Step Discharge Aquifer Test
M34/5707

Hurunui District Council

July 2016

Bowden Environmental
Resource Management Consultants

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Bowden Environmental

Step Discharge Aquifer Test Report

Groundwater Bore M34/5707

August 2016

1.0 Introduction

This report details the findings of a step discharge pumping test carried out on bore M34/5707 located in the Waipara region (Appendix 1). The Hurunui District Council holds consent CRC070201 for the public supply bore for a maximum pumping rate of 15 litres/second. The consent expires in 2018, and the Council wishes to explore the opportunity to increase the rate when applying for a replacement consent, to provide additional water to the expanding Amberley/Waipara region. A previous aquifer test carried out in 2006 determined that the maximum rate achievable from the bore was around 15 l/s. However, that test was a constant rate test rather than a well performance test such as a step test. In addition, the recent installation of a flow meter for consent compliance indicates that the actual rate of take from the bore is around half the consented rate.

The Council also wishes to examine the pump to confirm its capacity. Therefore, McMillans Well Drilling removed the existing pump to assess its capacity and state, carried out some re-development of the bore to ensure the screen was not clogged, put a down-hole camera into the casing to examine the state of the bore, and temporarily installed a larger capacity pump to carry out a step test to determine the capacity of the bore.

While the aim of the step test was to determine the bore performance, the opportunity was also taken to monitor nearby bores to confirm the previous test's aquifer parameters for future drawdown analyses. The bores used in the test are detailed in Tables 1 and 5. Bore logs are in Appendix 2.

Table 1

Bore	NZTM X	NZTM Y
M34/5707	1577088	5226281
M34/5653	1577206	5226239
M34/0682	1577487	5226418
M34/0667	1576608	5226181
M34/5684	1577608	5226126
M34/5603	1577931	5226388

Note that the correct field validated GPS location of bore M34/0682 is different to that recorded on the Wells Database.

2.0 Description Of The Environment

The Waipara Catchment, North Canterbury has an area of approximately 740 km^2, consisting of foothills, an alluvial basin and coastal ranges. The basin consists of folded and faulted Torlesse basement, overlain by Tertiary limestone, sandstone and mudstones, which are exposed on the hills and ridges along the eastern and western margins of the basin. The local folding and faulting resulted in the isolation of the Waipara Basin from the Canterbury Plains, giving rise to a distinct hydrogeological environment.

The groundwater resources utilised in the area include wells penetrating the Quaternary Canterbury and Teviotdale gravels, and the late Pliocene/early Pleistocene Kowai formation. In general, aquifer thicknesses and lithologies show rapid and unpredictable variations over short distances. The hydrogeological system can be described as a complex network of discrete, lithologically and hydraulically heterogeneous anisotropic semi-permeable to permeable channels. Permeabilities and yields are correspondingly variable and unpredictable, though moderate to low overall. Recharge of the gravel aquifers by upwards movement of deeper groundwater is suspected to occur.

The Waipara River is a perennial river that flows across the alluvial basin. Other significant waterways in the basin include Weka Creek and the Omihi Stream that flow into the middle reaches of the Waipara River. The Weka Creek generally does not contribute any surface flow to the Waipara River during summer, but does appear to contribute underflow. Omihi Stream by contrast, can supplement the surface flows of the Waipara River significantly.

Regionally, the geology of the Waipara basin is complex and locally the complexity is confirmed by bore logs of both the pumped bore and the observation bores used in the aquifer test. Strata present in the bore logs can be directly correlated between various bores when correcting for topographic relief, however in many cases bedding grades rapidly into other units or discretely interfingers adjacent strata so that no correlation is possible.

The high degree of heterogeneity in the geological profile directly impacts the dynamics of the groundwater system in this area of the Waipara Groundwater Zone. The aquifers beneath the property are therefore thought to be discrete and lack extensive lateral continuity. The heterogeneity of the geology and discreteness of the aquifer result in interference effect modelling that may provide erroneous results. Aquifer testing is therefore the only certain way to determine connection between wells.

Bowden Environmental has previously analysed aquifer testing in the vicinity of bore M34/5707. Two aquifer tests were carried out on M34/5642 over the period 20-21 April 2005 for the purpose of measuring effects on neighbouring bores and to determine the sustainable yield of M34/5642. An aquifer test was also conducted on bore M34/5603 an observation bore for this particular aquifer test. The results of test are provided in Appendix 2.

3.0 Step Drawdown Aquifer Test

The drawdown in a pumped bore consists of two components: the aquifer losses and the well losses. A well-performance test (such as a step-drawdown test) is conducted to determine these losses and provide some limited information about the aquifer characteristics.

Aquifer losses are the head losses that occur in the aquifer where the flow is laminar (i.e. at a sufficient distance away from the well). These are time dependent and vary linearly with the well discharge. Additional head loss induced by the partial penetration of a well is also included in this.

Well losses are divided into linear and non-linear head losses. Linear well losses are caused by damage to the aquifer during the drilling and completion of the well. They comprise, for example, head losses due to the compaction of the aquifer material during drilling, head losses due to the plugging of the aquifer by drilling mud, head losses in the gravel pack; and head losses in the screen. Non-linear well losses include turbulent losses inside the well screen and in the suction pipe where the flow is turbulent, and the head losses that occur in the zone adjacent to the well where the flow is usually also turbulent.

3.1 Step Test Procedure

A summary of the details of the step drawdown test carried out on 5 July 2016 on the bore M34/5707 is presented in Tables 2 and 3.

Table 2

Owner	Depth (m)	Diameter (mm)	Screen (m)	Initial Water Level (mbgl)
Hurunui District Council	146	250	120 – 130 138 - 146	12.04

Table 3

Pumping Well M34/5707					
Step	**Pumping rate (l/s)**	**Start**	**End**	**Duration (mins)**	**Maximum Drawdown from Start (m)**
Step 1	8.24	0	35	35	12.52
Step 2 – Pump Interrupt	0	35	51	16	1.80
Step 3	8.31	51	174	123	14.05
Step 4	12.24	174	296	122	23.71
Step 5	16.30	296	417	121	34.80
Step 6	23.87	417	1247	830	65.32
Recovery	0	1247	1444	197	5.80

Throughout the tests the discharge rates were measured using an in-line flow meter with datalogger and the water discharged into a large pit to the south. The pumped bore was fitted with an absolute pressure sensor which was set to record at one minute intervals. A BaroTroll was also recording atmospheric pressure at the same one minute intervals. However, it is not entirely necessary to utilise this data because the external influences caused by changing atmospheric pressure are usually assumed to be small considering the duration of a step test. The drawdowns are therefore simply the difference in total pressure measured by the pressure sensor. In any event, the BaroTroll data was used in this analysis. Other influences such as natural background water level trends are also assumed to be negligible for the short duration step test.

3.2 *Water Level Observations*

The water level observations are plotted in Appendix 3, along with the flow rate data recorded by the driller during the tests. The flow rate data shows that the pump was interrupted during the first step and was re-started. The final long duration step also shows a small declining trend in rate. This should not compromise the analysis. The water level data for the pumped bore also shows the pump interruption. However, the drawdown data is very steady and should provide a good analysis.

3.3 *Eden Hazel Analysis*

When analysing the data the following assumptions are used (Kruseman and de Ridder, 2000):

- The aquifer has seemingly infinite areal extent.
- The aquifer is homogenous, isotropic, and of uniform thickness over the area influenced by the test.
- All changes in the potentiometric surface are a result of the pumping well alone.
- Prior to pumping the potentiometric surface of the aquifer is horizontal and unchanging over the area influenced by the test.
- The pumping well penetrates the entire thickness of the aquifer and thus received water from horizontal flow.
- The water removed from storage is discharged instantaneously with a decline in head.
- All flow is radial towards the well during pumping.

The Eden Hazel (1973) solution specifically assumes that:

- The aquifer is pumped step-wise at increased discharge rates.
- The aquifer is confined.

The Eden Hazel (1973) analysis can be displayed graphically in a plot of drawdown versus H_n (which is a function of the abstraction rate and time). Assuming the aquifer test does not encounter any hydrogeological boundaries (impermeable, recharge etc.) a number of parallel datasets should plot in a trend with a similar angle. A consistent angle should give a very high level of confidence.

The computer software AquiferWin32 was used to analyse the data. This software provides three options for matching the data: a linear regression to one chosen step; a combined linear regression using all steps; or a

Marquardt (modified Gauss-Newton) non-linear least-squares fit to all the steps. It is prudent to try all options and to check the calculated fit to the actual data to obtain the best possible match.

The Marquardt regression using all steps was found to provide the best fit to the observed data. The match curves are in Appendix 4 and the analysis provided the transmissivity value reported in Table 4.

Table 4

Bore	Transmissivity
M34/5707	44 m^2/d

The transmissivity value is very similar to that obtained in the constant rate test carried out in 2006. An Aqtesolv analysis was also undertaken and the results are similar (Appendix 3).

Using the transmissivity and the coefficients analysed from the analysis it is possible to estimate what the maximum theoretical drawdown would be in a perfectly efficient well (Appendix 4, yield versus drawdown red line). The expected line of drawdown (marked as a black line on the yield versus drawdown graph) is used to estimate the maximum capacity of the bore. The available drawdown is assessed as follows:

- Assumed maximum depth to water = 15mbgl
- Top of screen = 120mbgl
- Allowance for leader = 2m
- Allowance for pump = 3m
- Pressure cutoff = 10m head above pump
- Cumulative drawdown interference allowance = 20m
- Resulting available drawdown = 70m

The yield/drawdown curve indicates that the bore is capable of a pumping rate around 25 - 30 litres/second. For planning purposes, a maximum rate of 25 l/s is considered prudent.

4.0 Constant Discharge Aquifer Test

While a constant rate test has been carried out on the bore in 2006, the opportunity was taken during this new step test to monitor bores located near the pumped bore. The bores used are shown on the map in Appendix 1, and are detailed in Table 5. All bores were fitted with absolute pressure sensors.

Table 5

Bore	Owner	Use in test	Depth (m)	Diameter (mm)	Screen (m)	Initial Water Level (mbgl)	Distance (m)
M34/5707	HDC	Pumped	146	250	120 – 130 138 - 146	12.04	0
M34/5653	Hulsman	Observation	32.2	150	29.2 – 32.2	6.16	125
M34/0682	Bartlett	Observation	9.5	914	nil	8.65	422
M34/0667	Gameson	Observation	24	150	22.5 - 24	5.94	490
M34/5684	Evans/Davis	Observation	78.18	200	76.18 – 78.18	7.49	543
M34/5603	McKean	Observation	108	200	69.5 – 71.5 101.5 – 104.5	9.05	850

Background atmospheric pressure was also logged on a barometric pressure sensor located at the site. All pressure sensors were time synchronised before the test allowing each monitoring device to be directly correlated without post-test time adjustment.

The aquifer testing took place over the period 4/7 July 2016. No irrigation abstractions had yet commenced for the season thus any external pumping influences that could have arisen would have come from stockwater and domestic supply and are likely to be minor. Table 3 summarises the test pumping procedure.

The aquifer test setup, running, and subsequent retrieval were operated over a relatively steady climatic background. All days were clear and sunny with very little in abrupt changes throughout the test.

Plots of the data are located in Appendix 3. The nearest observation bore, M34/5653, was pumped the day before the test and its self-induced drawdown is very large and takes several days to recover. There is no obvious response to the pumping from the HDC bore which is only 125 metres distant. The other shallow bores, M34/0682 and M34/0667, likewise showed no response to the pumping.

The two deep observation bores, M34/5684 at 543m distance, and M34/5603 at 850m distance, both show a response to pumping. The response is delayed, and the recovery is significantly delayed. This was also the case in the previous constant rate test over three days pumping in 2006. The observation bore M34/5603 water level plot from that test is also in Appendix 3 and is similar to what was observed in the recent shorter step test. What is also clear from the recent plots is that bore M34/5603 was itself pumped for three short periods to service the vineyard. Interestingly, bore M34/5684 responded directly to this pumping even though the two bores are of significantly different depths. However, the screening of the two bores (Table 5) shows that M34/5603 is double screened and its upper screen is similar to that of M34/5684. Clearly, there is good hydraulic connection between these two bores due to this commonality of screened depth. The connection to

M34/5707 is much less direct, and is likely to be a leakage effect between the layers, albeit with significant leakage.

The hydraulic connections were interpreted in the 2006 test as shown in the Table 6 below. However, it is apparent that there is better connection between screened depths from 70 metres downwards, and it is considered that any drawdown analysis should model all bores screened greater than 70 metres as being in the same layer. This will provide a conservative analysis.

Table 6

Bore Number	Screen Depths (metres below ground level)				
	Aquifer 1	Aquifer 2	Aquifer 3	Aquifer 4	Aquifer 5
M34/0670	23.0 – 24.0				
M34/0712	21.9				
M34/0738		68.0 – 78.0			
M34/0772		87.0 – 90.3			
M34/5606			112.0 – 118.0		
M34/5603		69.5 – 71.5		101.5 – 104.5	
M34/5707				120.0 – 130.0	138.0 – 147.0

5.0 Conclusions

The re-development of the bore M34/5707 appears to have improved its capacity. A maximum sustainable rate is now around 25 litres/second.

The results of the step test on the HDC bore M34/5707 confirmed the transmissivity value obtained from the previous constant rate test carried out 10 years earlier. In addition, separation between aquifers for future drawdown modelling purposes has been confirmed and bores less than 60 metres deep should be modelled in an overlying aquifer while all deeper bores should be in the same aquifer (this will be a conservative modelling set up). Very shallow bores, less than 10 metres deep, should be excluded from any drawdown assessment. The parameters from the previous test and this test are as follows:

- Transmissivity T = 87 m^2/d
- Storativity S = 0.00053
- Leakage L = 1194 m
- K'/B' = 0.000061 d^{-1}
- Sigma = 0.1
- T_0 = 100 m^2/d
- Separation at 60 metres between deep and shallow aquifers
- Hunt-Scott two-layer model for drawdown assessments.