Otago Regional Council - Aquifer test requirements

1.1 What is an aquifer test?

An aquifer test consists of pumping a bore at a specified rate for a certain duration and recording the change in water levels (drawdown) in the pumped and observation bores[1] at prescribed time increments. The monitoring of water levels in the pumped bore and observation bores then continues after the pumping ends until the water levels recover (i.e., return to the level before the start of pumping).

1.2 What is the purpose of an aquifer test?

The test provides key information on bore performance and the response of the aquifer to groundwater abstraction. It is a reliable way to "stress test" the aquifer at (or above) the proposed rate of take.

The results from the test form an important part of the application to take groundwater, providing key information for both the bore owner and Council who manages Otago's groundwater resources. The results help determine the volumes and rates of water that a bore can yield and are also necessary for determining aquifer parameters. These parameters are needed to assess the effects of the groundwater take on surrounding bores (i.e., does pumping causes the levels in surrounding bores to fall and by how much?) and surface water bodies (i.e., does it reduce their flow?).

This document summarises ORC's guideline for planning and implementing aquifer tests. Further information regarding the purposes, use, and undertaking of aquifer tests is provided in Aitchison-Earl & Smith (2008).

https://api.ecan.govt.nz/TrimPublicAPI/documents/download/1058665

1.3 How do I perform an aquifer test?

An aquifer test requires careful preparation and planning. It must be designed, managed, and analysed by a **suitably qualified and experienced** groundwater scientist or engineering equivalent. When planning the test, it is important to anticipate the potential effects of the groundwater take (e.g., on surrounding bores, surface water bodies, saltwater intrusion) and design the test so it will suitably monitor these impacts.

If the test is **not of sufficient quality** your groundwater take application **may be returned or the test may need to be repeated to an appropriate standard.** It is therefore strongly recommended that you discuss your aquifer test plan with the Council's groundwater scientists **prior to the test**. This can be done by emailing a detailed aquifer test plan to **aquifertests@orc.govt.nz**. Please put the bore consent number/water take application number/address in the subject line of the email.

[1] nearby bores where water levels are recorded during the test but are not pumped

1.4 What are the types of aquifer tests?

There are two main types of aquifer tests:

- **A Step Test** consists of pumping the bore at several increments (steps) where the pumping rate increases at the end of each step (i.e., without stopping the pumping between the steps). All steps should be of the same duration, preferably 1 hour. This test and its analysis provide a quick and economic way for the bore owner and Council to obtain the following key information:
    - Bore production rate and volume
    - Bore and screen efficiency
    - Optimised pump size and depth (which will save costs to the bore user)
    - Allocation of correct rate/volumes from the bore
    - A broad estimate of aquifer Transmissivity
    - Repeating a step test every 10-15 years can also determine changes in bore performance and identify whether further maintenance is needed (e.g., flushing the bore to remove silts that can clog it up)
- **A Constant Rate Discharge** test consists of pumping a bore at the same rate for a minimum of 1 day and recording the changes in groundwater level (drawdown) in the **pumped and surrounding observation bores**.

A Step Test mainly provides information on the pumped bore. Conversely, the longer duration and data from observation bores collected from a Constant Rate Discharge test provide good estimates of aquifer parameters like *Transmissivity*[2] and *Storativity*[3], alongside additional parameters such as leakage coefficients and boundary conditions (if present). These parameters are then used in the groundwater take application to assess the impact of pumping on surrounding bores and surface water bodies.

1.5 What are the specific aquifer test requirements?

The requirements for Step/Constant Rate Discharge tests are based on the proposed rate and volume of take from the bores and generally increase with higher rates/volumes. The requirements are summarised in Table 1 and further details are provided below. Specific requirements for Step and Constant Rate Discharge tests are provided in sections 1.7 and 1.8.

[2] The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It is a function of the aquifer material and the thickness of the porous media (Fetter, 2014)

[3] The product of the volume of water released per unit of porous medium per unit change in hydraulic head and the aquifer thickness (Fetter, 2014).

Table 1: Summary of aquifer test requirements

Maximum daily volume (rate of take)	Test type & duration	Monitoring bore requirements
<435m^3/day (or <5 Litres/second [L/s])	Step test	Pumped bore only
435 to 864 m^3/day (or 5-10 L/s)	Minimum 24 hours Constant Rate Discharge test	**Unconfined aquifers**: water levels must be monitored in the pumped bore AND **at least one** more observation bore located within the area of localised drawdown and screened in the same aquifer as the pumped bore. **Semi confined/confined aquifers:** water levels must be monitored in the pumped bore AND at least one observation bore in the source aquifer (i.e., screened at a similar depth as the pumped bore) AND at least one monitoring bore in the overlying aquifer (i.e., Semi confined/confined aquifers will need more monitoring bores).
>864m^3/day (or >10L/s)	Minimum 72 hours Constant Rate Discharge test	**Unconfined aquifers**: water levels must be monitored in the pumped bore AND **at least two** more observation bores located within the area of localised drawdown and screened in the same aquifer as the pumped bore. **Semi confined/confined aquifers:** water levels must be monitored in the pumped bore AND at least two observation bores in the source aquifer (i.e., screened at a similar depth as the pumped bore) AND at least one monitoring bore in the overlying aquifer within the area of localised drawdown (i.e. Semi confined/confined aquifers will need more monitoring bores).

1.6 What are the general aquifer test requirements?

The following requirements apply for **both** Step and Constant Rate Discharge tests:

1. The pumped bore has been **fully constructed and developed** (removal of fine material from the well screen by pumping/surging) before the test. Otherwise, the test may further improve the bore yield which will distort the analysis.
2. The groundwater level needs to be stable and recorded (using loggers) in the pumped bore and all observation bores before the test starts (24 hours before a Step test and 48 hours before a Constant Rate Discharge test). The **initial water level** right before the start of the test **must be recorded** in the monitoring sheet.
3. The **pumping rate** must be monitored and recorded automatically (e.g., using a flow meter) or manually (e.g. by measuring the amount of time it takes to fill a container with a known volume). Automatic monitoring should be done at 1-minute intervals during the test with a minimum accuracy of 95%. The automatic monitoring should also be regularly confirmed throughout the test using manual measurements. These should be **recorded in the monitoring sheets** below.

   The manual flow monitoring should be done in the following frequencies:

- **Step test:** manual flow rate monitoring should be at 1-minute intervals for the first ten minutes of **each step** then every 5-10 minutes or until the pump rate is very stable (Appendix 1). This frequency should be repeated for each step of the test.

  Step test manual data sheet

  Constant Rate Discharge test: manual flow monitoring should be at 1-minute intervals for the first 10 minutes then every 5-10 minutes until the pump rate is very stable. Further measurements should then be taken and recorded throughout the test (Appendix 2).

  Constant discharge test manual data sheet

4. The **water level** in the pumped and observation bores must be monitored automatically (using loggers) **and** manually (e.g., using a dip meter). Automatic monitoring is to be done using data loggers that record every 1 minute. Manual measurements are to be taken at the frequency shown in the monitoring sheets. **All data must be filled and clearly recorded in the monitoring sheets**.
5. The bore should be tested at the **highest** rate possible, which should be **at or above the proposed rate of take**. To determine the optimal rate for the test, it is recommended to measure the water level in the bore and then pump it at the maximum possible rate for around an hour prior to the step test. However, you must ensure that water levels **fully recover (i.e., return to the level before pumping started) before the actual test starts**. The results of the step test can then be used to determine the rate for the constant discharge test (which must be at or higher than the proposed rate of take).
6. **Barometric pressure** should be measured using a logger in 1-minute intervals before, during, and after the pumping period (at least until recovery is complete) to account for the impact of changes in barometric pressure on groundwater levels. It is recommended that the loggers for measuring groundwater levels and barometric pressures are synchronised to the same time increments and the same units (preferably metres H_2O).
7. After the test ends, the **recovery of groundwater levels must be monitored and recorded**. The recovery is to be monitored until the water levels recover at least 90% of the drawdown or for a duration of 24 hours (for a step test) or 48 hours (constant discharge test) after the end of pumping (whichever comes first).
8. **All raw and processed** automatic aquifer test data (flow rate, water level and barometric data) **must be electronically submitted** to ORC as part of the groundwater take consent application. The data must be submitted as **Excel/CSV** files alongside any data processing/correction and analysis files and the justification for the analysis method used. Copies of manual monitoring sheets must also be submitted electronically to ORC.

1.7 What are the detailed step test requirements?

1. The four steps should be exactly one hour each. The **change in rate between steps** should **be kept constant** (e.g. step 1: 5L/s; step 2: 10L/s; step 3: 15L/s; step 4: 20L/s). The transition to the next step must be **immediate** (i.e. when the time lapses at the end of each step, the pumping rate should immediately increase to the rate of the next step without stopping or reducing the pumping rate). For instance, using the example rates above, after pumping for 1 hour at 5L/s (step 1), the rate should immediately go up to 10L/s (step 2) without stopping or reducing the pumping rate.

2. At the **end of the 4th step the pump is to be turned off** and the **recovery should be monitored** in the same time increments shown in the monitoring sheet.

3. If the bore produces only low flow rates (e.g. <3 L/s), 3 steps may be practical. However, all previous monitoring requirements must still be met. In the worst case, when the flow is less than 1 L/s, one step might be all that is feasible. In that case make the test longer. Please record the water levels before and after the test, and during recovery. Please also submit the pumping rate and duration of the test.

1.8 What are the detailed Constant Rate Discharge test requirements?

1. All bore locations need to be verified with a hand-held GPS against the ORC Bores database. The location of bores on the Council's database can be found on the following GIS link: LocalMaps (orc.govt.nz) under Layers - Bore and Well Locations. The verified coordinates should be recorded with a photo confirming the GPS coordinates and bore number and provided to Council as part of the application with any discrepancies clearly reported. Distances between observation bores and a pumping bore that are less than 200 metres should be directly measured as the distance from the pumping bore substantially impacts the analysis. Please also record any bores that are not in the database and provide maximum information for them (e.g. location, diameter, depth, water level, etc.). These bores will then be assigned an ORC number and added to the database.

2. The **pumping duration** should be at least the minimum specified in Table 1 but you also need to ensure that the drawdown in the pumped and observation bores has stabilised. If the drawdown continues after the specified test duration, extend the pumping period by at least 4 hours, and then re-assess whether the drawdown has stabilised. Keep extending the test if needed until the drawdown is stable. If an extension is needed, continue the pumping and record the results without stopping the test.

3. The aim of the test is to have the **highest possible drawdown in the observation bores**, which improves the understanding of potential effects and the analysis of the data. Therefore, include as many monitoring bores as possible, especially ones that may be potentially affected by the proposed groundwater take. If there are no observation bores available within a 50-metre radius, consider drilling temporary observation bores. **Surface water bodies** (e.g., streams, springs, and wetlands) that are potentially affected should also be monitored if stream depletion is identified as a potential issue. Again, temporary observation piezometers may be needed.

4. To help obtain the highest drawdown and maximum information from the test, it is recommended to model the expected maximum drawdown in the observation bores prior to the test using estimated aquifer parameters. It is also recommended to monitor the nearest observation bore during the step test to ensure that there is sufficient drawdown. If the expected drawdowns are too small, consider drilling a temporary observation bore(s) closer to the pumped bore.

5. Use existing bore logs to determine the aquifer type, identify suitable monitoring bores, explain the observations, and help determine the method of test analysis.

6. Where saltwater intrusion is a potential issue, all measuring points need to be surveyed to a common datum (NZVD2016 or DUN58). This will establish the actual potential of saltwater intrusion.

1.9 Are there any other additional matters for consideration?

An aquifer test requires **careful preparation and planning**. If the test is not of sufficient quality your application may be returned or the test will need to be repeated to an appropriate standard. One of the challenges with long duration aquifer tests is assuming that all conditions which affect groundwater levels (e.g., pumping from nearby bores, rainfall, etc.) stay the same and that groundwater levels are only affected by the pumping from the test. Therefore, to minimise the impact of other factors:

a. Check the **weather forecast** and only test during a dry and stable weather period. Tests should also be done outside irrigation and frost protection seasons. Be prepared to postpone the test if needed.

b. The **discharge of pumped water** from the test needs to occur outside the zone of pumping effects. Water can be diverted to a drain, water race or surface water body that is not hydraulically connected to the pumped aquifer. This is often further away than you think.

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c. **Consents** may be required for an aquifer test. Rule 12.2.2.3 of the Regional Plan: Water for Otago (RPW) permits the taking of groundwater for down-hole pump testing providing the take does not exceed **2,000 cubic metres per day** and is carried out for a period **no longer than three consecutive days**. For the discharge of the aquifer test water to water or to land then permitted activity Rule 12.C.1.1 will need to be referred to. There should be no scouring or run-off as a result of the discharge. If this rule cannot be met, then a discharge permit will be required. Please contact public.enquiries@orc.govt.nz for more information.

d. Ensure that there are **no other bores pumping** within at least a 1-kilometre radius from the pumped bore during the test and recovery. If there are, you must try to minimise their impact. You could request that they are turned off (and may need to provide an alternative water supply, e.g., water tank) and record/monitor these takes as this data can help correct some of the interference on the test. Minimum recorded information should include: the exact bore location (bore number and GPS coordinates), the start and stop times of pumping, and an estimate of the flow. Monitoring before the start of the test can also help identify these impacts.

e. Include groundwater level observations of other bore(s) outside the zone of testing but close enough to show local trends. Use the data to correct observation bores for any groundwater level trends or fluctuations that might occur over the test period.

f. The data may need to be compensated to account for the aquifer barometric efficiency.

g. **Check** with ORC groundwater scientists before you design and execute the test. Send your plans to aquifertests@orc.govt.nz.

If for some reason you are unable to meet the recommended minimum test requirements, please contact the Otago Regional Council or your consultant to discuss appropriate alternatives.

1.10 What information do I need to submit to ORC?

The following information about the aquifer test should be provided to ORC with your groundwater permit application:

- ❑ A map of the site showing key features: pumping and observation bores, surface water features and pumped water discharge location
- ❑ Measured GPS coordinates of pumped and observation bores referenced by ORC bore number. If a bore is not found on ORC's database provide as much information as possible about it (e.g., GPS coordinates, total depth, diameter, depth to water, use, screen depth, bore log, etc.) so it can be added to the database. If possible, please do that before the test so an ORC bore number can be created which can then be used for the test report. Please also let ORC know if there are discrepancies between the location of a bore in the database and the actual location in the field. Please send this information to aquifertests@orc.govt.nz
- ❑ Surveyed elevations for pumped and observation bores measuring point used in the aquifer test and for nearby surface water levels (if assessing stream depletion or saline intrusion). This can be to a local common level.
- ❑ Bore logs, static water levels, and construction information, including total and screen depth and diameter for the pumped and all observation bores
- ❑ Discharge monitoring records, measurement method, and the location of the discharge of pumped water.
- ❑ A brief description of the test set up and results (e.g., date/time, pumped & observation bores details, pumping rate, initial water levels & maximum drawdown in each bore, meteorological conditions, any issues/interference with the test, and any other relevant information). A template for an aquifer test report can be found in Aitchison-Earl & Smith (2008) https://api.ecan.govt.nz/TrimPublicAPI/documents/download/1058665
- ❑ All records of measured test data format (data loggers raw data files & Excel/CSV, and copies of the manual monitoring datasheets). These must be in electronic format. All raw data must be supplied in addition to any processed data. This includes:
    - Groundwater levels in the pumped and observation bores referenced by ORC well number
    - Barometric pressure monitoring
    - Manual/automatic flow records
    - Records of measured or observed rainfall and river flows
- ❑ Analysis of aquifer test results and derived estimates of relevant aquifer parameters to support the Assessment of Environmental Effects. This should include details of any data corrections used, analysis methods & assumptions, plotted data, calculations used and discussion of data and analysis reliability as well as any other relevant information

1.11 References

Aitchison-Earl, P. and Smith, M. M. 2008. *Aquifer test guidelines (2nd Edition)*. Environment Canterbury Technical Report R08/25, Environment Canterbury, New Zealand. https://api.ecan.govt.nz/TrimPublicAPI/documents/download/1058665

Fetter, C.W. (2014). *Applied Hydrogeology (4th Edition)*. Prentice Hall.

Kruseman, G. P. and de Ridder, N. A. A. A. 1994. *Analysis and evaluation of pumping test data (2nd Edition)*. Publication 47: International Institute for Land Reclamation and Improvement, Wageningen, the Netherlands.

Appendix 1: Manual monitoring sheet – Step test

Step test manual data sheet

Bore No.:	Date:	Start of test (time):
Pre pumped (Static) Level (m):		Measured by:

		Start time of step:			End time of step:
Step	Clock time	Time into step (minutes)	Pumping rate (L/s)	Water level (m)	Comments
1		1			
1		2			
1		3			
1		4			
1		5			
1		10			
1		15			
1		20			
1		30			
1		40			
1		50			
1		60			

		Start time of step:			End time of step:
Step	Clock time	Time into step (minutes)	Pumping rate (L/s)	Water level (m)	Comments
2		1			
2		2			
2		3			
2		4			
2		5			
2		10			
2		15			
2		20			
2		30			
2		40			
2		50			
2		60			

		Start time of step:			End time of step:
Step	Clock time	Time into step (minutes)	Pumping rate (L/s)	Water level (m)	Comments
3		1			
3		2			
3		3			
3		4			
3		5			
3		10			
3		15			
3		20			
3		30			
3		40			
3		50			
3		60			

		Start time of step:			End time of step:
Step	Clock time	Time into step (minutes)	Pumping rate (L/s)	Water level (m)	Comments
4		1			
4		2			
4		3			
4		4			
4		5			
4		10			
4		15			
4		20			
4		30			
4		40			
4		50			
4		60			

Recovery: please record until at least 90% recovery has occurred				
Step	Clock time	Time into step (minutes)	Water level (m)	Comments
Recovery		1		
		2		
		3		
		4		
		5		
		10		
		15		
		20		
		30		
		40		
		50		
		60		

Recovery				

Appendix 2: Manual monitoring sheet – Constant Discharge Test

Aquifer test manaul datasheet	
Pumping bore number:	**Distance from pumping bore (m):**
Observation bore number:	**Pumping rate (L/s)**
Initial Water Level (m):	**Description of Measuring Point:**
	Person measuring:

Date	Clock time (24 hours)	Time into test (minutes): Pumping	Depth to water (m)	Pumping rate (L/s)	person measuring (initials)	comments
		-5				
		0				
		1				
		2				
		3				
		4				
		5				
		6				
		8				
		10				
		15				
		20				
		25				
		30				
		45				
		60				
		75				
		90				
		120				
		150				
Please turn over						

Date	Clock time (24 hours)	Time into test (minutes): Pumping	Depth to water (m)	Pumping rate (L/s)	person measuring (initials)	comments
		180				
		210				
		240				
		270				
		300				
		360				
		480				
		720				
		960				
		1200				
		1440				
		1680				
		1920				
		2160				
		2400				
		2640				
		2880				
		3120				
		3360				
		3600				
		3840				
		4080				
		4320				

Date	Clock time (24 hours)	Time into test (minutes): Recovery	Depth to water (m)	person measuring (initials)	comments
		0 (shut off of pump)			
		1			
		2			
		3			
		4			
		5			
		6			
		8			
		10			
		15			
		20			
		25			
		30			
		45			
		60			
		75			
		90			
		120			
		150			
		180			
		210			
		240			
		270			
Please turn over					

Date	Clock time (24 hours)	Time into test (minutes): Recovery	Depth to water (m)	person measuring (initials)	comments
		300			
		360			
		480			
		720			
		960			
		1200			
		1440			
		1680			
		1920			
		2160			
		2400			
		2640			
		2880			
		3120			
		3360			
		3600			
		3840			
		4080			
		4320			