GROUNDWATER EVALUATION FOR SANDY POINT, GULL LAKE, ALBERTA

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Executive Summary

Delta Land Development has tested three wells, herein termed Wells A, B and C, located about 0.5 km west of Gull Lake, in order to provide potable and irrigation water to an RV Park, camping area, marina and a golf course. The facility will operate mainly in the 120 day window of the tourist season. All three wells were completed in fractured bedrock aquifers of the Paleocene Paskapoo Formation. Well A is completed in a shallower aquifer than Wells B and C. Well A was tested at 196.5 m^3/day, Well B at 307.8 m^3/day and Well C at 576.3 m^3/day. Delta Land is applying for a diversion license of 62,279 m^3/year.

Each well was previously tested for a 24-hour pumping period in 2002. All were retested at higher discharge rates and for 48 to 72 hours in March 2011, in accordance with current requirements of Alberta Environment. During the test of each well, the other two were monitored as observation wells to detect any interference between them.

All three wells exhibited a slow gradual rise of non-pumping level during the 18 days of the testing program, except during the pumping of each well. Well A, completed in the shallower aquifer, is not affected by pumping of Wells B and C, nor does its pumping affect levels in the two other wells. The effect of pumping of Well B may be measured in Well C and vice-versa, being completed within the same aquifer.

Pumping at the maximum expected discharge rate for 120 days each year will create some interference in a number of wells belonging to other owners, but the interference in every case is much less than the available head.

During the aquifer testing program, water samples were taken for field measurement of pH and electrical conductivity from both the producing wells and from the lake nearby. No evidence of any hydraulic connection could be detected between groundwater and lake water, based on water quality considerations, and based on aquifer behavior during the aquifer tests.

It was found that Well A has sufficient capacity at 196.2 m^3/day to meet all requirements of the project for about the first 5 years. Thereafter, with expansion of the facility and the construction of a golf course, which will require some irrigation, Well C will be required which has a sustainable yield of 576.3 m^3/day. Not all of this yield will be needed, even at full build-out. Well B has poorer quality water than the other two wells and therefore should be kept for standby purposes only.

The water quality in Well A is much better than that of Well B or C. For this reason, it should be used to its fullest possible extent, and the production from Well C minimized insofar as possible. The water from Wells B and C has excessive levels of sodium and high sulfate. The pH is slightly excessive in all three. All these problems will require careful evaluation in terms of irrigation and water treatment.

Based on this study, it is recommended that Alberta Environment license a total groundwater diversion of 62,279 cubic metres per year, with 23,554 cubic metres produced from Well A and the balance of up to 38,735 cubic metres could be produced from Well C in the future when demand exceeds the capacity of Well A.

Well A, based on its Q_{20} calculation of 180.6 m^3 /day, could produce 65,919 cubic metres of water per year, about 5 per cent greater than the full application amount of 62,279 cubic metres per year. However, the $Q_{120\ day}$ discharge rate for the tourist season is just 196.2 m^3/day, or 23,544 cubic metres per tourist season.

Well B should be kept for standby use only due to its poorer water quality and lower productive capacity, which is inferior to that of Well C.

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1.0 Introduction

1.1 SITE LOCATION AND SETTING

Delta Land Development Inc. owns a property just west of Gull Lake on which it plans to develop a multi-use facility for recreational purposes. When fully developed, it will have RV facilities, camping areas, a marina and a golf course. Because of the scope of the development, it will be phased over several years with the rate of development dependent largely upon general economic conditions within Alberta. Tentatively, full development is scheduled to take about 10 years. The golf course phase will not be built for about 5 years.

The property is located about 4 km north and 2 km east of the Town of Bentley, on the western shore of Gull Lake (Figure 1.1). However, there is an environmental reserve along the shoreline such that all development must be set back from that reserve. The three water supply wells are located about 0.5 km west of the present shoreline.

No permanent streams flow into Gull Lake, and very few ephemeral streams contribute seasonal runoff to the lake. Lake level has been documented historically to have dropped by over 2.5 m since levels were first recorded in 1924. Although there are annual fluctuations, the lake level has stabilized at about 899.0 m amsl since 1970, because some of the spring runoff from the Blindman River is pumped into the lake in most years (Figure 1.2). At present, water levels are monitored at the Sunnyside Marina throughout the ice-free season several times daily under a joint federal-provincial program.

Three water wells were constructed and tested by a previous owner of the property in 2002. Water supply for the development will be from these existing wells for potable supply, plus use of natural runoff to supplement irrigation of a golf course. The golf links, when constructed, will be irrigated with a mix of treated wastewater from the facility, plus natural runoff, in order to minimize groundwater use and prevent deterioration of surface water quality entering into the lake.

The original testing program of the wells in 2002 no longer meets the requirements of Alberta Environment. Therefore the same three wells have been evaluated a second time in order to provide the water supply for all phases of the development. All are located within Lsd. 15-1-41-1-W.5. (The locations shown on the well records in Appendix A are incorrect). The shallowest well, designated Well A, contains the best quality water and will be used to the exclusion of Wells B and C to the greatest extent possible. Thereafter, as demand increases, the use of Wells B and C may be used as needed, but keeping their production to a minimum insofar as possible, in order to optimize the quality of water provided to the public and for irrigation purposes.

The resort is expected to be in use about 120 days per year (about May 15 to September 15), such that groundwater will be diverted during only about one-third of each calendar year. Although the developers expect to sell all their lots, actual full occupation of the lots will not likely occur at any time. Most use of the facility and of the water supply would begin on the May long weekend and continue until Labour Day, and mainly during the period when children are out of school. During the remaining two-thirds of the year, a few people will likely use the facility but only on occasional weekends such as the Christmas – New Year season. Therefore, during this period, the aquifers will not be used or remain almost unused and will therefore likely recover to their non-pumping levels. Annual theoretical demand, based on full occupancy for 120 days each year, would be 62,279 cubic metres per year; virtually all of which will be pumped during the summer tourist season. This is a daily production of 519 m^3/day. Real demand would be somewhat less, for the reasons explained above.

1.2 REGIONAL GEOLOGY

Surficial Geology

The unconsolidated surficial geological materials of the immediate area are composed of a variable thickness of silt, sand and clay, all of lacustrine origin. These materials are about 3 to 5 m thick in the area of Sandy Point. To the west, the lacustrine deposits are absent. Shetsen (1990) has mapped the unconsolidated deposits as being draped moraine, which is a variable and heterogeneous mix of sand, silt, clay and stones, deposited below or adjacent to continental glaciers during the Pleistocene period.

Bedrock Geology

The consolidated (or bedrock) strata of the area form part of the Paleocene Paskapoo Formation. This formation is of continental origin, that is, it was deposited in a shallow deltaic environment, not unlike the modern Mississippi River delta. The main rock types or lithologies are: shale, mudstone, sandstone, and minor fossil beds and coal. As such, there are many abrupt changes in lithology in all three dimensions and individual sandstone and coal bodies tend to be of limited areal extent.

Demchuk and Hills (1991, pp. 270 to 282) have subdivided the Paskapoo Formation into three main members. They are, in increasing elevation from the base: the Haynes Member, Lacombe Member, and Dalehurst Member. In the area of Gull Lake, the Lacombe Member is present. It is composed of interbedded siltstone, mudstone, shale and coal, with lesser thicknesses of sandstone and conglomerate. Any coal seams are very thin. The strata are almost flat-lying, dipping westward at about 4 m per km.

1.3 PREVIOUS HYDROGEOLOGICAL WORK

The first systematic hydrogeological studies of this area began over 47 years ago. Nielsen (1963) prepared a study of groundwater resources of the Blindman River basin, including the Gull Lake area, as part of the requirements for a M.Sc. thesis at the University of Alberta. Subsequently, Tokarsky (1970) prepared a hydrogeological evaluation of the Rocky Mountain

House map sheet at 1:250,000 scale, which shows on a regional basis the directions of groundwater movement, nature of aquifers, yields, and general groundwater quality.

Hydrogeological Consultants Ltd. prepared a regional groundwater assessment of Lacombe County in 2001, as part of a province-wide series of regional assessments which many counties and municipal districts commissioned, assisted by funding from PFRA.

Alken Basin Drilling Ltd. constructed the three wells on the Sandy Point property in 2002 on behalf of a different developer. They also carried out aquifer tests of 24-hours pumping and 24-hours recovery on each well. The three wells, from south to north, were named Well A (completed in a shallow aquifer) and Wells B and C (both completed in a different deeper aquifer). In 2008, the current owner of the property (Delta Land Development Ltd.) commissioned Waterline Resources Inc. of Calgary to evaluate the results of the testing carried out in 2002. Results of this evaluation were favorable, but the licensing requirements of Alberta Environment had become more stringent during the intervening years and the testing carried out in 2002 was no longer adequate for licensing purposes. In addition, Alberta Environment expressed to the current owners several other concerns which needed to be addressed in order to obtain a diversion license.

Accordingly, a new testing program was prepared by Stantec Consultants Ltd. and was carried out in March 2011. This report has reinterpreted the testing of 2002 and describes the additional testing program of 2011, as well as the results and interpretation obtained from it.

1.4 HYDROGEOLOGY

In this area, the surficial deposits are thin and do not form aquifers. All the aquifers in use are therefore within the bedrock strata of the Lacombe Member, Paskapoo Formation. Generally, the principal aquifer type is fine sandstone, so drillers try to complete their wells within these sandstone strata. Maximum water productivity occurs in areas where the sandstone aquifers are fractured. The degree of fracturing is variable, as is also the extent and thickness of the sandstone aquifers.

The configuration of the piezometric surface (the pressure surface to which water will rise above an aquifer within wells) is generally a subdued reflection of the topography of the land surface. The regional slope of the land surface is eastward toward Gull Lake. This indicates that the regional direction of groundwater movement is also toward the east within the immediate area of the lake. The non-pumping level in Well A is shallower than the non-pumping levels in Wells B and C (which wells are somewhat deeper than Well A). This indicates that the location is one of recharge, i.e., net downward movement of groundwater.

The depth at which groundwater becomes too saline for human consumption (4000 mg/L of total dissolved solids), is known as the “depth of groundwater protection” and is about 300 to 350 m deep in this area. Consequently, few if any water wells penetrate to this depth. Yields have been estimated for individual wells in this area to be 100 to about 300 m^3/day.

In terms of water quality, total dissolved solids were estimated at 500 to more than 1000 mg/L in this area. Chloride is almost universally below 10 mg/L and fluoride is generally below 0.5 mg/L. The groundwater is generally of a sodium-bicarbonate to sodium sulfate facies.

The shallowest well, Well A, has a surveyed ground elevation of 905.14 m amsl. The shallow aquifer is located at 22.3 to 24.7 m depth, or 882.9 to 880.5 m amsl.

A widely circulated map of soundings of Gull Lake (Figure 1.6) is based on a surface water elevation of 899.3 m amsl in August 1961. This map indicates a maximum water depth at that time of about 8.3 m, or elevation 891.0 m amsl, northeast of Sandy Point. Thus, the thickness of sediments separating the lake bottom and the shallow aquifer is about 891.0 – 882.9 = 8.1 m.

Well B has a surveyed ground elevation of 905.03 m amsl. The deeper aquifer in Well B is located at 32.61 to 51.82 m below ground level, or 872.4 to 853.2 m amsl. Since the deepest part of the lake bed is at about 891.0 m amsl, there is a thickness of 891.0 – 872.4 = 18.6 m of sediments separating the lake bed from this deeper aquifer. The corresponding sediment thickness and depth for Well C are nearly identical, as both Wells B and C are completed in the same aquifer.

Figure 1.4 is a hydrogeologic cross section from west to east, which shows the principal aquifers of the area as well as the configuration of the piezometric surface. Figure 1.5 is a north to south hydrogeologic cross section through the three wells which were tested in this study.

Figure 1.6 is a hydrographic map of Gull Lake showing the water depths as sounded in August 1961. Because the surface elevation of the lake has dropped since then, total depth and the area of the lake have also decreased since that date.

2.0 Scope of Work

1) Review and summarize the Alberta water well record files for the immediate area and a radius of 1 km around the property.

2) Review the behaviour of any Alberta Environment observation wells (if any) within a 20 km radius of the three wells.

3) Review and describe the groundwater quality from any existing chemical analyses within a 2 km radius.

4) Identify and tabulate all existing traditional agricultural registrations (TAR's), groundwater diversion licenses and approvals for a radius of 2 km of your property, in order to determine the level of existing use of groundwater in the area.

5) Describe the geological and hydrogeological setting of the property and prepare cross sections through the wells in north-south and east-west directions.

6) Describe the hydrogeological conditions of the region in question, based on published data from the Alberta Research Council and the regional groundwater evaluations.

7) Organize and carry out three Aquifer Tests as follows:
   - Survey the location and elevation of all three wells: A, B and C, prior to testing;
   - Measure the depth to water in wells A, B and C prior to pump testing;
   - Test well A at 20 igpm for 48 + 48 hours using wells B and C as observation wells;
   - Test well B at 40 igpm for 72 + 72 hours using wells A and C as observation wells;
   - Test well C at 85 igpm for 72 + 72 hours using wells A and B as observation wells; and
   - Sample each well for Full Routine Analysis to include metals and fecal coliform bacteria at the end of each pump test.

8) During the pumping tests, measure the:
   - Barometric Pressure;
   - pH, electric conductivity, and temperature of water in Gull Lake every 24-hours; and
   - pH, electric conductivity and temperature of the water from the wells every 12-hours.

9) Based on results from the aquifer tests, calculate the sustainable yield of the wells, using the methods outlined by Alberta Environment in their *Groundwater Evaluation Guidelines*.

10) Inventory by a field-verified survey all existing wells within a 2 km radius of the three wells. Alberta Environment requires documenting this information in order to determine the impact of pumping on their wells, in case of claims of damage to their wells.

11) Calculate the potential impact of the production from the three wells on all other wells within a 2 km radius.

12) Prepare recommendations specific to the investigation carried out, with respect to sustainable yield, any water treatment requirements, monitoring requirements and management of the groundwater supply.

13) Prepare a report summarizing all the information above and describing the suitability of the water quality and quantity to meet the intended needs, as well as the impact that the pumping will have on the wells of any neighbors.

14) Prepare and submit to Alberta Environment a license application under the *Water Act* on behalf of Delta Land Development for the diversion of the total amount of water to be licensed.

3.0 Work Done

3.1 EXISTING LICENSED DIVERSIONS

A survey was carried out in order to identify existing groundwater licenses and traditional agricultural registrations for all lands within a radius of 2 km of the proposed development. It was found that there are no licensed or registered groundwater diversions, only two surface water diversions for a total of 4 cubic metres per year of water from Gull Lake.

3.2 WELL CONSTRUCTION DETAILS

Drillers' records of the three production wells, identified herein as Wells A, B and C, are included in Appendix A. All were drilled by Alken Basin Drilling Ltd. in 2002, the same company which carried out the original aquifer testing and the additional testing for this program in 2011. The three wells were constructed as shown in Figure 1.3. They were drilled in a manner which meets all standards of the current Water (Ministerial) Regulation. Surface casing was driven with a drive shoe, and was sealed in place using bentonite to provide a tight seal. The casing extending above ground level is about 1 m high above natural ground level and the soil is sloped away from the casing to avoid ponding of surface water.

Table 3.1 summarizes the surveyed coordinates of the three wells.

Table 3.1
Coordinates of Water Supply Wells

WELL ID	NORTHING	EASTING	ELEVATION MAMSL	DESCRIPTION
A	9621.2135	6141.1122	905.136	Ground level
	9621.1612	6141.2459	906.13	Top of casing
B	9628.7863	6139.4688	905.028	Ground level
	9628.7863	6139.4688	905.95	Top of Casing
C	9714.0381	6109.0581	904.243	Ground level
	9713.9471	6109.2286	905.281	Top of casing

3.3 FIELD-VERIFIED SURVEY

Since preparation of Waterline Resources Inc.'s report on May 26, 2008, only two new wells are recorded as having been drilled within about 2 km of the site. Consequently, Waterline's Table A1 is reproduced herein in its entirely, but with the addition of these two new wells. The table is numbered Table 3.2 in this report.

Table: 3.1 Field Survey of Water Wells

WELL ID	W_M	RGE	TWP	SEC	LSD	Drilling Company	Date Complete (M/D/Yr)	DEPTH (m b GL)	USE	CHM	LT	PT	WELL OWNER	STATIC LEVEL (m bTOC)	TEST RATE (L/min)	CASING PERFS	
																FROM (m bGL)	TO (m bGL)
341921	5	1	41	1	10	ALKEN BASIN DRILLING LTD.	11/20/2002	54.864	Stock	0	9	24	SANDY POINT FARMS	6.7056	227.3	36.576	48.768
341922	5	1	41	1	10	ALKEN BASIN DRILLING LTD.	11/13/2002	54.864	Stock	0	12	20	SANDY POINT FARMS	7.3152	227.3	36.576	51.816
341923	5	1	41	1	10	ALKEN BASIN DRILLING LTD.	11/13/2002	27.432	Stock	0	13	20	SANDY POINT FARMS	7.0104	90.92	21.336	24.384
354465	5	1	41	12	NW	UNKNOWN DRILLER		38.1	Domestic	3	0	0	NORVIA, P.				
355320	5	1	41	1	6	ALKEN BASIN DRILLING LTD.	2/23/1988	18.288	Industrial	0	2	0	TRILOGY	4.572	204.57		
435633	5	1	41	1	13	UNKNOWN DRILLER	6/29/1953	329.184	Unknown	0	0	0	CALIFORNIA STANDARD CO# THE-500				
435853	5	1	41	2	15	UNKNOWN DRILLER		60.96	Domestic & Stock	0	5	0	HARRSTAD, EVERTT	32.004	68.19	54.864	60.96
435855	5	1	41	2	NE	UNKNOWN DRILLER		30.48	Domestic	0	0	0	MARRISON, H.G.				
435954	5	1	41	12	SW	UNKNOWN DRILLER		17.3736	Domestic & Stock	0	0	0	DICKAU, R.O.	6.096			
435955	5	1	41	12	4	FLINN DRILLING LTD.	5/5/1983	48.768	Stock	0	13	0	SANDY POINT FARMS	0	181.84	12.192	48.768
435956	5	1	41	12	12	ERICKSON DRILLING	1/1/1950	15.24	Domestic	1	0	0	NORRILA, P.				
435957	5	1	41	12	12	GERMAN R E	1/1/1963	15.24	Stock	0	0	0	NORRILA, PAUL				
435958	5	1	41	13	1	UNKNOWN DRILLER	10/31/1952		Industrial	0	0	0	IMPERIAL OIL LTD				
435962	5	1	41	13	4	UNKNOWN DRILLER	9/17/1952	304.8	Industrial	0	0	0	CALIFORNIA STANDARD CO# THE-500				
436169	5	1	41	11	6	ALKEN BASIN DRILLING LTD.	9/20/1987	48.768	Industrial	0	4	0	GEO SEARCH 5	18.288	181.84		
466369	5	1	41	11	3	ALKEN BASIN DRILLING LTD.	8/19/1996	67.056	Industrial	0	15	16	DOMEX/CACTUS 7#RIG	23.7744	20.457	48.768	67.056
478956	5	1	41	12	NW	ERICKSON DRILLING	1/1/1946	36.576	Domestic & Stock	0	0	0	NORVILLA, C.	4.572			
497115	5	1	41	12	6	TALL PINE DRILLING LTD.	8/22/2000	48.768	Industrial	0	5	11	FOUNDERS ENERGY LTD.	12.8016	250.03	36.576	48.768
1735102	5	1	41	2	1	TALL PINE DRILLING LTD.	10/29/2002	30.48	Industrial				PROGRESS ENERGY	4.8768	318.22	24.384	30.48
361599	5	1	40	35	0	UNKNOWN DRILLER			Domestic	1	0	0	ROSE, DOUGLAS M				
380562	5	1	40	36	13	J.C. DRILLING	11/16/1995	49.3776	Domestic	0	15	20	SIMPSON, FRED/JOANE	6.5532	45.46	43.2816	49.3776
442317	5	1	40	35	7	WATER RESOURCES	6/1/1971	3.048	Observation	0	4	0	ALTA ENV. 3GL34				
442318	5	1	40	35	7	WATER RESOURCES	6/1/1971	1.8288	Observation	0	3	0	ALTA ENV. 3GL35				
442319	5	1	40	35	7	WATER RESOURCES	6/1/1971	3.048	Observation	0	3	0	ALTA ENV. 3GL36				
442322	5	1	40	35	6	WATER RESOURCES	6/1/1971	3.048	Observation	0	2	0	ALTA ENV. 3GL31				
442323	5	1	40	35	6	WATER RESOURCES	6/1/1971	3.048	Observation	0	1	0	ALTA ENV. 3GL32				
442324	5	1	40	35	6	WATER RESOURCES	6/1/1971	3.048	Observation	0	2	0	ALTA ENV. 3GL33				
442339	5	1	40	36	6	ERICKSON ERNFRED	8/4/1958	29.2608	Domestic	0	3	0	DAVID, R.O.	6.7056	45.46		
442342	5	1	40	36	6	NELSON DRILLING & PLUMBING	7/1/1983	45.72	Domestic	0	9	0	PALMER, PERCY	7.62			
442344	5	1	40	36	NW	ALBERTA WW SERVICE	8/17/1967	28.0416	Domestic	0	12	0	ANDERS, H.	7.62	27.276	12.192	28.0416
442345	5	1	40	36	13	UNKNOWN DRILLER	1/31/1953	306.0192	Industrial	0	0	0	CALIFORNIA STANDARD OIL #K8				
443867	5	1	40	36	12	J.C. DRILLING	2/14/1996	45.1104	Domestic	0	8	25	SIMPSON, BILL/FRED	1.95072	68.19	20.7264	26.8224
494629	5	1	40	36	7	RANKIN DRILLING	9/3/1999	23.7744	Domestic	0	7	0	TAYLOR, BILL	8.2296	45.46	17.0688	23.1648
1060453	5	1	40	36	15	ALKEN BASIN DRILLING LTD.	10/4/2004	24.384	Industrial				MURPHY OIL/PD 621	3.048	318.22	12.192	18.288
1440002	5	1	40	36	NW	LAST CHANCE DRILLING	6/5/2003	45.72	Domestic				SIMPSON, FRED	2.4384	68.19	36.576	45.72
1575913	5	1	40	13	SW	PAPLEY DRILLING LTD.	4/20/2009	39.62	Domestic				RICK CROOK	3.83	63.65	33.53	39.62
1575993	5	1	40	11	13	PAPLEY DRILLING LTD.	6/21/2008	33.53	Domestic				ASHWANI SINGH	3.81	63.65	21.34	27.43

Source: Alberta Environment Water Well Database

Note: W_M - West of Meridian; TWP - Township; RGE - Range, SEC - Section; LSD - Legal Subdivision;
bGL - Below Ground Level; bTOC - Below Top of Casing; L/min - Liters per Minute;
CHM - No. of Chemistry Reports; LT - Lines of Lithology; PT - Lines of Pump Test

3.4 FIELD METHODS

The field program was designed to fully evaluate the sustainable yield of the three wells in question, in order to meet the phased water needs of Sandy Point RV Park. In addition, the program must meet the concerns of Alberta Environment, including an assurance that the proposed diversion will not impact the water level of Gull Lake. The level of Gull Lake has historically been documented to have dropped some 2.5 m since 1924 and the present level is sustained only be costly pumping most years. Therefore, the following field program was prepared:

- All three wells were redeveloped, as they had been sitting unused for nearly 9 years since the original testing in November 2002.
- Each of the three wells was tested at a rate considered to be at or near its maximum capacity for a period of 48 or 72 hours, depending on the discharge rate, plus a like period of recovery. The production rate for each well in this program was selected based on a careful interpretation of the original tests of 2002 (Figures 3.1 to 3.15) and is higher in all cases than that originally proposed in Section 2 of this report.
- During the testing of each well, levels in the other two were monitored to determine the degree of interference between them.
- All measurements of water levels were recorded by use of dataloggers.
- A barologger was installed in Well A from noon, March 11, 2011 until the morning of March 28, 2011, to record hourly barometric pressure during the entire testing program. This permitted barometric pressure corrections to be made, as required.
- To detect possible changes in water quality due to inflow via the aquifers from the lake, water quality was monitored every 24-hours using a field kit for pumping wells, and every 24-hours at an adjacent location in the lake. This field kit measured temperature, pH and electrical conductivity.
- Samples were collected from each well at the end of the pumping phase of the test to analyze for physico-chemical and bacterial parameters. The parameters selected for analysis meet the requirements of Alberta Environment's *Groundwater Evaluation Guidelines*.

3.5 ANALYTICAL METHODS

The original data from the tests of 2002 were reevaluated in order to re-determine the general aquifer characteristics present at the site. These data were reinterpreted using the Double Porosity Method rather than the Copper-Jacob Confined Method, which was used in the previous analysis (Waterline Resources Inc., 2008). It is considered that the Double Porosity Method better represents the hydrogeological conditions present at this location. The most current *AquiferTest Pro V. 2010* program, of Schlumberger Water Services, was used for all evaluations of the aquifer parameters.

The information from the dataloggers in the 2011 testing was downloaded and corrected for the barometric fluctuations before and during the test. Figure 3.1 shows the changes in barometric pressure during the entire testing period from March 11 until March 28. It was found that only the data from the test of Well B justified a barometric correction.

The/ hourly non-pumping and dynamic pumping levels were plotted for all three wells from March 11 until the morning of March 28, 2011. Figures 3.6, 3.17 and 3.27 show that during at least most of this period there was a very gradual rise of non-pumping water levels in all three wells, superimposed on the barometric fluctuations. This rise might be attributed to minor recharge during the early portion of the spring melt period. The data from the aquifer tests were plotted on semi-log and log–log curves to determine the aquifer characteristics present at the location, similar to the methods used for the older data from 2002. The plots were examined carefully to detect any possible boundary conditions which could affect the long-term security of the water supply and which might suggest a hydraulic connection with a surface water body.

Figures 3.2 to 3.5 show a reanalysis of the 24-hour test of Well A in 2002, carried out at 131 m^3/day. Figures 3.8 to 3.11 are time-drawdown and time-recovery plots of the 2011 test, conducted at 196.5 m^3/day for a period of 48-hours pumping and 48-hours recovery.

Figures 3.12 to 3.15 show the analysis of the 24-hour pumping and recovery test of Well B at 275 m^3/day in 2002. Figures 3.16 to 3.21 are the analysis of the test of Well B at 307.8 m^3/day for 61.3-hours pumping and 15.8 hours recovery. It was intended to conduct the test for 72-hours pumping, but the generator stopped due to a serious mechanical malfunction and could not be restarted. After another 15.8 hours, the recovery was virtually complete.

Figures 3.22 to 3.25 are plots of the test of Well C as the pumping well at a discharge of 576.3 m^3/day, but measuring the effects of the pumping in Well B used as an observation well in 2011.

Figures 3.28 to 3.31 are plots of time-drawdown and time-recovery in Well B, but measuring the effects of the pumping in Well C as an observation well in 2011.

Finally, Figures 3.32 to 3.35 are the plots of time-drawdown and recovery behavior in Well C at a discharge of 576.3 m^3/day during the testing of 2011.

4.0 Interpretation of Aquifer Analyses

4.1 AQUIFER PARAMETERS

Table 4.1 summarizes the parameters calculated from both the 2002 testing and the 2011 testing. All three of the 2002 tests responded as classic infinite artesian aquifers, but with a subtle indication of a recharge boundary after about 100 minutes in Observation Well B during pumping of Well C. The testing during 2011 was at higher discharge rates and for 48 to 72 hours, in accordance with the *Groundwater Evaluation Guidelines*. In several cases, the recovery was terminated earlier than this time because it was virtually complete.

Table 4.1
Aquifer Parameters

Well	Test Date	Discharge m3/d	Length of Test (hr)	Test	Transmissivity m2/d	Storativity -	Spec. Cap. m3/d/m	Q20 m3/d
A	13-Nov-02	131	24	Pumping, semi-log	28	-	20.9	136.6
		131	24	Pumping, log-log	28	-	20.9	136.6
		-	24	Recovery, semi-log	75.2	-	-	-
		-	24	Recovery, log-log	75.2	-	-	-
	14-Mar-11	196.5	48	Pumping, semi-log	71.2		20.6	180.6
		196.5	48	Pumping, log-log	71.2	-	20.6	180.6
		-	48	Recovery, semi-log	66.4	-	-	-
		-	48	Recovery, log-log	66.4	-	-	-
B	13-Nov-02	275	24	Pumping, semi-log	117	-	21.45	346
		275	24	Pumping, log-log	117	-	21.45	346
		-	24	Recovery, semi-log	133	-	-	-
		-	24	Recovery, log-log	133	-	-	-
	14-Mar-11	307.8	61.3	Pumping, semi-log	131	-	28.9	477.8
		307.8	61.3	Pumping, log-log	131	-	28.9	477.8
		-	15.8	Recovery, semi-log	181	-	-	-
			15.8	Recovery, log-log	181	-	-	-
B	20-Nov-02	556.4	24	Pumping, semi-log	396	5.83E-05	-	-
(Obs.Well)		556.4	24	Pumping, log-log	396	5.83E-05	-	-
		-	24	Recovery, semi-log	355	5.02E-05	-	-
			24	Recovery, log-log	355	5.02E-05	-	-
B	22-Mar-11	576.3	72.6	Pumping, semi-log	180	1.72E-05	-	-
(Obs.Well)		576.3	72.6	Pumping, log-log	180	1.72E-05	-	-
			39.7	Recovery, semi-log	204	1.65E-05	-	-
			39.7	Recovery, log-log	204	1.65E-05	-	-
C	20-Nov-02	556.4	24	Pumping, semi-log	357	-	95.9	1541.1

Well	Test Date	Discharge m3/d	Length of Test (hr)	Test	Transmissivity m2/d	Storativity -	Spec. Cap. m3/d/m	Q20 m3/d
		556.4	24	Pumping, log-log	357	-	95.9	1541.1
		-	24	Recovery, semi-log	355	-	-	-
		-	24	Recovery, log-log	355	-	-	-
C	22-Mar-11	576.3	72.6	Pumping, semi-log	132	-	66.5	1027.6
		576.3	72.6	Pumping, log-log	132	-	66.5	1027.6
		-	39.7	Recovery, semi-log	194	-	-	-
		-	39.7	Recovery, log-log	194	-	-	-
C	14-Mar-11	307.8	61.3	Pumping, semi-log	395	3.85E-05	-	-
(Obs.Well)		307.8	61.3	Pumping, log-log	395	3.85E-05	-	-
		-	15.8	Recovery, semi-log	266	4.83E-05	-	-
		-	15.8	Recovery, log-log	266	4.83E-05	-	-
Values Selected		**Well A**			71	1.80E-05*	20.6	181
		Well B			180	1.80E-05	28.9	478
		Well C			190	4.30E-05	66.5	1028

**Assumed*

The test of Well A behaved as an infinite aquifer with no barrier boundaries evident during the 48-hours pumping and recovery at a discharge of 196.5 m^3/day. As no observation well was used, the storativity selected is an assumed value.

The test of Well B at 307.8 m^3/day also behaved as an infinite aquifer during the time of pumping and recovery. Storativity was about 1.72E-05, based on results from observation well behavior. However, the plots of Well B as an observation well during testing of Well C at 576.3 m^3/day showed an apparent gradational recharge boundary after about 400 minutes of pumping. This boundary is subtle and likely represents a gradual thickening and/or increase in permeability of the sandstone aquifer at a distance from Well C. In a similar vein, the test of Well B showed a similar response in Well C, which was the observation well in this test. The change of slope in this test was after about the same period of pumping.

This recharge boundary is unlikely to represent any hydraulic connection with Gull Lake or any other surface water body. Such a connection, if present, would also show up and do so more rapidly in Well A, which is completed in a shallower aquifer. As shown earlier by surveying, there are over 18 m of sediment (bedrock and unconsolidated deposits) between the bed of the lake at its deepest point and the eastern extension of the aquifer of Wells B and C.

Figure 3.6 shows that during the entire 18 days of monitoring water levels, there was no impact whatsoever on the level in Well A, except from the pumping of this same well. The testing of Wells B and C had no impact on the shallower aquifer of Well A, showing that there is no hydraulic connection between the shallow and deeper aquifers.

In a like manner, the pumping of Well A showed no impact on the deeper aquifer used by Wells B and C. Indeed, the water level continued a very gradual rise in Well B and Well C (Figures 3.17 and 3.27) during the pumping of Well A.

4.2 IMPACT ON OTHER USERS

In order to evaluate the potential impact of pumping of the wells tested on any nearby well owners at varying distances, the program *WELLz* (Domenico and Schwartz, 1998, pp. 128-131) was used. The impact on their wells was calculated, assuming the full license application discharge of Wells A, B or C. The impact of course would be proportionally less if the wells to be licensed were to be pumped at lower discharge rates. The impact was calculated for a period of 120 days only, as this is effectively the time period each year that the wells will be in use.

The list of nearby well owners shown in Table 3.1 was reviewed to determine the estimated impact or interference which could be expected from pumping of Wells A, B and C at their full pumping rate. This analysis assumes no recharge during the 120 days of production each year, although Figures 3.6, 3.17 and 3.27 show that there will be some recharge. The ground elevations of the wells were extrapolated from contours of the topographic map of the area, scale 1:50,000, which is the most detailed map available. Table 4.2 shows the details of aquifer elevations and amount of impact in the neighboring wells which would be created by pumping from the Sandy Point wells at full build-out of the facility. It may be seen that there will be some interference to most of the wells, but in all cases, much less than the available head. Of all the wells for which adequate completion information was available, only three appear to be completed in other aquifers and hence would have no interference.

Table 4.2
Impact on Neighbouring Wells

Well ID	Owner	Location	Estimated Elev, m	Aquifer Depth, m	Aquifer Elev, m	N.P.W.L. m	Available Head, m	Distance, m	Hydraulic Connection to Well	Impact, m
341921	Sandy Point Farms	10-1-41-1-W.5	908.5	36.5	871.8	901.6	29.80	440	B, C	1.18
341922	Sandy Point Farms	10-1-41-1-W.5	908.3	36.5	871.8	901	29.20	440	B, C	1.18
341923	Sandy Point Farms	10-1-41-1-W.5	908.3	21.3	887	901.3	14.30	440	A	1.75
435853	Everett Harstad	15-2-41-1-W.5	832.7	54.9	877.8	900.7	22.90	1750	A	1.45
466369	Domex/Cactus#7 Rig	3-11-41-1-W.5	931.2	48.8	882.4	907.4	25.00	2500	A	1.05
1735102	Progress Energy	1-2-41-1-W.5	906.8	24.3	882.5	901.9	19.40	1750	A	1.45
442344	H. Anders	NW-36-41-1-W.5	900.7	12.2	888.5	893.1	4.60	1800	A	1.28
443867	Bill & Fred Simpson	12-36-40-1-W.5	900.1	20.7	879.4	891.9	12.50	2050	A	1.23
494629	Bill Taylor	7-36-40-1-W.5	900.1	17	883.1	898.1	15.00	2050	A	1.23

1440002	Fred Simpson	NW-36-41-1-W.5	911.4	36.6	874.8	909	34.20	1800	B, C	0.80

4.3 GOWN WELL #309 – GULL LAKE

Alberta Environment has maintained since 1965 a long-term observation well as part of its province-wide GOWN (Groundwater Observation Well Network) system, located at the north end of Gull Lake, about 14 km north of the Sandy Point development. This well is 223.4 m deep and has a completion zone from 91.4 to 223.4 m. Strictly speaking, this well does not meet current construction standards of the Water (Ministerial) Regulation and is completed in deeper aquifers than are present in Wells A to C. Figure 4.1 shows its hydrograph.

Although this well is completed in the same Paskapoo formation as are the production wells of the Sandy Point development, it is much deeper. Moreover, the attached explanatory note from Alberta Environment explains that the water levels are directly impacted by pumping of three private wells nearby. This explains the drop of about 5 m in water levels since 1998. This drop cannot be explained by the drop in the nearby lake level, which was documented to be virtually nil in the same time period, although with some minor annual fluctuations. Despite the above comments, there appears to have been a significant rise in water level in the well of 1.2 m between 1996 and 1998. This is likely due to above average precipitation during that period of time.

Based on all the above, this hydrograph cannot be considered a useful tool in evaluating the annual recharge/discharge relationships in the Paskapoo formation.

5.0 Sustainable Yields of Wells

In order to calculate the sustainable yield of a water well, the *Groundwater Evaluation Guidelines* provides two methods of calculation. The **Farvolden Method** uses the calculated transmissivity as part of the calculation, and ignores the initial well loss in the first minutes of a test. It may be seen in Table 4.1 that the transmissivities calculated may be interpreted in several different ways, and that transmissivity is not immutable. It may be affected by the discharge rate used in the test, or by other factors.

The **Moell Method** has the advantage that it does not require a calculation or interpretation of transmissivity, which Table 4.1 shows can vary considerably. In addition, it fully takes into account the presence of well loss in the initial part of an aquifer test. That is, this calculation is based entirely upon measured parameters, and not on interpreted calculations from these parameters. It generally gives more conservative, and hence safer and more correct results. For this reason, the Moell Method has been used to analyze the sustainable yields of the three wells evaluated in this report.

However, the Moell Method, as shown in the *Groundwater Evaluation Guideline,* has been presented in this report in two different ways. The first is to reflect the fact that these wells will be in use only one-third of each year, i.e., 120 days per year, and will not be pumped constantly for 20 years. This results in the formula:

$$Q_{120} = \frac{Q\,(H_A)0.7}{S_{100}+3.1\Delta S},$$

as 120 days represents 5.1 log cycles of time.

For Well A, the inputs are as follows:

H_A = 21.34 – 6.57 = 14.77 m

Q = 196.5 m^3/day

S_{100} = 8.895 m

ΔS = 0.471 m

Therefore: $$Q_{120\ days} = \frac{(196.5)(14.77)(0.7)}{8.895 + 3.1(0.471)}$$

= 196.2 m^3/day X 120 = 23,544 m^3/year.

The second method of calculating sustainable yield is to use the Moell Method exactly as presented on page 14 of the *Groundwater Evaluation Guideline*, basing the evaluation on nonstop pumping for 20 years:

$$Q_{20} = \frac{Q\,(H_A)\,0.7}{S_{100}+5\Delta S}$$

In this case, Well A would have the following sustainable yield over 20 years, pumping all year long:

$$Q_{20} = \frac{(196.5)(14.77)(0.7)}{8.895 + 5(0.471)}$$
$$= 180.6 \text{ m}^3\text{/day X } 365 = 65{,}919 \text{ m}^3\text{/year.}$$

In a like manner, the sustainable yield of Well B is calculated from the following inputs for 120 days/year:

H_A = 25.65 m
Q = 307.8 m^3/day
S_{100} = 9.967 m
ΔS = 0.32 m

Therefore: $$Q_{120\ days} = \frac{(307.8)(25.65)(0.7)}{9.967 + 3.1(0.32)}$$
$$504.3 \text{ m}^3\text{/day X } 120 = 60{,}516 \text{ m}^3\text{/year.}$$

If the standard Moell calculation is used for $Q_{20,}$ safe yield would be as follows for 365 days per year:

$$Q_{20} = \frac{(307.8)(25.65)(0.7)}{9.967 + 5(0.32)}$$
$$= 477.8 \text{ m}^3\text{/day X } 365 = 174{,}394 \text{ m}^3\text{/year.}$$

Also, the sustainable yield of Well C is calculated from the following inputs:

H_A = 25.74 m
Q = 576.3 m^3/day
S_{100} = 8.005 m
ΔS = 0.43 m

Therefore: $$Q_{120} = \frac{(576.3)(25.74)(0.7)}{8.005 + 3.1(0.43)}$$
$$= 1112 \text{ m}^3\text{/day X } 120 = 133{,}440 \text{ m}^3\text{/year.}$$

If we now use the standard Moell calculation for calculating sustainable yield of Well C, for 20 years, we have:

$$Q_{20} = \frac{(576.3)(25.74)(0.7)}{8.005 + 5(0.43)}$$

= 1022.5 m^3/day X 365 = 373,223 m^3/year.

However, in view of the rates at which the wells were tested, the lesser of the testing rate or the Moell Method calculation would be used as the maximum permissible production rate, i.e.;

Well A - 180.6 m^3/day	or	65,919 m^3/year
Well B - 307.8 m^3/day	or	112,347 m^3/year
Well C - 576.3 m^3/day.	or	210,350 m^3/year

In summary, if the modified Moell formula for 120 days production per year is used, Well A will be adequate for 23,544 m^3/year for 120 days per year. If however, the standard Moell formula for Q_{20} is used, Well A alone could meet all anticipated water demand of 62,279 m^3/year for the entire project at full development stage of 180.6 m^3/day. This would, however, require considerable storage, in order to not exceed the sustainable daily discharge rate. If Well A were to be pumped at the test rate of 196.5 m^3/day for 120 days per year, this would provide 23,580 cubic metres for the summer period, which is little more than the Q_{20} calculation.

6.0 Groundwater Geochemistry

Near the end of each aquifer test, water samples were retrieved to be analyzed for the physico-chemical and bacterial parameters present in the water. In the 2002 testing program, Alken Basin Drilling collected the samples and submitted them to WSH Labs (1992) Ltd. in Calgary for analysis. In addition to being much more complete, the analyses from 2011 were taken after considerably more pumping time than was the case in 2002. Hence, they are likely more valid than the earlier results, although results from both dates are similar. Samples were taken at the end of the pumping period in each case to assure that, insofar as possible, all particulate material in the wellbore and all resident stagnant water would be removed prior to sampling, and that the samples submitted for analysis represent the true physico-chemical condition of the water within the aquifer. All original laboratory reports are included in Appendix B.

The sampling program had a dual purpose. The first is to identify any parameters which might impact the safety of use of the water for human consumption. The second was to determine the suitability of the water for irrigation purposes. Based on the analytical results, treatment facilities may be designed and built to remediate any problem parameters.

Table 6.1 summarizes the parameters analyzed in the 2002 and the 2011 testing programs. It may be seen that the parameters repeated in both testing programs are not identical, but are very similar in their concentrations. Those parameters which exceed the *Guidelines for Canadian Drinking Water Quality* are shown in bold. Most are aesthetic in nature. The groundwater temperature was recorded by the datalogger in Well B and was shown to be 5.9^{o} C.

Table 6.1
Groundwater Quality

Parameter	Unit	Well A 15-Nov-02 WSH Labs	Well A 30-Mar-11 WSH Labs	Well B 15-Nov-02 WSH Labs	Well B 30-Mar-11 WSH Labs	Well C 28-Nov-02 WSH Labs	Well C 1-Apr-11 WSH Labs
Saturation index	mg/L	0.7	0.29	0	0.31	0.3	0.26
Calcium	mg/L	11.3	3.1	2.8	5.9	5	4.7
Iron	mg/L	0.014	<0.03	0.005	<0.03	<0.002	<0.03
Magnesium	mg/L	3.1	0.9	0.1	1.4	1	1.1
Manganese	mg/L	0.009	<0.01	<0.0006	<0.01	<0.0006	<0.01
Potassium	mg/L	0.8	<0.8	1.1	1.1	0.8	1
Sodium	mg/L	**214**	**219**	**468**	**500**	**420**	**429**
Ammonium	mg/L	<0.1	<0.9	<0.1	<0.9	<0.1	<0.9
Bicarbonates	mg/L	531	469	452	434	444	408
Bromides	mg/L	<0.6	<0.1	<0.6	<0.1	<0.6	<0.1
Carbonates	mg/L	7	36	9	23	8	27
Chloride	mg/L	1.1	1	7.5	9	6	7.8

Parameter	Unit	Well A 15-Nov-02 WSH Labs	Well A 30-Mar-11 WSH Labs	Well B 15-Nov-02 WSH Labs	Well B 30-Mar-11 WSH Labs	Well C 28-Nov-02 WSH Labs	Well C 1-Apr-11 WSH Labs
Fluoride	mg/L	0.2	0.25	0.4	0.41	0.5	0.52
Nitrate	mg/L	<0.2	0.2	<0.2	0.1	<0.2	<0.02
Nitrite	mg/L	<0.3	<0.02	<0.3	<0.02	<0.3	<0.02
NO2+NO3	mg/L	<0.2	0.2	<0.2	0.1	<0.2	<0.02
Phosphate	mg/L	N/A	<0.4	N/A	<0.4	N/A	<0.04
Sulfate	mg/L	67	56	**584**	**656**	494	492
Elect. Conductivity	µS/cm	950	906	2130	2070	1950	1936
Hardness	mg/L	41	11	7	20	17	16
Total alkalinity	mg/L	450	457	390	402	380	389
Total dissolved solids	mg/L	**568**	**555**	**1290**	**1415**	**1160**	**1170**
pH	pH units	**8.51**	**8.69**	**8.59**	**8.57**	**8.55**	**8.62**
SAR		14.54	28.15	73.47	48.03	44.82	46.26
Total coliforms	CFU/100ml	0	1	1	0	13	0
Fecal coliforms	CFU/100ml	0		0		2	
E-coli	CFU/100ml		0		0		0
Sum of cations		10.14	9.75	20.18	22.15	18.61	18.98
Sum of anions		10.38	10.11	20.13	21.83	18.03	18.09
% difference		-1.16	-3.6	0.11	0.014	1.6	1.05
Sulfides	mg/L		<0.03		<0.03		
Turbidity	NTU		6.1		0.4		0.3
Color	TCU		<5		<5		<5
Kjeldahl Nitrogen	mg/L		,0.9		<0.9		<0.9
Phenol	mg/L		<0.08		0.1		0.1
Boron	µg/L		146		255		422
Aluminum	µg/L		529		13.5		8.8
Chromium	µg/L		0.6		<0.1		<0.1
Copper	µg/L		1.3		1.2		<0.08
Zinc	µg/L		22.8		6.2		1.1
Arsenic	µg/L		0.4		0.2		0.1
Selenium	µg/L		<0.04		<0.04		<0.04
Silver	µg/L		<0.04		<0.04		<0.04
Cadmium	µg/L		<0.05		<0.05		<0.05
Antimony	µg/L		<0.3		<0.3		<0.3
Barium	µg/L		49		6.2		5.6
Mercury	µg/L		<0.05		<0.05		<0.05
Lead	µg/L		0.9		0.2		<0.1
Uranium	µg/L		0.2		<0.04		<0.04

A pH above the aesthetic limit of 8.5 may result in the water causing incrustation in both the well's completion zone and in the distribution system and plumbing facilities. The pH in all six samples from 2002 and 2011 is barely over the aesthetic limit and should therefore create no problem in this regard. Higher pH values may also affect the efficiency of chlorine disinfection, although the pH values detected here are nearly within the standards of the *Guidelines for Canadian Drinking Water Quality*.

Total dissolved solids are barely over the aesthetic limit of 500 mg/L in Well A, but much higher in Wells B and C. Because few natural groundwaters in Alberta have total dissolved solids below 500 mg/L, the *de facto* limit generally applied is 1000 mg/L. Wells B and C are still well above this level. The sulfate content exceeds the aesthetic limit in Well B and is almost at the limit in Well C. The upper aesthetic limit of 500 mg/L was established primarily for considerations of taste. However, high concentrations may also affect the efficiency of chlorination, and may foster the presence of certain types of bacteria.

Sodium is slightly excessive in Well A, but over twice the aesthetic limit in Wells B and C. This may be a minor concern for drinking water, but could pose serious problems in the use of this water after potable use and treatment for irrigation of the proposed golf course. Excess sodium is deleterious to many plants and can negatively impact the physical structure of clay-rich soils. Some grasses are salt-tolerant and sandy soils facilitate the flushing of accumulated sodium compounds. An agricultural specialist should examine all facets of the soils and water quality, in order to better identify the nature and size of the problem and to devise an appropriate solution.

All the metals analyzed are either below the acceptable level or below detection limit. The SAR (Sodium Adsorption Ratio) is high and, as mentioned above, will require careful study should the water be used for irrigation purposes.

Figure 6.1 is a Piper Plot which shows the relative concentrations of the main cations and the main anions. A Piper Plot, however, does not show absolute concentrations. The plot shows the similarity in quality of water in Wells B and C and that the water in Well A has a very distinct signature from the other two.

The negative effects on the users of the excessive total dissolved solids, sulfate and sodium in Wells B and C will be largely offset by pumping most of the water required from Well A, insofar as possible, and blending it with lesser amounts of the poorer quality water from Wells B or C. For irrigation purposes, there will also be some dilution of the treated waste water using local runoff. This will further improve the quality of water used for irrigation green areas.

With an aquifer test of 48-hours, the water in Well A showed a minor increase in sodium compared to the shorter test of the same well in 2002, balanced by a minor decrease in calcium and magnesium. Bicarbonates and sulfate decreased but carbonate increased. The end result was a near doubling of SAR to 28.15 in Well A.

At the end of 61.3 hours pumping of Well B, calcium, sulfate, carbonates, sodium and total dissolved solids increased slightly in concentration but bicarbonates decreased slightly, compared to the original analysis of 2002.

A comparison of the 2002 and 2011 analyses of water from Well C shows very little change. Bicarbonate decreased and Carbonate increased, but only to a minor degree. Inasmuch as the water quality in Well C is marginally superior to that of Well B, and since well C also has a higher sustainable yield, it is recommended to use Well C to the exclusion of Well B insofar as possible. This will marginally improve water quality for irrigation and for treatment prior to potable use. Well B should be kept for mainly for standby in case of problems with either of the other two wells.

In addition to the sampling for laboratory analysis and the results described above, analysis of pH and electrical conductivity was also carried out using a field testing kit during the tests of the three wells. Samples of groundwater were taken every 24 hours during the pumping phase of each well test and analyzed for temperature, pH and electrical conductivity. In addition, the same parameters were also analyzed in water from Gull Lake every 24 hours during the same tests, at a location as close as possible to the three wells. Table 6.2 shows the results of these analyses. The purpose of this exercise was to detect any change in groundwater quality construed to be caused by infiltration of lake water or other extraneous source to the aquifers during the pumping period.

Table 6.2
Electrical Conductivity and pH During Well Testing

TESTED	DATE	WELL pH LEVEL	WELL CONDUCTIVITY LEVEL, µmhos/cm	LAKE pH LEVEL	LAKE CONDUCTIVITY LEVEL, Mmhos/cm
A	14-Mar	8.23	868	8.46	1651
	15-Mar	8.54	898	8.47	1652
	16-Mar	8.47	897	8.46	1651
B	18-Mar	8.84	915	8.49	1657
	19-Mar	8.88	902	8.47	1653
	20-Mar	8.72	891	8.46	1651
	21-Mar	8.88	900	8.46	1652
C	24-Mar	8.17	1273	8.47	1650
	25-Mar	8.84	1301	8.52	1656
	26-Mar	8.67	1229	8.51	1669

The field groundwater quality testing above in Table 6.2 suggests that the water in Well B is of superior quality to that of Well C. However, the laboratory results shown in Table 6.1 indicate the opposite. This difference may be attributed perhaps to inherent limitations of precision in the sampling and analytical abilities of a field instrument.

Although the pH measured in Well A overlaps that of the lake, the significant difference in electrical conductivity shows that, at least during the period of the test, there is no evidence of a hydraulic connection between them. The electrical conductivity was very different and didn't change significantly. The analyses for Well B show a consistently higher pH in the well than in the lake and a consistently lower electric conductivity than in the lake. Well C shows some fluctuation in pH over the testing period which overlaps the pH range in the lake water. At least some of this variation may be limitations in the precision of a field instrument. The electrical conductivity of the water from Well C is somewhat higher than for Well B, but still much lower than that of lake water.

No trend upward or downward was evident in pH values during the testing of the three wells, despite some fluctuations. The same is true for the electrical conductivity measurements. In summary, there is no evidence of a hydraulic connection between the lake and the groundwater in Wells A, B and C, based on the geochemical considerations shown above.

7.0 GWUDI Evaluation

Alberta Environment's "*Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems", Appendix E (2006)* outlines the screening procedures which should be followed to determine whether a groundwater supply is considered GWUDI (Ground Water under Direct Influence of Surface Water). This determination is of considerable practical importance. If the source is determined to be GWUDI, the treatment protocols to protect the water and its users are much more stringent than if the water is not GWUDI.

The GWUDI screen is subdivided into several phases. This screen will be applied below:

<u>PHASE 1: GWUDI Screen</u>

1) Sensitive setting – The source consists of three deep wells, with their production zones more than 15 m below ground surface. All three have their production zones starting at 21.3 to 36.6 m below ground level. All three are completed in confined aquifers with a considerable thickness of low-permeability shale and clay overlying the completion zones (Figure 1.3).

2) Proximity to surface water – all three wells are almost 0.5 km west of Gull Lake, which is the nearest surface water body.

3) Well construction – all three wells were constructed with steel surface casing and drive shoes and sealed with bentonite in order to assure an adequate seal against infiltration of surface water. The soil around each well is sloped away such that any snowmelt or rainfall will drain away readily. The surface casing extends approximately 1 m above natural ground level in each case.

4) Water quality – the quality of the water shows no evidence of surface water contamination.

Based on the above considerations, the water from these wells is considered not to be GWUDI.

8.0 Conclusions

- Three wells, termed Wells A, B and C were drilled in 2002 into sandstone aquifers of the Paskapoo Formation, about 0.5 km west of Gull Lake. Well A is completed in a shallower aquifer than that of Wells B and C.
- The three wells were tested in 2002 for 24-hours each, and again in 2011 for 48 to 72 hours each. Water samples were taken in both cases for physico-chemical and bacterial analysis.
- In the program of 2011, water levels in all wells and ambient barometric pressure were monitored continuously over an 18 day period, from before starting the tests until after all the tests were completed.
- Barometric corrections were required for interpreting the test of Well B, but were found to be unnecessary for Wells A and C.
- There will be some calculated interference to several neighbouring wells, but in all cases, much less than the available head, based on expected production at full build-out of the facility. Real demand, taking into consideration that the facility will not be used at full occupancy 120 days each year, will result in somewhat lower interference than that calculated.
- During the entire testing program of 2011, non-pumping water levels slowly rose in all three wells during the 18 days, likely due to infiltration and aquifer recharge at the beginning of the spring snowmelt period.
- The documented non-pumping rise in water levels was 0.114 m in Well A during 18 days of measurements.
- The non-pumping rise was 0.071 m in Well B during 7.38 days. Thereafter, it could not be measured due to the impact of pumping Well B and its use as an observation well in pumping of Well C.
- The rise in non-pumping level in Well C was 0.171 m during 7.38 days. Again, it could not be measured subsequently because of pumping Well C and its use as an observation well during the test of Well B.
- The significant documented recharge shows that drawdown and interference during the 120 day period of use each year will in fact be less than that calculated.
- The aquifer testing showed no evidence of connectivity between the shallow and deep aquifers, and none between the aquifers and Gull Lake.
- Geochemical considerations also showed no evidence of connectivity during the time of the tests between groundwater and lake water.
- Upon development of the facility, water use will be essentially limited to 120 days per year with wells being in recovery/recharge during the remaining 245 days.
- Sustainable yield for 120 days each year, based on the testing results, is 196.2 m/day in Well A, 307.8 m^3/day in Well B and 576.3 m^3/day in Well C.

- Groundwater from the shallower aquifer used in Well A alone will meet the needs of the subdivision for about the first 5 years, based on projected rate of development of the first phase. It will not be required for irrigation of the golf course for that period of time because the golf course is projected to be built in a later phase. If Alberta Environment approves the approach of using the standard Moell calculation for 20 years, the sustainable yield would be 180.6 m^3/day or 65,919 m^3/year, which is greater than the application amount of 62,279 m^3/year. However, using the calculation for 120 days per year would provide a greater sustainable yield of 190.2 cubic metres per day. This is adequate for the first phase of development of the subdivision.
- However, sustainable yield, based on the Q_{20} calculations of the Moell method would provide a slightly lower daily yield, but much higher total annual sustainable yield. For Well A, the sustainable yield would be 180.6 m^3/day, or 65,919 m^3/year. If this approach is adopted, no other well would be required to meet the needs of the development. However, pumping in this manner would require a very large storage facility, which is not likely practical.
- The water quality is best in Well A, poorer in Well C and poorest in Well B. None of the samples exceed acceptable public health guidelines for potable water, but sodium, sulfate, and total dissolved solids all seriously exceed aesthetic standards in Wells B and C.
- The quality of water from Wells B and C could create difficulties in its use for irrigation.

9.0 Recommendations

- It is recommended the use Well A exclusively in Phase 1 up to the sustainable yield of 180.6 cubic metres per day because of its water quality being superior to that of the other two wells. This would likely be for about the first 5 years.
- At the time when the production from Well A attains its sustainable yield, it is recommended to carry out a review of its production history and determine whether it would be preferable to drill a second well into the same aquifer, or to put into production some pumping from Well C.
- It is recommended that Well A be licensed for an annual diversion of 62,279 cubic metres at a maximum discharge rate of 180.6 m^3/day.
- It is recommended that Well B be reserved for standby in case of emergency issues with the other two wells, at a maximum discharge rate of 307.8 m^3/day.
- Groundwater used for irrigation should be mixed and diluted with surface runoff to the greatest extent possible, to mitigate harmful effects on soils and vegetation.
- It is recommended to carry out an agronomic investigation of the soils to be irrigated and the selection of appropriate salt-tolerant vegetation for the green areas of the development.
- Because of the considerable amount of the proposed groundwater diversion, it is recommended that the owners monitor and keep a permanent record of weekly groundwater production and groundwater levels in all three wells during the tourist season of about 4 months per year.
- It is recommended that water levels and groundwater production be monitored and recorded on a monthly basis during the remaining 8 months of each year.
- Finally, it is recommended that the owners submit these data to Alberta Environment, in accordance with their current protocols.
- It is recommended to review the water production and water level records when the annual production from Well A will have reached 23,554 cubic metres per year to determine whether this well will be capable of a greater productive capacity than what is predicted in this report.

10.0 References

Alberta Environment, 2003, Groundwater evaluation guideline; Feb. 6, 2003.

Alberta Environment, 2006, Standards and guidelines for municipal waterworks, wastewater and storm drainage systems; Drinking water Br., Environmental policy Br., Environmental assurance Div., Jan, 2006.

Demchuk, T.D. and Hills, L.V., 1991, A re-examination of the Paskapoo formation in the central Alberta plains: the designation of three new members; Bull. Canadian Pet. Geol., vol. 39, No. 3 (Sep, 1991), pp. 270-282.

Health Canada, 2008, Guidelines for Canadian drinking water quality, summary table; May 2008.

Hydrogeological Consultants Ltd., 2001, Regional groundwater evaluation, Lacombe Co., Alberta

Nielsen, Grant L.., 1963, Groundwater resources of the Blindman River valley; M.Sc. thesis, Univ. of Alberta, Edmonton, dated May, 1963.

Shetsen, I, 1990, Quaternary geology, Central Alberta; Alberta Research Council

Schlumberger Water Services, 2006, AquaChem, V. 5.1, Waterloo, ON.

Schlumberger Water Services, 2010, AquiferTest Pro, V. 2010; Waterloo, ON.

Tokarsky, O., 1970, Hydrogeology of the Rocky Mountain House area, Alberta; ARC Report 71-03

Waterline Resources Inc., 2008, Well and aquifer evaluation report, proposed 3000-lot recreational vehicle development, Sandy Point, 01 and 12-1-01-041-01-W.5, Gull Lake, Alberta; consulting rept., dated May 26, 2008.

11.0 Corporate Authorization

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