Guidelines for analysing and reviewing aquifer tests that support consent applications and/or comply with consent conditions

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Environment Canterbury has produced this guideline to assist Environment Canterbury staff and consultants involved in analysing and reviewing aquifer tests. It updates and replaces the 2010 guideline of Ezzy and Smith (2010) on the same topic.

Introduction

The purpose of this guideline is to outline Environment Canterbury's expectations for submitting and reviewing aquifer tests in relation to consent applications and compliance with consent conditions. This guideline should be read in conjunction with Environment Canterbury's Aquifer Test Guidelines (Aitchison-Earl and Smith, 2008) which provide best practice guidelines for the design, analysis and reporting of aquifer tests.

This document is divided into two parts:

1. expectations of the analyst
2. expectations of the reviewer

The **analyst** is the party or person who has undertaken the analysis of the aquifer test data on behalf of the consent applicant or holder to estimate aquifer parameters used to assess environmental effects. The party or person who designs, undertakes and oversees the aquifer test may or may not be the analyst.

The **reviewer** is an Environment Canterbury staff member or a consultant acting on behalf of Environment Canterbury. The reviewer's role is to impartially audit the test and analysis provided by the analyst. The reviewer must adopt a precautionary approach when reviewing an aquifer test. This means that if estimates of aquifer parameters are uncertain, the reviewer must adopt appropriately conservative parameters for the particular situation they are being applied to.

Environment Canterbury encourages open communication between the reviewer and the analyst. Environment Canterbury does not need to facilitate this dialogue when the reviewer is a consultant.

1 Expectations of the analyst

1.1 Is an aquifer test required?

An assessment of environmental effects is required for every consent application to take groundwater[1]. Environment Canterbury reserves the right to determine the level of hydrogeological information required to support a consent application or comply with consent conditions on a case by case basis.

Guidance on the level of hydrogeological information required to support a consent application is outlined in the attached Environment Canterbury practice note - "What supporting information do I need for my application to take groundwater – aquifer testing" (Attachment 1).

1.2 Aquifer test design

Environment Canterbury recommends that a suitably experienced professional be involved in the design and supervision of aquifer tests. In our experience, this will reduce errors and oversights which may later result in problems in the analysis and review of the test. In the worst case, an inadequate test will result in a requirement to repeat the test.

1 Under Part 6 of the RMA, Section 88 requires that applications be accompanied by an Assessment of Environmental Effects (AEE) at a level of detail that "corresponds with the scale and significance of the effects that the activity may have on the environment."

Environment Canterbury recommends that an aquifer test is designed to achieve more than 0.2 m of pumping induced drawdown in at least one observation well where possible. This will maximise the chances of obtaining usable observation data from the aquifer test. The analyst can find equipment considerations and test design checklists, test data sheets and summary sheets in the Aquifer Test Guidelines (Environment Canterbury, 2008). We encourage undertaking a step test prior to a constant rate test to constrain the transmissivity and determine pumping rate/drawdown.

Environment Canterbury is happy to review and provide comment on aquifer test design plans, but we reserve the right to withhold the assessment of the adequacy of any test until it is complete and the results have been evaluated and applied to a specific assessment of environmental effects.

1.3 What information to provide to Environment Canterbury

In order to effectively review an aquifer test, we will require a written aquifer test report and, in electronic format, water level data collected during the test. Failure to provide adequate documentation may cause delays in the review process or rejection of a resource consent application. The written test report must:

- describe the test (e.g. dates, pumping rates, static water levels, etc.), and any problems encountered during the test (e.g. changes in pumping rate during a constant rate test)
- detail any corrections applied to the raw data (e.g. barometric, linear, tidal)
- describe the analysis of the test results, including the applicability of the chosen solution to the conceptual hydrogeological model
- recommend aquifer parameter values (or a range of aquifer parameter values) and specify their appropriate use (e.g. for use in a well interference assessment)
- justify any assumptions recommended for an assessment of environmental effects (e.g. cut-off depths for well interference assessments).

The test must provide sufficient information about the likely range of parameter values to allow a reliable assessment of environmental effects. Different aquifer parameter combinations may provide a good fit of the model to the observation data and will result in non-unique, uncertain aquifer parameter values. Therefore, a range of parameters may be given and appropriate judgement should be used when applying the results. The level of scrutiny of the analysis should correlate to the level of potential effects the proposed activity may have.

2 Expectations of the reviewer

2.1 Timeframes

Reviewers must adhere strictly to RMA timeframes. Timeframes differ depending on whether the review is for a consent in process or for compliance with a particular consent condition. Expectations will be communicated to reviewers by Environment Canterbury before commitment to a test review.

2.2 Purpose of the review

The purpose of the aquifer test review is to:

1. determine if the testing is fit for purpose
2. assess the appropriateness of the conceptual model and assumptions (e.g. cut-off depths)
3. verify the data and analysis to determine whether the aquifer testing provides a reliable estimate of aquifer parameters
4. determine whether the aquifer parameter estimates will result in an appropriately conservative prediction of effects on the environment
5. assess the quality of the aquifer test
6. document the review

Each of these steps is discussed in more detail in sections 2.3 to 2.7 below.

2.3 Determine if the test is fit for purpose

When determining the adequacy of the test, the reviewer will need to consider the purpose of the test and whether that purpose has been achieved. The reviewer will need to be satisfied that the analyst has taken all practicable steps to ensure the success of the test. An inadequate test may result in a requirement that the test be repeated. The reviewer should consider the following points in relation to the adequacy of the test:

- is the timing of the test appropriate (e.g. has it been undertaken at a time when there will be minimal pumping interference)?
- is the selection of monitoring wells appropriate?
- were the groundwater levels in the pumping and observation wells measured at reasonable time intervals?
- have all required observations been recorded (e.g. time, pumping rates, static water levels, barometric pressure etc.)
- have there been any changes that have affected the test results (e.g. rainfall events, changes in pumping rate)?
- has the well been pumped at the proposed rate of take? If not, why?
- is the discharge location of pumped water appropriate (i.e. is the pumped water discharged somewhere that it will not affect the water level responses in observation wells)?

2.4 Verification of data and analysis

When determining whether the aquifer parameters are appropriate and defendable, the reviewer must verify the data and analysis of the aquifer test. The reviewer may review the data and analysis in any way they consider appropriate. When verifying the data and analysis, the reviewer should consider:

- are all the required data sets present?
- are the test details within the report consistent with the data and appendices?
- does drawdown in pumping and observation wells start at logical times after pumping has commenced?
- does the aquifer recover to near pre-test levels? If not, why not?
- are significant changes in pumping times and rates described and accounted for?
- have corrections been made (e.g. barometric, linear, tidal)? If so, are they appropriate and necessary?
- is the conceptual model defendable and representative of the local aquifer system?
- is the selected analytical solution appropriate?
- are estimated parameters appropriate for their intended use in an assessment of environmental effects?
- have the recovery data been analysed, and how do the aquifer parameters estimated from the recovery data compare to those estimated from the pumped data?
- are the well numbers and depths consistent across the database, report and analysis?

2.5 Determine appropriate parameters to be used in environmental assessments

Aquifer parameters estimated during aquifer test analysis will often be non-unique (i.e. a range of possible aquifer parameters could provide a good fit of the model to the observation data). Therefore, there can be an element of uncertainty when analysing aquifer tests and recommending parameters for assessments of environmental effects. Environment Canterbury's default approach is that the aquifer parameters which provide the most conservative estimates of the environmental effect of that groundwater abstraction should be used in assessments.

2.6 Aquifer test quality rating

Aquifer tests maintained in Environment Canterbury's archives are rated for data reasonableness, analysis method validity, model fit and corrections. The Environment Canterbury rating system is a simple ranking exercise that generates a rating for both the test and estimated parameters. The rating form is attached at the end of this document (Attachment 2). Every test will be rated and these values will end up in the Environment Canterbury's Wells Database.

2.7 Documentation of the review

We require the reviewer to complete Environment Canterbury's aquifer test review summary form (Attachment 2) to document the aquifer test review. The reviewer may complete a written report in addition to this if they wish. The reviewer must provide the aquifer test review summary form to both Environment Canterbury and the analyst at the completion of the review. Any additional information provided directly to reviewer from the analyst must also be provided to Environment Canterbury with the aquifer test review summary form. The form and any additional report should include:

- clearly stated **recommended** aquifer parameters, along with their intended use (e.g. a transmissivity value of 1,000 m^2/day is recommended for use in well interference assessment)
- clearly stated aquifer parameters which **generally** characterise the aquifer. These general parameters **may** be different to the parameters used to predict environmental effects, and they are the parameters which will be recorded in Environment Canterbury's Wells Database (see section 3)
- whether the reviewer's recommended aquifer parameters differ from those estimated by the analyst, and a justification for these differences if this is the case
- a short description of the test and/or analysis techniques that were used
- a description of shortcomings of the test and/or analysis techniques (if necessary). This could include those aspects of the test that were lacking and/or influence predicted effects, and any other issues or irregularities discovered.

3 What values are recorded in Environment Canterbury's Wells Database?

Environment Canterbury maintains a Wells Database containing information on wells in Canterbury, including details of aquifer tests. Environment Canterbury updates the database with new aquifer test information obtained from the consenting processes. Users of the data in this database should satisfy themselves that the data are fit for their purpose. This may involve checking comments, quality codes and re-analysing tests before using the data.

Since December 2014, Environment Canterbury has recorded the most reasonable general aquifer parameters in the Wells Database. These general aquifer parameters may be different to aquifer parameters used to assess environmental effects (which could be more conservative than the general parameters). If this is the case, there will be a comment on the test record in the Wells Database specifying the parameters used to assess environmental effects. Users of aquifer test data need to be aware that tests entered prior to December 2014 will not have followed the procedure of entering general parameters AND parameters used in environmental assessments.

Environment Canterbury has specifically designed the attached aquifer test review summary form to capture the information required to enter an aquifer test into the Wells Database efficiently. The reviewer must complete this form.

4 Disagreements

In the case of disagreement between analyst and reviewer, Environment Canterbury is available to provide input and advice. If the reviewer is an Environment Canterbury staff member, a neutral third party can be engaged at the applicant's cost. Environment Canterbury encourages direct discussion between the reviewer and analyst of any issues to identify a clear and practical way forward. All communication between the analyst and the reviewer must be professional and respectful.

5 References

Aitchison-Earl, P. and Smith, M. 2008: Aquifer test guidelines (2nd Edition). Environment Canterbury Technical Report R08/25, 53 p.

Environment Canterbury, 2010. Practice note: What supporting information do I need for my application to take groundwater? - Aquifer testing. http://ecan.govt.nz/publications/General/aquifer-testing-practice-note-exemptions.pdf

Ezzy, T. and Smith, M., September 2010. Guidelines for reviewing aquifer tests for proposed consents or for compliance with consent conditions. Environment Canterbury practice note.

Attachment 1:

ENVIRONMENT CANTERBURY PRACTICE NOTE:
What supporting information do I need for my application to take groundwater? – Aquifer testing

A critical assessment of environmental effects (AEE) is required for every resource consent application[2], including those to take and use groundwater. This document is intended to provide guidance to resource consent applicants in determining the level of hydrogeological information required in support of their AEE. As the scale and significance of groundwater takes increases beyond those 'permitted' under the PNRRP, the need for more supporting hydrogeological information increases. For some applications, site-specific aquifer testing may not be needed, as the level of supporting hydrogeological information (and other relevant information) is adequate to complete a critical AEE. However, in those instances, a clear justification for estimates of aquifer parameter values, aquifer type, and modelling assumptions will still be required to satisfy confidence in predicted environmental effects. An example of this justification would likely include analytical modelling of effects using appropriate sensitivity analysis.

For guidance on what level of hydrogeological information will be required to support an AEE, a 'Principles for exemption' list has been developed by Environment Canterbury. This list provides details of situations where an aquifer test will not be required to support an application. This list should be considered in context of Table 1 and Figure 1. The 'Principles for exemption' list will be expanded over time, to reflect case-by-case circumstances where Environment Canterbury's requirements can be satisfied without site-specific aquifer test data.

Keep in mind that the applicability of any exemption is determined by the purpose(s) for which an aquifer test is expected to serve. In the context of applications for groundwater take permits these include:

- confirmation that a well is able to yield the rates being applied for;
- determination of well interference effects;
- determination of stream depletion effects.

[2] Under Part 6 of the RMA, Section 88 requires that applications be accompanied by an Assessment of Environmental Effects (AEE) at a level of detail that "*corresponds with the scale and significance of the effects that the activity may have on the environment*."
Schedule 4 states, in more detail, what an AEE must contain. This includes: "*an assessment of the actual or potential effect on the environment of the proposed activity*".

Principles for exemption

Testing requirements & exemptions as at October 2009:

1. Step testing[3] is to be undertaken in all cases unless a reliable step test has been carried out in the last 15 years.

2. Aquifer testing, with observation wells, is required unless:

    - there are no neighbouring wells within 2 km of the abstraction well, and there is no potential for direct stream depletion[4];
    - the transmissivity calculations from the step test are used in conjunction with the Theis (1935) drawdown model in a WQN10 assessment, and there is no potential for direct stream depletion;
    - written approvals are provided for all wells within 2 km, and there is no potential for direct stream depletion;
    - an aquifer test with observation wells has been carried out in the same aquifer, within 500 m of the proposed abstraction location, the results from which are considered by Environment Canterbury to be reliable;
    - the well has been used as an observation well in an aquifer test and a corrected drawdown greater than 0.2 m was observed in this well.
    - the application is for a renewal with no change to pumping rates, or significant well location changes

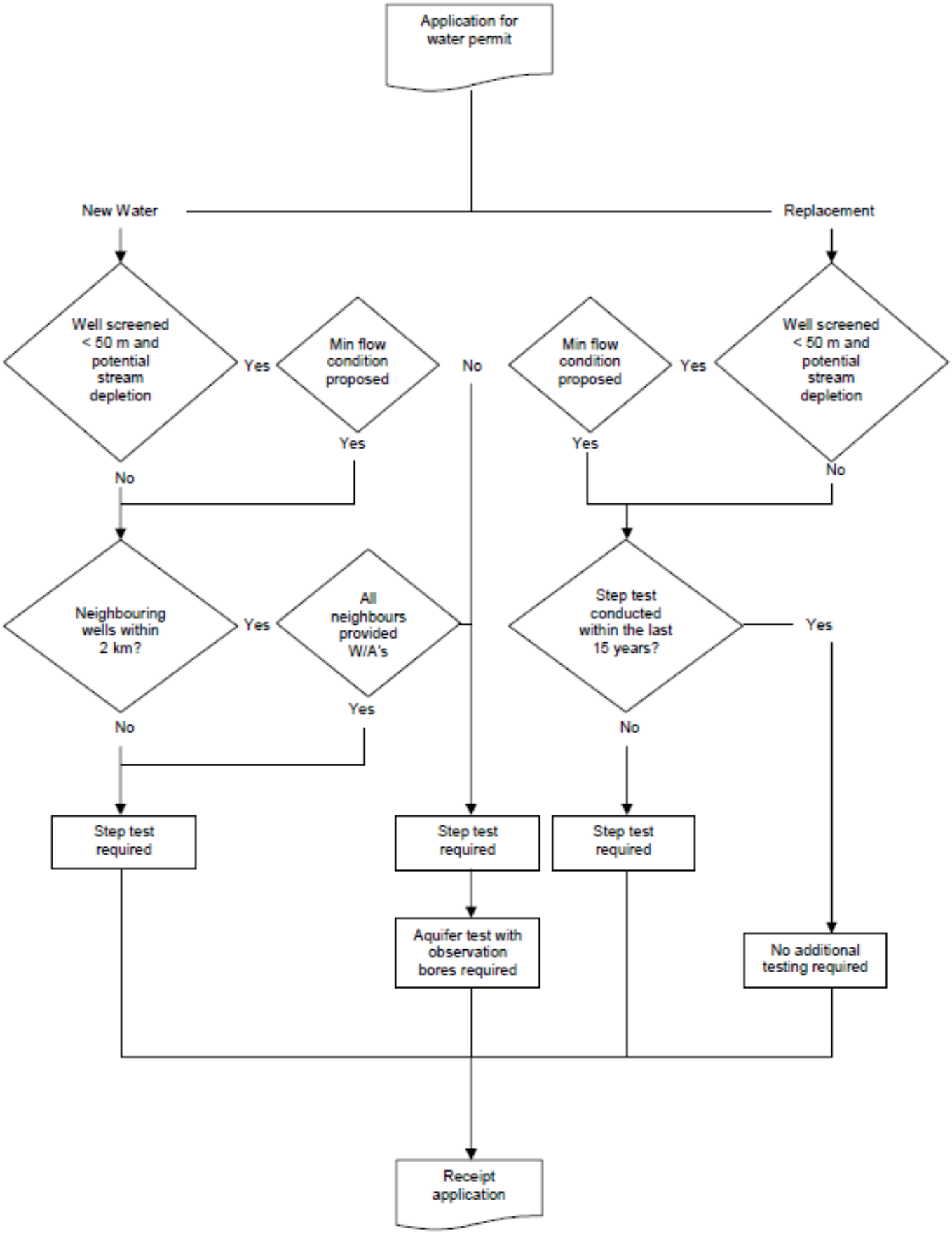
Where the results from any aquifer testing are uncertain e.g. no response in observation bores, the interpretation and application these test results should be discussed with Environment Canterbury groundwater staff and will be considered case by case.

[3] A step test will: confirm well yield, both short term and long term; provide a measure of well efficiency; and, give a conservative (low) estimate of transmissivity.
[4] To be exempt from a stream depletion assessment a well must be screened deeper than 50 m and/or be located more than 3 km from any surface water body.

Type of consent	Potential Effects	Test required
Replacement (No well-interference assessment required under PNRRP) (No location change)	Stream depletion Allocation: Rate of take should not exceed rate being yielded from the bore	Aquifer test with observation wells[5]
	No stream depletion	Step test to confirm yield[6]
Change of conditions – deepening bore	Allocation: Rate of take should not exceed rate being yielded from the bore	Step test to confirm yield Aquifer test with observation wells to generate WQN10 parameters[7]
	Stream depletion	Aquifer test with observation wells[5]
Change of conditions – Location change	Allocation: Rate of take should not exceed rate being yielded from the bore	Step test to confirm yield[6] Aquifer test with observation wells to generate WQN10 parameters[7]
	Stream depletion	Aquifer test with observation wells[5]
Change of conditions – New bore	Well-interference (no stream depletion)	Step test to confirm yield[6] Aquifer test with observation wells to generate WQN10 parameters[7]
	Stream depletion	Aquifer test with observation wells[5]
Transfer site to site (new location)	Well-interference (no stream depletion)	Step test to confirm yield[6] Aquifer test with observation wells to generate WQN10 parameters[7]
	Stream depletion;	Aquifer test with observation wells[5]
New application	Well-interference; no stream depletion; cumulative effect (effect on allocation block); Allocation: Rate of take should not exceed rate being yielded from the bore	Step test to confirm yield[6] Aquifer test with observation wells to generate WQN10 parameters[7]
	Stream depletion;	Aquifer test with observation wells[5]

[5] Where a minimum flow condition is proposed, only a step test is required to confirm well yields.
[6] Step test not required, where a full step test has been carried out within the last 15 years,
[7] Where justified, a well interference (WQN10) assessment using Theis (1935) on all wells is an accepted alternative to full aquifer testing. Estimate of transmissivity will be based on analysis of step test.

Decision path for aquifer test requirements at time of application



Attachment 2:
AQUIFER TEST REVIEW SUMMARY FORM AND QUALITY RATING SHEETS

Complete this form and send to:

Environment Canterbury
Attention: Groundwater Science Section
PO Box 345
Christchurch 8140

Providing all the information in this form:

(a) is a requirement of undertaking an aquifer test review, Environment Canterbury will inform you if further information is required.

(b) will assist with the prompt processing of a consent and the entry of the aquifer test data into the Wells Database.

Please refer to the guideline for reviewing aquifer tests document when completing this form.

Signature: _____

Name (printed): _____

Date: _____

Part A: Basic information

Consent No:	
Test date (start of pumping):	
Pumping well:	
Report name and number:	
Total pumping time (mins):	
Constant or max flow rate (l/s)	
Consultant (original analyst):	
Reviewer:	

Part B: Comments on report and aquifer analysis

Is the test fit for purpose? ☐ Yes ☐ No

General comments on the test:

Shortcomings and/or problems of the test (if applicable):

Justification for different aquifer parameter estimates (if applicable):

Other comments:

Part C: Pumping well analysis

(Please check all applicable fields)

Main analysis method

- ☐ Boulton (1963)
- ☐ Cooper-Jacob (1946)
- ☐ Eden Hazel (1973)
- ☐ Hantush (1960) with aquitards
- ☐ Hantush-Jacob (1955)
- ☐ Hunt Scott (2005)
- ☐ Hunt Scott (2007)
- ☐ Hvorslev (1951) Slug
- ☐ Jacob-Lohman (1952) free flow
- ☐ Moench (1985)
- ☐ Neuman (1972)
- ☐ Neuman-Witherspoon (1969)
- ☐ Theis (1935)
- ☐ Theis (recovery)
- ☐ Other (please specifiy)

:

Aquifer type condition

- ☐ Confined
- ☐ Semi-confined
- ☐ Unconfined
- ☐ Not specified
- ☐ N/A

Test type

- ☐ Constant rate with observation wells
- ☐ Step
- ☐ Slug
- ☐ Other, please specify:
- ☐

Boundary condition

- ☐ Not Encountered
- ☐ No Flow Boundary
- ☐ Recharge Boundary

Parameter rating

- ☐ 1 Excellent
- ☐ 2 Good
- ☐ 3 Fair
- ☐ 4 Marginal
- ☐ 5 Inaccurate

Test rating

- ☐ 1 Good
- ☐ 2 Fair
- ☐ 3 Unreliable

Refer to Appendix C of the Aquifer Test Guidelines (attached) for rating guidelines

Analysis results recommended for use in the AEE)

Transmissivity (m^2/d)	
Storativity	
Leakage (m)	
K'/B' (day^{-1})	
Conductivity (m/d)	
Stream bed leakage, lambda (m/s)	
Overlying layer transmissivity (m^2/d)	
Overlying layer storativity	
Type of assessment parameters recommended for (*e.g. well interference, stream depletion etc.*)	

General analysis results (if different from above)

Transmissivity (m^2/d)	
Storativity	
Leakage (m)	
K'/B' (day^{-1})	
Conductivity (m/d)	
Stream Bed Leakage (m/s)	
Overlying layer transmissivity (m^2/d)	
Overlying layer storativity	

Static water levels and well locations

Well number	Easting	Northing	Observation or pumping well?	Static groundwater level from measuring point (m)	Measuring point description	Measuring point distance from ground level (m)
						above / below ground
						above / below ground
						above / below ground
						above / below ground
						above / below ground

Part D: Results of the yield/drawdown/ and/orstep test

Well number	Test Date	Step	Pumping rate (l/s)	Drawdown in well (m)	Total lapsed time from start of test (minutes)	Step duration (minutes)

Part E: Observation wells in the aquifer test with individual analysis results

Well number	Distance (m) to pumped well	Max drawdown (m)	Transmissivity (m^2/d)	Storativity	Leakage(m)	K'/B'	Overlaying		Depth of observation well (m)	Top of upper screen (m)
							Transmissivity	Sigma		

Aquifer test quality ratings

Well # _____ Test Date ____/___/___ Rated by _____

Environment Canterbury aquifer test and parameter rating Form

Preliminary check

☐ Pumping rate (s) ☐ Well locations/ distances ☐ Data sets
If any of the above criteria are missing then the test is considered to be unreliable

Test rating:

Type and duration:

1	**Slug test**
	Step test
0	1 step
1	2 to 3 steps
2	3+ steps
	Duration:
0	<0.5 hour per step
1	0.5 to 1 hour per step
2	>1 hour per step
3	**Multiple well test** (with at least one observation well)
	Duration:
1	<24 hours
2	1 to 2 days
3	>2 days

Well details

0	Depths unknown
1	All depths unknown(some screens known)
2	All screen locations known

Well locations

0	No observation wells
1	Observation wells in overlying (or underlying) aquifer
2	Observation wells in pumped aquifer
3	Observation wells in pumped and overlying (or underlying) aquifer

Reported info

1	Static water levels
1	GPS locations
1	Test date
1	Barometric data

Test rating

Total ___ out of 15

Score	Wells Database rating
<5	3 Unreliable
5-10	2 Good
10+	1 Fair

Objectives – Did testing meet design purpose?

No

Partially

Yes

Parameter rating:

Analysis method & fit of model

0	Invalid analysis
1	Poor fit of model to observations
2	Reasonable fit of model to observations
4	Excellent fit of model to observations

Boundaries

0	Not identified, but present
1	Identified and corrected for
2	Not present

Corrections

0	Required, but not applied
1	Required and applied
2	Not required

Drawdown in observation well (max, non-pumping)

0	<0.1 m
1	0.1 to 0.2 m
2	>0.2 m

Parameter reasonableness rating
Total ___ out of 10

Score	Wells Database rating
<2	5 Inaccurate
2-4	4 Marginal
4-6	3 Fair
6-8	2 Good
8+	1 Excellent

Comments: