Guidelines for Groundwater Reports and Well Testing in Support of a CPCN[1]

1. General Information

Well performance and aquifer capabilities must be adequately assessed where a groundwater supply is to be developed for community use. Certain procedures must be followed in well testing and the presentation of groundwater information to the Comptroller of Water Rights for a CPCN under the Water Utility and Utilities Commission Acts. The intent of these requirements is not to lay down rigid rules but to avoid unnecessary delays or retests at the applicant's expense due to inadequate test procedures or report presentations. The Comptroller will, on request and with the assistance of the Groundwater Section, review the requirements for any particular case with the applicant or the applicant's professional hydrogeologist[2] prior to the well test.

2. Retain a Professional Hydrogeologist at the Start

The applicant is advised to retain the services of a consulting professional hydrogeologist before the well is drilled and tested. In the past, some applicants have had the well drilled and/or tested prior to hiring a professional hydrogeologist. In these cases, the professional hydrogeologist would not have had adequate input into the well siting, design, and testing stages of the work. This has resulted in having to retest and, in some cases, re-drill the well because testing was inadequate or the well was not properly sited or constructed.

The need for a professional hydrogeologist can not be over-emphasized. Retain a hydrogeologist to design, supervise and report on the development of the groundwater supply from start to finish to ensure adequate well construction and testing procedures are followed.

[1] This document also replaces Appendix No. 5, Community Water Supply Wells – Groundwater Reports and Well Tests in Support of a Certificate of Public Convenience and Necessity in *Guidelines for Minimum Standards in Water Well Construction, Province of British Columbia* (1982).
[2] A professional hydrogeologist is a person who is registered as a Professional Geoscientist (P.Geo.) or a Professional Engineer (P.Eng.) with the Association of Professional Engineers and Geoscientists of British Columbia with competency in the field of hydrogeology.

3. Contents of the Groundwater Report

The final groundwater report presented should discuss such points as:

1. water supply requirements,
2. well design, construction and development methods,
3. well lithology and hydrogeologic setting,
4. type of aquifer and aquifer boundaries,
5. recharge conditions,
6. well interference,
7. potential impact on licensed water users and existing wells,
8. water quality,
9. possibility of pollution, including salt water and other unpotable water,
10. long-term well capacity and how it was calculated,
11. recommendations on operation of the well, e.g., over pumping, backwashing, raw hiding, redevelopment, etc.,
12. recommendations on a future monitoring program, installation and monitoring of observation well(s),
13. recommendations on well and aquifer protection, e.g., estimating the recharge area to the well, identifying the potential groundwater protection issues in the area and outlining a well protection plan to address those issues.

The report should include a site plan showing locations of the well sites, locations of any unsuccessful test well sites, and any neighbouring wells. Show the sites in relation to existing gazetted roadways, streams and lakes, sanitary land fills, septic field disposal, and the boundaries of any municipalities, improvement districts, etc., in the vicinity. The site plan should show the locations of water sources of other water works within 1 km (one half mile) of the boundaries of the proposed utility. The location of any wells that may be affected through interference by pumping of the applicant’s well should also be indicated. Show the legal description of the proposed well site areas, including registered plan and lot numbers as assigned by the Local Land Registry Office. Approximate elevations (to within +/- 0.5 m) should be given on each well and on important adjacent features such as lake levels, river levels, etc. This is especially important for wells located near the ocean, since the pumping water level relative to sea level is a determining factor in estimating well capacity.

The report should contain a copy of the well driller's original log for every hole drilled under the program, and also a sketch showing well design specifications for each completed well. For wells completed in fractured bedrock, report the location and flow rate of each major water-bearing fracture. Details should be given of the pumping equipment used, and the method of measurement for water well readings and for flow.

The report should also include a cross-section(s), where appropriate, showing the subsurface hydrogeology, location and extent of the aquifer, and known piezometric water levels. Relevant information (e.g., location of other wells and main topographic features) should also be shown. Indicate the location of the cross-section(s) on the site plan.

4. Well Testing

There are standard procedures for pumping tests, recording of data (e.g., Driscoll, 1986) and report preparation. For example, the drawdown and recovery measurements in the pumped well and in the observation wells should be measured in metres to the nearest 0.005 metre (or feet to the nearest one hundredth of a foot). The time intervals for both drawdown and recovery readings should be short enough to adequately record any rapid drawdown during start of pumping and any rapid recovery immediately after pump shut-down. The time interval after these initial periods can of course then be lengthened between the readings. The pumping rate Q is to be expressed in litres per second (L/s) or U.S. or Imperial gallons per minute. The pumping rate Q is to remain constant throughout the period of pumping, in the final "constant rate" test. This test will involve continuous pumping at a constant rate for 24 hours or longer (see below). Step drawdown tests or "maximum drawdown" tests can be used initially to determine the Q rate.

To prevent well water from returning to the aquifer during the pumping test period, lay sufficient discharge pipe away from the test well. Refer to the tables at the end of this section for the type of information to be recorded in pumping and recovery tests. Report records of any rainfall, tidal variation, or barometric variation immediately before, during and after the well test, if applicable. Also report the start and stop of pumping of any nearby wells that may interfere with the drawdown in the pumping well.

Boundary Conditions

If recharge or discharge boundaries are detected, then more frequent measurements are also recommended. This can best be done by returning to the time interval set out for the start of the test, i.e., "every minute from 1 to 10 minutes," etc. It is important to continue pumping long enough to establish the drawdown trend affected by the boundary condition. The physical basis for the interpretation of the type of boundary condition should be explained. For example, did the water level in the pumping well stabilize because of induced infiltration from a nearby lake or because of an increase in aquifer transmissivity? What physical evidence is there?

Induced Infiltration

This condition could apply in well sites located adjacent to a surface water body: river, lake, etc. If equilibrium test conditions are clearly shown, that is, a stable water level in the well in conjunction with a uniform rate of pumping, the test may be terminated prior to the recommended standard 24 hour pumping period.

Fractured Bedrock

For wells located in fractured bedrock, the pumping rate should be at or in excess of the supply requirements of the application. Hold the pumping rate constant throughout the testing period, which should last for a minimum of 72 hours. Report the location and estimated flow rate of each major water-bearing fracture in the well. In the Gulf Islands and in coastal areas wells should only be tested in the middle and late summer and early fall periods when recharge is minimal. In the interior of the province, wells are only to be tested in the fall to spring period when water levels are not affected by snow melt. The applicant and professional hydrogeologist should coordinate their activities to conduct well testing during the stipulated periods. This would avoid unnecessary delays and facilitate a more accurate estimate of well performance.

It is also recommended that prior to testing wells completed in fractured bedrock, public notices be posted in the local area or written notices be provided to neighbouring property owners to inform residents that a pump test will be conducted. The residents can bring forward for consideration, prior to the pump test, any concerns or requests for having their well monitored, so these concerns can be addresses.

Flowing Artesian Condition

In this special case it is essential to check the artesian pressure head prior to and after a pumping test to assess whether the water level recovers completely after pump testing. The artesian pressure is usually measured with a pressure gauge sealed at the well head; at least two readings, before pump testing and after recover, should be made.

Sometimes the artesian pressure head is not measured but is assumed to be at ground level (or top of casing). This assumption, however, causes the available drawdown in the well to be under-estimated, resulting in a lower capacity calculated for the well and does not allow recovery after pump testing to be adequately assessed.

Coastal Aquifers

It is important that the recommended procedures for taking samples of the pumped well water for full chemical analyses be followed.

It is also strongly recommended that a field test kit be available for testing specific conductance and/or the chloride content of the pumped water during the pumping test. The field kit should measure specific conductance to within +/- 5 μS/cm and chloride to within +/- 5 mg/L. The purpose is to try to determine possible sea water encroachment. The professional hydrogeologist should determine, prior to the pump test, the maximum specific conductance and/or chloride concentration that should not be exceeded during pumping. If encroachment is evident, the pump test may have to be terminated. In coastal aquifers the professional hydrogeologist should include data on local tidal fluctuations where these are affecting the apparent drawdown in the test well. Tidal effects should be filtered out of the drawdown and recovery data prior to interpretation (see Dawson and Istok, 1991, for techniques). The elevation of the pumping and non-pumping well water level should also be reported (to within +/- 0.5 m) because the water level relative to sea level may affect how the long-term well capacity is calculated for wells in coastal aquifers.

Developed Springs and Seepage Sites

In the case of springs and seepage areas developed by excavation into ponds and "holding reservoirs" the following procedures are recommended. The excavation dimensions should be measured. Pump the reservoir dry (if practical) and take recovery measurements as specified above. Obtain the full recovery. Make notes regarding entry of water into the excavation where possible.

5. Water Quality

Take at least one sample of the pumped well water near the end of the pump test and send it for chemical analyses. The analyses should include all major ions, iron and manganese, and tests for other metals if known to be present in the groundwater of the area. A list of recommended parameters is given in Section 1. Preferably, take two water samples; one near the end of the pumping test and one near the beginning of pumping, e.g., almost one hour after start of pumping. The professional hydrogeologist is expected to make arrangements with a commercial laboratory for this service. Adhere to the laboratory's requirements for sample collection, handling and delivery. Take samples for bacteriological analyses according to the requirements specified by the local health authority. (See Section 2.)

In reviewing water quality for water supply wells, the Groundwater Section, Ministry of Water, Air and Land Protection, considers the following:

1. the cation/anion charge balance of the sample and the amount of total versus dissolved concentrations to check gross errors,

2. potability of the water for intended use, and

3. potential for the water to encrust or corrode, which may affect maintenance costs and operational life of the well.

In addition to collecting samples for laboratory analyses, water quality should be monitored in the field with field analysis kits. Two water quality parameters recommended for monitoring in the field are pH and specific conductance. Measurement of field pH is important because pH in the sample bottle may change during transit to the laboratory. Measurement of specific conductance may provide clues to potential for sea water encroachment or interception of source of surface water recharge, for example.

6. Well Interference

Assess the impact of pumping of the water well on other private wells in the area. In assessing well interference, the hydrogeologist should measure drawdown in nearby wells, wherever possible during the pumping test.

7. Impact on Licensed Water Users

Assess the impact of pumping of the water well on surface water and springs in areas where water licences are known to exist. It may be necessary to monitor flows of nearby spring and surface water sources during the pumping test.

8. Estimating Well Capacity

In reviewing long-term capacities for water supply wells, the Groundwater Section, Water Management Branch, considers the following four main criteria:

1. adequacy of the pump test procedures,
2. the performance of the well as indicated by the long-term specific capacity,
3. the available drawdown in the well,
4. other factors that may impact well capacity.

Pump test procedures are discussed above. In assessing well performance, the well's specific capacity after 100 days of continuous pumping is estimated from the drawdown data. The 100 days of continuous pumping represent a period where no recharge occurs (summer and fall months in coastal areas and fall and winter months in the interior). Recharge is assumed to occur annually with winter rains or snow melt. The available drawdown in a well is typically the distance between the non-pumping water level and the top of the well screen, top of the confining layer, to sea level, to the uppermost major water-bearing fracture (bedrock well), depending on the appropriate situation. A safety factor, usually 30% of the available drawdown, is allowed in calculating the well capacity. Estimate well capacity by multiplying the specific capacity at 100 days with the safe available drawdown in the well (total available drawdown minus the 30% safety).

Other factors that may affect well capacity, such as well interference, impact on licensed surface water, aquifer mining, sea water encroachment, for example, are considerations in estimating the long-term capacity.

The estimated capacity for the well **should not exceed** the flow rate at which the well was pump tested. One exception would be if the pump test results indicate that the aquifer's yield is significantly greater than the well requirements.

9. Special Requirements Attached to the Certificate

Certain conditions may be attached to the certificate with regard to the well source. For example, further collection of data during subsequent well operations and possibly a hydrogeological report may be needed. These special requirements may be applied where legal problems arise in the development of groundwater supplies, such as groundwater withdrawals affecting stream and spring flows which may be under licence, where supplies of water to an adjacent well may be affected by pumping or where a producing aquifer is suspected of being limited in extent or capacity.

10. References

Dawson, K.J. and J.D. Istok, 1991. Aquifer Testing-Design and Analysis of Pumping and Slug Tests. Lewis Publishers, Inc., Chelsea, Michigan, 344 pp.

Driscoll, F.G., 1986. Groundwater and Wells. Second edition, Johnson Division, St. Paul, Minnesota, 1089 pp.

Ministry of Environment, 1982. Guidelines for Minimum Standards in Water Well Construction, Province of British Columbia. Groundwater Section, Water Management Branch, 35 pp.

11. Acknowledgements

We thank A. Badry, P.Geo., B. Ingimundson, P. Geo., L. Topp, P. Geo., and G. Wendling, P. Eng., for reviewing a draft of this appendix and providing useful comments.

Pumping Test

Depth to water in well from top of casing before test: ___________ metres

Time	Time Since Start of Pumping (minutes)	Depth to Water in Well from Top of Casing (metres)	Discharge from Well (litres/minute)	Field water quality measurement	Comments

For the above table, readings should be taken every minute from 1 to 10 minutes and then every 10 minutes from 10 to 120 minutes (2 hours), then readings every 1½ hours thereafter.

A preferred method for ease in plotting the data, but one that is harder to comply with is as follows:

1. Readings every 30 seconds from 1 to 5 minutes
2. Readings every minute from 5 to 10 minutes
3. Readings every 2 minutes from 10 to 20 minutes
4. Readings every 5 minutes from 20 to 50 minutes
5. Readings every 10 minutes from 50 to 100 minutes
6. Readings every 50 minutes from 100 to 500 minutes
7. Readings every 100 minutes thereafter

Whenever possible, monitoring of the drawdown and recovery in other wells in the vicinity is recommended. Electronic data loggers can be used to measure the well water level but the logger readings should be calibrated through manual readings.

Recovery Test

Time	Time Since Start of Pumping (minutes)	Time Since Pumping Stopped (minutes)	Depth to Water in Well from Top of Casing (metres)

For the above table, readings should be taken every minute from 1 to 10 minutes and then every 10 minutes from 10 to 120 minutes (2 hours), then readings every 1½ hours thereafter. Slow recovery may require that the last readings be spaced as much as 8 to 12 hours apart.

A preferred method for ease in plotting the data, but one that is harder to comply with is as follows:

1. Readings every 30 seconds from 1 to 5 minutes
2. Readings every minute from 5 to 10 minutes
3. Readings every 2 minutes from 10 to 20 minutes
4. Readings every 5 minutes from 20 to 50 minutes
5. Readings every 10 minutes from 50 to 100 minutes
6. Readings every 50 minutes from 100 to 500 minutes
7. Readings every 100 minutes from 500 to 1,000 minutes
8. Readings every 500 minutes from 1,000 to 5,000 minutes

Section 1

List of Recommended Parameters for Chemical Analyses*

	Units
Phen. Alkalinity	mg/L
Total Alkalinity	mg/L
Sulphate ($SO_4^{=}$)	mg/L
Nitrite-Nitrogen and Nitrate-Nitrogen (NO_2-N + NO_3-N)	mg/L
Total Kjeldahl Nitrogen (TKN)	mg/L
Total Phosphorous (P)	mg/L
Fluoride (F^-)	mg/L
Chloride (Cl^-)	mg/L
Calcium (Ca^{++})	mg/L
Magnesium (Mg^{++})	mg/L
Sodium (Na^+)	mg/L
Potassium (K^+)	mg/L
Manganese (Total and dissolved) (Mn)	mg/L
Iron (Total and dissolved) (Fe)	mg/L
Silica (SiO_2)	mg/L
Sp. Conductance	□mhos/cm at 250°C
pH	relative units
Total Dissolved Solids (T.D.S.)	mg/L
Total Hardness ($CaCO_3$)	mg/L
Turbidity	(J.T.U.)

- Additional parameters may be required by the local authorities where known or suspected sources of pollution or naturally occurring water quality concerns exist (e.g., Arsenic, Uranium, Volatile Organic Compounds). In the Vancouver Island and Coast Garibaldi regions, the local health authority may require additional parameters for analysis, depending on whether the well is shallow or deep (e.g., colour, total or dissolved organic carbon, ammonia, turbidity, sulphide, metals, iron and sulphate reducing bacteria).

Section 2

Bacteriological Quality and Collection Procedures

Take a sample on all wells to determine bacteriological quality. For new or repaired wells AWWA AIOO-66 recommends collecting any sample for determination of bacteriological quality following the disinfection of the well. First remove chlorine solution from the well by pumping, and reduce chlorine residual to less than 2 ppm before the sample is taken. Take special care in collecting the sample to avoid contacting the inside of the bottle or the cap with fingers. Request that the local public health inspector obtain a sample for bacteriological analyses when the water is to be used for a public water supply system. In situations where this is not possible, obtain sample bottles and advice on sampling techniques through the local health district.

Reliability of Sample Results

The quality of any drinking water supply cannot be determined with confidence from the result of a single sample. Determining water quality is possible only by observing the results of several samples over a long period of time. Shallow wells that may be influenced by surface contamination near the well may produce water of varying quality depending on the climatic and physical conditions. Therefore, if a sanitary survey shows a well water supply to be obviously subject to pollution, the water may be condemned regardless of the test results.