Environmental Science 505.22

Hydrology of Big Hill Springs

By: Marie-Eve Caron

Supervisors: L. Bentley, S. Grasby, B. Mayer.

Ensc 505.22: Big Hill Springs Hydrology

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I Abstract

Big Hill Springs were studied for flow, temperature, geochemistry and $\delta^{18}O$ isotopes in order to determine the extent of the recharge area – is it a local or regional system? Big Hill Springs' flow, coming out of Paskapoo Sandstone fractures cut by a coulee, was steady and constant within the 5 months of the study, on average being 0.07 m^3/s. The slope of the flow over time could not be statistically differed from zero. Similarly, the temperature of the springs held at a near constant level of 5.8 °C, above the yearly average temperature of 4.1 °C according to Environment Canada and other sources. In another similar fashion, the isotopic values of $\delta^{18}O$ were held constant at -18.16 $\delta^{18}O$ and with very little variation. All of the above (flow, temperature and isotopic composition of $\delta^{18}O$) indicate a regional system. When the recharge area is estimated, an area of approximately 105 km^2 is needed to account for 4-5% of yearly precipitation rates emerging into Big Hill Springs. This supports the hypothesis of a large regional aquifer feeding the springs. Additionally, isotope $\delta^{18}O$ values also indicate a groundwater age of a minimum of few months, to approximately 6.36 years. It could also be much older. Looking at the geochemistry of the springs and comparing it to a nearby well, some confusion arises because the springs end up above the water table as shown by the well (#352476). The geochemistry is also slightly different between the two waters. Total dissolved solids of both waters range between 506-514 mg/L.

II List of Figures and Tables in Order of Appearance

1) Background and Introduction

The main question to answer in this study is whether Big Hill Springs are from a local or regional system. In general, local systems tend to have springs with variable temperature and isotopic composition. These variations reflect changes in the local climate and precipitation. Discharge may increases in magnitude in the spring after the snowmelt and increased runnoff and infiltration. The geochemistry would reflect a young, clean source and therefore showing lower total dissolved solids (TDS) values. On the other hand, regional systems tend to attenuate local patterns and have more stable and constant temperature, isotopic composition and flow. The geochemistry of the springs would show older groundwater with higher TDS values. The following background and introduction explains these differences and concepts into more depth. This Big Hill Springs study is a project within a bigger, more comprehensive study currently being undertaken by the Geological Survey of Canada of the Paskapoo Formation.

Topography:

Big Hill Springs Provincial Park falls within the western part of the Municipal District (MD) of Rocky View, on the edge of the foothills of Southern Alberta, Canada. Figure 1 shows the outline of the park, water wells, sampling locations and chemical analysis locations for the springs. The MD of Rocky View is outlined in red in Figure 2. The water coming out of Big Hill Springs eventually joins with Big Hill Creek and then the Elbow and Bow Rivers. Big Hill Springs Provincial Park has 3 of the 64 groundwater springs of the MD of Rocky View. This park also has the springs with the highest flow rates of the region within a range of 20-1600 liters per minute (Hydrogeological Consultants, 2002). The elevation of the MD ranges between 850 and 1450 m above mean sea level, the highest points being in the western parts of the M.D., where the Provincial Park is situated. (Hydrogeological Consultants, 2002)

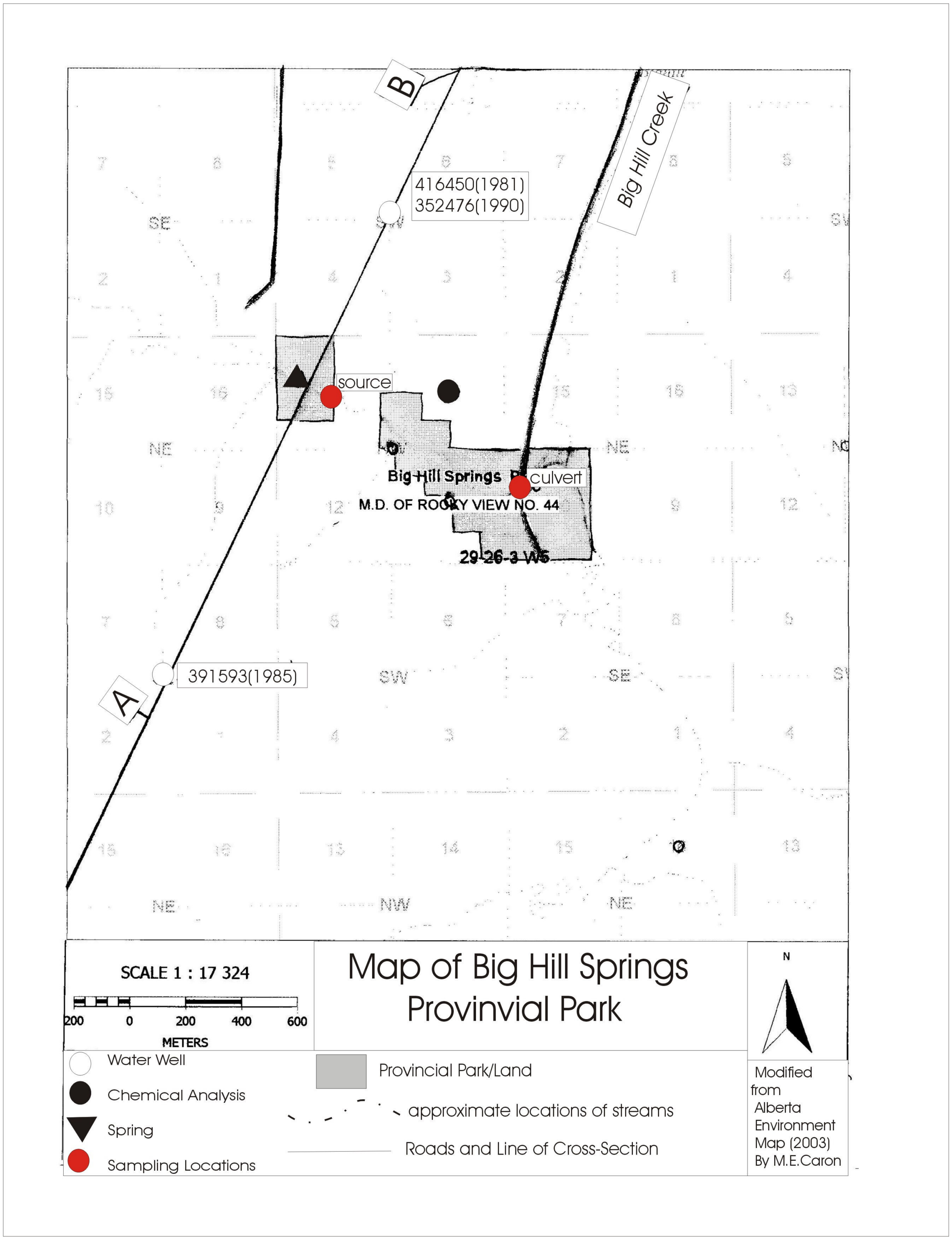


Figure 1: Map of the Provincial Park and Surrounding Water Wells. (modified from AB Env, 2002)

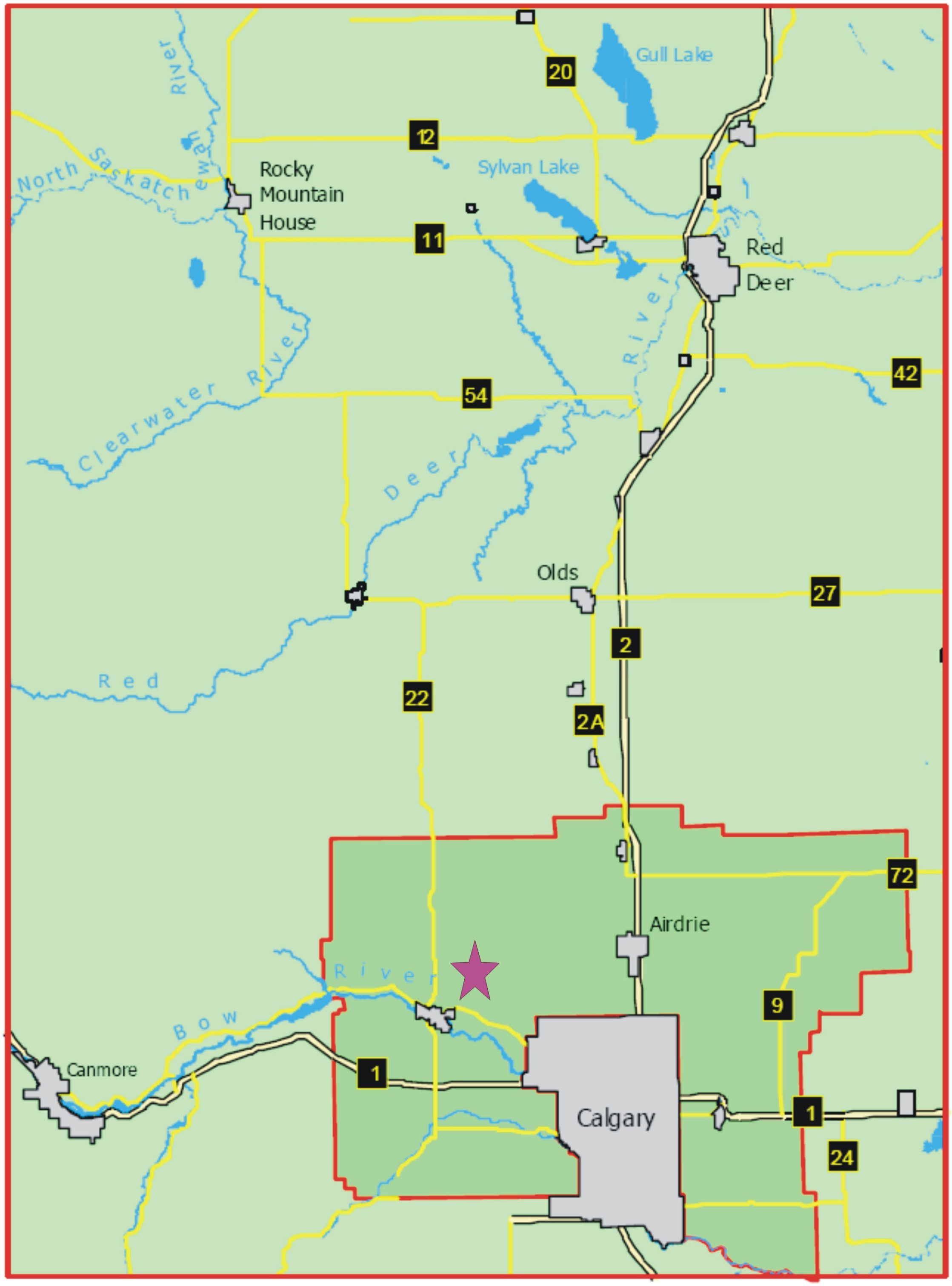


Figure 2: MD and Park Location (modified from Hydrogeological Consultants, 2002).

Climate:

The MD of Rocky View is located in the Boreal Mixedwood and Aspen Parkland ecological regions of Canada. The climate is that of long, cool summers and severe winters without a dry season. The mean monthly temperatures are -8.6 C° in the cooler months and 16.0 C° in the warmer months. The mean annual temperature of the area is 4.0 C°, the mean annual precipitation is 441 mm, and the calculated annual potential evapotranspiration is 494 mm (Hydrogeological Consultants, 2002; Peng et al., 2003).

Geology:

The MD of Rocky View consists of surficial deposits and bedrock. The deposits include gravel, sand, till, clay and silt. They are usually less than 50 m thick. These tills and meltwater deposits are found in conjunction with glacial meltwater channels in the northwestern part of the MD and near Big Hill Springs Provincial Park.

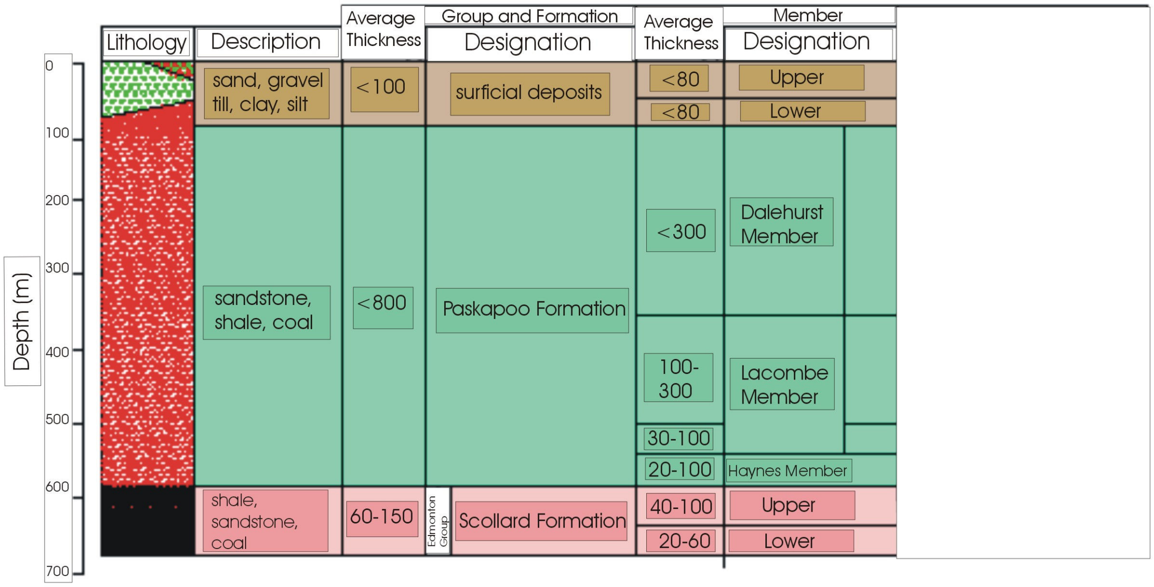


Figure 3: General cross-section of the possible formtations of the MD (modified from Hydrogeological Consultants, 2002).

These deposits are home to two aquifers: the Upper and Lower Sand and Gravel Aquifers. There are 222 wells in the surficial deposits compared to 6887 in the bedrock of the MD (Hydrogeological Consultants, 2002). As illustrated in Figure 3, these deposits are underlayed by the Paskapoo Formation. This Formation is between 800-1,200 m thick in the MD of Rocky View and consists of cyclic layers of sandstone, siltstone and mudstone. This formation is divided into 3 Members: the Dalehurts, Lacomber and Haynes Members. These outcrop throughout the MD as shown in Figure 4. Big Hill Springs Provincial Park occurs in the Dalehurst Member area in the western part of the MD, which rests against the Disturbed Belt. The Dalehurst Member consists of shale and siltstone with sandstone, bentonite and coal seams/zones. The Scollard Formation underlies the Paskapoo Sandstone Formation. Each of these bedrock formations and members are home to their own aquifers except for the Scollard Formation (which is too deep for the wells of the region). (Hydrogeological Consultants, 2002)

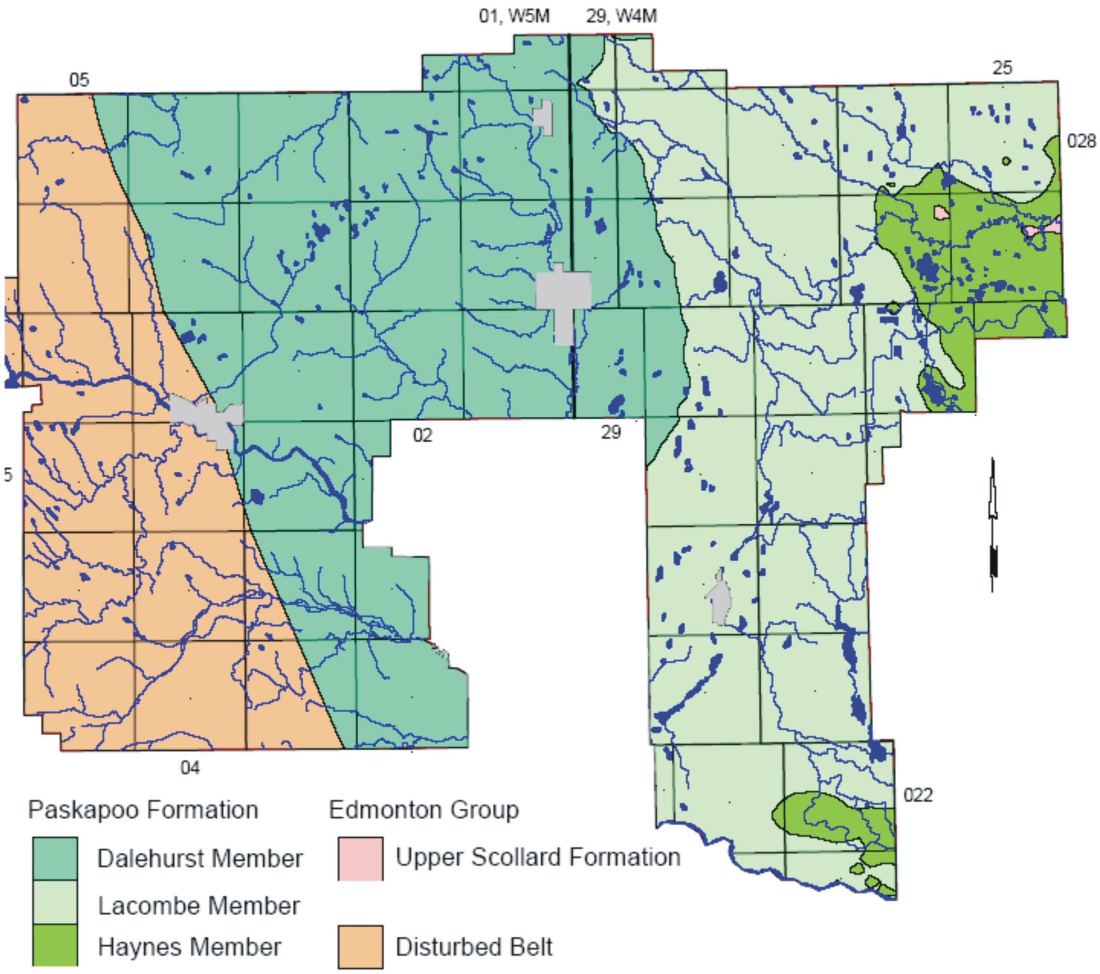


Figure 4: Bedrock geology of the MD (Hydrogeological Consultants, 2002).

Geochemistry:

The wells in the upper surfcial deposits and the upper bedrock surrounding Big Hill Springs Provincial Park have the highest apparent water well yields of the MD. Groundwater from the *surficial deposits* is chemically hard, with high dissolved iron content. Nitrate + nitrite concentrations do not exceed 10 mg/L. Groundwater from the *upper bedrock* has TDS concentrations that range from 500-3000 mg/L. It is frequently chemically soft, and has low concentrations of dissolved iron and high concentrations of sodium. TDS values get progressively lower in the western direction of the MD, such as near the Big Hill Springs. This is attributed to more active flow systems and shorter flow paths due to increasing relief. The two bedrock aquifers closest to the provincial park are the Disturbed Belt and the Dalehurst aquifers. The park is actually situated above the Dalehurst Member. Groundwater from the *Disturbed Belt* aquifer is mainly bircarbonate-type with no dominant cation. Ninety percent of samples have TDS less than 1000 mg/L, sulfate concentrations less than 100 mg/L, and chloride concentrations less than 10 mg/L. Groundwater from the *Dalehurst* aquifer is mainly bicarbonate-sulfate type, with Ca-Mg or Na as the main cation. TDS is mainly less than 1000 mg/L, sulfate below 500 mg/L, and chloride less than 10 mg/L. See Figure 4 for an approximate locations of the related bedrock locations. (Hydrogeological Consultants, 2002)

Provincial Trends of Springs:

TDS values of springs in Alberta are typically less than 1000 mg/L, indicating good quality spring water (Borneuf, 1983). There also exists a trend of increasing TDS values from the mountains to the plains due to longer flow paths and the shaley nature of the sediments (Borneuf, 1983). Ca-Mg-HCO3 type waters are common throughout the province (42%), including most mountain, foothills and the western interior plains closest to the foothills (Borneuf, 1983). There also exists 14% that are Ca-Mg-SO4 (widespread area), 9% that are Na-SO4 (only in the interior plains), 7% that are Na-HCO3 (interior plains), and 4% that are Na-Cl. The latter are found almost exclusively in the NE region of the province with the highest TDS values of all the province -- up to 300 000mg/L.

The remaining 24% are of other mixed-chemical types and are also located in the interior plains (Borneuf, 1983).

There is a provincial trend of decreasing spring discharge as you get further away from the Rocky Mountains due to the combined effects of gentler gradients, lesser inter-granular permeability, lower precipitation and the nature of the sediments (Borneuf, 1983). Local occurrences of permeable alluvium or bedrock channel sediments can be the exception to this trend (Borneuf, 1983).

There are 4 main types of springs in Alberta (Borneuf, 1983). The are contact springs, occuring between two layers of rocks of different permeabilities such as sandstones overlying shales. There are karst springs such as the ones in Maligne Canyon. There are resurgence of waters such as the Butte Springs. Finally, there are springs from fractures/fissures which are commonly found in the Rocky Mountains and Foothills of Alberta.

Big Hill Springs in Particular:

Big Hill Springs are interpreted to be issuing from fractures and fissures in the Paskapoo Formation. The Paskapoo Formation is tertiary in age and extends from north-western Alberta and parrallels the Rocky Mountains in a wide belt as far east as Grande Prairie, making up an important Albertan aquifer. Other similar springs issuing from this aquifer include Obed Springs, in the northwestern plains, and Rockyford Springs, in the southern plains. All three of these springs described in Table 1 are issuing from sandstone, are permanent and fractures are the nature of their permeability. (Borneuf, 1983)

Table 1: Spring Characteristics Issuing from the Paskapoo Sandstone (Borneuf, 1983)

Spring	**Elev (ft)**	**Flow Rate (l/s)**	**EC**	**Temperature (degrees C)**	**TDS (mg/L)**	**Mineral Deposit**
Big Hill	3900	11.36	545	7.3	307	Calc. tufa
Obed	3600	18.20	450	9.7	320	Calc. tufa
Rockyford	2900	4.5	3450	7.1	2618	Salt

Big Hill Springs have calcareous tufa deposits related to them. Tufa is a calcium carbonate deposit that is very soft and porous, often precipitating around branches, leaves, etc, which is related to the degassing of CO2 as the springs come up to the surface. In one place there is a large dam of tufa, perpendicular to the stream and 3-4m tall. It is hypothesized that it precipitated around an old beaver dam and the stream has eroded it (Borneuf, 1983).

Isotopes:

The isotopic composition of groundwater often tends to an intermediate value of spring and fall rain, which will be close to the mean of annual precipitation (Figure 5) (Fritz and Clark, 1997).

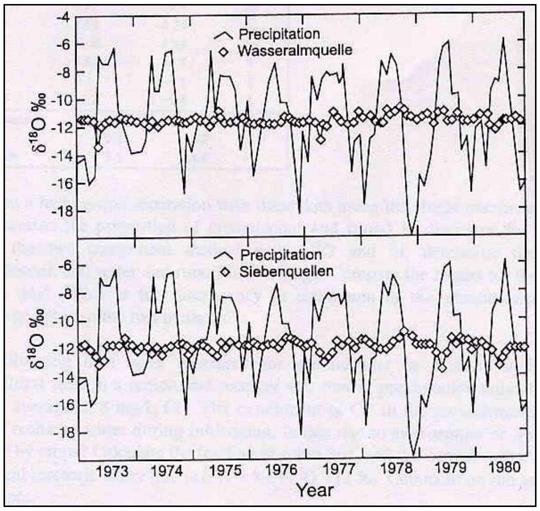


Figure 5: Variations in ^{18}O for precipitation and discharge from the alpine karst in southeastern Austria. Long-term circulation in the fissures and porous matrix network attenuates the precipitation-input signal. (modified from Fritz&Clark, 1997)

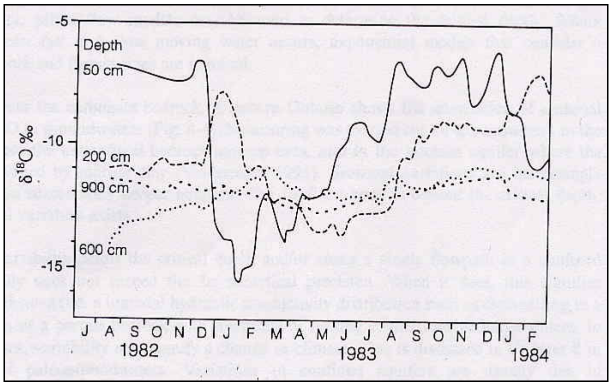


Figure 6: Attenuation of seasonal &18O signal at various depths during infiltration through Quaternary gravels near Munich. (modified from Fritz&Clark, 1997)

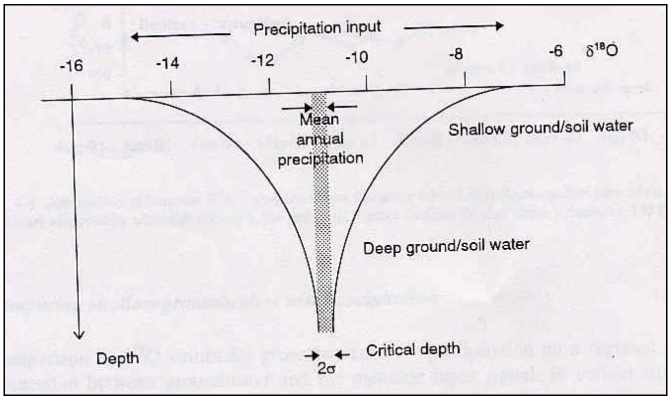


Figure 7: Schematic attenuation of seasonal isotope variations ($\delta^{18}O$ or $\delta^{2}H$) in recharge waters during infiltration through the unsaturated zone and movement within the saturated zone, and the critical depth below which isotopic variability is less than the analytical precision (2σ). (modified from Fritz&Clark, 1997)

The depth of the groundwater affects how attenuated the isotopic signal is (Figure 6). More importantly, Figure 7 shows the critical depth, at which point the isotopic variation is less than twice the standard deviation (2σ) of the $\delta^{18}O$ analysis. This critical depth varies from 3-5m in fine-grained soil where there are no fast flow paths, and up to tens of meters or more in fractured rocks. This critical depth is often found below the water table, where minor seasonal variations are preserved in shallow groundwaters. Unconfined aquifers also contain more seasonal variations than confined aquifers. (Fritz and Clark, 1997)

Deviations from the mean weighted annual composition of precipitation by groundwaters can shed light on the recharge mechanisms. These include infiltration from a surface environment to an underground one through soils and vegetation, non-saturated flow through heterogeneities porosity, losses to evaporation and transpiration, seasonal variations, and long term changes, affecting the residence time within the recharge environment (Fritz and Clark, 1997).

Estimating Recharge:

Temporal variations in properties of the springs such as temperature or discharge can be used to characterize the groundwater system as a whole, and snowmelt in the springtime is usually the main recharge (Manga, 1999).

In Manga 1998, some springs varied by less than 0.1-0.2 degrees celcius over 2 years, while others show temperature variations of several degrees. The nearly constant temperature reflects the large volume of the aquifers and residence time of groundwater (near a decade), which effectively averages annual temperature variations, and will even damp climatic temperature variations on the time scale of decades (Manga, 1999).

Direct recharge decreases in significance with increasing aridity, and increasing localized and indirect recharge (Figure 8). Procedures used to quantify recharge include direct measurement, water-balance methods, Darcian approaches, tracer techniques and empirical methods. Direct recharge is also very variable (de Vries and Simmers, 2002).

Localized recharge has been visualized to be influenced at three different scales (de Vries and Simmers, 2002). First is the micro-scale pathways (cm-dm), including shrinkage cracks, roots, and burrows of animals. Secondly, there is the meso-scale (0-10's m), which consists of local topographic or lithological variations. Thirdly, there is the macro-scale (100's m) which includes major landscape features like karst sinks or playa basins.

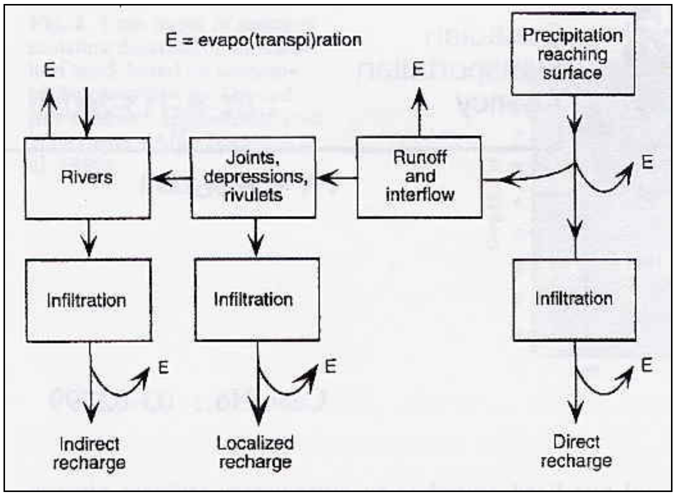


Figure 8: The various mechanisms of recharge in a semi-arid area. (modified from de Vries & Simmers, 2002)

Areas of pronounced topographic relief tend to have dominant local flow systems, and areas of nearly flat relief tend to have dominant intermediate and regional flow systems (Sophocleous, 2002).

2) Methods:

Big Hill Springs provincial park's entrance road is accessible from highway #567 (Big Hill Springs Road), well marked by a provincial park sign. Water flow was measured approximately every week at the source and culvert locations, using Global Water's "FP101-FP201 Global Flow Probe". The channels were divided into areas of 20 cm widths, and an average flow was taken at each interval. The source was measured near a big rock by the eastern boundary of the isolated part of the provincial land. The culvert measurement was taken at the culvert at the entrance of the park, under the road. Please refer to Figure 1 for these sampling locations.

Anions and cation samples were taken every other week from the source. Isotope samples were taken every week from the source at the western boundary of the isolated part of the provincial land, where water trickles down from a fracture in the sandstone. Fresh snow samples were also taken when possible. Temperature and EC were measured in the field every week with a Barnant's "Thermocouple thermometer Type T" and VWR Scientific's "EC Meter Model 2052".

Alkalinity, anions and cations were analysed at the Geological Survey of Canada (Calgary) laboratory. Alkalinity was determined using an Orion 960 auto-titrator. Anions were measured by Ion Liquid Chromatography (ILC), and cations were measured by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and (AA). All samples were tested in two "batches", with differences found between cations of the first and second batch due to the different analyses done. A simple calculation was done to equivalate the two batches consisting of taking the average difference between them, dividing it by two, and adding/substracting it appropriately.

The $\delta^{18}O$ analysis was done in the University of Calgary's Department of Physics and Astronomy's Isotope Laboratory by dual inlet isotope ratio mass spectrometry with the Micromass SIRA II. (Isotope Science Laboratory, 2003). The precision of this method is better than +/- 0.2‰. (Eipstein and Mayeda, 1953; Horita et al., 1993; O'Neil et al., 1975 and Sofer, 1972)

3) Results & Discussion

Flow

Flow was plotted vs. time in Figure 9. It is not possible to distinguish the slope of the lines corresponding to flow vs. time as different from zero at the 95th percentile (source slope: between –0.00017 and 0.000323 $m^3/s*day$, t = 0.760, P = 0.476, df = 7; culvert slope: between –0.000072 and 0.000176 $m^3/s*day$, t = 1.03, P = 0.341, df = 7). Within the time frame of this study, no change of flow was found to exist over time at either the culvert or source locations. Statistically, the flow of the two locations overlap, and therefore are not statistically different (source flow: between 0.0453 and 0.0894 m^3/s, t = 7.475, P = 0.000296, df = 7; culvert flow: between 0.0546 and 0.0767m^3/s, t = 14.505, P = 0.00000673, df = 7). The only difference is that the flow at the source location was more difficult to measure due to uneven ground and large rocks. The culvert location had the flow constricted to a nearly flat bottom. This is is reflected in the narrower range of values in the culvert than with the source. When a two-sample t-test assuming unequal variences was applied to the source and culvert sampling locations, the means were 0.073 and 0.070 m^3/s, respectively, but no statistically significant difference could be found between the two (t = 0.76, P = 0.23, df = 12).

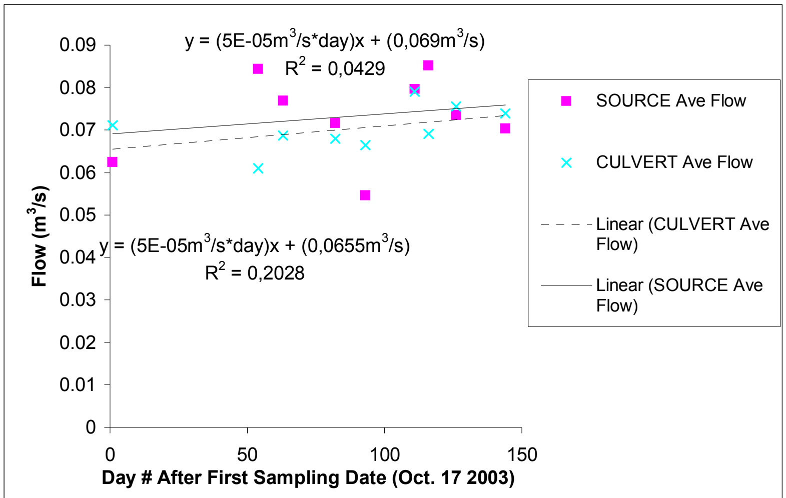


Figure 9: Flow of Big Hill Spring

By looking at flow alone, it is difficult to tell if the Big Hill Spring system is a local or regional one, especially considering that the sampling took place over the fall and winter months. The changes that would occur in the flow of a local system would be more obvious in the spring. After snowmelt water runnoff and infiltration the flow and chemistry is dominated by surface water. This study can then be used as a baseline for such a spring study in the future.

Temperature

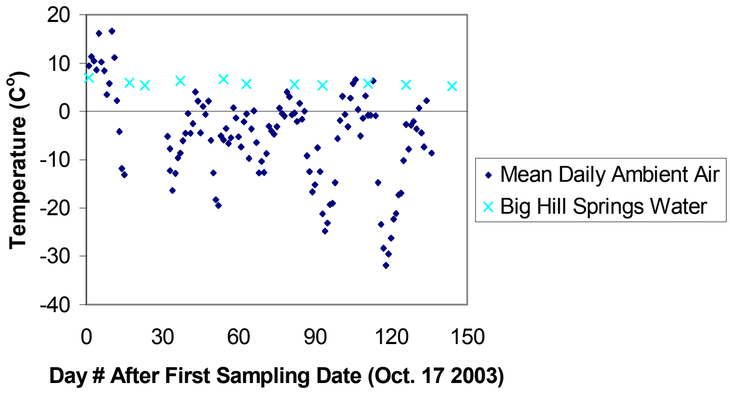


Figure 10: Environment Canada Data from Calgary International Airport Plotted in Conjunction with Big Hill Spring Water Temperatures

In Figure 10, temperature of the springs is plotted along with the ambient temperature vs. time. It appears to be that the spring water temperature is fairly constant over time with a slightly decreasing trend over the 5 month sampling period. The slope of the line of the springs' temperature vs. time was found to be between –0.015 and -0.001°C/day at the 95th percentile of a regression analysis (t = -2.58, P = 0.03, df = 10). This is a slightly decreasing temperature, reflecting the progressively decreasing local daily ambient temperatures. This trend could indicate a local origin of the springs. It does not vary as much as the local daily ambient temperatures. Its standard deviation is 0.6 °C. Its average is 5.9 °C, which is a few degrees warmer than the annual ambient temperature average of 4.1 °C (Environment Canada; Peng et al., 2003). This could potentially be due to the geothermal gradient (Hitchon, 1984).

Looking at the historical data provided by Komex International Ltd and Alberta Environment (Table 2), the temperature appears to be somewhat variable with a standard deviation of 2.13 °C and an average of 5.78 °C. No discernable pattern is found but there does appear to be some kind of variation throughout the years.

Geochemistry

The GSC analysis results of BHS samples were plotted over time in Figures 11 and 12. The geochemistry of the well (352476) was also plotted along with the spring water, which seems to be similar to it in terms of cations, but not in anions. Concentrations do not appear to be changing very much over time, and the only differences that can be seen are between the source and the well # 352476. The cations Ca, Na and K exist in slightly lower concentrations in the well than in the spring water. The well also has slightly lower Cl and higher SO4 than the spring water.

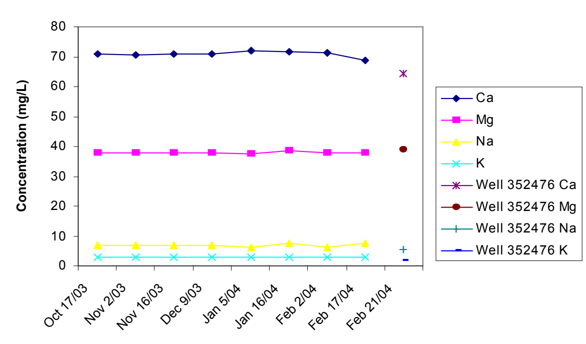


Figure 11: Cations

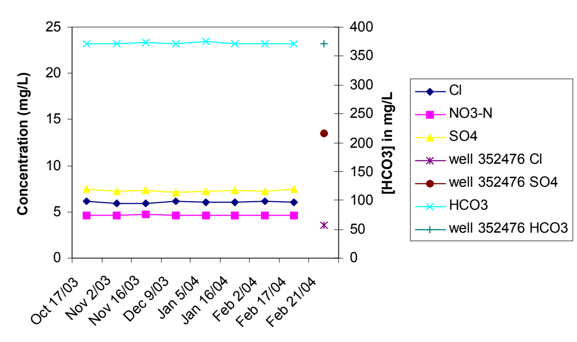


Figure 12: Anions

Figure 13 shows the piper plot for both the spring water and the well 352476. Both waters are a calcium-magnesium bicarbonate type, with similar TDS values. The average TDS values over all the historical period (from Table 2) is 509 mg/L with a standard deviation of 10 mg/L. These low TDS values agree with lower TDS values in the bedrock of the western part of the MD of Rocky View. In contrast, surficial deposits typically have higher TDS values (Hydrogeological Consultants, 2002). For example, 80% of water from the surficial deposits in this region have TDS values above 500 mg/L, except for the Disturbed Belt aquifer. It is difficult to tell where the spring water is coming from because Big Hill Springs Provincial Park is near the boundary of the Disturbed Belt and Dalehurst aquifers, as well as in an area of high amounts of surficial deposits from meltwater channels.

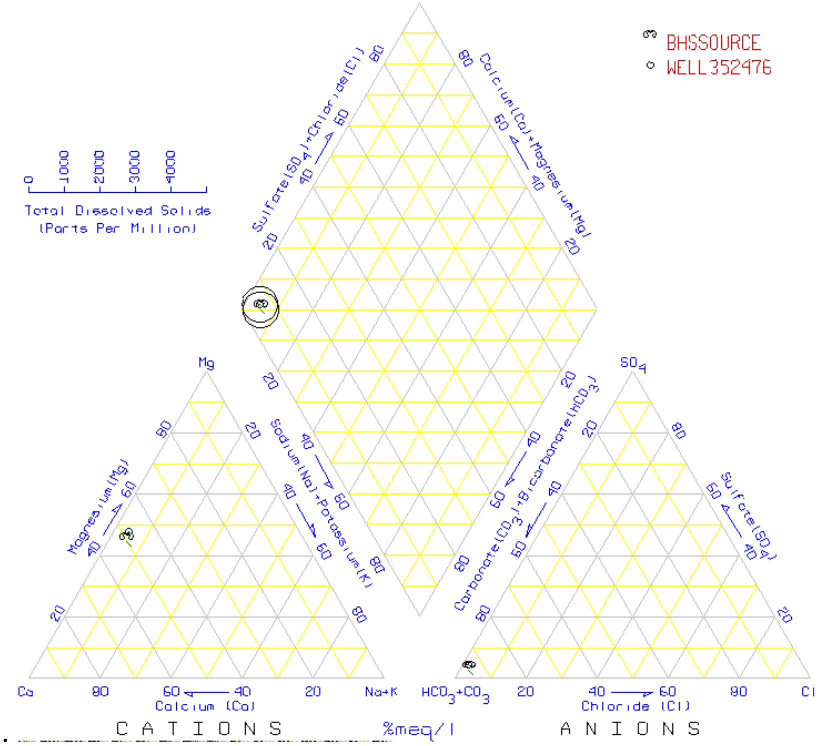


Figure 13: Piper plot of the average geochemistry of the source water along with well 352476.

Table 2 shows the result of past chemical analytical tests performed on water from the source of the springs. The first three histrorical samples have unknown analysers but they are reported by Komex International. The next three historical samples (458814, 458817, 458818) are located as “chemical analysises” on Figure 1 and are from the Alberta Environment data base. They are of the water of Big Hill Springs. The samples WQ1-5 are also of the water from Big Hill Springs at 5 different springs throughout the provincial land and performed by Komex International. The results done by the GSC are also shown and are the most current, done for this study, and also include one analysis from a nearby well (352476) as seen in Figure 1. Overall, all of the analyses in Table 2 were performed on spring water except for the last one (well 352476). It also appears to be that the older water analyses in Table 2 are less reliable. They are incomplete and they differ from the more current values by a large portion, especially with TDS and temperature.

Table 2: Geochemistry of Big Hill Spring Source - all units in mg/L unless otherwise noted. GSC values have been interpolated between two analyses.

ID	**Date**	**Ca**	**Mg**	**Na**	**K**	**Fe- field/lab**	**Mn**	**Cl**	**NO3-N**	**SO4**	**HCO3- field/lab**	**Temp- field C°**	**EC- field/lab uS/cm**	**TDS**	**Analysis Done by:**
Historical 1	May 10/68	nd	nd	nd	nd	nd/3	0	4,0	0,0	10,0	nd	11,1	nd/nd	17	Komex
Historical 2	Sep 20/68	nd	nd	nd	nd	nd/3	0	4,0	0,0	12,0	nd	13,9	nd/nd	19	Komex
Historical 3	Jul 07/76	65	32	7,5	2,90	nd/0	nd	6,0	7,20	6,8	349	7,3	nd/545	476	Komex
458814	Mar 03/86	70,0	31,0	6,9	2,37	0,03/0.02	0,01	2,84	1,68	9,60	375/373	3,0	260/500	499	AB Env
458817	Jul 15/86	66,0	32,8	6,9	2,37	0,03/0.1	0,01	1,78	1,40	9,60	378/370	5,0	325/510	499	AB Env
458818	Jun 21/90	67,2	33,1	9,2	2,77	0,02/<0.01	<0.005	3,91	1,50	10,56	372/373	7,9	580/590	500	AB Env
WQ1	Jul 11/97	76,4	35,7	8,11	2,94	nd/<0.01	<0.001	5,5	1,69	10,6	385	4,8	nd/565	526	Komex
WQ1	Aug 07/97	75,6	33,7	7,53	2,58	nd/<0.01	<0.001	5,3	1,82	11,0	385	4,8	nd/592	523	Komex
WQ1	Oct 20/97	70,0	33,2	7,5	2,70	nd/<0.01	0,007	8,5	1,60	10,6	388	4,5	nd/573	522	Komex
WQ2	Jul 11/97	77,1	34,8	8,01	2,94	nd/<0.01	<0.001	5,7	1,90	9,0	380	4,7	nd/562	519	Komex
WQ2	Aug 07/97	77,1	33,8	7,66	2,72	nd/<0.01	<0.001	5,6	1,97	9,3	380	4,6	nd/532	518	Komex
WQ2	Oct 20/97	71,3	32,7	13,4	3,20	nd/<0.01	<0.001	16,8	1,75	9,3	377	4,7	nd/572	525	Komex
WQ3	Jul 11/97	76,2	34,3	7,92	2,93	nd/<0.01	<0.001	5,8	1,93	8,9	378	4,6	nd/564	516	Komex
WQ3	Aug 07/97	70,4	33,6	7,69	2,69	nd/<0.01	<0.001	5,7	2,02	9,1	375	4,7	nd/540	506	Komex
WQ3	Oct 20/97	70,7	33,0	7,5	2,70	nd/<0.01	<0.001	5,8	1,86	9,8	371	4,6	nd/569	502	Komex
WQ4	Jul 11/97	76,0	34,0	7,77	2,98	nd/<0.01	<0.001	5,8	2,09	8,6	377	4,5	nd/561	514	Komex
WQ4	Aug 07/97	70,8	33,9	7,58	2,91	nd/<0.01	<0.001	5,9	2,16	9,0	373	4,7	nd/529	505	Komex
WQ4	Oct 20/97	70,1	32,7	7,3	2,80	nd/<0.01	<0.001	6,3	1,97	9,2	375	4,8	nd/569	505	Komex
WQ5	Jul 11/97	71,9	34,8	7,86	2,69	nd/<0.01	<0.001	4,2	1,39	11,5	375	4,9	nd/552	509	Komex
WQ5	Aug 07/97	68,0	32,8	7,47	2,45	nd/<0.01	<0.001	4,2	1,53	11,4	373	5,3	nd/529	501	Komex
WQ5	Oct 20/97	67,1	33,3	7,3	2,50	nd/<0.01	<0.001	5,1	1,42	10,3	377	5,5	nd/565	504	Komex
BHS source	Oct 17/03	71,03	37,87	6,97	2,88	nd/<0.01	<0.005	6,17	4,58	7,41	371,48	7,0	330/nd	506	GSC
BHS source	Nov 2/03	70,63	37,97	6,87	2,88	nd/<0.01	<0.005	5,97	4,58	7,21	372	6,0	340/nd	506	GSC
BHS source	Nov 16/03	70,83	37,97	6,97	2,88	nd/<0.01	<0.005	5,97	4,68	7,31	373	nd	nd/nd	508	GSC
BHS source	Dec 9/03	70,93	37,77	6,87	2,88	nd/<0.01	<0.005	6,17	4,58	7,11	371	6,7	333/nd	506	GSC
BHS source	Jan 5/04	71,94	37,62	6,30	2,89	nd/nd	nd	5,99	4,57	7,19	375	5,6	349415	514	GSC
BHS source	Jan 16/04	71,53	38,54	7,50	2,88	nd/nd	nd	6,01	4,66	7,29	372	5,4	354/403	512	GSC
BHS source	Feb 2/04	71,13	37,78	6,35	2,88	nd/nd	nd	6,13	4,65	7,27	371	5,8	355/445	509	GSC
BHS source	Feb 17/04	68,71	37,77	7,58	2,88	nd/nd	nd	6,03	4,58	7,49	372	5,5	363/456	510	GSC
352476	Feb 21/04	64,39	38,97	5,45	1,89	nd/nd	nd	3,54	nd	13,49	371	nd	nd/466	nd	GSC

Isotopes

Due to the fact that there is little variation in the isotopic composition of the spring water (Figure 14), it can be said that the water is more than a few months old, probably more than a year, but also probably younger than the last ice age (Mayer, B., 2004). According to a regression analyis of the line of δ^{18}O vs. time, the intercept was found to be between -18.33 and –18.00 ‰ of δ^{18}O (t = -242.66, P = 3.73x10-25, df = 14). The slope was found to be between 0.0003 and 0.0004 ‰ of δ^{18}O per day (t = 5.52, P = 0.03, df = 14) a slightly positive value but still very close to zero. The δ^{18}O values are also closer to the spring and summer precipitation values as opposed to the yearly average in Figure 15.

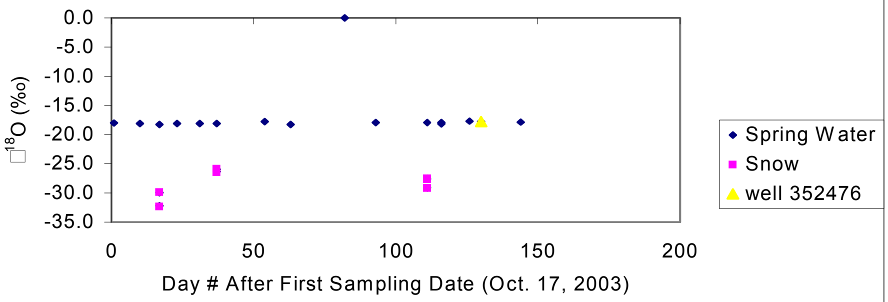


Figure 14: Del -^{18}O Values for Big Hill Springs, Surrounding Snow, and Well 352476

Another way to estimate the age of this groundwater without actually testing for other isotopes such as tritium, is to use the natural variation of the isotopic signal. As described in the introduction, a bigger variation will occur in younger, shallower waters, which reflect changes in the precipitation signals, although it is not possible to determine the extent of the regional or local nature of the groundwater from these isotopic analysises (Mayer, 2004).

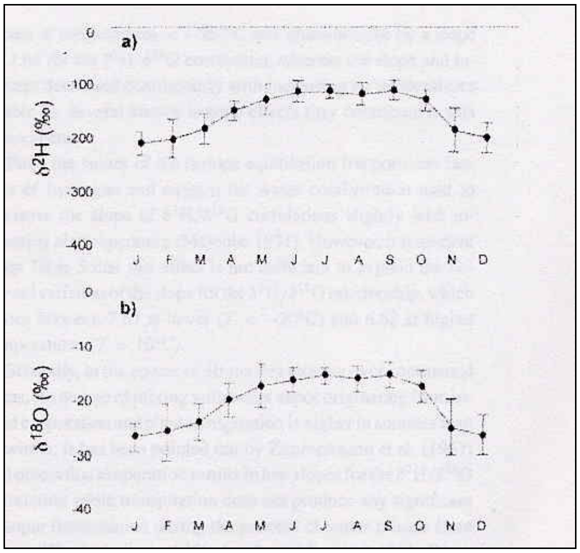


Figure 15: Ten-year amount-weighted monthly average δ^2H (a) and δ^{18}O (b) values for precipitation in Calgary with standard deviations. (modified from Peng et al, 2003)

Estimate of the age of the spring water:

To= age of groundwater

To= $\{[(1/f^2)-1]^{1/2}\}/2\pi$,

where f = B/A

B = groundwater measurement error/natural variation = 0.5‰

A = precipitation measurment error/natural variation = 20 ‰ (approximation from Figure 14)

Therefore f = 0.025

And To = $\{[(1/0.025^2)-1]^{1/2}\}/2\pi$ = 6.36 years

(Mayer, 2004)

Recharge Area Estimate

A topographically defined area of recharge was determined to be 26km^2 by Komex International Ltd (Figure 16). This area followed the outline of topographic high points around the Big Hill Spring watershed. Multiplying the watershed area by the yearly average precipitation of 412.6mm/year (Environment Canada, ????) yields a flow rate of 0.344m^3/s. The measured BHS flow rate is 0.06985 m^3/s. The springs therefore accounted for 20.25% of the flow rate due to precipitation alone. This value is quite high considering the aridity of the region, where a value of 4-5% would be much more reasonable due to strong evapotranspiration and transpiration (de Vries & Simmers, 2002). In order to get this more appropriate percentage, an area of 105 km^2 would have to be understood as the recharge area of the Big Hill Spring watershed. Consequently, the recharge zone of the spring may not be defined by topography alone. A zone of enhanced recharge might exist within the watershed.

The cross-section of the area (refer to Figure 1 for the map showing the line of cross-section and Figure 17 for the cross-section) on the other hand shows a peculiar situation: the springs are situated above the piezometric surface defined by the well logs used to make the cross-section. Since the piezometric surface in the deep wells is below the local water table as indicated by the elevation of the springs, the region appears to be a recharge for the deeper flow system while the springs are the discharge of a shallow and

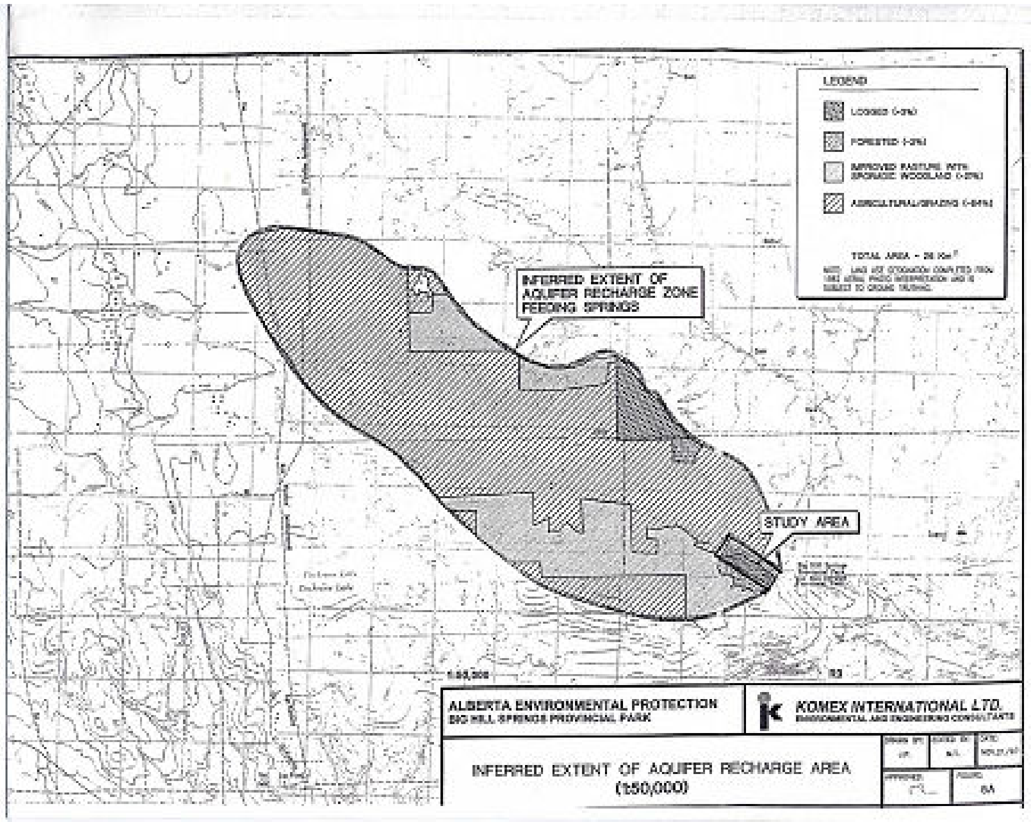
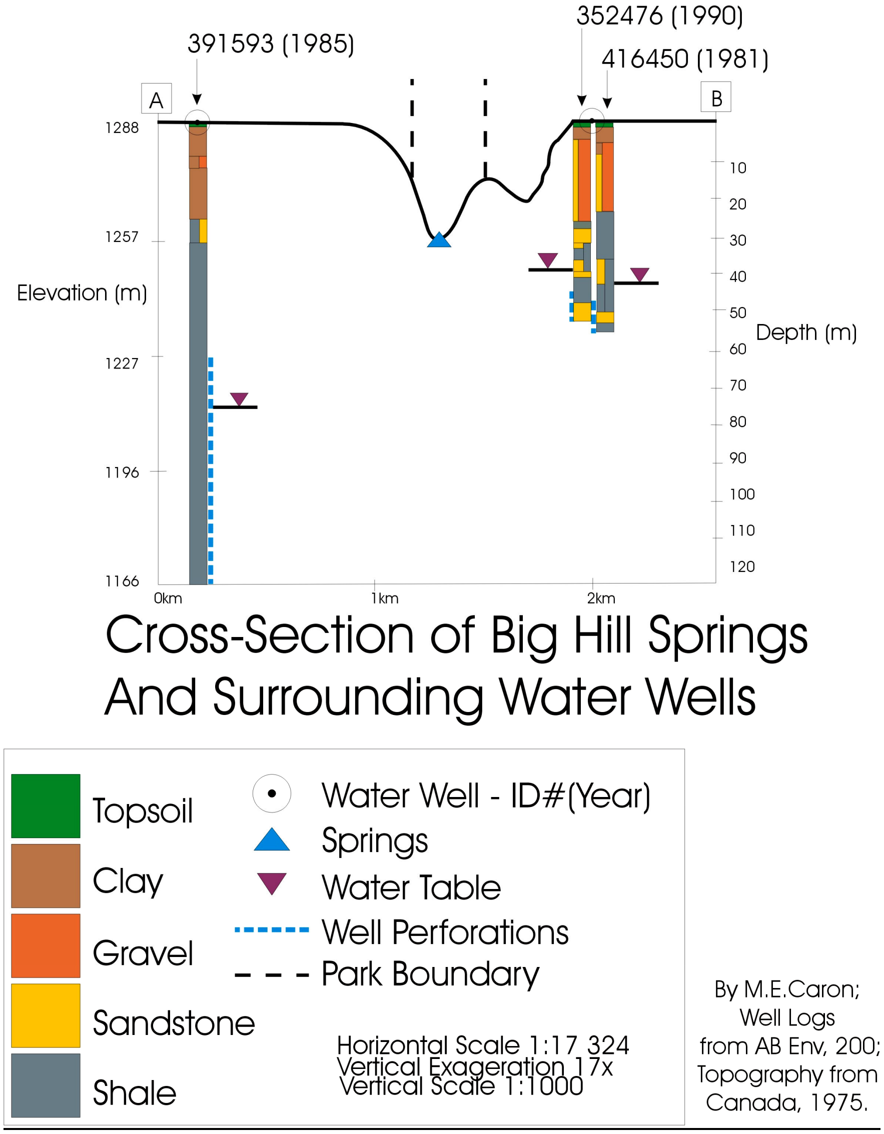


Figure 16: Estimate of recharge area for Big Hill Springs according to Komex (modified from Komex International Ltd, 1998).



By M.E.Caron;
Well Logs
from AB Env, 200;
Topography from
Canada, 1975.

Figure 17: Cross-section of Big Hill Springs and surrounding water wells.

4) Conclusion

This study was done as a "reconnaissance" project of Big Hill Springs, as it falls nicely within the context of the regional Paskapoo Formation project of the GSC. Plans have been made for a permanent weir or tranducer to be put inside the culvert location in order to continuously record the flow of the springs. The answer to the question "are the springs regional or local in origin" was attempted to be found.

So far, flow and isotope values that were obtained in this study indicate a large, regional system. This is due to their unchanging nature over the course of 5 months covering late fall and winter (Oct 2003 – Febuary 2004). Isotope values also indicate a groundwater age of between 6 months and 6.36 years. This idea is also supported by the recharge estimate by Komex, which was determined to be too small to account for the discharge of the springs when multiplied by yearly average precipitation and therefore had to be made larger. This supports the idea that the Big Hill Springs are regional in extent. On the other hand, the temperature, geochemistry and the physical location of the springs tell a different story. The remperature data show a decline over the sampling period of this study, and historical data show variabilities. The water chemistry from the wells (#352476) seems to differ from the water of the springs slightly, especially with some of its its cations, sulfate and chloride. The low total dissolved solid values are consistent with the area of the MD but inconsistent with a regional system. The cross-section that was made indicates the source of the springs to be above the piezometric surface as determined by two surrounding wells (Figure 17) and therefore shallow and local.

In conclusion, more study must be done in order to determine what happens to the springs during the spring months. The only suggestion that can be explored with the data obtained so far is that there exists a water table regional in extent with some enhanced recharge areas.

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