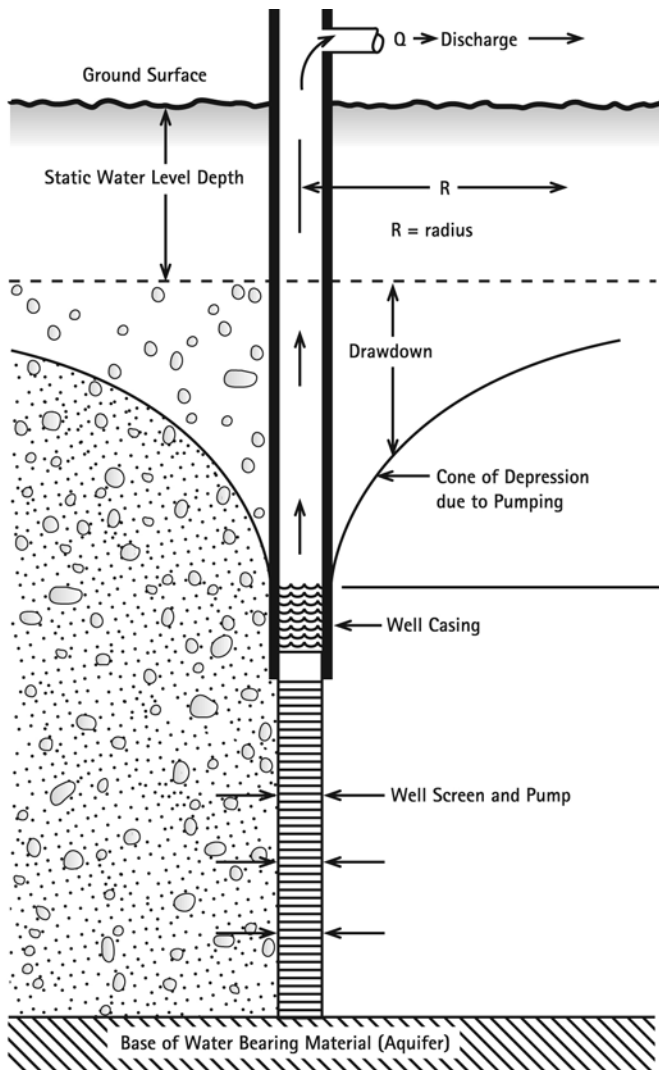


Figure 10.3: Definition of well terms

are measurements of the change in water level at observation wells. In other words there must be measurements in three dimensions over time to calculate a volumetric change in groundwater stored in an aquifer. Sometimes the information provided by pumping a single well will be all that is required, providing information such as aquifer transmissivity, well capacity and efficiency.

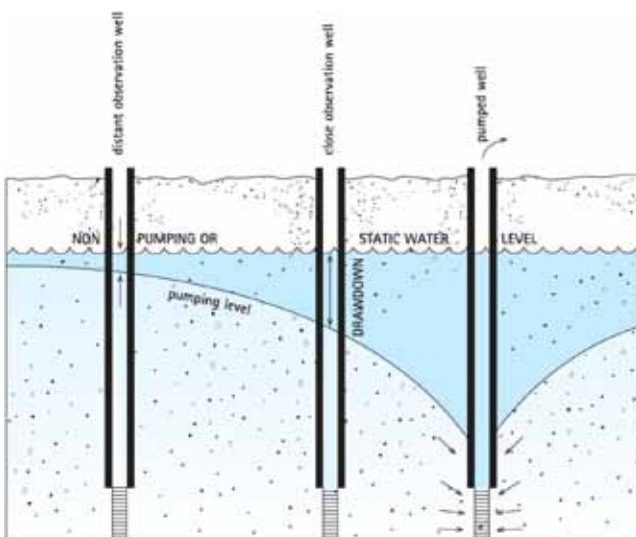


Figure 10.4: Aquifer test layout

No two aquifer tests are the same because of the uniqueness of aquifer properties and individual well circumstances. Generally tests in unconfined aquifers last longer than those performed on wells tapping confined aquifers. This reflects the naturally higher storage properties associated with unconfined aquifers, meaning that the effects of the pumping are spread more slowly over space and time. This delay is an important consideration if interference effects are being assessed.

The minimum duration of a test for an unconfined aquifer is usually three days, compared to one day for the same flow rate in a confined aquifer. The aim of the test will also have a major bearing on the test duration and must be looked at on a case by case basis.

Tests can be broadly split into those using a constant flowrate, and those with a pumping rate that varies over time. Step drawdown tests are a common type of variable flow test which involve pumping a well at a variety of rates over a short period for the purpose of measuring its yield and efficiency (Fig. 10.5). The analysis of this information allows the behaviour of the well to be mathematically described and provides a very useful way of forecasting its performance under different operating scenarios based on the well efficiency.

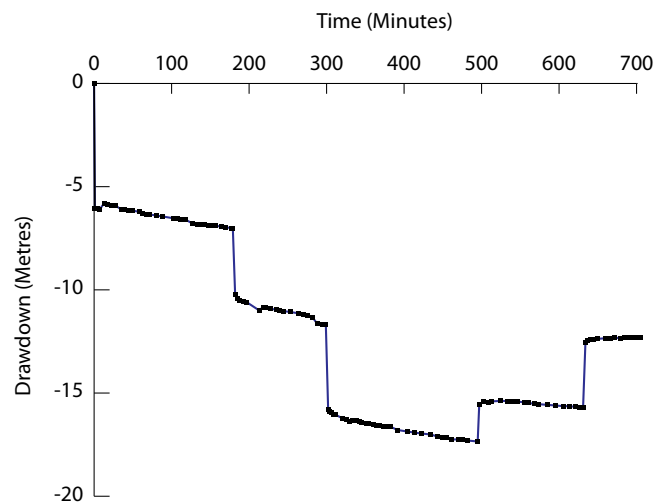


Figure 10.5: Step drawdown test procedure for well 0864 tapping the Benmorven Aquifer during the late 1980s. Each step represents a different flow rate

Constant discharge tests provide information about the interaction of a well with its neighbour, and just as importantly the nature of any aquifer boundaries. A commonly asked question is whether an aquifer is large or small or does a particular well interact with a nearby spring or river? The nature of the test results plotted in a standard manner can identify what are known as boundary effects with each type having a distinctive signature.

Large aquifers have more storage than smaller ones, and as a consequence the cone of depression developed when a well is pumped, is unlikely to expand radially outwards sufficiently far to intercept a boundary. However if a well tapping a geographically small or low yielding aquifer bounded by basement rock is pumped at a high enough rate, the drawdown will steepen over time. This indicates the cone of depression has intercepted the edge of the aquifer.

## Aquifer response to pumping

Wells respond in characteristic ways to pumping, which tell a story about their hydraulic properties and boundaries.

A feature of the drawdown generated by aquifer tests is the symmetry between the well or aquifer response during the initial drawdown phase caused by the pump starting, compared to the later recovery phase when the pump stops (Fig. 10.6).

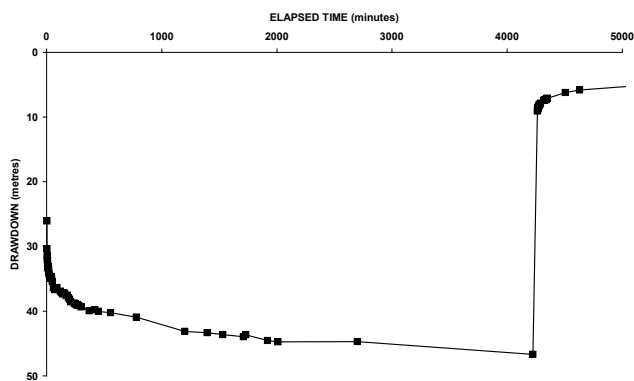


Figure 10.6: Constant discharge test well response for confined aquifer well 3291 tapping the Deep Wairau Aquifer in 1998

During a 1998 constant drawdown test carried out on well 3291 penetrating the Deep Wairau Aquifer, pumping occurred at a rate of 3,100 m<sup>3</sup>/day for three days (Fig. 10.6). The static or non-pumping pressure at well 3291 was measured to be 12.7 metres above the well-head prior to the test using a long clear hose and a cherry picker. This was almost as high as the nearby power lines.

A special type of drawdown response occurs within unconfined aquifers involving gravity drainage of groundwater (Fig. 10.7). During the first ten minutes of the unconfined aquifer test, the drawdown is similar to that of a confined aquifer with groundwater mainly being sourced by horizontal flow. During the middle part of the test the rate of drawdown starts to level off. This response is known as delayed yield and is caused by the vertical drainage of water stored in the overlying sand. In the later part of the test, after about an hour, this storage is used up and the curve starts to follow the response of a confined aquifer again.

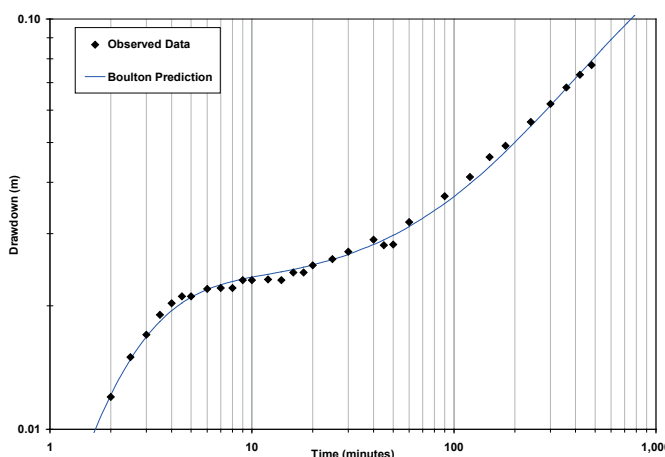


Figure 10.7: Constant discharge test well response for unconfined Rarangi Shallow Aquifer

## Aquifer boundaries

Distortions to the cone of depression occur when an aquifer boundary is encountered. There are two main types of boundary, an impermeable boundary such as bedrock and a recharge boundary such as a stream (Fig. 10.8). A steady flow allows the effects of aquifer boundaries to be identified.

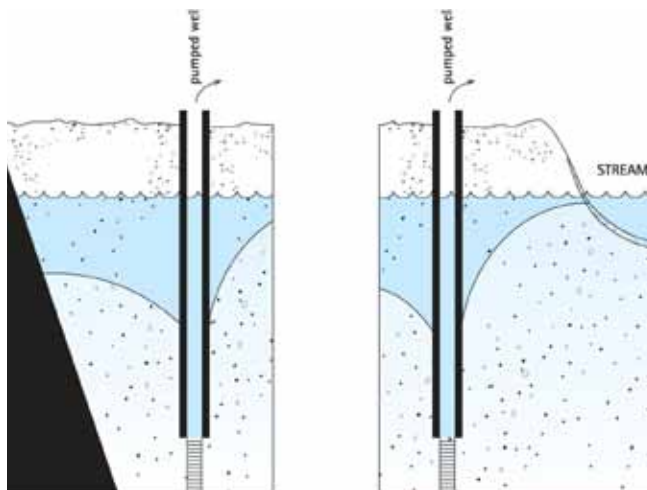


Figure 10.8: Aquifer boundary types

An example, the 1998 pump test of well 3278 showed two changes of slope at 900 and 1800 minutes, indicating the presence of several impermeable barriers nearby (Fig. 10.9). With a knowledge of aquifer storage it is possible to estimate the distance to these boundaries based on the travel time of the cone of depression and the time since pumping started. The time the cone of depression has taken to expand outwards to intercept this well coincides with the fall in well level at around 250 minutes, in which time it has travelled a distance of 1,600 metres. Water levels did not rebound to their original level after pumping stopped at 4,000 minutes. Instead of groundwater levels bouncing back, they have remained subdued. This indicates a low storage aquifer with more water being pumped out than is naturally replacing it and is consistent with the presence of boundaries and an aquifer of limited extent.



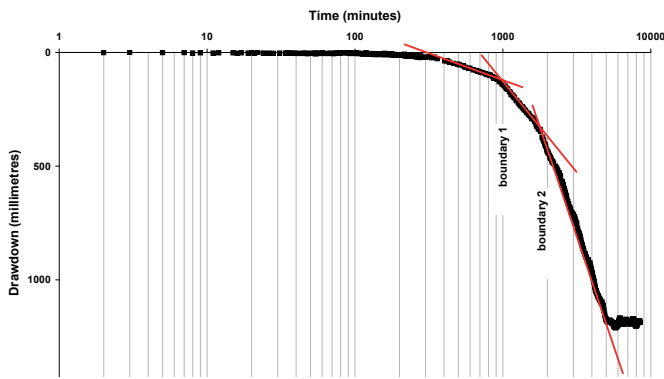


Figure 10.9: Multiple barrier boundaries at well 3278 located 1600 metres north-west of the pumped well.

The opposite occurs in an aquifer that is leaky or connected to a recharge source such as a nearby stream, as the drawdown curve will flatten over time as more groundwater is drawn into the aquifer in response to pumping (Fig. 10.10). In other words, the fall in groundwater levels is lessened.

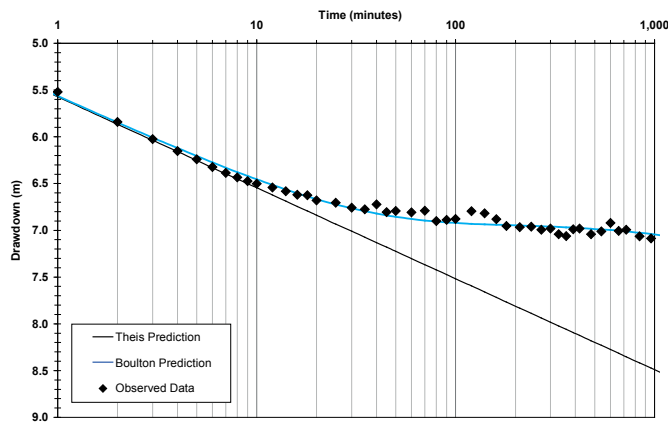


Figure 10.10: Drawdown test conducted on the Huia well 4402 in the Riverlands Aquifer

## Test methods and procedures

There are many practical difficulties to contend with when it comes to aquifer testing under Marlborough conditions. Most revolve around having stable environmental conditions so there is no external interference to the test. It is important to avoid recharge events such as heavy rain or river floods, or the influence of other pumping which can disturb drawdown measurements.



Figure 10.11: Manually measuring groundwater level in a shallow well (1856) at Benmorven in 1990



Figure 10.12: Temporary standpipe erected to measure the artesian pressures during the Benmorven Aquifer test in December 1990. The observer had to climb up the ladder and read the level of groundwater sitting in a clear plastic tube attached to the pole. This wasn't as easy as it sounds at night.

Some natural effects such as ocean tides are always present at coastal wells and can't be avoided, but can be allowed for. The measurements from longer term tests normally require correction as natural background changes in aquifer status either through drainage or recharge have a significant influence after several days.

Accurate measurement of test flows and the resulting changes in groundwater level, are essential for correctly evaluating aquifer and well hydraulic properties. In the past the depth to the water table was measured using an oversized tape measure which consisted of a calibrated tape with a weight on the end (Fig. 10.11). When the water table was reached, a circuit was completed and a light or buzzer went on at the surface. Automatic water level recorders are now more commonly used as they can take more frequent measurements, including the leadup and recovery phases.



Figure 10.13: Bar test well flow measurement. Three orifice flow meters were required to measure the large flows involved with the testing of the MCRWB Bar test well (1733) tapping the high yielding coastal Wairau Aquifer in 1987.



Figure 10.14: A single flow meter was sufficient for the small test rate used to evaluate the very low yielding Deep Wairau Aquifer involving the exploratory bore 2917 in September 1995. The person standing in the foreground is Mr C. Woodford, owner of Waimea Drilling Company Ltd. The rain which fell is less important when testing deep wells such as this where water bearing layers are several hundreds of metres below the surface.

Due to the presence of artesian groundwater levels during some tests, stand pipes consisting of clear plastic tubes are sometimes used to measure their elevation (Fig. 10.12).

Orifice flow meters have been the most common method of measuring test flow rates, although electronic meters are becoming more prevalent. Orifice meters work on the principle that the flow of water through a hole of a given size is proportional to the pressure in the vessel and measured in stand pipes (Fig. 10.13 and Fig. 10.14).

Another consideration is the recirculation of discharged groundwater back into the aquifer. This is a particular



Figure 10.15: Discharged test water being piped north along Mill Road at Wairau Valley to Mill Stream during the December 2006 MDC test.

problem in free draining, unconfined aquifers where water will rapidly return to the water table and cause drawdown measurements to be smaller than would otherwise be the case. To overcome this, water is piped well away from the measurement wells to avoid affecting them, often to a stream which has a sealed bed (Fig. 10.15 and Fig. 10.16).

One of the major differences in the test response of wells tapping high versus low yielding aquifers is the degree to which equilibrium conditions develop with time. When measurements show the water table remains at a constant depth over time this shows a balance exists between the rate groundwater is being pumped from the well versus the rate of aquifer recharge. This is referred to as steady state conditions and is commonly associated with high yielding or leaky type aquifers, and also where a stream is a major source of recharge.

Unsteady conditions reflect a falling well water table over time due to more water being removed from the aquifer than is being naturally replaced. This is the normal situation in low yielding aquifers such as those underlying the Southern Valleys catchments.

Unchanging or steady state conditions make it difficult to meaningfully interpret the value of aquifer hydraulic properties because they are masked by boundary influences. High yielding wells or aquifers require higher test pump rates than low yielding aquifers to generate sufficient drawdown to calculate aquifer properties. In turn this determines the pump size and affects how the test water is disposed of. All are important practical considerations.



Figure 10.16: Test discharge water being disposed of at RNZAF Base Woodbourne in the early 1980s. A lined trench has been excavated to allow water to be directed away without infiltrating back to groundwater.