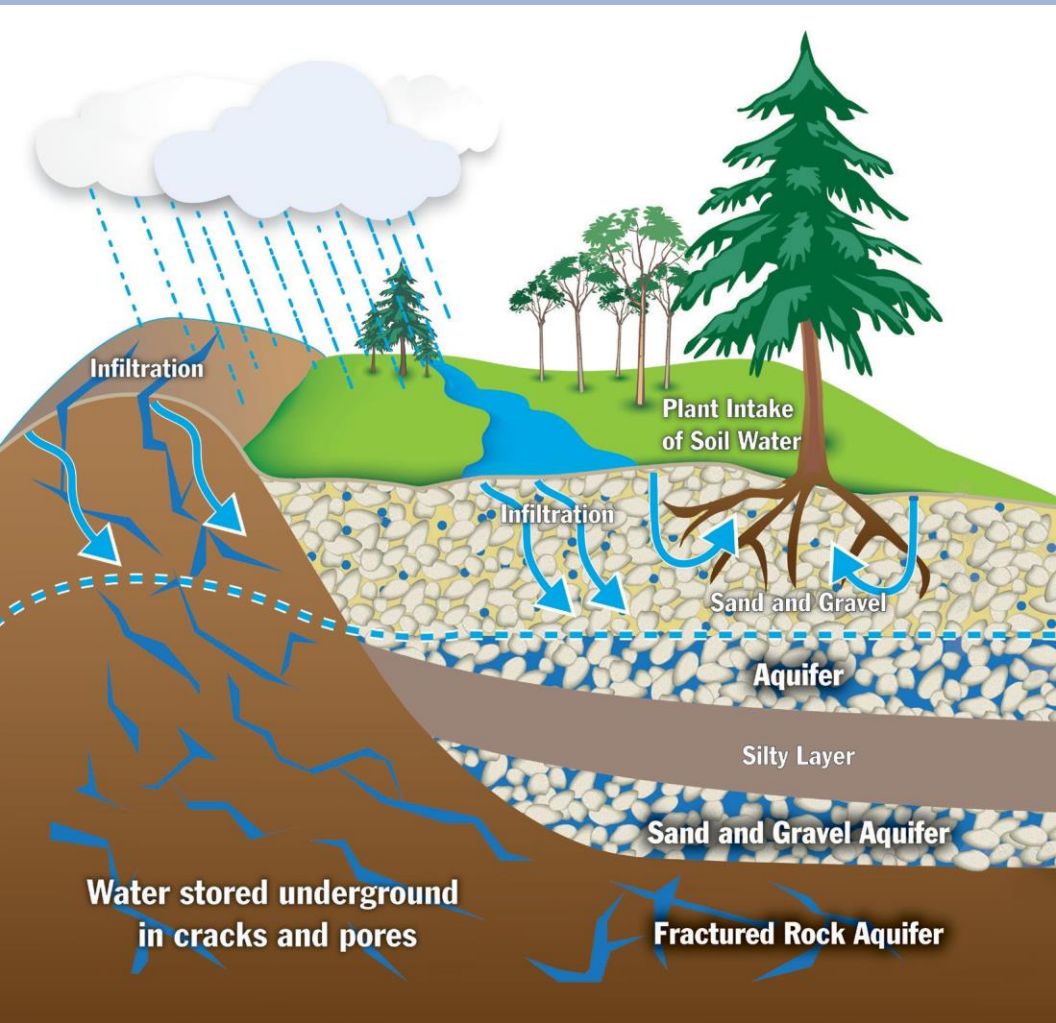
Aquifer Testing
GUIDELINES

Aquifer

...an underground water bearing formation from which groundwater can be extracted. Groundwater flows between interconnected pores in unconsolidated materials, such as sand and gravel, or though fractures in rock.



Introduction

Aquifer tests are used to calculate the quantitative parameters of an aquifer, such as how much sustained water can be produced by the aquifer and the storage capacity of the aquifer. Long-term aquifer tests are also referred to as pumping tests

This guideline provides general information on best practices based on the legislative authority to complete aquifer tests. The most important issues that this guideline will address and emphasize are:

- Good record keeping methods and
- Maintaining a constant pumping rate.

The guidelines are intended to provide this information to qualified well drillers, qualified pump installers, developers, and municipal governments. Most pumping tests completed in Newfoundland and Labrador are a collaboration between the Department of Environment and Conservation, the Department of Municipal Affairs, the municipality, the driller and the qualified professional who is overseeing the test.

Legislative authority

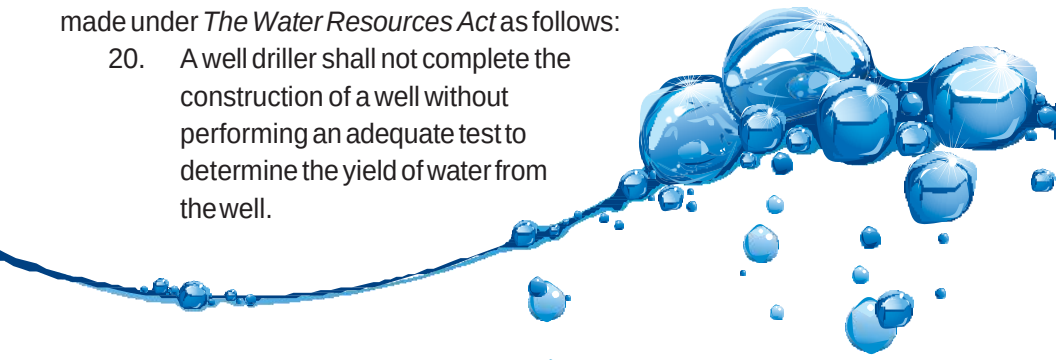
Provision for specifying the method and requirements to be observed in testing well yields is set out in **Section 64 (k)** of *The Water Resources Act* which reads as follows:

64. *The Lieutenant-Governor in Council may make regulations*

(k) Respecting the method and requirements to be observed in testing well yield, and respecting the control and use of the flow of water from a well during and after drilling operations.

The requirement for determining the yield of water from a well is set out in **Sections 20** to **22** of the *Well Drilling Regulations* made under *The Water Resources Act* as follows:

20. A well driller shall not complete the construction of a well without performing an adequate test to determine the yield of water from the well.



21. (1) Where a well is intended to supply water for domestic purposes to a single family dwelling unit, an adequate test for the purpose of **Section 20** shall be either, a bail test of not less *than one hour duration, or a pump test of not less than one hour duration, or an air lift test of not less than one hour duration*.

(2) A test made under subsection (1) shall be performed in a manner approved by the minister.

22. (1) *Su*bject to **subsection (3)** where a well is intended to supply water for any purpose other than set out in **Section 21**, an adequate test for the purpose of **Section 20** shall be a pump test of 6 to 72 hour duration depending upon the size of the proposed water supply system.

(2) The test make under subsection (1) shall include recovery measurements.

(3) The test and measurements made under this section shall be conducted in a manner approved by the minister.

(4) The results of any test or measurement made under this section shall be reported to the minister in the form required by the minister within 30 days of the completion of the test.

The purpose of these guidelines is to set out the requirements of the Department with regard to water well yield testing, as provided for in *The Water Resources Act*. The following sections specify who is responsible for carrying out the tests, what test procedures are recommended, how the tests should be conducted and the format in which the results are to be reported.

Types of aquifer tests under the well drilling act

Well yield tests and pumping tests are considered under the well drilling act. Well yield tests are explained briefly in the following section. Pumping tests are the primary concern of these guidelines and will be discussed in detail throughout this report.

Well yield test

Under **Section 21**, a well yield test of one hour duration is required. It is completed by a qualified well driller to provide a rough estimate of the well's yield. This yield value must be recorded in the well construction record by the driller. Ideally, well yield tests are completed by using a submersible pump such that a steady pumping rate is maintained. Water levels should be collected every minute for the first five minutes, every five minutes for the next 25 minutes and every 10 minutes for the remaining 30 minutes of the test. Bail tests and airlifting methods are much more common, though not recommended. Well yield tests are not as reliable as a pumping test when well yield is low, where maximum yield from the well is required, when reliable estimates of aquifer properties are needed, and when assessing impacts of proposed pumping on neighbouring wells.

Pumping test

Under **Section 22**, a constant rate pumping test between 6-72 hours is required for municipal water supply. A pumping test is a practical and reliable method of estimating well performance, well yield, the zone of influence of the well and aquifer characteristics, such as the ability to store and transmit water, aquifer extent, presence of boundary conditions and possible hydraulic connection to surface water.

A pumping test consists of pumping groundwater from a well at a constant rate and measuring water levels in the pumped well and in any nearby wells or surface water bodies during and after pumping (Figure 1). Drawdown data are used to plot drawdown and recovery (Figure 2).

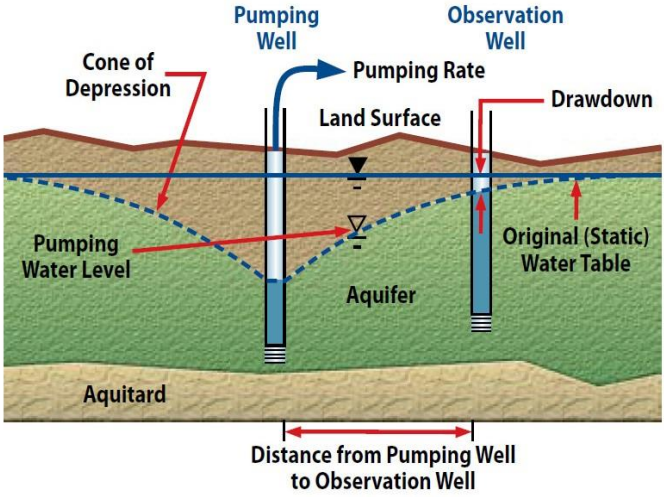


Figure 1. This cross section shows what occurs during a pumping test of an unconfined aquifer. As the water is pumped from the well, the water draws down forming a cone of depression surrounding the well. Drawdown in the observation well is much less than in the pumping well. Figure courtesy of BC MOE.

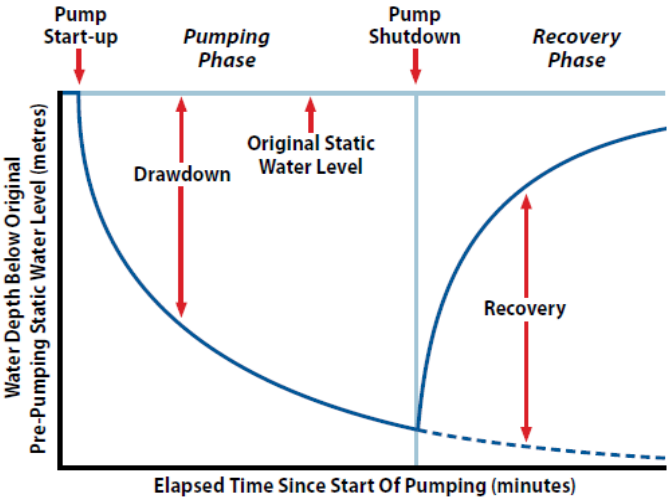


Figure 2. This graph shows the pumping and recovery phases of a pumping test. Figure courtesy of BC MOE.

Responsibility

The Regulations under the *Well Drilling Act* (**Section 20**) specify that the water well driller is ultimately responsible for testing the well. This responsibility applies to wells both for domestic, single family dwelling (**Section 21**) and for groundwater supplies that are intended for any other purpose (**Section 22**) non domestic well permit. The requirements of **Section 21** are usually met during the development phase water well construction. A professional geoscientist or engineer practicing hydrogeology, as defined in the *Engineers and Geoscientists Act* (2008), are ultimately responsible for the long term pumping test stipulated in **Section 22.** The work can be carried out by the driller under the direction of the groundwater professional on behalf of the owner of the well. The groundwater professional must prepare the report since the interpretation of the results is necessarily technical and involves the application of groundwater flow theory and principles of geology.

In the past, some conflicts have arisen in compliance with **Section 22** between the driller, the consultant, and the well owner. The responsibilities of each are sometimes not clear. While the regulations specify that the driller is responsible for the testing, the owner of the well will not get environmental approval for its use unless the necessary testing is completed and the results are submitted, in the required format, to the Department of Environment. It is, therefore, incumbent upon the owner to make sure that the necessary testing is done. These problems are eliminated if the driller includes the cost of the testing in his original estimate as outlines above, and retains a qualified consultant for supervision of the test and report preparation.

Planning a pumping test

Length of test

Section 22 of the Regulations, under the *Well Drilling Act*, specifies that a pumping test of 6 to 72 hour duration is required for wells that are intended for water supply purposes other than single family dwellings. A general rule of thumb has been to require a 24 hour test when the aquifer is composed of porous media and a 72 hour test when fractured media is involved. The greater time stipulated for fractured reservoirs is often necessary for two reasons:

1. Actual dewatering of the aquifer can take place, especially where there is shallow overburden (common in Newfoundland). However, the dewatering effects of pumping are often delayed.
2. The size of fractured aquifers is often limited and not well defined. The well may yield sufficient flow for many hours and then when the drawdown cone reaches the boundary of the aquifer the pumping level may drop quickly. Such effects may not be observed for many hours.

The following guidelines must be followed to meet the requirements of **Section 22**. The duration of the required aquifer test will depend both on the intended use of the water and the quantity desired.

- All wells constructed in fractured bedrock and that are intended for limited public or private use, at a rate not exceeding 22 L/min, must be tested for a minimum of 6 hours.
- All wells constructed in overburden materials (i.e. porous media) must be tested for a minimum for 24 hours.
- All wells that are constructed in fractured bedrock and that are intended for public or private use, at a rate not exceeding 45 L/min, must be test for a minimum of 24 hours.
- All wells that are constructed in fractured bedrock and that are intended for public use, at a rate exceeding 35 L/min, must be tested for a minimum of 72 hours.
- All wells that are constructed in fractured bedrock and that are intended for private use, at a rate exceeding 45 L/min, must be tested for 72 hours or until steady state conditions are reached, whichever is less.

Figure 3. In-line flow meter.

Figure 4. A bucket and stopwatch can be used to time the length of time to fill a container of known volume.

Figure 5. Example of a water level meter that can be used to manually collect water level data. www.solinst.com

Selecting pump level

In wells that are completed with well screens, the pump should be placed slightly above the well screen to maximize the available drawdown. The pump should not be placed within the well screen as increased groundwater velocities can cause screen plugging, sanding, casing deterioration. In bedrock wells with no well screens, the pump should be placed at, or slightly above the uppermost major water-bearing fracture that is noted on the well driller's record.

Pumping rate selection

Prior to commencing a long-term aquifer test, that a step drawdown test must be conducted to estimate the rate that can be maintained by the well for extended periods of time. The step drawdown test should consist of at least 4 steps and each step should be of at least 30 minutes duration. The pumping rates that are used for this test are determined from the driller's estimate of the well yield. If four steps are used, the first one

should be conducted at a rate of about one-quarter of the well yield estimate provided by the driller. This rate is maintained for 30 to 60 minutes and then the second step is at a rate that is approximately double the one before it. The step drawdown test must be evaluated by a qualified professional prior to the constant rate pumping test to evaluate a sustainable pumping rate.

Other considerations for setting the pumping rate include the recommended transmitting capacity of the well screen and that bedrock wells should not be overpumped to avoid turbulence that may damage the uppermost water bearing fracture and result in excessive turbidity in the water.

Pumping rate monitoring

It is very important that the pumping rate remain constant throughout the duration of the pumping test. Control of the pumping rate allows for reliable collection of drawdown data. A gate valve should be used to adjust the pumping rate. the pumping rate can be monitored using an inline flow meter (Figure 3), and inline calibrated pitot tube, a calibrated orifice weir or flume, or timing the length of time to fill a container of known volume (Figure 4).

During a constant rate pumping test, the pumping rate must be measured correctly and recorded regularly. In general, the lower the pumping rate, the more accurately the flow measurement must be. An unrecorded change of as little as two percent in the pumping rate can affect the interpretation of the data. The pumping rate should be set and stabilized as quickly as possible at the beginning of the test. Pumping rates should be recorded frequently at the beginning at the test (approximately every 15 minutes) and hourly thereafter. Checking the pumping rate allows for adjustments to be made if the rate has drifted, and confirms the selected pumping rate has been maintained. Adjustments to the pumping rate should be recorded along with the measured rate and water levels during the test.

Water level monitoring during and after the test

Water levels can be measured using water level meters (Figure 5) and pressure transducers (Figure 6). Pressure transducers should be used as back up measurements only and should be corroborated with manual water level readings using a water level meter. Pressure transducers must be calibrated with barometric pressure. A second pressure transducer can be used for calibration (Figure 6).

Initial conditions should be established by measuring static water levels in the well and any observation wells that will be used for the test. The same measuring point should be used on the top of the well casing for each well. If static water levels in the aquifer are changing due to recharge or other factors, a qualified professional should be consulted on establishing the water level prior to the test.

A pumping test form for reporting water levels collected during the pumping and recovery tests can be found on website for the Water Resources Management Division, Department of Environment and Conservation, with the guidelines. The recommended minimum intervals for measuring water levels during the pumping and recovery tests are included in Table 1. It may not always be possible to collect measurements at the specified intervals. Water levels should always be recorded with the actual time that the drawdown was recorded, even if it wasn't collected during the specified interval.

Recovery measurements should be collected at the same time intervals as was collected during the pumping phase of the test. Early time recovery data

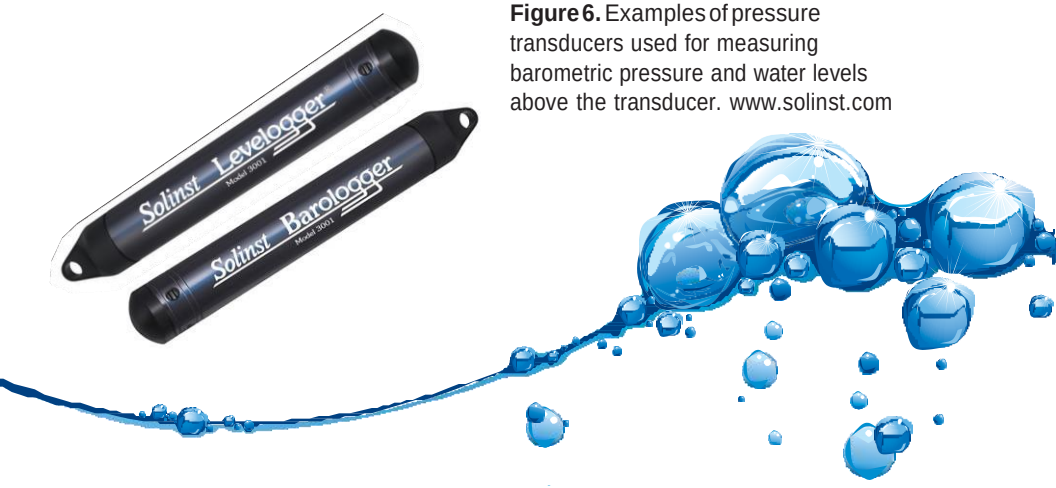


Figure 6. Examples of pressure transducers used for measuring barometric pressure and water levels above the transducer. www.solinst.com

is much easier to collect than early time pumping data since pumping rate variance and turbulence to the water is eliminated. To obtain accurate recovery data, a check valve should be installed at the bottom of the pump discharge pipe to eliminate backflow of water into the well. Recovery measurements should be monitored for the same duration of the pumping test or at least until 80 percent recovery has been achieved. The pump should not be removed from the well until the water level has returned to 80 percent of the pre-pumping or static water level. Pump removal should be recorded on the pumping test data sheet.

Table 1.
Recommended minimum intervals for water level measurements for pumping tests.

Water level measurement intervals During pumping and recovery:
Every minute for the first 10 mins
Every 2 mins from 10 mins to 20 mins
Every 5 mins from 20 mins to 60 mins
Every 10 mins from 60 mins (1 hour) to 90 mins (1.5 hours)
Every 20 mins from 90 mins (1.5 hours) to 120 mins (2 hours)
Every 30 mins from 120 mins (2 hours) to 240 mins (4 hours)
Every 60 mins (1 hour) from 240 mins (4 hours) to 1440 mins (24 hours)
Every 120 mins (2 hours) from 1440 mins (24 hours) to 2880 mins (48 hours)
Every 240 mins (4 hours) from 2880 mins (48 hours) to 4320 mins (72 hours)

Good record keeping is essential to interpreting the data collected from a pumping test. occaisionally, fluctuations in the water level will occur, due to nearby pumping of another well, sudden rainfall events, or tidal variations. It is important to note down data to record events that occur during the pumping tests. Key points to note are:

- Changes in the pumping rate;
- Any periodic cycling on and off of well pumps in the area;
- Staff changes during the pumping and recovery tests;
- Changes in equipment, such as the water level meter or pressure transducer;
- Time that the pump was pulled out;
- Precipitation that occurred during the test;
- Presence of sediments in the pumped water;
- Presence of odour from the discharged water, such as hydrogen sulphide; and
- Evidence of cascading water inside the well.

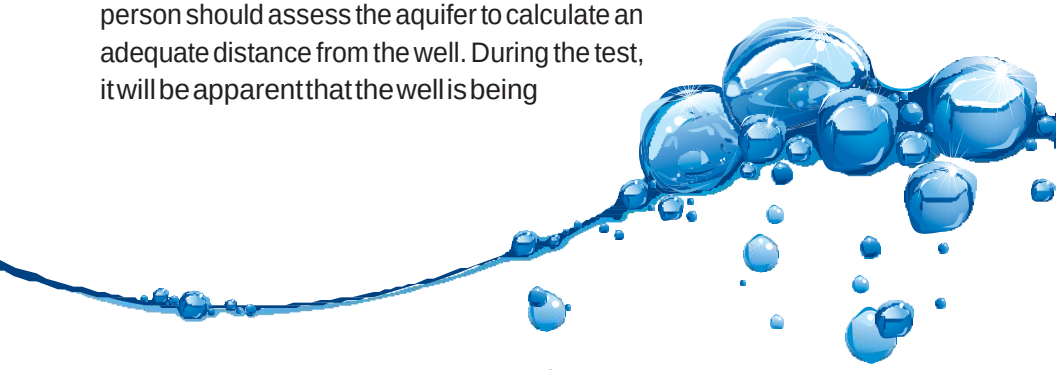
Observation well and surface water monitoring

Collecting draw down data from observation wells significantly increases the reliability of the pumping test interpretation. In addition, storage and distance/drawdown calculations can only be completed with observation well data. It is also important to monitor observation wells and surface water bodies if the pumping rate is high or neighbouring wells or stream levels could be impacted by the pumping.

Existing wells can be used if they are completed within the same aquifer formation and the well owner has provided consent. The observation well should not be pumped during the pumping test. Data should be collected in the observations well(s) at the same intervals as the pumping well.

Groundwater discharge during the test

Groundwater from the pumping test must be discharged such that the discharge water does not affect the pumping test or adversely affect a nearby surface water body. It is important to ensure that discharge waters do not cause erosion, flooding, or sediment deposits in surface water bodies. If the water is discharged on land, water must be discharged a sufficient distance from the well in a down gradient direction. A qualified person should assess the aquifer to calculate an adequate distance from the well. During the test, it will be apparent that the well is being



recharged by discharge waters (or a nearby surface water body) if water levels stabilize or recharge during the test. In urban settings, discharge water may be discharged to a storm sewer.

Water sample collection

A pumping test is an ideal time to collect water quality samples to assess the chemical, physical and bacterial properties of the water. Two water samples should be collected during the test, one within the first thirty (30) minutes and one within the last hour of the test. Water samples must be collected by the qualified professional and results must be reported with results of the pumping test.

Field measurements, such as pH, temperature, conductivity, alkalinity, dissolved oxygen, and turbidity, should be collected throughout the pumping test. A hand-held multi-probe with data logging capabilities is ideal for collecting field measurements.

Aquifer test interpretation

Pumping tests must be interpreted by a qualified professional with expertise in hydrogeology.

Report requirements

A technical report, containing the results of a pumping test, is required under **Subsection 22(4)** of The Well Drilling Act. The contents and format of this report should follow closely to that prescribed below. As the test data and analysis are of a technical nature it is advisable that the report be prepared by a qualified engineering or groundwater consultant. The well testing report, to the acceptable, must contain the following information:

1. A map of the well location.
2. A description of the site, including the general geology, hydrogeology, physiography, and climate conditions.
3. A quantitative and qualitative description of the intended use of the well, including the required yield.

4. A geologic log of the well and a copy of the Water Well Record as provided by the driller.
5. A listing of all water level measurements and pumping rates for the step-drawdown test, the aquifer test and the recovery test.
6. An analysis of all tests for the determination of optimum yield, including all graphs and calculations.
7. A discussion of the results in light of the required yield and recommendations for the optimum use of the well.
8. A water quality analysis showing the total and fecal coliforms and the following chemical and physical parameters:

Approval

Reports that do not meet the above requirements will be returned for alterations/additions. Approval may not be granted for distribution systems or subdivisions where the required testing has not been completed or where no report is available.

References

British Columbia Ministry of the Environment. Guide to Conducting Well Pumping Tests.
www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/guide_to_conducting_pumping_tests.pdf

Sterret R.J., 2007. Groundwater and Wells. 3rd edition. New Brighton: Johnson Screens.

Fetter, C.W., 2001. Applied Hydrogeology. 4th edition. Prentice Hall.

Contact Information

Groundwater Manager

Water Resource Management Division
Environment and Conservation
4th Floor Confederation Building
West Block
709.729.2563
groundwaterinfo@gov.nl.ca

Newfoundland Labrador

Environment and Conservation