2.0 Aquifer Analysis – Pumping Well

2.1 TESTING PROCEDURES

The drilling contractor drilled a test hole adjacent to a small pond in the western part of the property. It failed to produce the desired discharge, so an additional pumping well (Well 3) and two other monitoring wells (MW-1 and MW-2) were subsequently drilled in the same area. The two monitoring wells are located 49 and 50 m away from the production well, but in different directions. Locations are shown in Figure 1.2. As the production well appeared to have sufficient capacity, it was tested at 98.2 m^3/day for 24-hours, then allowed to recover for another 24-hours. Effects of the pumping and recovery were also measured in the two monitoring wells during the same period. Shortly before termination of the pumping phase, samples were taken to be submitted to WSH Labs (1992) Ltd. in Calgary for routine analysis and metals and bacterial analysis.

The tests were carried out by the Contractor under direction of the Client, and information was then passed on to Stantec Consulting Ltd. for interpretation of the results.

2.2 AQUIFER PARAMETERS

The aquifer parameters within the immediate area were evaluated from the long-term tests. The time-drawdown and time-recovery plots are shown in Figures 2.1 to 2.13 for all three wells.

Results are summarized below in Table 2.1. The Double Porosity analytical method was used for interpreting all aquifer test results, as this procedure is the one recommended in this hydrogeological environment by Schlumberger Water Services, the firm which markets AquiferTest Pro, v. 2010, v.1, the program used for these interpretations.

Table 2.1 - Aquifer Parameters in the Study Area

Well	Test	Transmissivity (m^2/day)	Storativity	Spec. Cap. (m^3/d/m)
Production Well	Pumping, semi-log	57.8		157.1
	Pumping, log-log	57.8		157.1
	Recovery, semi-log	61.4		
	Recovery, log-log	61.4		
Monitor Well 1	Pumping, semi-log	63.8	2.28E-07	
	Pumping, log-log	63.8	2.28E-07	
	Recovery, semi-log	59.6	1.51E-06	
	Recovery, log-log	59.6	6.12E-06	
Monitor Well 2	Pumping, semi-log	61.7	7.55E-04	
	Pumping, log-log	61.7	7.55E-04	
	Recovery, semi-log	71.2	9.25E-04	
	Recovery, log-log	71.2	9.25E-04	
	Value used	**62.6**	**8.50E-04**	**157.1**

Stantec

Stantec Consulting Ltd.
600 - 4808 Ross Street
Red Deer, AB T4N 1X5
Tel. 403-341-3320

Pumping Test Analysis Report

Project: Chinook Ridge Lodge and Golf Course
Number: 149104750
Client: Chloe Cartwright

Location: SE-31-28-3-W.5	Pumping Test: Aquifer Test	Pumping Well: Well 1
Test Conducted by: Wild Rose Water Wells Ltd.		Test Date: 11/10/2010
Analysis Performed by: Grant Nielsen	Pumping Well	Analysis Date: 12/2/2010
Aquifer Thickness: 3.70 m	Discharge: variable, average rate 98.132 [m³/d]	

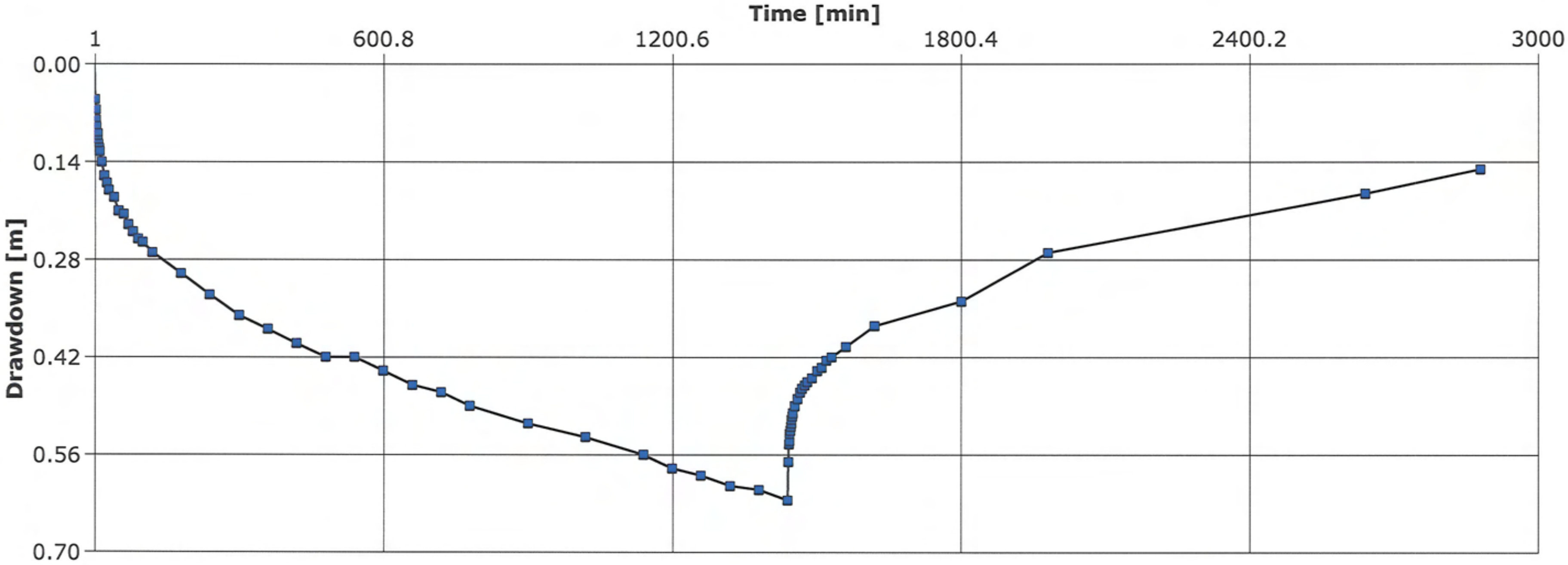
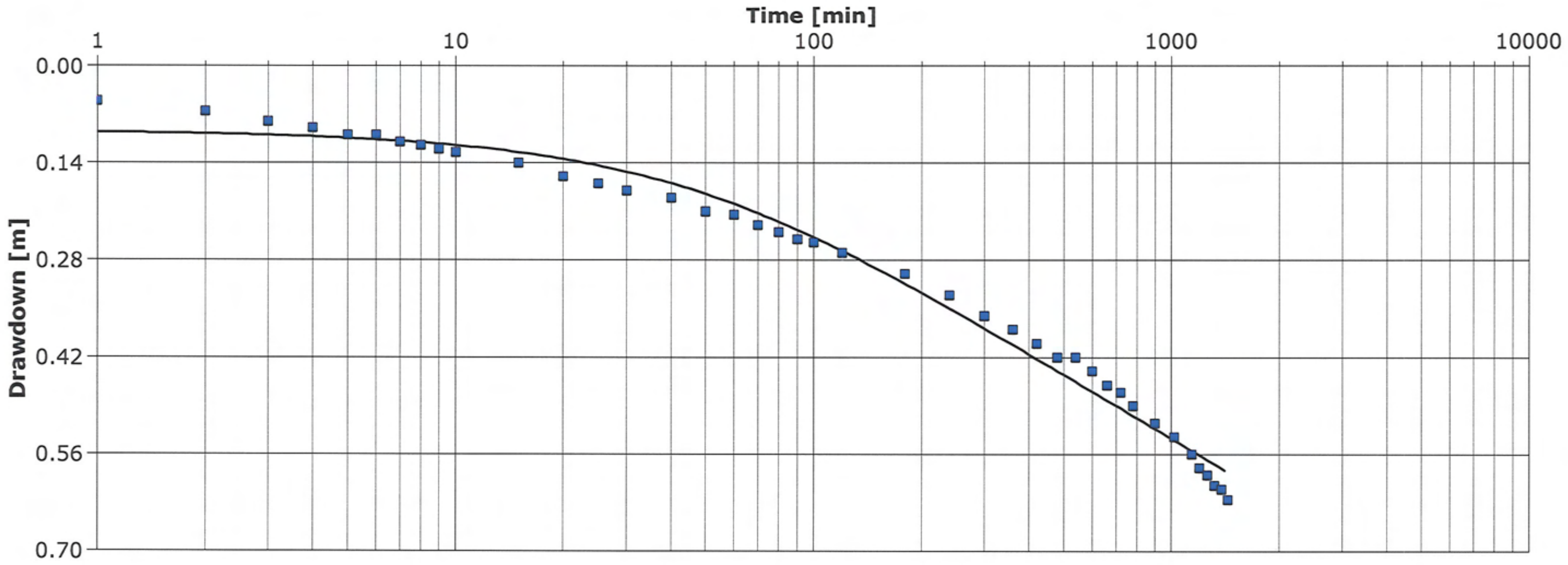


Figure 2.1 . Linear time-drawdown and recovery curve

Stantec Stantec Consulting Ltd. 600 - 4808 Ross Street Red Deer, AB T4N 1X5 Tel. 403-341-3320	**Pumping Test Analysis Report** Project: Chinook Ridge Lodge and Golf Course Number: 149104750 Client: Chloe Cartwright	
Location: SE-31-28-3-W.5	Pumping Test: Aquifer Test	Pumping Well: Well 1
Test Conducted by: Wild Rose Water Wells Ltd.		Test Date: 11/10/2010
Analysis Performed by: Grant Nielsen	Pumping Well	Analysis Date: 12/2/2010
Aquifer Thickness: 3.70 m	Discharge: variable, average rate 98.132 [m³/d]	



Calculation using Double Porosity

Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Specific storage	Sigma	Lambda	Radial Distance to PW [m]	
Well 1	5.78×10^{1}	1.56×10^{1}	9.92×10^{-2}	4.37×10^{3}	1.30×10^{0}	0.06	

Figure2.2 Semi - log time-drawdown curve

Stantec

Stantec Consulting Ltd.
600 - 4808 Ross Street
Red Deer, AB T4N 1X5
Tel. 403-341-3320

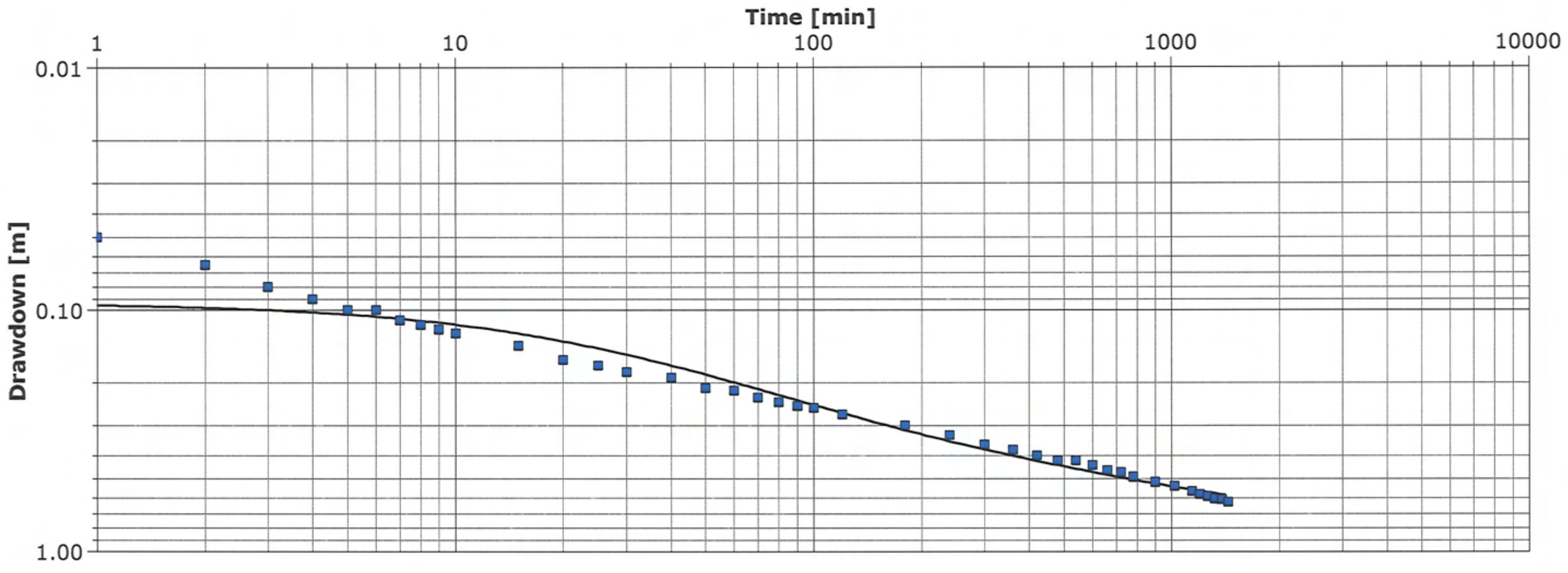
Pumping Test Analysis Report

Project: Chinook Ridge Lodge and Golf Course

Number: 149104750

Client: Chloe Cartwright

Location: SE-31-28-3-W.5	Pumping Test: Aquifer Test	Pumping Well: Well 1
Test Conducted by: Wild Rose Water Wells Ltd.		Test Date: 11/10/2010
Analysis Performed by: Grant Nielsen	Pumping Well	Analysis Date: 12/2/2010
Aquifer Thickness: 3.70 m	Discharge: variable, average rate 98.132 [m³/d]	



Calculation using Double Porosity

Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Specific storage	Sigma	Lambda	Radial Distance to PW [m]	
Well 1	5.78×10^{1}	1.56×10^{1}	7.53×10^{-2}	5.75×10^{3}	1.30×10^{0}	0.06	

Figure 2.3 Log - log time-drawdown curve

Stantec

Stantec Consulting Ltd.
600 - 4808 Ross Street
Red Deer, AB T4N 1X5
Tel. 403-341-3320

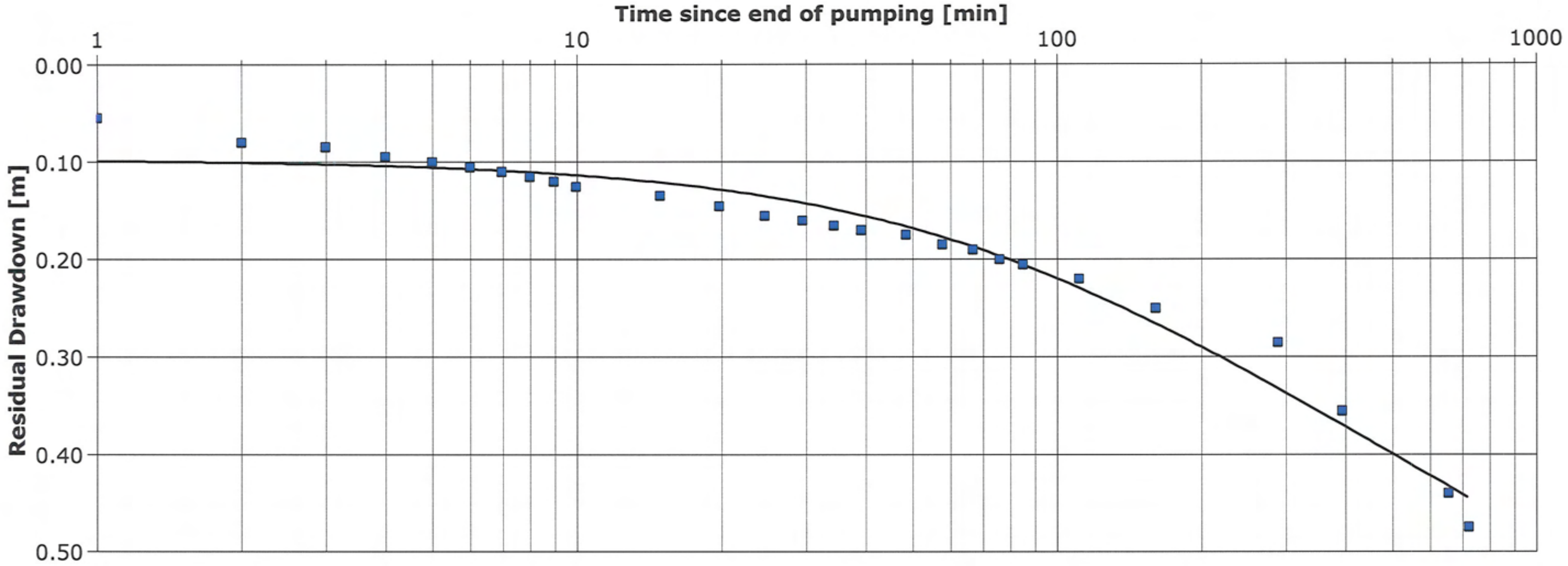
Pumping Test Analysis Report

Project: Chinook Ridge Lodge and Golf Course

Number: 149104750

Client: Chloe Cartwright

Location: SE-31-28-3-W.5	Pumping Test: Aquifer Test	Pumping Well: Well 1
Test Conducted by: Wild Rose Water Wells Ltd.		Test Date: 11/10/2010
Analysis Performed by: Grant Nielsen	Pumping Well	Analysis Date: 12/2/2010
Aquifer Thickness: 3.70 m	Discharge: variable, average rate 98.132 [m³/d]	



Calculation using AGARWAL + Double Porosity

Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Specific storage	Sigma	Lambda	Radial Distance to PW [m]	
Well 1	6.14×10^1	1.66×10^1	1.06×10^{-1}	5.11×10^3	1.14×10^0	0.06	

Figure 2.4 Semi - log time-recovery curve

Stantec
Stantec Consulting Ltd.
600 - 4808 Ross Street
Red Deer, AB T4N 1X5
Tel. 403-341-3320

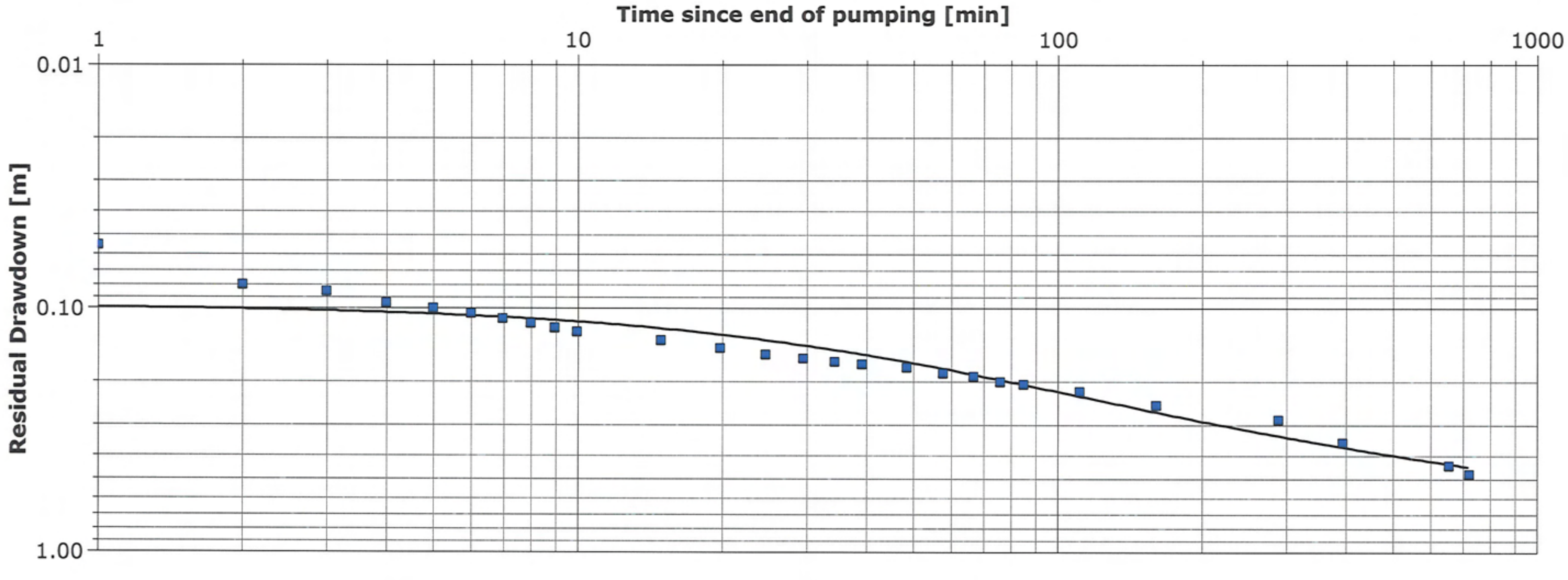
Pumping Test Analysis Report

Project: Chinook Ridge Lodge and Golf Course

Number: 149104750

Client: Chloe Cartwright

Location: SE-31-28-3-W.5	Pumping Test: Aquifer Test	Pumping Well: Well 1
Test Conducted by: Wild Rose Water Wells Ltd.		Test Date: 11/10/2010
Analysis Performed by: Grant Nielsen	Pumping Well	Analysis Date: 12/2/2010
Aquifer Thickness: 3.70 m	Discharge: variable, average rate 98.132 [m³/d]	



Calculation using AGARWAL + Double Porosity

Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Specific storage	Sigma	Lambda	Radial Distance to PW [m]	
Well 1	6.14×10^{1}	1.66×10^{1}	8.37×10^{-2}	6.46×10^{3}	1.14×10^{0}	0.06	

Figure 2.5 Log - log time-recovery curve

Stantec
Stantec Consulting Ltd.
600 - 4808 Ross Street
Red Deer, AB T4N 1X5
Tel. 403-341-3320

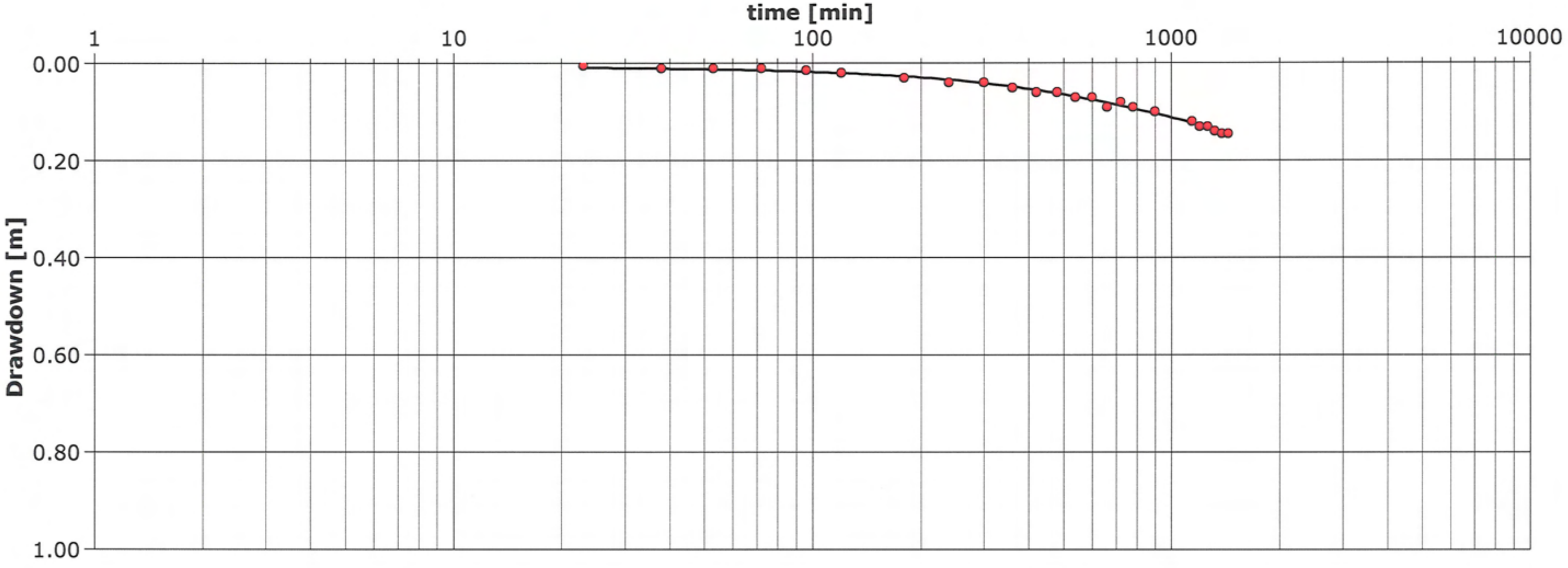
Pumping Test Analysis Report

Project: Chinook Ridge Lodge and Golf Course

Number: 149104750

Client: Chloe Cartwright

Location: SE-31-28-3-W.5	Pumping Test: Aquifer Test	Pumping Well: Well 1
Test Conducted by: Wild Rose Water Wells Ltd.		Test Date: 11/10/2010
Analysis Performed by: Grant Nielsen	Observation Well No. 1	Analysis Date: 12/2/2010
Aquifer Thickness: 3.70 m	Discharge: variable, average rate 98.132 [m³/d]	



Calculation using Double Porosity

Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Specific storage	Sigma	Lambda	Radial Distance to PW [m]	
Monitoring well #1	6.38×10^{1}	1.73×10^{1}	2.28×10^{-7}	1.00×10^{5}	1.00×10^{1}	49.0	

Figure 2.6 Semi - log time-drawdown curve, Monitoring Well No. 1

Stantec
Stantec Consulting Ltd.
600 - 4808 Ross Street
Red Deer, AB T4N 1X5
Tel. 403-341-3320

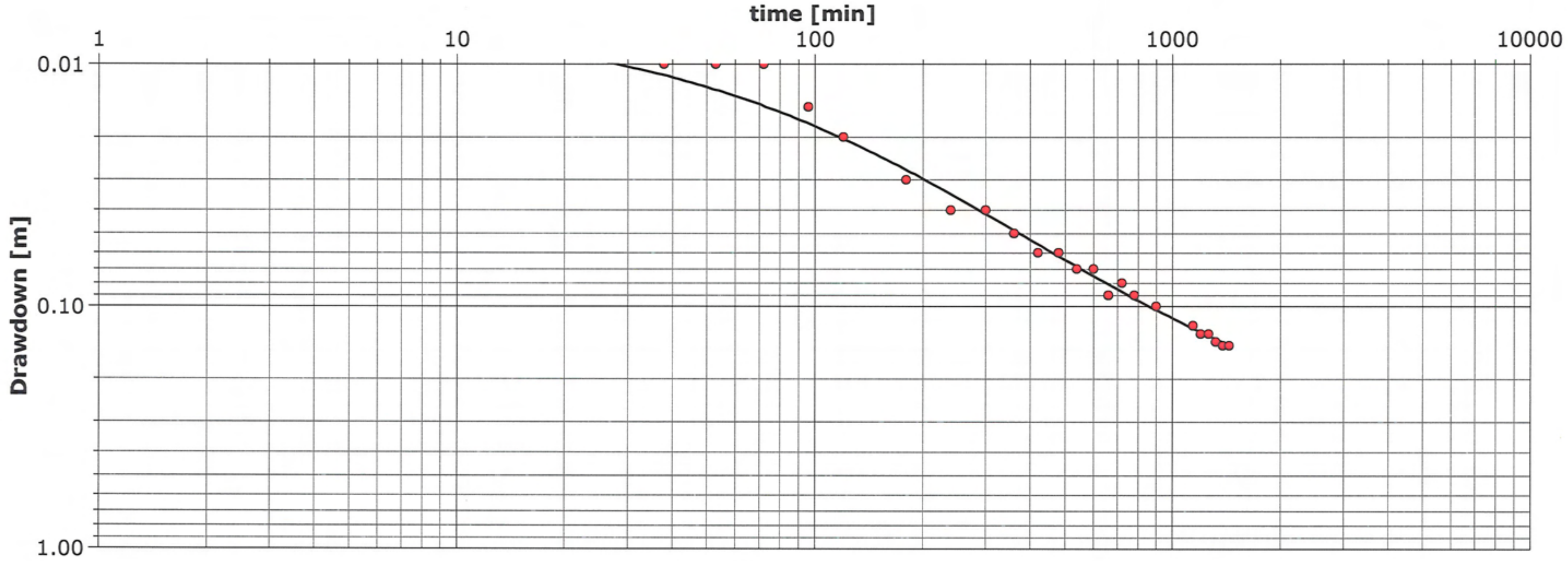
Pumping Test Analysis Report

Project: Chinook Ridge Lodge and Golf Course

Number: 149104750

Client: Chloe Cartwright

Location: SE-31-28-3-W.5	Pumping Test: Aquifer Test	Pumping Well: Well 1
Test Conducted by: Wild Rose Water Wells Ltd.		Test Date: 11/10/2010
Analysis Performed by: Grant Nielsen	Observation Well No. 1	Analysis Date: 12/2/2010
Aquifer Thickness: 3.70 m	Discharge: variable, average rate 98.132 [m³/d]	



Calculation using Double Porosity

Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Specific storage	Sigma	Lambda	Radial Distance to PW [m]	
Monitoring well #1	6.38×10^1	1.73×10^1	2.28×10^{-7}	1.00×10^5	1.00×10^1	49.0	

Figure2.7 . Log - log time-drawdown curve, Monitoring Well No. 1

Stantec

Stantec Consulting Ltd.
600 - 4808 Ross Street
Red Deer, AB T4N 1X5
Tel. 403-341-3320

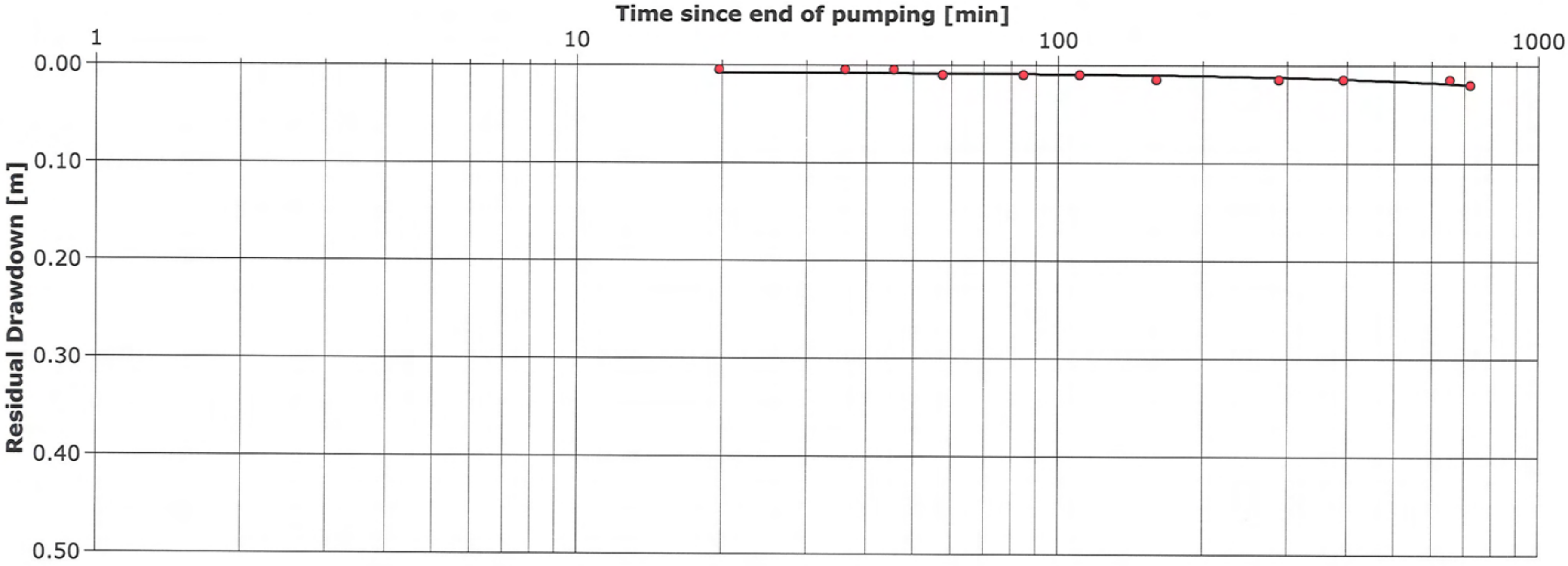
Pumping Test Analysis Report

Project: Chinook Ridge Lodge and Golf Course

Number: 149104750

Client: Chloe Cartwright

Location: SE-31-28-3-W.5	Pumping Test: Aquifer Test	Pumping Well: Well 1
Test Conducted by: Wild Rose Water Wells Ltd.		Test Date: 11/10/2010
Analysis Performed by: Grant Nielsen	Observation Well No. 1	Analysis Date: 12/2/2010
Aquifer Thickness: 3.70 m	Discharge: variable, average rate 98.132 [m³/d]	



Calculation using AGARWAL + Double Porosity

Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Specific storage	Sigma	Lambda	Radial Distance to PW [m]	
Monitoring well #1	5.96×10^{1}	1.61×10^{1}	1.51×10^{-6}	1.00×10^{5}	1.00×10^{1}	49.0	

Figure 2.8 Semi- log time-recovery curve, Monitoring Well No. 1

Stantec

Stantec Consulting Ltd.
600 - 4808 Ross Street
Red Deer, AB T4N 1X5
Tel. 403-341-3320

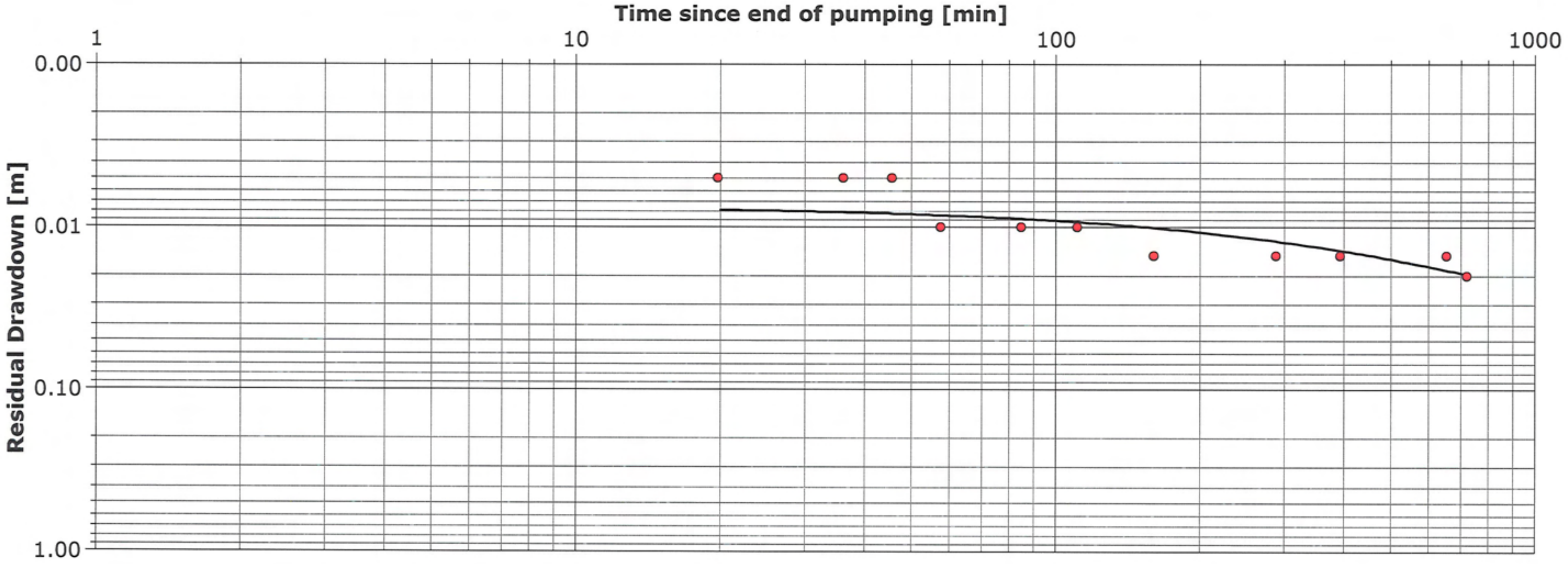
Pumping Test Analysis Report

Project: Chinook Ridge Lodge and Golf Course

Number: 149104750

Client: Chloe Cartwright

Location: SE-31-28-3-W.5	Pumping Test: Aquifer Test	Pumping Well: Well 1
Test Conducted by: Wild Rose Water Wells Ltd.		Test Date: 11/10/2010
Analysis Performed by: Grant Nielsen	Observation Well No. 1	Analysis Date: 12/2/2010
Aquifer Thickness: 3.70 m	Discharge: variable, average rate 98.132 [m³/d]	



Calculation using AGARWAL + Double Porosity

Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Specific storage	Sigma	Lambda	Radial Distance to PW [m]	
Monitoring well #1	5.96×10^{1}	1.61×10^{1}	6.12×10^{-6}	2.47×10^{4}	1.00×10^{1}	49.0	

Figure 2.9 . Log- log time-recovery curve, Monitoring Well No. 1

Stantec Consulting Ltd.
600 - 4808 Ross Street
Red Deer, AB T4N 1X5
Tel. 403-341-3320

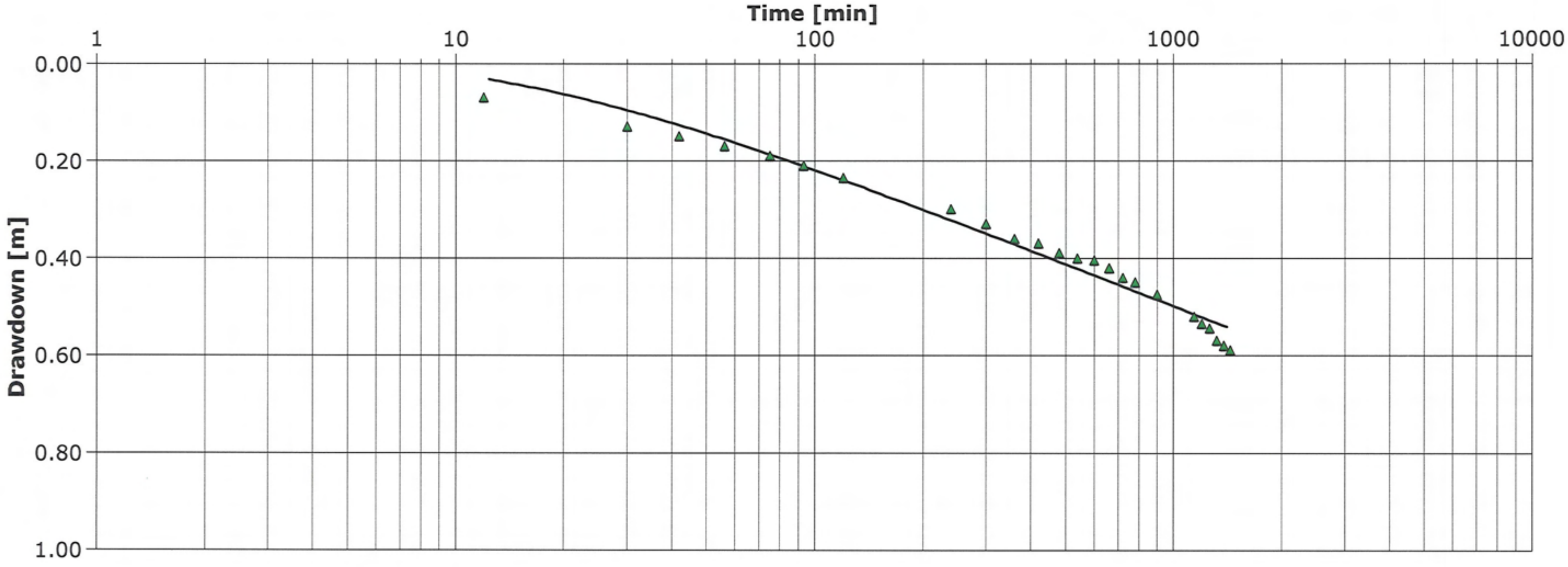
Pumping Test Analysis Report

Project: Chinook Ridge Lodge and Golf Course

Number: 149104750

Client: Chloe Cartwright

Location: SE-31-28-3-W.5	Pumping Test: Aquifer Test	Pumping Well: Well 1
Test Conducted by: Wild Rose Water Wells Ltd.		Test Date: 11/10/2010
Analysis Performed by: Grant Nielsen	Observation Well No.2	Analysis Date: 12/2/2010
Aquifer Thickness: 3.70 m	Discharge: variable, average rate 98.132 [m³/d]	



Calculation using Double Porosity

Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Specific storage	Sigma	Lambda	Radial Distance to PW [m]	
Monitoring well 3	6.17×10^{1}	1.67×10^{1}	7.55×10^{-4}	1.25×10^{0}	1.19×10^{-15}	50.0	

Figure 2.10 Semi- log time-drawdown curve, Monitoring Well No. 2

Stantec
Stantec Consulting Ltd.
600 - 4808 Ross Street
Red Deer, AB T4N 1X5
Tel. 403-341-3320

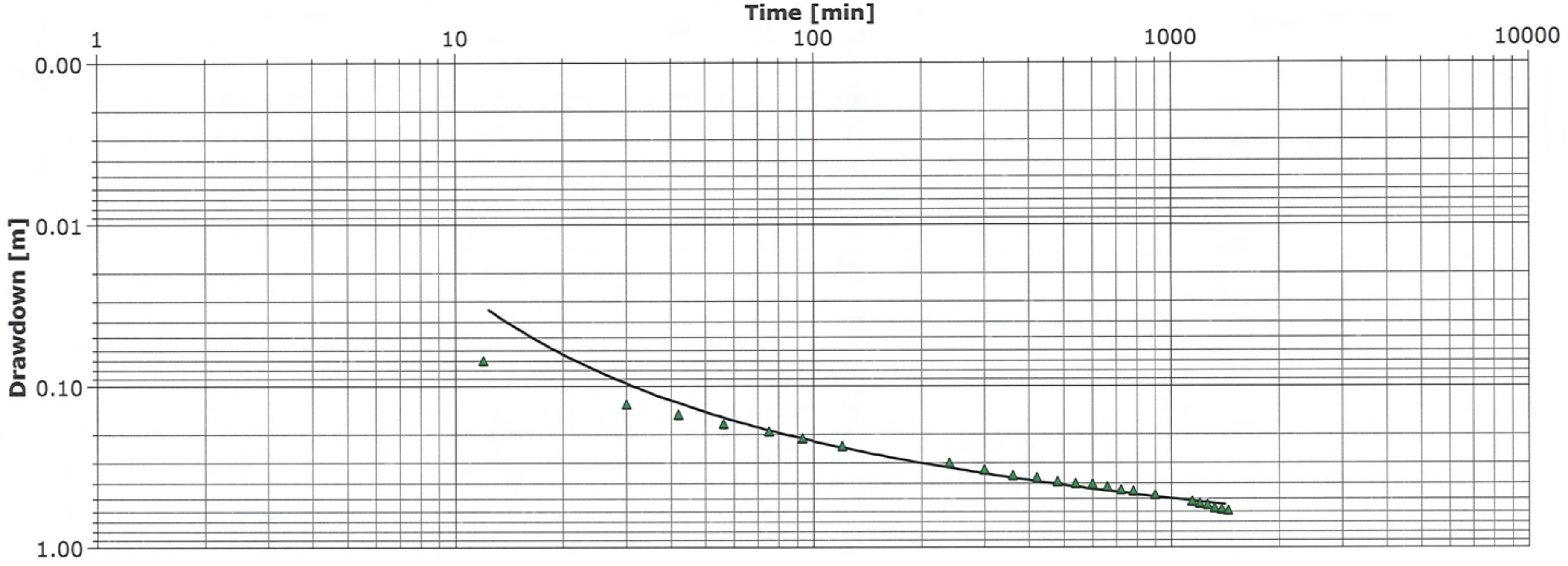
Pumping Test Analysis Report

Project: Chinook Ridge Lodge and Golf Course

Number: 149104750

Client: Chloe Cartwright

Location: SE-31-28-3-W.5	Pumping Test: Aquifer Test	Pumping Well: Well 1
Test Conducted by: Wild Rose Water Wells Ltd.		Test Date: 11/10/2010
Analysis Performed by: Grant Nielsen	Observation Well No.2	Analysis Date: 12/2/2010
Aquifer Thickness: 3.70 m	Discharge: variable, average rate 98.132 [m³/d]	



Calculation using Double Porosity

Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Specific storage	Sigma	Lambda	Radial Distance to PW [m]	
Monitoring well 3	6.17×10^{1}	1.67×10^{1}	7.55×10^{-4}	1.35×10^{0}	1.20×10^{-15}	50.0	

Figure 2.11 Log- log time-drawdown curve, Monitoring Well No. 2

Stantec

Stantec Consulting Ltd.
600 - 4808 Ross Street
Red Deer, AB T4N 1X5
Tel. 403-341-3320

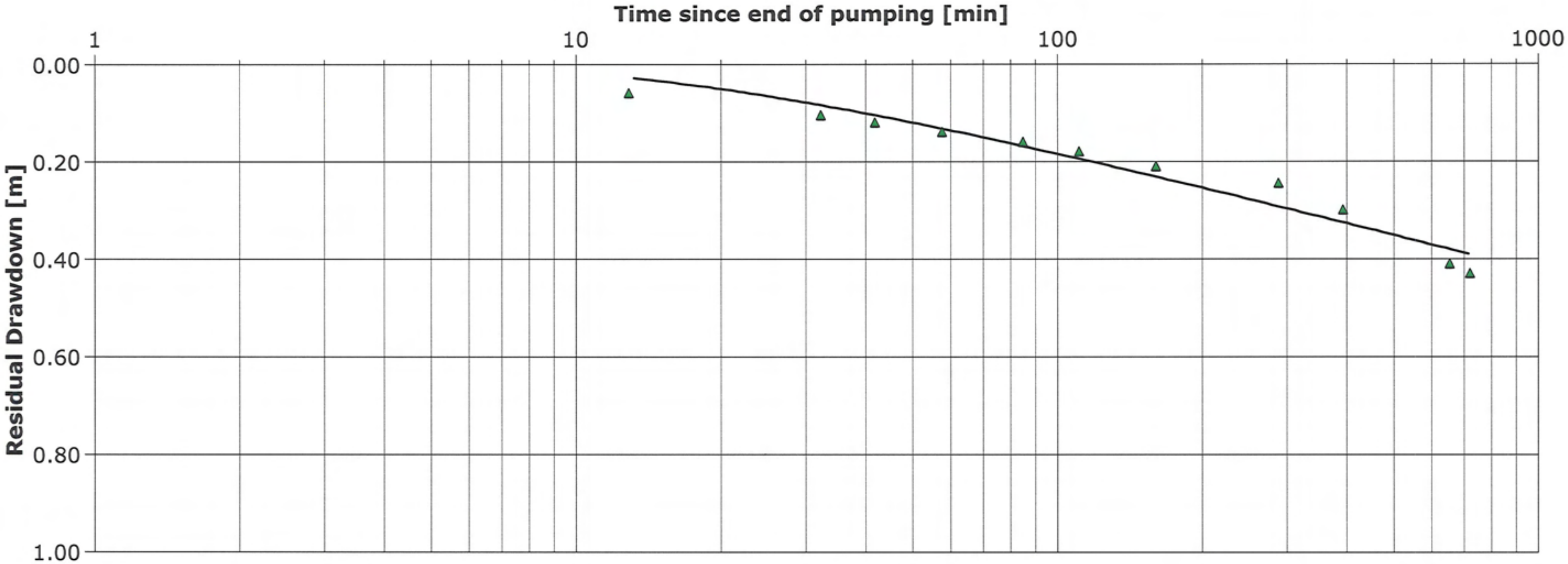
Pumping Test Analysis Report

Project: Chinook Ridge Lodge and Golf Course

Number: 149104750

Client: Chloe Cartwright

Location: SE-31-28-3-W.5	Pumping Test: Aquifer Test	Pumping Well: Well 1
Test Conducted by: Wild Rose Water Wells Ltd.		Test Date: 11/10/2010
Analysis Performed by: Grant Nielsen	Observation Well No.2	Analysis Date: 12/2/2010
Aquifer Thickness: 3.70 m	Discharge: variable, average rate 98.132 [m³/d]	



Calculation using AGARWAL + Double Porosity

Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Specific storage	Sigma	Lambda	Radial Distance to PW [m]	
Monitoring well 3	7.12×10^{1}	1.92×10^{1}	9.25×10^{-4}	1.02×10^{0}	1.02×10^{-15}	50.0	

Figure 2.12 Semi- log time-recovery curve, Monitoring Well No. 2

Stantec Consulting Ltd.
600 - 4808 Ross Street
Red Deer, AB T4N 1X5
Tel. 403-341-3320

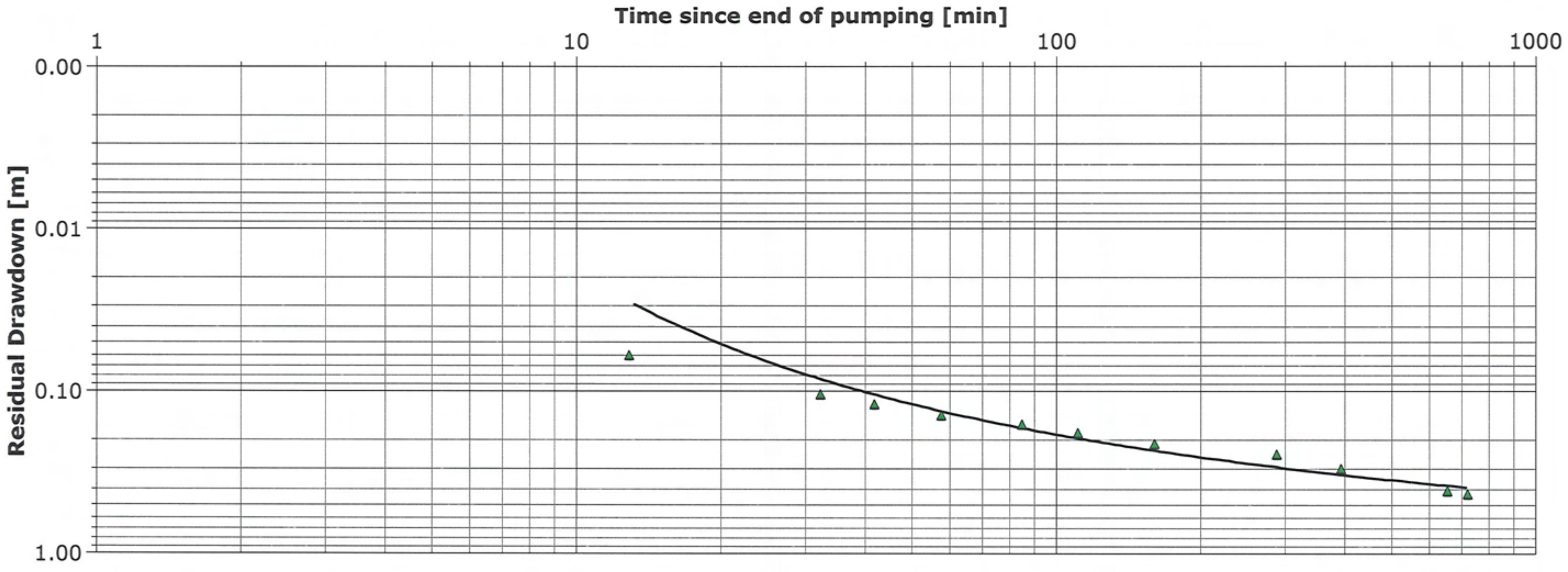
Pumping Test Analysis Report

Project: Chinook Ridge Lodge and Golf Course

Number: 149104750

Client: Chloe Cartwright

Location: SE-31-28-3-W.5	Pumping Test: Aquifer Test	Pumping Well: Well 1
Test Conducted by: Wild Rose Water Wells Ltd.		Test Date: 11/10/2010
Analysis Performed by: Grant Nielsen	Observation Well No.2	Analysis Date: 12/2/2010
Aquifer Thickness: 3.70 m	Discharge: variable, average rate 98.132 [m³/d]	



Calculation using AGARWAL + Double Porosity

Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Specific storage	Sigma	Lambda	Radial Distance to PW [m]	
Monitoring well 3	7.12×10^{1}	1.92×10^{1}	9.25×10^{-4}	1.00×10^{0}	1.00×10^{-15}	50.0	

Figure2.13. Log- log time-recovery curve, Monitoring Well No. 2

Based upon the interpretation of the tests, as summarized above, an average transmissive capacity of 62.6 m^2 /day was calculated and a storativity of 0.00085 has been assumed for all further calculations. There are some minor differences in transmissivity between the three wells, which is to be expected as few, if any, aquifers are completely isotropic and homogeneous. The storativity selected was the one calculated between Monitor Well 2 and the production well (Well No. 3).

The specific capacity of a well is calculated by dividing the productive capacity of a well by its drawdown. Since drawdown normally increases with time, this parameter is somewhat time-dependent, but drillers and others frequently use it as a means of comparing the relative productivity of different wells in an area.

In this case, the discharge of the well during the constant rate test was 98.2 m^3 /day and the maximum drawdown after 24-hours pumping was 0.625 m. Thus, the specific capacity of the well is 98.2/0.625 = 157.1 cubic metres per day per metre of drawdown. That is, for each metre of drawdown during pumping the well is capable, theoretically, of producing 157.1 cubic metres of water per day.

The theoretical long-term safe yield of the pumping well may be calculated by two main methods, the **Farvolden Method** and the **Moell Method**, based upon results of the aquifer testing. The Farvolden Method is expressed as follows:

Q_{20} = $(0.68)(T)(H_A)(0.7)$, in which
Q_{20} = calculated safe yield for 20 years continuous pumping, in m^3 /day
T = transmissive capacity, in m^2 /day
H_A = available head, the difference between nonpumping water level and the top of the completion interval of the well, in m.
0.7 = a safety factor, to compensate for unknown limiting factors.

In the case of the Pumping Well, the 20 year safe yield was calculated as follows:

$$Q_{20} = (0.68)(62.6)(3.52)(0.7) = 104.9\ m^3/day$$

The Moell Method is expressed as follows:

$$Q_{20} = \frac{(Q)(H_A)(0.7)}{s_{100} + 5\Delta s}\text{, in which}$$

Q_{20} = calculated safe yield for 20 years continuous pumping, in m^3 /day
Q = pumping rate used during the aquifer test, in m^3 /day
H_A = available head, the difference between nonpumping water level and the top of the completion interval of the well, in m.
0.7 = a safety factor to compensate for unknown limiting factors
s_{100} = the observed drawdown after 100 minutes pumping, in m
Δs = the drawdown per log cycle, in m.

The 20 year sustainable yield as calculated by the Moell Method is as follows:

$$Q_{20} = \frac{(98.2)(3.52)(0.7)}{0.255 + (5)(0.7)}$$

$$= 64.4 \text{ m}^3\text{/day.}$$

The Farvolden calculation is much greater that of the Moell calculation. In order to be conservative, the Moell result will be used for all further calculations. It is recommended that the long-term discharge not exceed this rate of 64.4 m^3/day, although it could be exceeded for short periods of a few days. It must not be exceeded however on an annual basis. Peak demand will be during dry periods within the 3 to 4 months of the summer season when irrigation will be needed and will be much lower during the colder part of the year.

2.3 INTERPRETATION OF AQUIFER TEST RESULTS

Both the pumping and the recovery portions of the test show that the transmissive capacity of the aquifer at this location is about 62.6 m^2 /day. The AquiferTest Pro program calculates storativity also, but when calculated from the pumping well measurements only the result is meaningless, as an accurate measurement of the distance between the point of production and the point of measurement is needed.

Storativity is a dimensionless parameter, because it is based on a calculation of volume divided by volume. Since only the log of storativity is used in predicting interference at different distances, a value which is imprecise does not greatly change the end result. A storativity of 0.00085 was selected, based on results from monitoring Well No. 2, for the calculations which follow in this report.

Although most aquifers are more or less confined and vary in confinement only by degree, the aquifer tested at this location appears to be well confined on its upper surface, based on the lithology described for the well. There are over 9 m of impermeable or nearly impermeable clay till and shale above the production zone in the Production Well and the two monitoring wells.

Both the constant-rate pumping test and the constant-rate recovery show a gradually steepening curve. This is interpreted to mean that the groundwater reservoir is limited in size, which is also confirmed by other past drilling further east within the same property. The value of ΔS used in the Moell calculations was taken from the last few points of drawdown measurements in the production well, which would provide the steepest curve if extrapolated to a log cycle of time.

Both of the monitoring wells also exhibit a similar behavior, although of course their total drawdown is much less than in the production well. There are small differences in the transmissivity calculated for the three wells, which is to be expected as no aquifer meets the theoretical standard of being of fully isotropic and homogeneous.

It was noted that recovery was incomplete in all three wells used in the test. The production well lacked 15 cm out of a total drawdown of 62.5 cm. Monitoring Well No. 1 recovered only 2 cm out of a total drawdown of 14.5 cm. Monitoring Well No. 2 drew down 59 cm and recovered 43 cm. These figures strongly suggest that the hydrogeological reservoir, or aquifer, is of limited size. The lack of success in exploration for groundwater in previous boreholes in the same quarter section confirms this concept. Thus, while the analysis carried out followed all the requirements of the *Groundwater Evaluation Guidelines*, it is essential to monitor very carefully the behavior of the aquifer and its response to pumping during the first one to two years, to determine its long-term response to diversion. The abundant precipitation of the area provides recharge however, which to some extent compensates for the restricted size of the aquifer. It is also important to note that although there will be some groundwater production all year long, it will be minimal outside the four months of the summer tourist season.

3.0 Impact Assessment

In order to calculate the degree of interference at different distances from the pumping well and at different times, the following parameters have been used, as derived from the aquifer test and other calculations:

Pumping rate = 64 cubic metres per day
Transmissive capacity = 62.6 m^2/day
Storativity = 0.00085 (dimensionless)

The impact, or interference, at different times and distances from the pumping well is calculated from two basic equations:

$$U = r^2 S/4Tt, \text{ or } 7.98\text{ E-}9{*}r^2$$

$$S = QW(u)/4\pi T, \text{ or } 0.0703\ W(u)$$

Since the calculations using these formulae are somewhat laborious for each time and/or distance increment, the computer program ***WELLz*** was used. It is based on the same mathematical processes described above and accomplishes the same results much more rapidly.

The calculations of interference shown in Table 3.1 on the following page are based on the assumption that the well will pump without stopping for 20 years, and that there will be no recharge to the aquifers during that time. It also assumes that the aquifers are extensive and that interference will occur only within the same aquifer that is used in the Production Well. Obviously all these assumptions are incorrect, as there will certainly be interruptions of the pumping time as described above and there will also be some recharge to the aquifer from infiltration of snowmelt and rainfall. The water demand calculated in Section 1 is based on full occupancy of the facilities during the entire year. While this would certainly be desirable from the owner’s point of view, the reality is that use will almost certainly decrease somewhat during the winter period.

In addition, the aquifers in this area are in the form of fractured strata and are not necessarily regionally extensive. Thus, the table shows only a “worst case scenario” of what might happen. In reality, the aquifer will likely exhibit less drawdown and interference than these calculations would indicate because of the recharge,

In addition, the maximum interference indicated below would take place only in wells which are completed in the same aquifer interval. Wells which are completed in shallower or deeper zones would probably show little or no interference. However, in the context of the hydrogeology of this area, the strata are dipping rather steeply to the east as this location is just west of the trough of the Alberta Geosyncline. Aquifers appear to consist of locally fractured zones, which may not respect any particular stratum, but were determined by the orogenic forces of the Laramide orogeny. Thus, the calculations shown in Table 3.1 may not fully represent reality in this hydrogeologic environment.

Table 3.1 - Interference Caused by Pumping of the Production Well

Distance (m)	1 Year	2 Years	5 Years	10 Years	20 Years
200	0.60	0.65	0.73	0.78	0.84
440	0.47	0.52	0.60	0.66	0.71
750	0.38	0.44	0.51	0.57	0.62
1000	0.33	0.39	0.47	0.52	0.58

Because many well-owners could be contacted in the field, Table 1.2 also includes the records of all adjacent water wells in the Alberta Environment website, except for those of purely a temporary nature which were mainly those used to supply water to oilfield drilling operations on a short-term basis only. A very few could not be contacted or refused to provide information.

The aquifers of Alberta are known to be generally discontinuous, lenticular, anisotropic and heterogeneous in their configuration. This gives rise to a number of concerns that must be considered in the calculation of long-term pumping rates and the design of water systems. Among these concerns are the following;

- Transmissive capacity is not constant everywhere in an aquifer, nor in time. The hydrogeologic cross-section (Figure 1.4) shows the extent to which unit thickness and hence transmissive capacity may vary, even in short distances (although part of the variability may result from differences in driller interpretation). Even within the same lithostratigraphic unit, there are significant variations in thickness, permeability, degree of fracturing, variation in cementation, etc. All these factors contribute to create a wide range of transmissive capacity, and hence of well yield.

- Because of the lenticular nature of most aquifers in Alberta, even neighbouring wells are often completed in different and distinct water-bearing strata. Therefore, one cannot necessarily assume that adjacent wells are connected hydraulically to each other. This is particularly true of this area for the reasons explained above.

- Nor is it likely, as the above analysis assumes, that a well will be pumped on a continuous basis over its lifetime. There are always periods of lower or no pumping during well maintenance, or when the owner is absent. In fact, peak demand will be during the summer months. While it is expected that the lodge will be in use during the off-peak season, its needs will certainly be lower than during the summer, when the golf course is active.

The basic assumptions behind the Theis analytical procedures for calculating transmissive capacity are that the aquifer is horizontal, of infinite extent, homogeneous and isotropic, and that the wellbore is of infinitesimal diameter. In reality, none of these assumptions is strictly true. The variations from the ideal can usually be recognized however and corrections made.

4.0 Groundwater Geochemistry

The regional groundwater assessment for Rocky View County (2002) indicates that groundwater in this area is mainly of the sodium-sulfate to bicarbonate type, particularly within the Dalehurst Member of the Paskapoo Formation. It states that chlorides are very low (less than 100 mg/L) and that fluoride is often excessively high (PFRA, 2002).

After 24-hours of pumping during the aquifer test on November 10 to 11, 2010, samples of the water were taken for routine analysis, metals analysis and bacteriological analysis. The samples were refrigerated and sent to WSH Labs (1992) Ltd. in Calgary. The results are shown on the following page in Table 4.1, and the original documents from the laboratory have been included in Appendix D. Although the water is very hard (427 mg/L of hardness), none of the parameters exceeds the standards of the *Guidelines for Canadian Drinking Water Quality*. Thus, the water is perfectly safe for all purposes without special treatment.

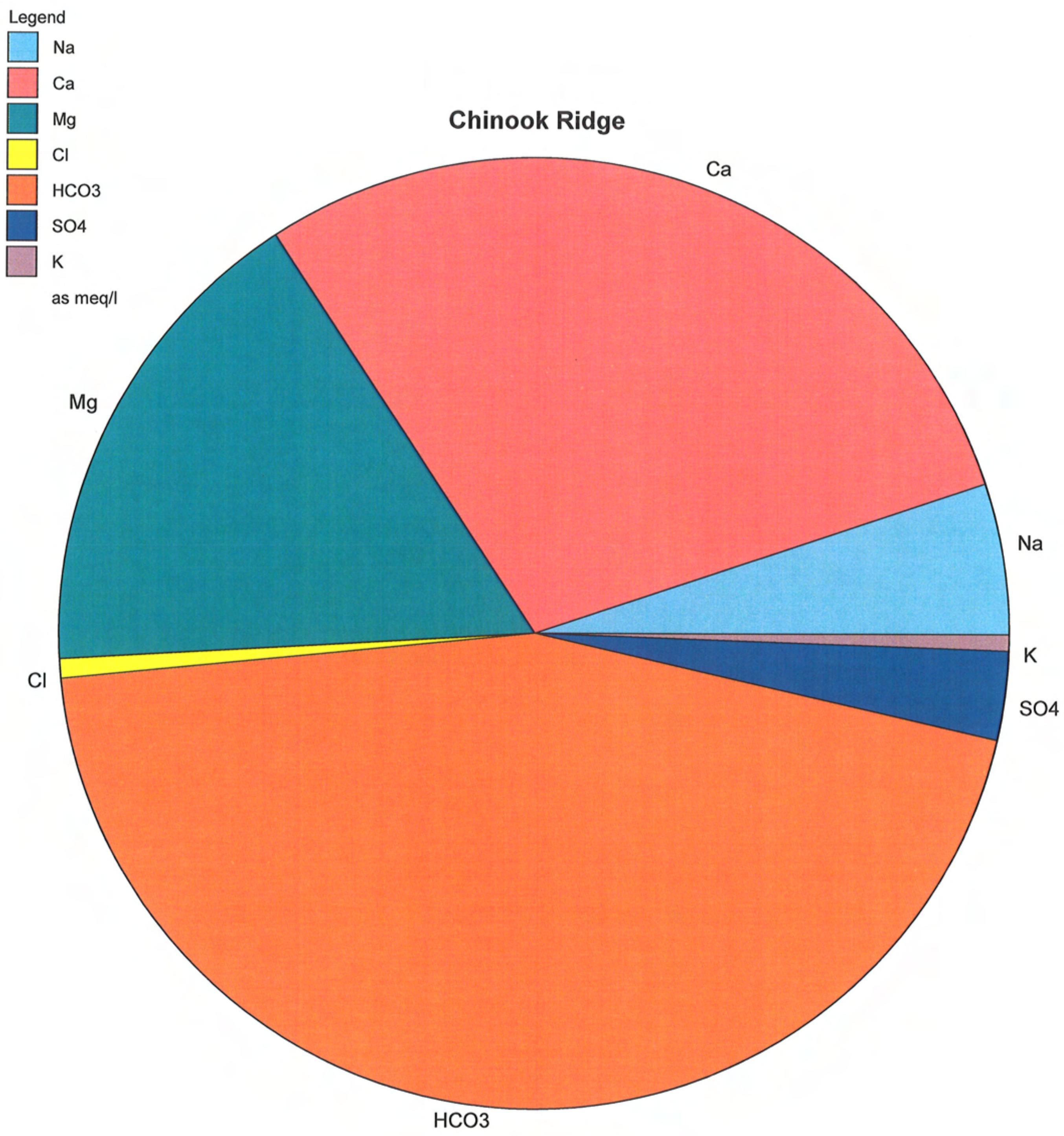
However, the excessive hardness can create incrustation within water pipes and heaters over time. It would be advisable to investigate the use of water softeners in areas where water is used for cooking or bathing.

The water is seen to be of a calcium-magnesium-bicarbonate type. Figure 4.1 is a pie diagram which shows graphically that calcium, magnesium and bicarbonate are the predominant ions, and that all others are minor in comparison. The above analysis shows that the water meets all the *Canadian Drinking Water Guidelines*. Appendix D includes analyses of other samples from the immediate area.

The water is free from coliforms, fecal coliforms and E coli.

Table 4.1 – Groundwater Geochemistry

Parameter	Unit	Result	GCDWQ Standard
Calcium	mg/L	109	
Iron	mg/L	0.03	0.3
Magnesium	mg/L	37.8	
Manganese	mg/L	0.01	0.05
Potassium	mg/L	4.1	
Sodium	mg/L	22	200
Bicarbonate	mg/L	511	
Bromide	mg/L	<0.1	
Carbonate	mg/L	0	
Chloride	mg/L	4.4	250
Fluoride	mg/L	0.17	1.5
Nitrates	mg/L	1.2	10
Nitrites	mg/L	<0.02	1
Sulfates	mg/L	27	500
Electrical Cond.	µS/cm	796	
pH	pH units	7.82	6.5-8.5
Hardness	mg/L	427	
Alkalinity	mg/L	419	
Total dissolved Solids	mg/L	457	
Total coliforms	CFU/100ml	0	0
E Coli	CFU/100ml	0	0
Boron	µg/L	29.3	5000
Aluminum	µg/L	6.2	100
Chromium	µg/L	<0.1	50
Copper	µg/L	0.3	1000
Zinc	µg/L	1.2	5000
Arsenic	µg/L	0.4	10
Selenium	µg/L	3.4	10
Cadmium	µg/L	<0.05	6
Antimony	µg/L	0.6	6
Barium	µg/L	149	1000
Mercury	µg/L	<0.05	1
Lead	µg/L	<0.1	10
Uranium	µg/L	7.1	20



DESCRIPTION:	Figure 4.1 . Pie chart of groundwater quality		
PROJECT:	Chinook Ridge Lodge and Golf Course	PROJECT NO:	149104750
CLIENT:	Chloe Cartwright	DATE:	Dec. 6, 2010

Company

5.0 GWUDI Considerations

Alberta Environment has prepared a screening method to determine if groundwater supplies are to be considered as GWUDI, or groundwater under the direct influence of surface water. The importance of this screen is that those supplies which are under the direct influence require a much more comprehensive and consequently more costly program of treatment, in order to assure the safety of the supply to its users. The screening process in this case will follow the procedures outlined in Appendix E of Environment's "*Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems*" *(January, 2006).*

PHASE 1 – GWUDI SCREEN

1. Sensitive Setting
    a. The source is not a spring, infiltration gallery, shallow collector system, artificial recharge system, bored well or dug well.
    b. The well has a production zone **which is less than 15 m below ground level**, ie, it is at just over 9 m depth in this case, overlain by clay till and shale.
    c. The well is in a confined aquifer.
    d. The well is not in fractured or karst bedrock exposed at or near the land surface.
2. Proximity to Surface Water - The pumping well and the two monitoring wells are adjacent to a small shallow pond, whose greatest total depth is less than 0.3 m.
3. Well Construction - The well has been drilled in a manner which meets the requirements of the current version of the Alberta Water (Ministerial) Regulation, with 150 lb. of bentonite slurry and bentonite chips emplaced in the first 9.1 m. around the casing. This has sealed the casing and aquifer against any direct downward leakage of surface water.
4. The water quality shows no evidence of contamination by surface water, with e.coli and other bacteria being absent and almost the complete absence of nitrates and nitrites. The water meets all criteria of the *Guidelines for Canadian Drinking Water Quality*. The extreme hardness, at 427 mg/L, while not desirable, is a level virtually never found in surface water in Alberta. This supports the thesis that there is no contact with surface water.

Because items 1b and 2 above do not meet GWUDI criteria, it is necessary to proceed to Phase 2a.

PHASE 2A – HYDROGEOLOGICAL REVIEW

The 11 m of geological material above the aquifer is composed of brown and grey clay till and grey to brown shale. These are materials of very low hydraulic conductivity, ranging from 10E-8 to 10E-11 m/sec (*Todd and Mays, 2005, p. 94*).

The only surface water body nearby is a small ephemeral pond whose maximum seasonal depth is perhaps 0.3 m, situated in a low spot of the till and forming part of a minor drainage course toward the northwest. The aquifer test, carried out for 24-hours at 98.2 m^3/day, showed no indications of recharge to the aquifer.

There is no documented history of past groundwater quality and surface water quality monitoring in this area, as the wells were constructed immediately before the testing described in this report.

Based on the textbook values of hydraulic conductivity quoted above, estimated theoretical travel time for infiltration of surface water to the aquifer, using the maximum hydraulic conductivity above, would be about:

Time (sec) = distance(m)/velocity(m/sec)

= 11/1X10E-8

= 1,100,000,000 sec = 12,731 days or 34.9 years.

If the minimum hydraulic conductivity were used from above, the travel time would be 3 orders of magnitude greater, or about 3,490 years. Since the sealing layer above the aquifer is composed of materials from both extremes, a reasonable theoretical estimate of travel time would be 350 to 1,000 years. Real travel time would likely be somewhat less.

In conclusion, it appears obvious that there are no GWUDI concerns in this hydrogeologic environment.

6.0 Conclusions

- The well which was tested was completed in a consolidated sandstone aquifer of the Dalehurst Member, Paskapoo Formation.
- The aquifer is confined and its level responds in minor part to fluctuations in barometric pressure. The well and aquifer are not therefore considered to be groundwater under the influence of surface water.
- There should be no impediment for Alberta Environment to license diversions of groundwater for commercial purposes in this project.
- This well and the aquifer were tested at a constant rate of 98.2 cubic metres per day for a 24-hour period, followed by another 24-hours of recovery.
- The aquifer has a transmissive capacity at this location of 62.6 m^2/day, a storativity of 0.00085 and a specific capacity of 157.1 m^3/day/m.
- The well is shown to be capable theoretically of producing a discharge of about 64 cubic metres per day by the Moell calculation.
- The discharge of 64 cubic metres per day will not create undue interference to the neighbours' wells, less than 0.65 metre in the closest well constructed within the same hydrostratigraphic zone, ignoring recharge which would serve to reduce the interference.
- The water has no parameters which exceed the *Canadian Drinking Water Guidelines*, but is very hard.
- No bacterial parameters were present in the water.
- The groundwater at this location would not be considered as GWUDI.

7.0 Recommendations

- It is recommended that the long-term maximum daily discharge rate should not exceed 64 cubic metres per day, except for brief periods not exceeding to 3 or 4 days at a time. The annual average should not exceed 64 cubic metres per day.

- For these short periods of up to several days, the daily discharge rate may attain 98.2 m^3/day.

- The high quality of this water will permit its use for all purposes, but it is recommended to consider the use of softeners in certain locations to avoid buildup of deposits in water pipes.

- It is recommended that Alberta Environment license this diversion for up to 23,360 cubic metres per year, principally for use in a lodge and a restaurant, with the excess over these potable needs to be available for irrigation during the summer period.

- It is recommended to use the most environmentally friendly water consuming appliances possible in all the facilities of the lodge and restaurant, in order to minimize water consumption. These would include low-volume toilets, special shower heads, low-volume dish washers, etc.

- For the first two years of full operation of the lodge and golf course, it is recommended to meter on a weekly basis the water production from the production well, and to measure each week the dynamic water level in the Production Well and Monitoring Well no. 2. This data should be recorded so that aquifer performance can be monitored and if needed, appropriate corrective measures taken.

- At the end of two years of monitoring as outlined above, results should be reviewed, and the monitoring program might then be relaxed, depending on results.

8.0 References

Alberta Environment, 2003, Groundwater Evaluation Guideline; Government guideline for licensing requirements, Feb. 5, 2003.

Alberta Environment, 2006, Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems; Drinking Water Branch, Environmental Policy Branch, Environmental Assurance Division, Jan., 2006.

Demchuk, Thomas D. and Hills, L.V., 1991, A Re-examination of the Paskapoo Formation in the Central Alberta Plains: the designation of three new members; Bul. Can. Pet. Geology, vol. 39, No. 3, Sept, 1991, pp. 270-282.

Hamilton, W. N., Price, M.C., and Langenberg, C.W. (compilers), 1999, Geological Map of Alberta; Geological Survey of Alberta, Alberta Energy and Utilities Board, Map 236, Edmonton.

Health Canada, 2004, Summary of Guidelines or Canadian Drinking Water quality; prepared by the federal-provincial-territorial committee on drinking water, Ottawa.

PFRA, 2002, Regional groundwater evaluation, County of Rocky View No. 44; Consulting report by Hydrogeological Consultants Ltd., dated March, 2002.

Schlumberger Water Services, 2010, AquiferTest Pro 2010; Waterloo, Ontario

Shetsen, I., 1990, Quaternary Geology, Central Alberta; Alberta Geological Survey, Alberta Energy and Utilities Board, Edmonton.

Todd, D.K., and Mays, L.W., 2005, Groundwater Hydrology; 3rd edition, John Wiley & Sons, Hoboken, N.J.

9.0 Corporate Authorization

This document entitled "**Groundwater Evaluation - Chinook Ridge Lodge and Golf Course, SE-31-28-3-W.5**" was prepared by Stantec Consulting Ltd. for Chloe Cartwright. The material in it reflects Stantec Consulting Ltd.'s best judgment in light of the information available to it at the time of preparation. Any use which a third party makes of this report, or reliance on or decisions made based on it, are the responsibilities of such third parties. Stantec Consulting Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

PERMIT TO PRACTICE
STANTEC CONSULTING LTD.
Signature
Date January 21, 2011
PERMIT NUMBER: P 0258
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

CORPORATE AUTHORIZATION

GRANT L. NIELSEN
Jan. 10, 2011

RESPONSIBLE ENGINEER