Golder Associates Ltd.

220 - 1755 Springfield Road
Kelowna, British Columbia, Canada V1Y 5V5
Telephone (250) 860-8424
Fax (250) 860-9874

REPORT ON

GROUNDWATER PROVENANCE AND WATER LEVEL ASSESSMENT FAULDER, BRITISH COLUMBIA

Submitted to:

Regional District of Okanagan-Similkameen
101 Martin Street
Penticton, BC V2A 5J9

DISTRIBUTION:

3 Copies - Regional District of Okanagan-Similkameen
1 Copy - Golder Associates Ltd.

August 2008 08-1440-0029 (2100)

Golder Associates Ltd.

220 - 1755 Springfield Road
Kelowna, British Columbia, Canada V1Y 5V5
Telephone (250) 860-8424
Fax (250) 860-9874

August 6, 2008 08-1440-0029 (2100)

Regional District of Okanagan-Similkameen
101 Martin St.
Penticton, BC
V2A 5J9

Attention: Mr. Andrew Reeder, Director of Engineering and Public Works

RE: Groundwater Provenance and Water Level Assessment
Faulder, British Columbia

Dear Mr. Reeder:

Golder Associates Ltd. (Golder) is pleased to provide this report to the Regional District of Okanagan-Similkameen (RDOS), presenting the results of a groundwater provenance and aquifer water level assessment for the Community of Faulder (Faulder), British Columbia. The scope of work for the project was developed in conjunction with the RDOS, subsequent to Golder's completion of an assessment and rehabilitation program for the Faulder Community Well, located at 133 Kettle Place, in Faulder, BC. The work included sampling of water for isotope and age-dating analyses, measurement of water levels and the review of climate data and historical water levels in observation wells.

The purpose of this investigation is to assess the declining water levels within the Faulder Community Well, such that a determination can be made regarding future water supply options for the Community of Faulder. Authorization to proceed with the age dating and water supply assessment was provided by Mr. Bill Harvey of Associated Engineering on April 20, 2008.

1.0 BACKGROUND

The Community of Faulder is located approximately 7 km to the west of Summerland, BC (Figure 1) and obtains potable water from a single supply well (hereafter referred to as the "Community Well") located in the Community. The Community Well is completed in the Meadow Valley Aquifer, which according to the BC Ministry of Environment (MoE) Water Resource Atlas (WRA) is listed as Aquifer No. 299, covering an area of approximately 10 km^2. The Meadow Valley Aquifer contains both unconfined and confined sand and gravel aquifers and extends north and southeast of Faulder.

In addition to the Community Well, numerous private wells are completed in the Meadow Valley Aquifer. Two additional wells of importance are the Gibbs Well and the Mearns Well, both of which are nearby. The following provides a brief summary of all three wells:

Faulder Community Well

The Faulder Well was constructed in 1993 under the supervision of Pacific Hydrology Consultants Ltd. (PHCL) and is located approximately 20 m to the northwest of Trout Creek. Subsurface conditions encountered during drilling consisted of an upper-most unit of compact sand, gravel and clay to a depth of approximately 47.2 m below ground surface (m bgs) followed by sand and gravel to a depth of 65.8 m bgs. Drilling was discontinued when bedrock was encountered at a depth of 66.5 m bgs. The reported static water level at the time of drilling was approximately 47 m bgs, while the lowest recorded static water level was 53.7 m bgs, measured on June 27, 2008.

Based on pumping tests completed immediately after the well was drilled, the well yield for the well was determined to be 22.1 L/s (350 US gallons per minute), based on utilizing 70% of the 11.8 m of total available drawdown from the static water level to the top of the well screens) (PHCL, 1993). As water levels have declined since the well was drilled, the total available drawdown has decreased to 5.1 m (based on the static water level measured on June 27, 2008 and the depth of the pump intake). As a result, the rate at which the well is being pumped has been reduced from 10.1 L/s (160 USgpm) to 6.8 L/s (108 USgpm) in the past two years.

Gibbs Well

The Gibbs Well is located approximately 75 m to the east of the Community Well, and on the east side of Trout Creek. The Gibbs Well was constructed in 1992. Subsurface conditions encountered during drilling consisted of interlayered clay, sand and gravel, described as glacial till to a depth of 52.7 m bgs. This was further underlain by sand and gravel to a total well depth of 83.5 m bgs. According to conversations with the driller of the well (Leo Litwin, personal communications July 2008), drilling was terminated at this depth due to difficult drilling conditions (i.e. cobbles and boulders). Bedrock was not encountered during the drilling of the Gibbs Well. The reported static water level at the time of drilling in 1992 was 50.1 mbgs, while the current static water level is approximately 53 mbgs (July 2008).

At the time of drilling in 1992 the well completion report states that "the theoretical capacity of the Gibbs Well is as much as three times the testing rate of 17.04 L/sec (270 USgpm)" (PHCL, 1992). We understand the well is currently in use, providing potable water for a single residence. However, it is understood that a development proposal is currently being assessed by RDOS for the property on which the Gibbs Well is located, which would see the Gibbs Well providing approximately 11.4 L/sec (181 USgpm) of water for the development.

Mearns Well

The Mearns Well is a private, out-of-use well, located approximately 80 m to the north/northwest of the Community Well. According to the well log for this well, it was constructed in 1981. The well log provides limited information on lithology; however, the presence of gravel, clay and sand are noted. The total depth of the well is recorded as 53.6 m. The static water level in the well at the time of drilling was recorded to be approximately 47.5 m bgs, while the most recent static water level is reported to be 53 m bgs (May 2008). The Mearns well was dry between 1988 and 1991, meaning the water level in the aquifer dropped below the depth to which the well was drilled. Based on conversations with Mr. Mearns, the well owner, use of the well was discontinued in the early 1990s, once the Community Well was used to provide water.

Well logs for the three wells (Community Well, Gibbs Well and Mearns Well) are provided in Appendix I, and well locations are shown on Figure 2.

According to Mr. Rob Palmer of RDOS, it is understood that the water level at the Community Well has declined significantly since August 2006. As a result, in March of 2008, RDOS commissioned Golder to conduct an efficiency assessment of the well. The results of the well assessment and rehabilitation are provided under separate cover, and summarized in our August 2008 report entitled *"Status Assessment and Rehabilitation of Faulder Community Well, Faulder, British Columbia"*. It was suspected that the decline in water levels and well efficiency was due to declining specific capacity (efficiency) resulting from chemical or biological encrustation on the well screens or due to the migration of fine-grained sand in the aquifer towards the well screens. Preliminary testing was not conclusive in verifying the drop in specific capacity; nonetheless, well rehabilitation was completed to clean the well screens. The results of the post rehabilitation testing indicated that the specific capacity of the Community Well increased; however, water levels continued to drop in the aquifer, reducing the amount of available drawdown in the well such that the pumping rate in the well had to be reduced to maintain flow without breaking pump suction.

Based on a preliminary review of water level data provided to Golder during the course of the assessment and well rehabilitation investigation, it was inferred that the decline in water level was not likely due to a decline in well efficiency. Subsequently, a more thorough review of historical water levels in the Community Well indicated that although recharge to the aquifer is generally observed on an annual basis (between spring and summer), no recharge to the aquifer was indicated during 2007.

Based on discussions with RDOS, a workplan was developed to undertake a groundwater age-dating and water isotope investigation in order to identify the recharge area for the Aquifer, specifically in the Faulder area, and review any available information regarding activities in the identified recharge area(s) which may have caused a decline in water levels in recent years. Age-dating and water isotope analyses were selected as methodologies because they are inexpensive to conduct relative to the costs of drilling monitoring wells. These methods can also provide significant information regarding the recharge characteristics of an aquifer in a relatively short amount of time. In addition to the field investigation, a review of water level information for various wells in the area, and a review of precipitation data, were conducted to assess whether regional changes to the climate (i.e. precipitation) were occurring, thereby having an impact on water levels within the Aquifer.

2.0 METHODOLOGY

The methodology for this assessment consisted of conducting the following tasks:

- Review of available information including: i) water levels in the Community Well, two private wells (Gibbs and Mearns) and selected MoE Observation wells in the area and in the Okanagan Basin to assess water level trends, ii) climate data from three climate stations to assess precipitation for the area, iii) existing groundwater chemical data for the Community and Gibbs Well, and iv) a previous report conducted by Gordon Wilson Associates Inc. for the north end of Meadow Valley (Gordon Wilson Associates Inc., 1990).

- Review of anecdotal information regarding construction and historical water levels at Thirsk Reservoir.

- The collection and analyses of the following samples:
  - Groundwater sample from the Community Well and the Gibbs Well for tritium (3H) and/or dissolved helium (3He), and
  - Surface water samples from Thirsk Reservoir, two locations along Trout Creek and two locations along Darke Creek for isotope analyses.

A more detailed methodology regarding the age-dating and isotope analyses is provided in Appendix II.

3.0 GROUNDWATER CHEMICAL ANALYSES

Prior to conducting the groundwater sampling program, historical general chemistry data for the Community and Gibbs Well were examined to determine whether the concentrations of dissolved constituents supported the assumption that the two wells accessed water from the same aquifer. Since the general chemistry data are similar for the two wells, and since the observed trends in static water level measurements (discussed in Section 4.0) in the wells are similar, it is inferred that the assumption of the two wells withdrawing water from the same aquifer is valid.

Tritium/Helium Age-Dating

Results of the groundwater age-dating assessment indicated that the tritium (3H) concentration within groundwater collected from the Gibbs well was 6.8 tritium units (TU), corresponding to a groundwater age (time elapsed since the water was recharged into the subsurface) between five to ten years (Motzer, 2007). This is considered “modern” water.

The helium (^{3}He) analysis did not produce the expected results due to the influence of crustal helium production in the aquifer sediments. The sample obtained from the Community Well was likely impacted by degassing in the well, and as such, the results were not considered to be representative of groundwater conditions in the aquifer. Conversely, the sample obtained from the Gibbs well is inferred to more accurately reflect local aquifer conditions. However, the Gibbs Well sample was also influenced by the subsurface production of helium in the sediments, which interferes with the interpretation of the results. Using a standard value for the crustal helium (^{3}He/^{4}He) production resulted in a groundwater age of 43 years. However, the relatively high concentration of ^{4}He observed indicates that a larger correction value is likely required, due to the specific tectonic setting of central BC. Note that an increase in this correction factor would decrease the resulting groundwater age estimate.

In summary, the groundwater age range obtained from the various age-dating analyses is 5 to 43 years. A copy of the complete helium analytical results and data interpretation provided by the laboratory is included in Appendix III.

Water Isotopes

Results of the water isotope analysis indicate that groundwater collected from the Community Well has the same isotopic fingerprint as the Gibbs well, verifying that the wells are likely completed in the same aquifer. In addition, the results indicated that groundwater in the wells is characteristic of water recharged during the late winter or spring.

Water isotope fingerprints of the surface water samples collected from Thirsk Reservoir, Trout Creek and Darke Creek are similar to the fingerprint of the groundwater sample collected from the wells. Thus it can be inferred that both the Trout Creek and Darke Creek watersheds likely contribute recharge to groundwater in the area of the wells. Although the groundwater samples had water isotope ratios relatively slightly more closely similar to the Darke Creek samples, the relative contribution of recharge from each watershed cannot be determined as the data is limited. The surface water sampling locations are shown on Figure 3, with a summary of results provided below.

Table 1: Water Isotope Analysis Results

	Sample ID	δ^2**H** ‰	δ ^{18}**O** ‰
Groundwater	*Gibbs Well*	-134	-16.4
	Faulder Well	-134	-16.4
Surface Water	*Darke Creek*	-132	-16.3
	Trout Creek Lower	-138	-17.2
	Trout Creek Middle	-137	-17.4
	Thirsk Reservoir	-136	-17.1

Notes: Results are reported relative to the Vienna Standard Mean Ocean Water (VSMOW) reference in the delta per mil (‰) notation: δ(‰ = [(R_{sample}/$R_{standard}$) – 1] * 1000, where R_{sample} and $R_{standard}$ denote the $^2H/^1H$ or $^{18}O/^{16}O$ isotopic ratios in the sample and the reference material, respectively. The error in the reported values is ±2.0‰ for δ^2H and ±0.2‰ for $\delta^{18}O$.

4.0 ASSESSMENT OF PRECIPITATION AND RECHARGE RELATIONSHIP

Groundwater Levels

Historical water levels for the Community Well, Mearns Well and BC MoE Observation Well Nos. 366 and 367 were reviewed, with the following observation made. A graphical display of the water levels is provided in Figures 4 and 5.

- Data for the Community Well is limited to a period of time between January 2006 and the present, while water level information for the Mearns Well exists only between April 1993 and January 1995, and between September 2003 and the present. Data for MoE Observation Well No 367 is limited to between February 2006 and February 2008, while data for MoE Observation Well No 366 is limited to a short period of time between March 2005 and February 2007.

- Based on well completion details, screen depth installations and location, these wells are all inferred to be completed within the same confined aquifer, with the aquifer trending to semi-confined in the Faulder area.

- Although there are considerable data gaps between 1995 and 2003, recharge to the confined aquifer generally begins in April or May and ends in July or August of each year. Water levels have been observed to fluctuate as much as 6.2 m (observed in the summer of 1993). However, two periods of minimal recharge were observed in the spring of 2004 and the spring of 2007.

- In the spring of 2004 water levels increased approximately 0.3 m in the Mearns Well between April and June 2004, after which time the water level stabilized until November 2004. Between November 2004 and April 2005 water levels in the Mearns Well declined approximately 0.3 m. In the spring of 2005, water levels rose approximately 4.6 m.

- No recharge (increase in water levels) to the confined aquifer was noted in the spring of 2007 at the Mearns Well and the Community Well. However, the rate at which water levels were dropping decreased slightly in May 2005, inferring that some recharge, although be it minimal, was likely occurring.

- The time of recharge in 2008 was observed to late, with water levels in the Community Well, Mearns Well and Gibbs Well continuing to decline until approximately June 27, 2008. Following this, water levels appeared to begin increasing.

- No recharge was also observed at MoE Observation Well No. 367 in the spring of 2007, located approximately 4 km to the southeast of the Community Well, near the Summerland Rodeo Grounds.

- A decline in water levels at MoE Observation Well Nos. 366 and 367 was observed between August and October of 2006. It is possible that the pumping of the District of Summerland Wells located in the area of the Summerland Rodeo Grounds could have caused the decline in water levels in the observation wells.

- Of additional observation well information reviewed, no other MoE Observation Wells in the Valley indicated this declining water level trend in 2007. Other MoE Observation Wells in the Summerland area indicated that recharge generally occurred each year between 1966 and early 2007 (data is not available subsequent to early 2007).

Based on the above, it can be inferred that the decline in water levels noted in 2007 was observed in several wells completed within the confined portion of the Meadow Valley Aquifer, both in the Faulder area and approximately 4 km to the southeast in the Summerland area. As the lack of recharge during this period was not observed in other wells throughout the Okanagan Basin, it can be assumed that this is a localized phenomena in the Meadow Valley confined aquifer, and as such, not a result of a climatic change in precipitation.

Precipitation Data

Precipitation data was reviewed for three climate stations. Information regarding the climate stations is provided in the following table. The locations of the Climate Stations are shown on Figure 3.

Table 2: Environment Canada Climate Stations near Faulder, BC

Station Name	Elevation (m)	Period of Record
Jellicoe	929	1995-2008
Brenda Mines	1520	1968-1993
Summerland	454	1961-2008*
* Snowfall data is unavailable for the period 1990-2008, with the exception of 2003		

For comparison purposes, the elevation of the Community Well in Faulder is approximately 676 m, while the upland areas of the Trout Creek and Darke Creek watershed have a maximum elevation of 1,900 m and 1,700 m respectively.

The Cumulative Precipitation Departure (CPD) for each climate station was calculated using total annual precipitation data for years with complete data sets. The CPD represents the deviation from the mean annual precipitation and can aid in determining precipitation trends. In general, the CPD has been above the mean since approximately the early 1980s. However, there appears to be a decreasing trend of the CPD since 1990. CPD data is shown graphically on Figure 4.

Although historical water level data is minimal for the Faulder area, the water level at the Mearns Well (as expected) follows a similar trend with CPD data, in that the maximum water levels recorded each year indicate a decreasing trend between 1990 and the present.

Based on the results of the CPD analyses, it can be inferred that the cumulative departure from the mean precipitation has been decreasing since the 1990s, resulting in an approximate 1.8 m decrease in the static water level within the Meadow Valley Aquifer, observed between September 1993 and August 2008.

5.0 WATER BALANCE

A water balance was conducted as part of an investigation completed by Golder for the area in 1995 (Golder, 2005) which indicated that the volume of water recharging the Faulder area ranges from 10,600,000 m^3/yr (based on Darcy's Law) to 9,500,000 m^3/yr (based on precipitation data). The recharge estimate based on precipitation was based on the assumption that approximately 5% of precipitation recharges groundwater. However, based on a more recently completed study completed by Golder for the Okanagan Basin, it has been noted that the actual infiltration rate of precipitation to groundwater is in the range of 10%. As such, the 2005 water balance based on precipitation is considered to be a conservative estimate.

According to the 2005 Golder report, approximately 88% of the recharge was inferred to be contributed from the Trout Creek catchment and approximately 12% was inferred to be contributed from the Darke Creek catchment. This recharge breakdown cannot be refined basin on currently available data, although the results of the isotope analyses indicate that the groundwater samples displayed more similar characteristics to Darke Creek than Trout Creek. It is possible that the sample results could have been influenced by the timing of the sampling, specifically that the sample was collected in the spring when Darke Creek has a greater influence on recharge than it does throughout the rest of the year.

Based on our review of the Gordon Wilson Associates Inc. (Wilson) report (1990), a portion of the groundwater in the northern area of Meadow Valley is thought to flow northward and discharge via Acland Spring towards Garnet Lake and Eneas Creek.

Garnet Lake and Eneas Creek are located within a separate catchment area to the north/northeast of Meadow Valley and Darke Creek. It is understood that Acland Spring flows year around at a rate of approximately 19 L/sec (300 USgpm). Although Wilson identifies the direction of groundwater flow as being to the north at the north end of Meadow Valley, there is also a southerly component of groundwater flow through the Darke Creek valley. The distribution of groundwater flowing north versus south cannot be assessed based on available information, although it is possible that Darke Creek contributes less water to the total recharge of the Aquifer in the Faulder area than originally thought. As Darke Creek only represents up to 12% of the catchment area up-gradient of Faulder, it is concluded that differing theories on flow at the north end of the Meadow Valley does not greatly influence the outcome of the water balance.

Golder's previous estimate of groundwater withdrawal collectively from the Community Well, private wells in the Faulder Area and estimated irrigation volumes, groundwater extraction in the aquifer was approximately 1,600,000 m^3/yr or 16% of the estimated recharge to the area (Golder Associates, 2005a). Taking into consideration the discharge from reported in the Wilson Report to occur into a separate catchment, the estimated groundwater withdrawals would increase to 2,230,000 m^3/yr or 23% of the total conservative recharge estimate of 9,500,000 m^3/yr. The net water balance is considered to be conservative, as i) the extraction estimates for the Faulder Well and private wells were based on continual pumping at maximum pump discharge rates, ii) the estimate did not consider water which is reintroduced to the ground surface by irrigation and wastewater disposal (septic fields) to ground, iii) precipitation estimates are conservative (low) as they are based on data from the Summerland Research Station located at a lower elevation than Faulder, and iv) the percentage of recharge of precipitation to groundwater is inferred to be higher than the 2005 estimate.

6.0 RECHARGE AREA ASSESSMENT

In order to identify potential recharge areas to the Meadow Valley Aquifer in the area of the Community Well, the average linear groundwater velocity was estimated and the velocity used to estimate distances to recharge boundaries. Based on hydraulic parameters estimated in the area of the Community and Gibbs Wells, the following relationship was used to estimate velocity:

$\upsilon = ki/n$ where k (hydraulic conductivity) = $4\text{x}10^{-4}$ m/s to $9\text{x}10^{-4}$ m/s
i (hydraulic gradient) = 0.02
n (porosity) = 0.25 (Freeze and Cherry, 1979)

Based on a range in hydraulic conductivities (Golder Associates, 2005b), the estimated average linear groundwater flow velocity ranges from approximately 1,000 m/year (based on a hydraulic conductivity of $4x10^{-4}$ m/s) to 2,300 m/year (based on a hydraulic conductivity of $9x10^{-4}$ m/s).

Using this range in average linear groundwater velocity, and based on the result of the age-dating analyses indicating the groundwater to be between 5 and 43 years old, the following table presents the range in distances from the Community Well to possible recharge areas.

Table 3: Distance to Recharge Area

Hydraulic Conductivity	Groundwater Age	Average Linear Groundwater Velocity	Distance from Wells to Possible Recharge Area(s)
$4x10^{-4}$ m/s	5 years	840 m/year	5
	10 years		10
	43 years		43
$9x10^{-4}$ m/s	5 years	1,900 m/year	1
	10 years		23
	43 years		98

In summary, the distance from the Community Well to the possible recharge area(s) ranges from approximately 5 km to 98 km. The boundary of the watershed area is located approximately 30 km (linear) to the north and northwest (hydraulically up gradient) of the Community Well, and it is unlikely that the recharge area for the Aquifer crosses this watershed boundary. The distance to the recharge area can therefore be further refined to range from 5 km to 30 km to the north or northwest of the Community Well.

Land uses between 5 km and 30 km from the Community Well mainly consists of undeveloped forested land, several lakes, including Thirsk Reservoir, the Headwater chain of lakes, Darke Lake, and the communities of Faulder and Meadow Valley, which consist of residential and agricultural properties.

7.0 ADDITIONAL INFORMATION

7.1 Thirsk Reservoir

Thirsk Reservoir is located approximately 25 km to the northwest of the Community Well, at the west end of the Trout Creek Valley, and collects and stores surface water from further up-gradient (to the north of the dam) areas for use by the District of Summerland as one of their water reservoirs. Based on conversations with Mr. Joe Fitzpatrick of the District of Summerland, it is understood that water levels at Thirsk Reservoir were lowered in 2006 and early 2007 to allow for construction activities to take place at the Reservoir. In addition, Mr. Fitzpatrick indicated that water levels within the Reservoir were "very low" in 2003, likely a cumulative effect of lower than normal precipitation that year and the resulting increased demand for irrigation water in Summerland.

The reported low water levels at the Thirsk Reservoir appear to correlate to the two periods of low water levels in the confined aquifer in the area of the Community Well in 2004 and 2007, with a one year lag time noted between the lowering of the water level at Thirsk and the inferred reduced recharge in the confined aquifer. It is possible that the decrease of water levels within the Reservoir, as well as possible higher surface water gradients within Trout Creek caused by the release of larger volumes of water from Thirsk, have had an effect on the recharge rates to the Meadow Valley confined aquifer. It is important to note that the one year lag time to observe the response does not necessarily correspond to a one year travel time for water from Thirsk Reservoir to reach the Meadow Valley Aquifer in the area of the Community Well. Rather, the lack of recharge noted in the Meadow Valley Aquifer may be a result of a change in pressure created in the system as a result of lowering water levels at Thirsk Reservoir.

Attempts to confirm water levels at Thirsk Reservoir have to date been unsuccessful. In addition, Mr. Fitzpatrick stated that historical water level data for Thirsk was only readily available from 2004 onward, and that water levels prior to 2003 are stored off-site.

7.2 Water Use in Meadow Valley

An area reconnaissance of Meadow Valley was conducted on June 27, 2008 by Ms. Jacqueline Foley of Golder, Mr. Andrew Reeder of RDOS and Mr. Al Weins, resident of Meadow Valley and operator of the Meadow Valley Irrigation System. Mr. Weins indicated that the Meadow Valley Irrigation System uses mainly surface water to irrigate local crops, and that over the last several years irrigation demand has decreased in the Meadow Valley area. No recent, large volume groundwater withdrawals for the Meadow Valley area were reported by Mr. Weins.

8.0 CONCLUSIONS

Based on the results of this investigation, the following summary is provided:

- The age-dating analyses indicated that groundwater within the confined aquifer in the area of the Community and Gibbs Wells can be classified as "modern" (5 to 43 years of age).

- The characteristics of the isotope analyses conducted on groundwater samples indicated the water is characterized as winter and spring recharge, as opposed to summer and fall recharge, identifying that winter and spring precipitation play a dominant role in the recharge of the aquifer.

- Based on the range of the age-dating results, as well as the assumptions stated in Section 6.0, the distance of the recharge area from the Community Well and Gibbs Well ranges from 5 km to 30 km.

- Land uses within a 30 km radius up-gradient from the Community Well consist mainly of undeveloped forested land, with residential and agricultural activity noted in the Faulder area. Thirsk Reservoir is located approximately 25 km to the northwest of the Community Well, with clear-cut areas noted farther up in the watershed. Other lakes are also located within this 30 km radius.

- One additional groundwater withdrawal was noted at the north end of Meadow Valley (Acland Spring), and discharging at a rate of approximately 19 L/s (300 USgpm). No additional groundwater withdrawals other than those identified within the Golder 2005 report exist based on available information.

- A review of available historical water levels for the Community and Mearns Wells indicates that recharge to the confined aquifer typically begins in April or May and ends between July and August. However, very minimal recharge was observed in the spring of 2004 and in the spring of 2007. This lack of recharge in 2007 was also observed in MoE Observation Well No. 367, located approximately 4 km to the southeast and completed in the same aquifer as the Community Well. This lack of recharge noted within these wells in 2007 was not observed in numerous other wells reviewed as part of this assessment.

- Water levels within Thirsk Reservoir were noted to be lowest in 2003, 2006 and early 2007, when water demands were either high due to decreased precipitation (as seen in 2003) or where the water level within Thirsk was lowered to allow for construction to take place at the Reservoir (as seen in 2006 and part of 2007).

- The cumulative precipitation departure from the mean annual precipitation for three climate stations in the area indicates that current precipitation is currently above the mean, but a long term decreasing trend exists for the region.

- The water balance initially provided in the Golder 2005 report is considered to be a conservative (low) estimate of the volume of water available within the Meadow Valley Aquifer in the Faulder area. Based on a recent basin-wide study by Golder for the Okanagan Basin Water Board, it was noted that actual infiltration rates of precipitation to groundwater are in the order of 10%, rather than the 5% used in the previous estimate.

Initially, the lack of recharge to the Faulder Community Well, as well as the Mearns Well and MoE Observation Well No. 367, was suspected to be attributed to one, or a combination of, the following: i) a regional climatic change in precipitation and thus recharge to the aquifer, ii) increased withdrawals from the aquifer, or iii) a change in the characteristics of the recharge area.

Based on the results of this investigation, it can be inferred that the most likely cause for the reduced recharge in the Aquifer in 2007 was a result of lower than normal water levels within Thirsk Reservoir in 2006 and 2007, which in turn impacted the pressure within the aquifer. This resulted in a change in water levels in areas downgradient to the recharge area. It can be concluded that Thirsk Reservoir and the Trout Creek channel immediately down-gradient of the Reservoir are collectively a dominant recharge area for groundwater that is extracted in the Faulder area. This conclusion is supported by a similar minimal recharge period noted at the Mearns Well in the spring of 2004, which corresponds to lower than normal water levels within Thirsk Reservoir in 2003. It appears that there is approximately a one year delay in the effect of lowering water levels within Thirsk to a corresponding response of water levels for wells completed within the deeper confined Meadow Valley Aquifer.

It is unlikely that the lack of recharge noted in 2007 can be attributed to i) increased withdrawals from the aquifer, as none were identified or ii) a change in annual precipitation, as the lack of recharge response noted within the Community Well, Mearns Well and MoE Observation Well was not observed in other wells throughout the Okanagan Valley. Finally, although it is our opinion that historical precipitation volumes were not the primary cause of the lack of recharge observed in the wells, it can be inferred that it has had some overall effect on the slight decline observed in historical water levels within the upper end (near the Community Well) of the aquifer.

9.0 CONCERNS RAISED BY RDOS

It is understood that that the RDOS has concerns regarding the Community Well and aquifer in the Faulder area. RDOS's concerns were provided to Golder via e-mail on July 21, 2008 and are presented in italics below, with response from Golder.

Does the Faulder Community Well have enough water inflow into the aquifer to support the current consumption or are we "mining" the aquifer? Is there enough water long term?

Based on available information, it can be inferred that the Meadow Valley Aquifer in the area of the Community Well has sufficient recharge to support the estimated current consumption. Not accounting for any additional future groundwater extractions or a dramatic long-term change in the future precipitation volumes, it can be inferred that there is sufficient water within the Aquifer to support current needs into the future.

Can you confirm whether or not the conclusions of the 2005 Golder Associates Meadow Valley Aquifer study are correct or not? Is there less water available than previously thought?

Golder has not reviewed each conclusion made in the 2005 study as part of this assessment. However, in regards to the water balance for the Meadow Valley Aquifer, available information indicates that the volume of water previously believed to be present in the area of Faulder and the Summerland Rodeo Grounds is correct, and is likely a conservative (lower than actual volumes) estimate. This is based on the results of a more current study being completed by Golder for the Okanagan Basin Water Board (OBWB) water supply and demand study for the entire Okanagan Basin, which indicates that approximately 10% of precipitation recharges local aquifers, as opposed to the estimated 5% used in the 2005 Golder study.

In order to further assess recharge areas to the Meadow Valley Aquifer, the volume of groundwater recharging the Aquifer and the breakdown of the Darke Creek and Trout Creek contributions, additional monitoring wells must be drilled within the Trout Creek and Darke Creek watershed areas. Wells should be located along each creek valley bottom, with nested well screens installed at location.

Are we in danger of the well running dry?

Although it is unlikely that the water level within the Community Well will drop to a depth below the base of the well screens (i.e. "run dry"), it is possible that the volume of water currently being extracted from the well would decrease significantly due to the declining water level. This decrease in pumping rate has already been noted by RDOS. As a result of the declining water level at the Community Well, the total available drawdown within the well is also declining, which adversely impacts well yields and pumping rates.

Based on the observed drop in water levels within the Community Well between August 2006 and June 2008, should the rate of declining water levels continue, the potential exists that the water level within the well will drop below the pump intake. Although water levels within the Community Well have started to increase, unless freshet in 2009 is larger than normal, it is unlikely that the water level will return to August 2006 levels by the end of this summer, thus resulting in less available drawdown for the coming year (2009).

Are there any conclusions that you can draw from the age dating? Can you give us a range of solutions to the questions above?

The age-dating analysis was not as useful as was initially thought, as the samples were adversely impacted by crustal helium concentrations resulting from the close proximity to bedrock, which potentially biases the age of the groundwater. However, based on the results of the age-dating and isotope analyses, the inferred age of the groundwater is approximately 5 to 43 years old. Based on a range in groundwater velocities, the range in age, and the watershed boundaries, the recharge area has been estimated to be within 30 km of the Community Well.

Is the depth of the Gibbs well sufficient, should we decide to proceed?

The Gibbs Well is screened between approximately 79.9 m bgs and 83.5 m bgs, with the current static water level at approximately 53 m bgs (July 2008). The current total available drawdown within the well is approximately 24.5 m, based on a 1.5 m long pump installed above the top of the screen assembly. In comparison, the Community Well is screened between 59.3 m bgs and 63.8 m bgs, with the lowest static water level recorded on June 27, 2008 of approximately 53.7 m bgs. Based on a depth of the intake on the pump at 58.8 m bgs, the total available drawdown is estimated to be approximately 5.1 m, which is almost five times less than the total available drawdown within the Gibbs Well.

It is difficult to comment on whether the total depth of the Gibbs Well is sufficient to meet the needs for the Community of Faulder. However, assuming that the lack of recharge to the aquifer observed in 2007 and early 2008 was a result of the increased demand on Thirsk Reservoir in 2006 and early 2007, and assuming that water levels are increasing in Thirsk Reservoir and will not decline to 2003 or 2006/2007 levels, it is likely that the depth of the Gibbs Well is sufficient to meet RDOS's existing needs.

It is also possible that future years of similar increased demand on Thirsk Reservoir would create a similar "lack of recharge". Golder cannot comment on the effect this will have on water levels within the aquifer, as it will be relative to the levels within Thirsk Reservoir. However, this is considered unlikely, as the construction to increase the capacity of Thirsk Reservoir has recently been completed, thus enabling Summerland to more adequately meet water demands for the District. In addition, should the demand on Thirsk increase in subsequent years, it appears that the one year lag time in the observed response will allow time for the RDOS to implement water conservation measures in preparation of the potential response to water levels.

Do we need to be on water restrictions now? Are they doing any good?

It is our opinion that current water restrictions are necessary, considering the following:

1. Although the water level at the Community Well is currently increasing, the water level is still low and not near the August 2006 levels.

2. It is anticipated that water levels will continue to rise within the aquifer until August 2008, after which time water levels will likely begin their seasonal decline. As such, it is important to allow water levels within the aquifer to increase as much as possible this year, to meet winter potable water supply demands.

In order to assess whether or not water restrictions are providing any positive benefit, a more detailed analyses regarding actual water usage, pumping rates and water levels at the well would be required. However, generally speaking, it can be inferred that water conservation provides positive benefits to local groundwater regimes.

10.0 RECOMMENDATIONS

Based on the results of this assessment, the following recommendations are provided:

1. In order to verify the relationship between water levels at Thirsk Reservoir and within the confined portion of the Meadow Valley Aquifer, it is recommended that the RDOS work together with the District of Summerland to compile the historical water levels for Thirsk Reservoir. Water levels for the Reservoir should be entered into a database program such as Microsoft Excel, so that trends in water levels within the Reservoir can be monitored and compared with trends in

water levels at the Community Well and MoE Observation Well No. 366 and 367. Once compiled, the existing data should be reviewed by a qualified professional on a yearly basis.

2. Ongoing monitoring of pumping and static water levels, as well as discharge rate within the Community Well, Mearns Well and Gibbs Well should be conducted.

3. Should the RDOS wish to determine the percentage of recharge being contributed to the confined aquifer via the Darke Creek watershed as opposed to Trout Creek watershed, additional field work would be required. This field work could consist of a geophysical survey across selected areas in the Trout Creek and Darke Creek valleys, the drilling and installation of several monitoring wells farther up the Trout Creek and Darke Creek valleys, and the conducting of pumping tests to assess aquifer properties within each monitoring well. Data loggers should also be installed within each monitoring well to record water level data through the year.

4. The RDOS should consider securing a backup water supply, whether it consists of the acquisition of the Gibbs Well, the drilling of a new well or the securing of a surface water supply. Regardless if the water levels continue to decrease in the Community Well, a backup water supply should be considered as it will allow for maintenance to be conducted on one water supply source while the backup system is delivering water.

5. Based on available information, it can be inferred that the depth of the confined aquifer is significantly deeper than 83.5 m bgs (the depth of the Gibbs Well). It is recommended that the RDOS explore the option of drilling a new water supply well farther to the east of the Community Well and the Gibbs Well. In order to maximize the potential that the well is in the approximately center of the Trout Creek Valley (i.e. the deepest portion of the aquifer), it is recommended that a geophysical survey be completed to aid in identifying the most suitable area of the aquifer to drill. Initially an exploratory well can be drilled, and provided a suitable aquifer is identified, a well can be constructed. The benefit to constructing a new well is the potential for increased well depth, resulting in an increased total available drawdown, and in turn, the capacity to tolerate larger annual fluctuations in water levels without reduction in sustainable yield. However, with increasing depth also comes the potential for increased dissolved metal concentrations.

11.0 LIMITATIONS AND USE OF THIS REPORT

This report was prepared for the exclusive use of the Regional District of Okanagan-Similkameen and their representatives and is intended to provide an assessment of groundwater age and aquifer water levels in the aquifer which provides water to the Faulder Community Well. Any use which a third party makes of this report, or any reliance on, or decisions to be made based on it, are the responsibilities of such third parties. Golder accepts no responsibility for damages, if any, suffered by a third party as a result of decisions made or actions taken based on this report.

The assessment of the well and groundwater conditions presented has been made using historical and technical data collected and from information sources noted in the report. The methodologies used to conduct the field investigation, to analyze information, and for the preparation of a technical report were performed according to current professional standards and practices in the groundwater field.

Golder has relied in good faith on information provided by third parties noted in this report. We accept no responsibility for any deficiency, misstatements, or inaccuracies contained in this report as a result of omissions, misinterpretations, or fraudulent acts of others.

Furthermore, if new information is discovered during future work, including borings or other studies, Golder should be requested to provide amendments as required.

12.0 CLOSURE

We trust that this provides you with the information you require at this time. Should you require additional information, please contact the undersigned at your earliest convenience.

Yours very truly,

GOLDER ASSOCIATES LTD.

Pattie Amison, M.Sc.
Hydrogeologist

Jacqueline Foley, M.Sc.
Senior Hydrogeologist

Remi Allard, M.Eng., P.Eng.
Associate, Senior Hydrogeologist

PVA/JF/RA/cfh

Attachments:

Figure 1:	Key Plan
Figure 2:	Well Location Plan
Figure 3:	Wide Area Plan
Figure 4:	Water Levels in Faulder Wells and Cumulative Precipitation Departure
Figure 5:	Water Levels in MoE Observation Wells
Appendix I:	Well Logs
Appendix II:	Groundwater Age Dating and Water Isotope Methodologies
Appendix III:	University of Ottawa Results and Data Interpretation for Groundwater Age Dating Analyses

http //capws/p824015wellrehabilitation/reports/wp_final/phase 2100/faulder age dating letter aug 6-08 doc

REFERENCES

BC Ministry of Environment, 2008. Water Resource Atlas, http://www.env.gov.bc.ca/wsd/data_searches/wrbc/index.html

Freeze, Allan R. and John A. Cherry, 1979. Groundwater. Prentice Hall, Toronto, ON.

Golder Associates Ltd., 2005a. Preliminary Hydrogeological Assessment for the Development of an Aquifer Monitoring Program, Faulder, BC. October 4, 2005. Golder Ref. No. 04-1440-255

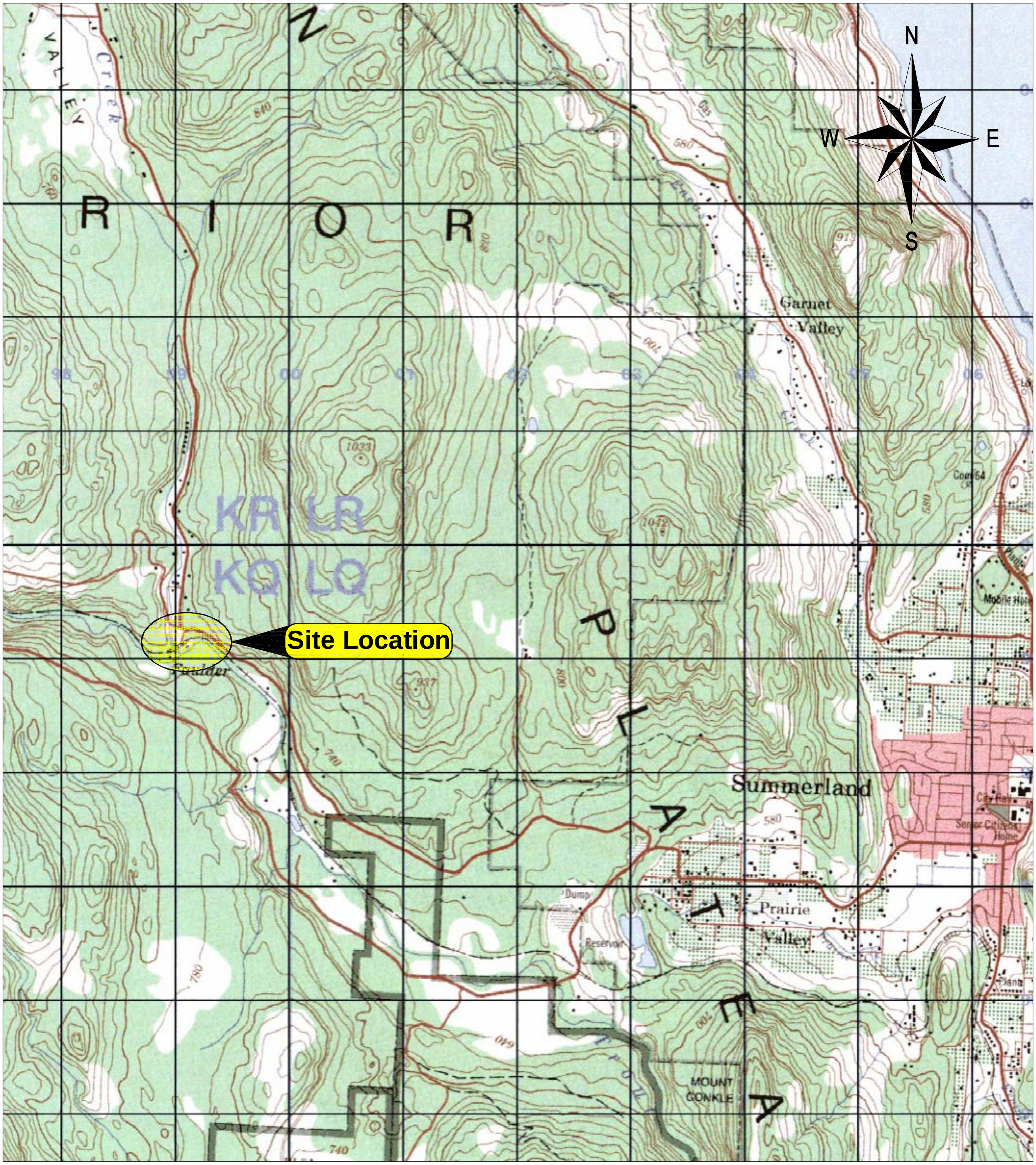
Golder Associates Ltd., 2005b. Hydrogeological Assessment, West Half of DL 1072, Faulder, BC. June 8, 2005. Golder Ref. No. 05-1440-087

Gordon Wilson Associates Inc., 1990. Report on the Groundwater and Surface Water Hydrology at Meadow Valley

Motzer, William E., 2007. Tritium Age Dating of Groundwater, In Hydro Visions Vol. 16, No. 2. Groundwater Resources Association of California.

PHCL, 1992. Completion Report, Construction and Testing of a Water Supply Well on the West Half of D.L. 1072 at Summerland, BC.

PHCL, 1993. Completion Report, Construction and Testing of a Water Supply Well for the Community of Faulder RDOS File No. 5603.01 & 5603.02.



1 0 1

SCALE KILOMETRES

PROJECT

RDOS
FAULDER GROUNDWATER AGE DATING INVESTIGATION
FAULDER, B.C.

TITLE

KEY PLAN

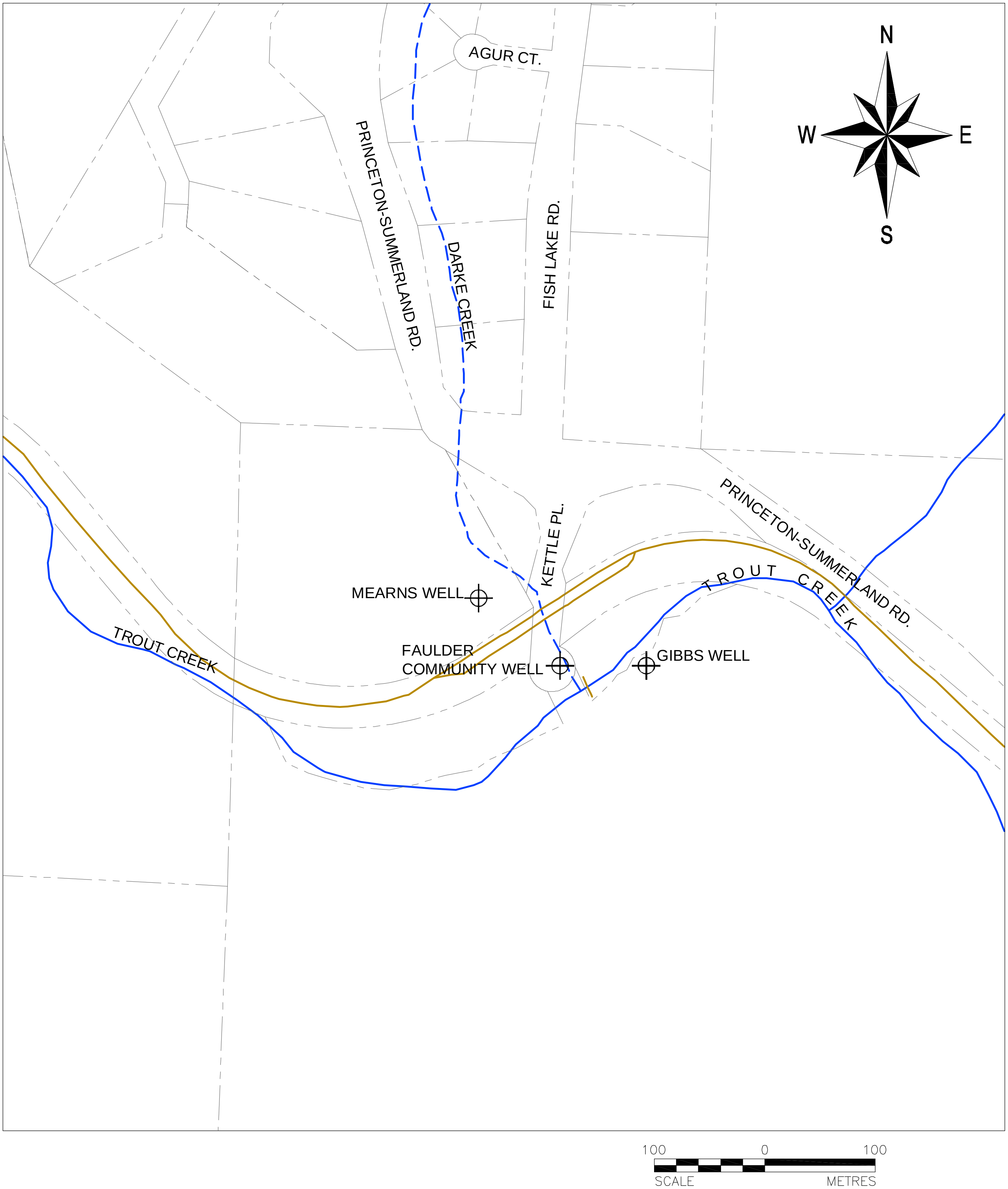
REFERENCES

1.) **COORDINATE REFERENCE: UTM ZONE 11n, NAD83**
MAP REFERENCE: PRODUCED UNDER LICENSES GRANTED BY HER MAJESTY THE QUEEN IN RIGHT OF CANADA, REPRESENTED BY THE DEPARTMENT OF NATURAL RESOURCES, AND BY SOFTMAP TECHNOLOGIES INC.

Golder Associates
Kelowna, BC

PROJECT No. 08-1440-0029(2100)			FILE No. 0814400029_2100_1.dwg		
DESIGN	PVA	28/JUL/08	SCALE	1:50,000	REV. 0
CADD	SWD	01/AUG/08	**FIGURE: 1**		
CHECK	PVA	06/AUG/08			
REVIEW	JF	06/AUG/08			

N:\Active\2008\1440 – Kelowna\08-1440-0029 Faulder Well Rehabilitation\Drafting\Task 2100\CAD\ Drawing file: 0814400029_2100_1.dwg Aug 06, 2008 – 2:26pm



LEGEND

- WELL LOCATION
- ROAD
- CREEK/RIVER
- PROPERTY LINE

REFERENCES

1.) BASEMAP DATA PROVIDED BY THE DISTRICT OF SUMMERLAND.

PROJECT

RDOS
FAULDER GROUNDWATER AGE DATING INVESTIGATON
FAULDER, B.C.

TITLE

WELL LOCATION PLAN

Golder Associates
Kelowna, BC

PROJECT No. 08-1440-0029(2100)			FILE No. 0814400029_2100_2.dwg	
DESIGN	PVA	28/JUL/08	SCALE 1:5,000	REV. 0
CADD	SWD	01/AUG/08		
CHECK	PVA	06/AUG/08	**FIGURE: 2**	
REVIEW	JF	06/AUG/08		

N:\Active\2008\1440 - Kelowna\08-1440-0029 Faulder Well Rehabilitation\Drafting\Task 2100\CAD\ Drawing file: 0814400029_2100_2.dwg Aug 06, 2008 - 2:32pm

LEGEND

- APPROXIMATE CREEK SAMPLING LOCATION
- ENVIRONMENT CANADA CLIMATE STATION
- BC MOE OBSERVATION WELL

REFERENCES

1.) ORTHO PHOTO OBTAINED FROM BC WATER RESOURCES (2006).

4 0 4
SCALE KILOMETRES

PROJECT
RDOS
FAULDER GROUNDWATER AGE DATING INVESTIGATION
FAULDER, B.C.

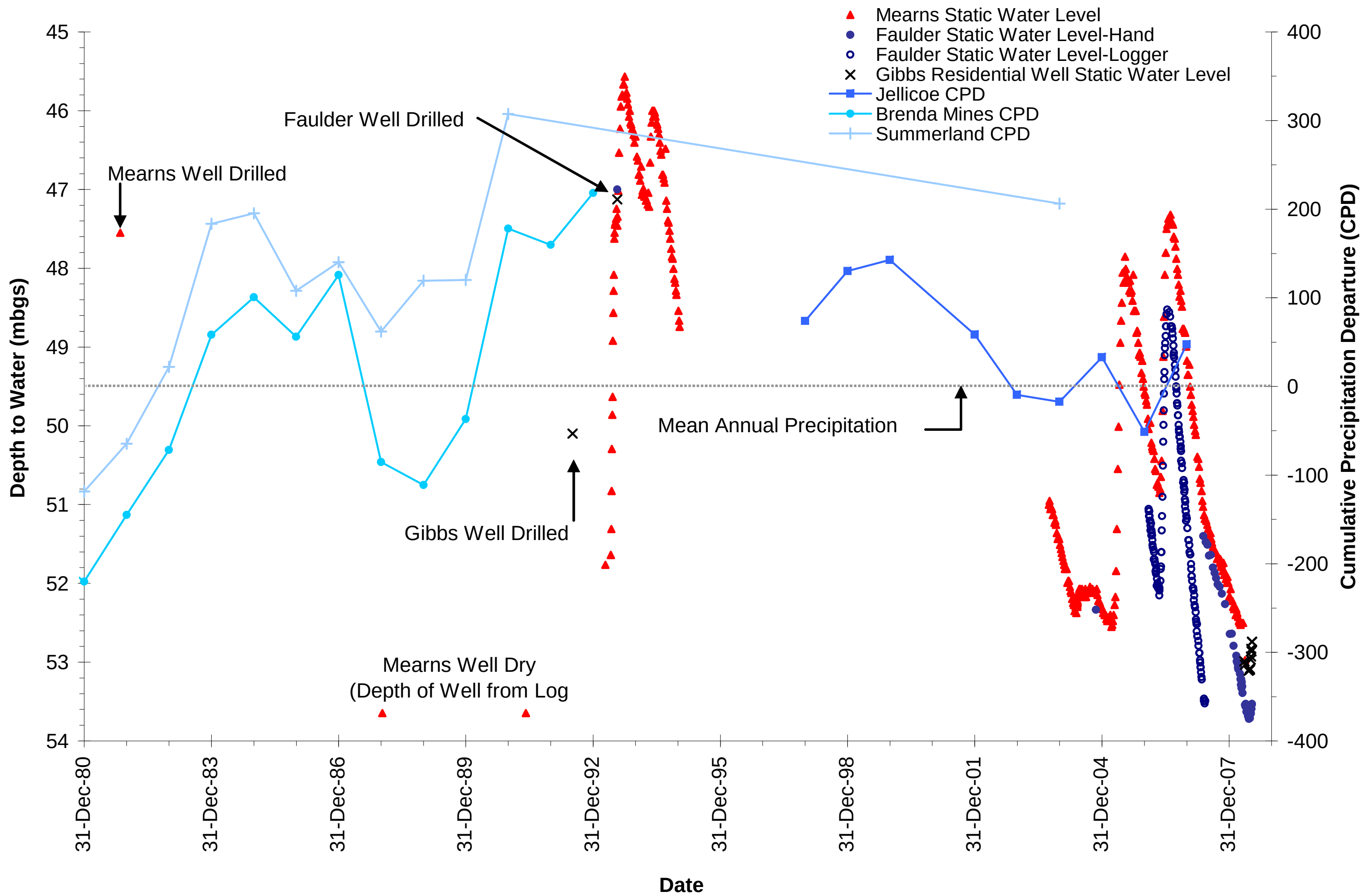
TITLE
WIDE AREA PLAN

Golder Associates
Kelowna, BC

PROJECT No. 08-1440-0029(2100)			FILE No. 0814400029_2100_3.dwg
DESIGN	PVA	28/JUL/08	SCALE 1:200,000 REV. 0
CADD	SWD	06/AUG/08	FIGURE: 3
CHECK	PVA	06/AUG/08	
REVIEW	JF	06/AUG/08	

N:\Active\2008\1440 - Kelowna\08-1440-0029 Faulder Well Rehabilitation\Drafting\Task 2100\CAD\ Drawing file: 0814400029_2100_3.dwg Aug 06, 2008 - 2:36pm

N:\Active\2008\1440 – Kelowna\08–1440–0029 Faulder Well Rehabiliation\Drafting\Task 2100\CAD\ Drawing file: 0814400029_2100_4.dwg Aug 06, 2008 – 3:10pm



PROJECT

RDOS
FAULDER GROUNDWATER AGE DATING INVESTIGATON
FAULDER, B.C.

TITLE

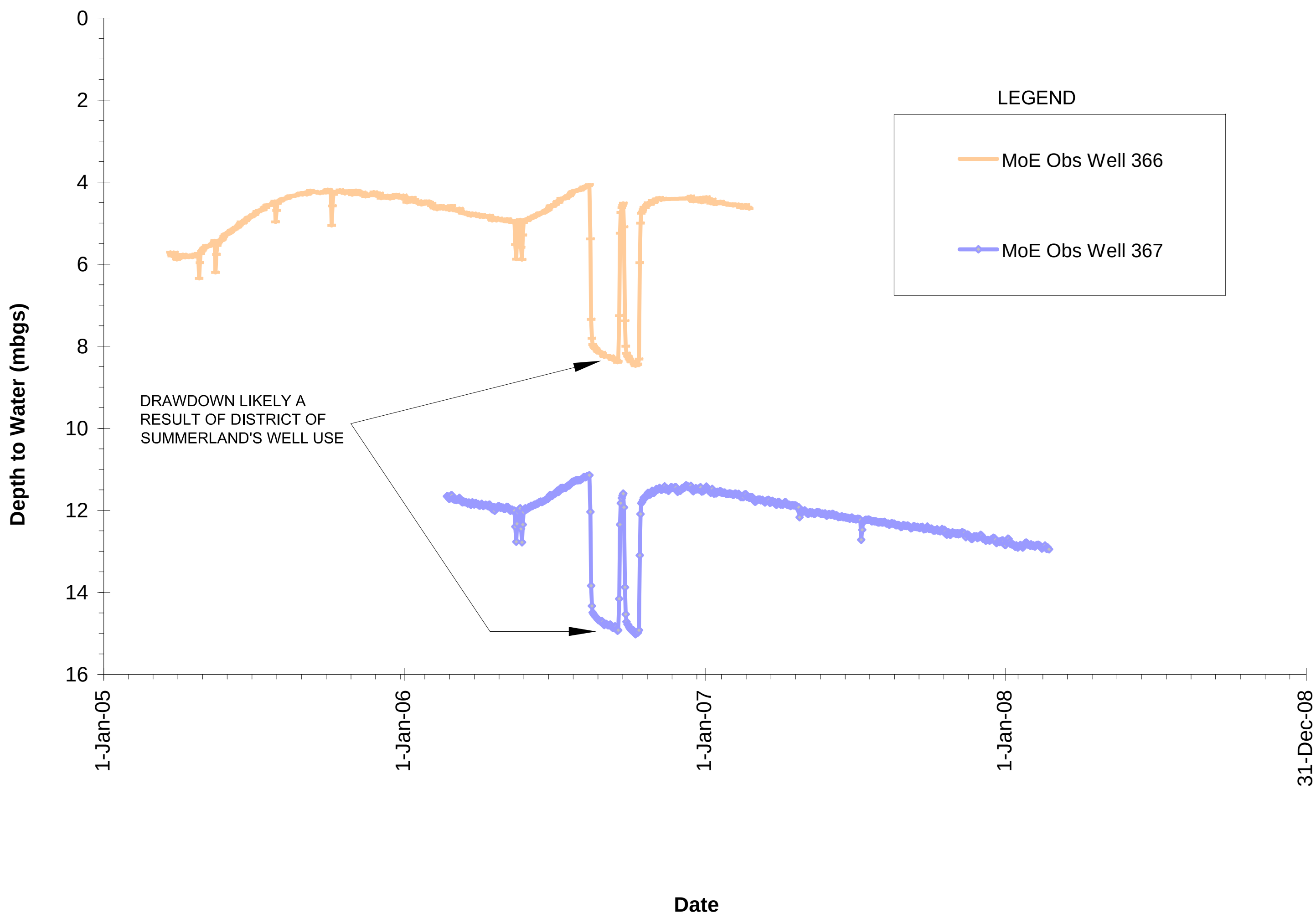
WATER LEVELS IN FAULDER WELLS AND CUMULATIVE PRECIPITATION DEPARTURE

Golder Associates
Kelowna, BC

PROJECT No. 08-1440-0029(2100)		
DESIGN	PVA	06/AUG/08
CADD	SWD	06/AUG/08
CHECK	PVA	06/AUG/08
REVIEW	JF	06/AUG/08

FILE No. 0814400029_2100_4.dwg
SCALE N/A REV. 0

FIGURE: 4



PROJECT	RDOS FAULDER GROUNDWATER AGE DATING INVESTIGATON FAULDER, B.C.	
TITLE	**WATER LEVELS IN MoE OBSERVATION WELLS**	

Golder Associates
Kelowna, BC

PROJECT No. 08-1440-0029(2100)			FILE No. 0814400029_2100_5.dwg	
DESIGN	PVA	06/AUG/08	SCALE N/A	REV. 0
CADD	SWD	06/AUG/08	**FIGURE: 5**	
CHECK	PVA	06/AUG/08		
REVIEW	JF	06/AUG/08		

APPENDIX I

WELL LOGS

FAULDER COMMUNITY WATER SUPPLY WELL

Location: In Regional District of Okanagan-Similkameen, in the northwest part of D.L. 1072, on the north side of Trout Creek near its intersection with the Darke Creek Valley at Faulder, at a site approximately seven kilometres west of Summerland.

Date of construction: July 1993.

Drilling contractor: Robbins Water Well Drilling & Pump Services.

Drillers litholog:

0.3 - 2.1 m (1 - 7 ft)	sand and gravel with small cobbles
2.1 - 2.7 m (7 - 9 ft)	large boulders and small gravel; "some water"
2.7 - 6.1 m (9 - 20 ft)	cemented sand and gravel; tight
6.1 - 9.1 m (20 - 30 ft)	compact sand with gravel
9.1 - 12.5 m (30 - 41 ft)	brown sand with gravel; loose
12.5 - 15.2 m (41 - 50 ft)	sand and gravel; tight
15.2 - 18.3 m (50 - 60 ft)	sand and gravel with cobbles and brown clay
18.3 - 21.3 m (60 - 70 ft)	brown sand and gravel with clay; very tight
21.3 - 24.3 m (70 - 80 ft)	brown sand with large cobbles; loose
24.3 - 25.6 m (80 - 84 ft)	brown clay with cobbles; tight
25.6 - 27.4 m (84 - 90 ft)	brown sharp sand with large gravel
27.4 - 30.5 m (90 - 100 ft)	medium to large gravel with some brown sand
30.5 - 33.5 m (100 - 110 ft)	large cobbles mixed with brown sand
33.5 - 36.6 m (110 - 120 ft)	medium to hard brown clay; "drilled"
36.6 - 39.6 m (120 - 130 ft)	brown sand and gravel; "tight"
39.6 - 42.7 m (130 - 140 ft)	brown sand and medium to small gravel; tight ("drilled")
42.7 - 45.4 m (140 - 149 ft)	medium to small gravel; tight with fine sand
→ 45.4 - 47.2 m (149 - 155 ft)	brown sand and medium to coarse gravel; sharp and tight
47.2 - 48.8 m (155 - 160 ft)	brown sand with small gravel; some polished and some sharp
48.8 - 51.8 m (160 - 170 ft)	brown sand and medium to sharp gravel
51.8 - 53.3 m (170 - 175 ft)	large and small gravel mixed with brown sand
53.3 - 53.9 m (175 - 177 ft)	medium to large gravel and coarse sand
53.9 - 54.2 m (177 - 178 ft)	strip of brown clay
54.2 - 56.1 m (178 - 184 ft)	brown fine sand
56.1 - 57.6 m (184 - 189 ft)	brown clean coarse sand; "good" water-bearing
57.6 - 58.5 m (189 - 192 ft)	brown sand and large to medium gravel; a "little dirty"
58.5 - 60.4 m (192 - 198 ft)	medium to large gravel with brown sand
60.4 - 62.5 m (198 - 205 ft)	brown sand with medium to large gravel
→ 62.5 - 64.0 m (205 - 210 ft)	brown sand with big rocks; a "little dirty"
64.0 - 65.2 m (210 - 214 ft)	brown fine sand, with small gravel "mixed in"
65.2 - 65.8 m (214 - 216 ft)	cemented gravel with large cobbles and brown clay on rocks
65.8 - 66.5 m (216 - 218 ft)	broken rocks
66.5 - 67.4 m (218 - 235 ft)	bedrock.

FAULDER COMMUNITY WATER SUPPLY WELL (cont'd)

Diameter: 200 mm (8") with 250 mm (10") diameter casing to 45 m (147.5 ft).

Completed depth of well: 63.7 m (209 ft).

Static water level: 47.0 m (154.10 ft) below ground on July 27, 1993.

Completion:

The Faulder Community Well is completed with the following 200 mm (8") nominal diameter Johnson stainless steel well screen:

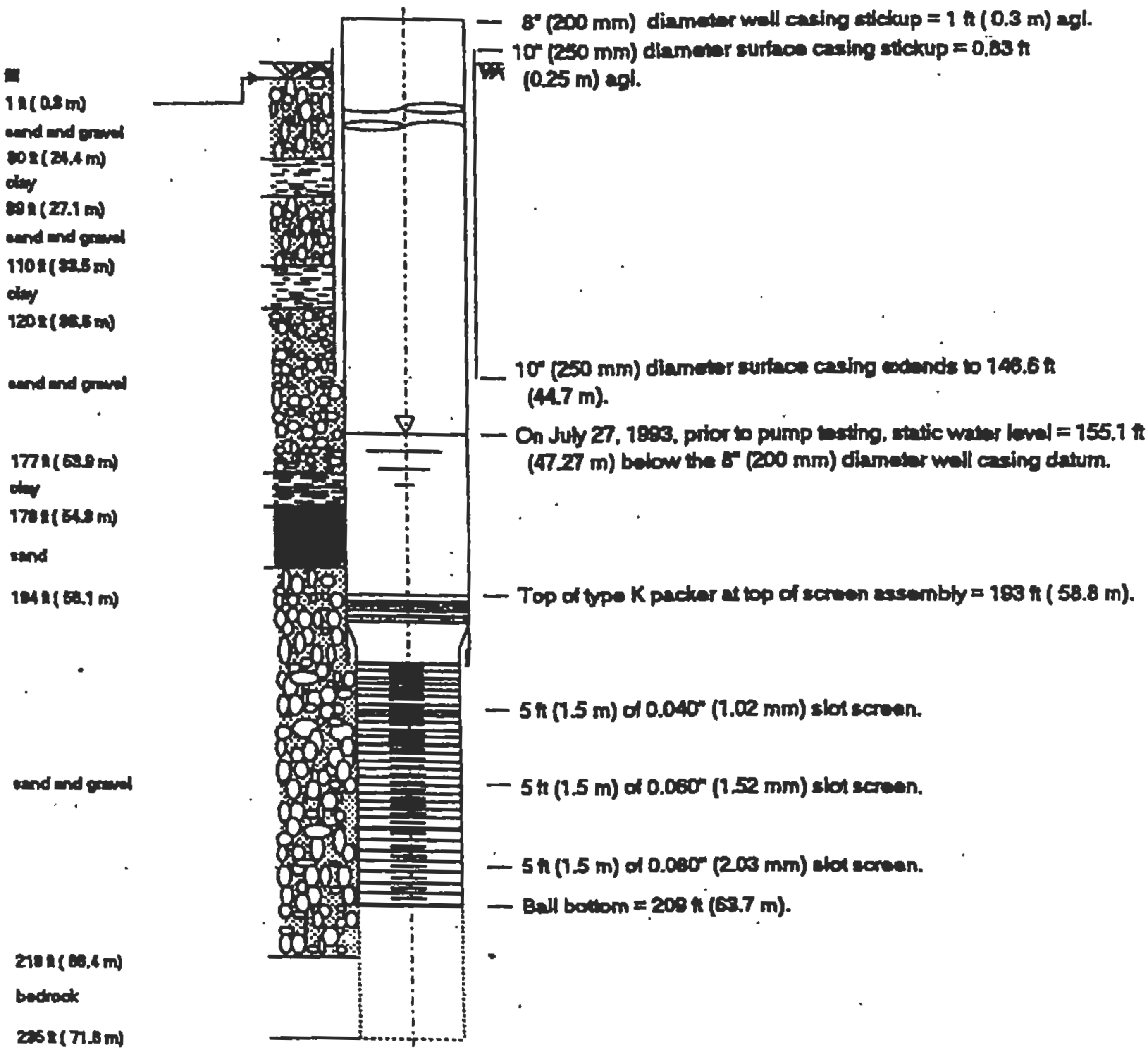
at top at 58.8 m (193 ft)	type K packer and riser pipe
1.5 m (5 ft) of	1.02 mm (0.040") slot screen
1.5 m (5 ft) of	1.52 mm (0.060") slot screen
1.5 m (5 ft) of	2.03 mm (0.080") slot screen
at bottom at 63.8 m (209 ft)	bail bottom.

Measurements are below ground level at the time of well construction.

Well performance: During pump testing at a final constant rate of 18.3 L/sec (290 USgpm) between 120 and 1440 minutes on July 27 and 28, 1993, the final drawdown in the Faulder Well was 6.8 m (22.4 ft), giving a specific capacity of 2.7 L/sec/m (12.93 USgpm/ft).

Well capacity: Rated according to standard procedure the theoretical capacity of the Faulder Community Well is as much as 22.5 L/sec (350 USgpm); however, under the prevailing geologic conditions, the Well should not be pumped in excess of 18.93 L/sec (300 USgpm) without additional testing at an higher rate. At the planned pumping rate of 9.08 L/sec (120 igpm), the projected pumping water level is estimated to be about 50.3 m (165 ft) below ground.

FIGURE 3	FAULDER COMMUNITY WELL - CONSTRUCTION DETAILS



Notes:

1. The sketch is not to scale.
2. The well screen is 8" (200 mm) nominal diameter Johnson stainless steel.
3. All measurements are below ground unless otherwise indicated.

MARTIN GIBBS WELL

Location: On the west half of District Lot 1072 at Faulder, at the south end of Fish Lake Road on the south side of Trout Creek.

Date of construction: July 1992.

Contractor: All-Western Drilling '89 Ltd.

Driller's Litholog:

0 - 3.7 m (0 - 12 ft)	clay and boulder
3.7 - 5.5 m (12 - 18 ft)	gravel
5.5 - 13.1 m (18 - 43 ft)	glacial till
13.1 - 24.4 m (43 - 80 ft)	hardpan
24.4 - 30.8 m (80 - 101 ft)	clay and coarse gravel
30.8 - 35.1 m (101 - 115 ft)	sand and gravel
35.1 - 51.2 m (115 - 168 ft)	glacial till
51.2 - 52.7 m (168 - 173 ft)	clay and fine gravel
52.7 - 68.3 m (173 - 224 ft)	sand and gravel
68.3 - 71.0 m (224 - 233 ft)	heaving sand
71.0 - 73.2 m (233 - 240 ft)	fine gravel
73.2 - 78.7 m (240 - 258 ft)	heaving sand
78.7 - 83.5 m (258 - 274 ft)	coarse sand.

Diameter: 150 mm (6").

Completed depth of well: 83.5 m (274 ft).

Static water level: 50.1 m (164.45 ft) on July 8, 1992.

MARTIN GIBBS WELL (cont'd)

Completion:

The Gibbs Well is completed with the following assembly of 150 mm (6") nominal (telescopic) diameter Johnson stainless steel well screen and 127 mm (5") riser pipe:

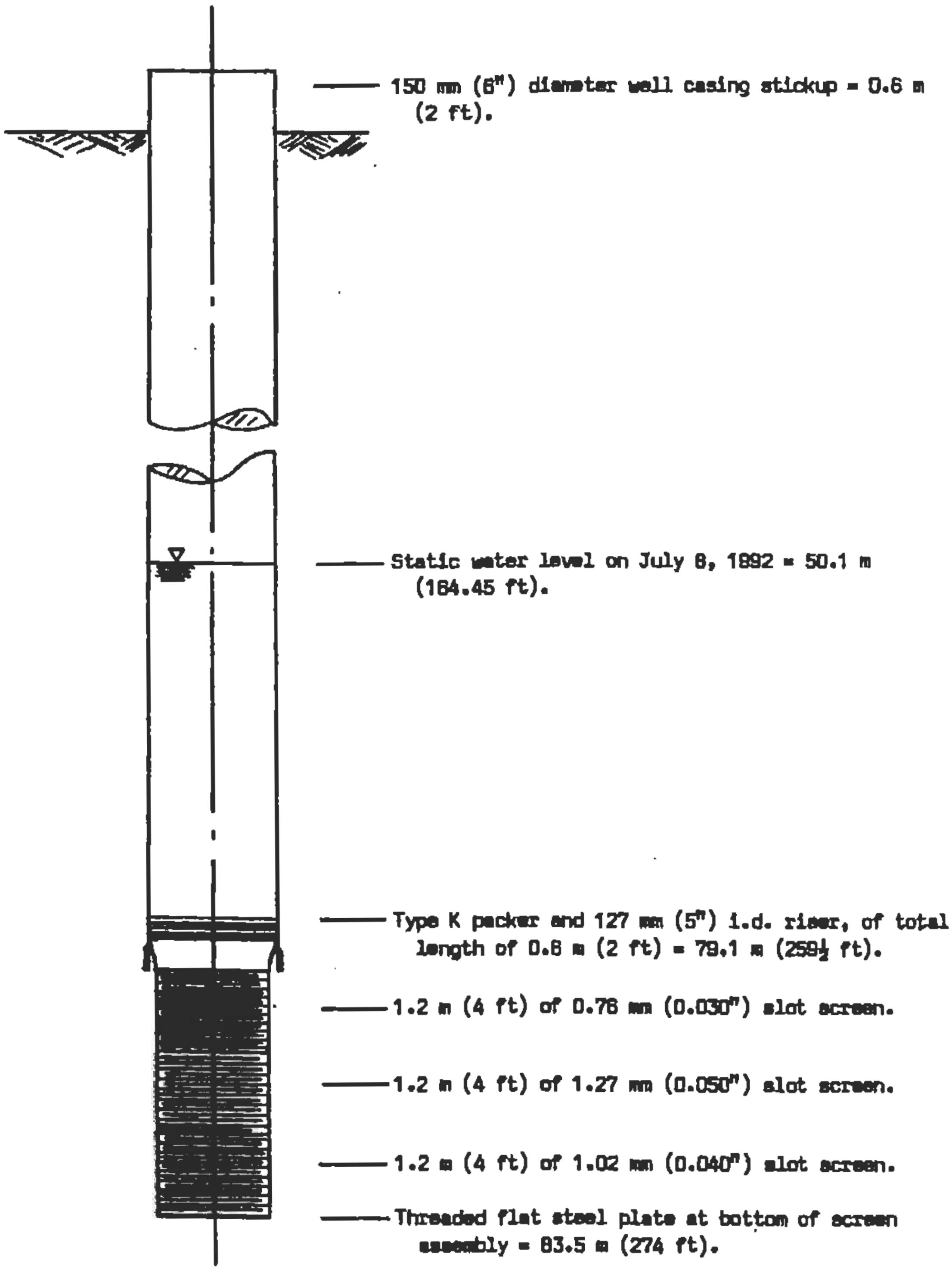
at top at 79.1 m (259½ ft)	type K packer and riser pipe, 0.6 m (2 ft) long
1.2 m (4 ft) of	0.76 mm (0.030") slot screen
1.2 m (4 ft) of	1.27 mm (0.050") slot screen
1.2 m (4 ft) of	1.02 mm (0.040") slot screen
at bottom at 83.5 m (274 ft)	threaded flat steel plate.

Measurements are below ground at the time of well construction.

Well performance: During pump testing on July 8, 1992, the maximum drawdown, after pumping at a rate of 17.04 L/sec (270 USgpm) between 40 and 440 minutes, was 5.58 m (18.30 ft) for a specific capacity of 3.05 L/sec/m (14.75 USgpm/ft).

Well capacity: Rated according to standard procedure, the **theoretical** capacity of the Gibbs Well is as much as three times the testing rate of 17.04 L/sec (270 USgpm); the **practical** capacity is controlled by the size of pump that can be obtained to pump from a 150 mm (6") diameter casing.

FIGURE 3	CONSTRUCTION DETAILS OF GIBBS WELL



Notes:

1. The sketch is not to scale.
2. The well screen is 150 mm (6") nominal diameter Johnson stainless steel.
3. All measurements are below ground unless otherwise indicated.

WELL DRILLING LOG

Drilling Log for Well at ([illegible]) MEARNS WELL [illegible]

Name of Contractor [illegible]

Date Nov 6/81

Total depth of well in feet 176

Depth of well casing 176

Static water level in feet 156 156

Inside dia. of well casing 5

Type of Well casing Steel

CAPACITY TEST

Test Apparatus (Pump or bailer)

Pump

Test Capacity in G.P.M. 10 Imp/US*

Time of Pumping test in hours 2

Total drawdown in feet 5

Time in hours required for well to recover from drawdown to static level

[illegible]

WELL DRILLER'S RECOMMENDATIONS

Depth of Pump Suction Setting

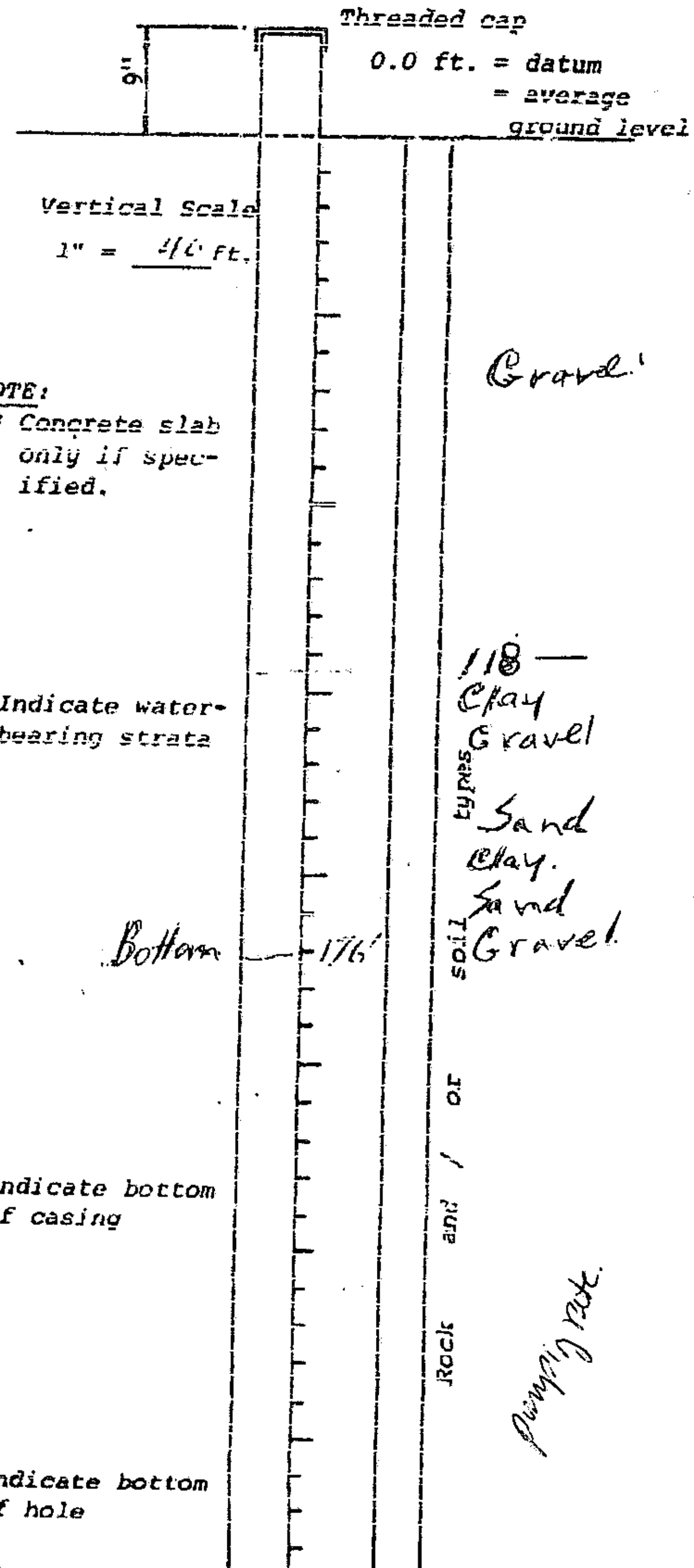
175 feet

Recommend Operating Capacity of Well

3600 ~~US gals~~./hr.*

WELL LOG

On the right hand side of the sketch of [illegible]l casing, indicate soils, gravel, sand, [illegible]c., encountered, and the depth.



Screen - 4ft of screen

APPENDIX II

GROUNDWATER AGE-DATING AND WATER ISOTOPE METHODOLOGIES

GROUNDWATER AGE-DATING

Groundwater age-dating consisted of two types of analyses 1) analysis of tritium (^{3}H) concentrations and 2) analysis of dissolved ^{3}He concentrations. Whereas groundwater age estimation using ^{3}H alone provides only semi-quantitative "ball park" estimates of groundwater age, the ^{3}H-^{3}He method, when applicable, provides more precise values of groundwater age[1].

The ^{3}H-^{3}He method has limitations under certain geologic conditions. There are four sources of helium isotopes in groundwater, 1) atmospheric, which consists of helium contained in percolating rain- and snow water and includes the excess air component, 2) tritogenic, which is ^{3}He produced from tritium decay, 3) in situ or nucleogenic, which is helium produced from the fission of ^{6}Li neutrons in the subsurface sediments, and 4) mantle or crustal, which is helium produced from the radioactive decay of Uranium and Thorium.

Each of the various helium sources have characteristic $^{3}He/^{4}He$ ratios, which correlate to specific $^{3}He/^{4}He$ ratios in groundwater. Typically, the amount of ^{3}He measured in the gas sample collected from the diffusion sampler is corrected by the lab to account for atmospheric ^{3}He that is dissolved at the time of recharge. Atmospheric helium is differentiated from tritogenic helium by measuring other dissolved gases in the groundwater, such as neon. Then, a standard correction is made for the very small amount of helium that is typically contributed from crustal sources and any ^{3}He above the concentration expected from atmospheric and crustal sources is assumed to be from the decay of ^{3}H (tritogenic helium). The estimated concentration of tritogenic 3He is used with the measured concentration of ^{3}H to estimate the groundwater age (details provided in Appendix III). If sources of helium such as nucleogenic and mantle are present in significant quantities, dating by $^{3}H/^{3}He$ has limited accuracy.

Samples for ^{3}H were collected from the Faulder Well and Gibbs Well on May 15, 2008. Samples were left unfiltered and collected in 1000 ml polyethylene bottles. ^{3}H age dating was completed by the University of Waterloo Environmental Isotope Laboratory, Ontario. Samples for ^{3}He analysis were obtained using down-hole diffusion samplers provided by the G.G. Hatch Stable Isotope Laboratory at the University of Ottawa, Ontario. The diffusion samplers consist of a diffusion membrane and a copper tube reservoir. The diffusion samplers were deployed in the Community Well and Gibbs Well and left in place for a minimum of six days to allow the concentration of gasses in the copper reservoir to equilibrate with the concentration of gasses in the groundwater. When the sampler was removed from the well, the end of the copper reservoir was

[1] *Groundwater Age*, by Gholam, A. Kazemi, Jay H. Lehr and Pierre Perrochet. John Wiley & Sons, Inc. 2006

clamped to isolate the air sample. The concentration of ^{3}He in the collected sample was then determined by the lab using a magnetic sector mass spectrometer.

WATER ISOTOPES

Analysis of the water isotopes $^{2}H/^{1}H$ and $^{18}O/^{16}O$ were conducted for the purpose of comparing the water isotope "fingerprints" of the Faulder Community Well and Gibbs wells with surface water bodies in the area to further assess the recharge area(s) of the wells.

Samples for the water isotopes were left unfiltered and collected in 4 or 30 ml HDPE bottles at the time of sampling and filled so that no, to minimal, headspace remained. Water isotope analyses were completed at Environment Canada's National Water Resources Institute (NWRI) in Saskatoon, SK. Results were reported relative to the Vienna Standard Mean Ocean Water (VSMOW) reference in the delta per mil (‰) notation: δ(‰ $= [(R_{sample}/R_{standard}) - 1] * 1000$, where R_{sample} and $R_{standard}$ denote the $^{2}H/^{1}H$ or $^{18}O/^{16}O$ isotopic ratios in the sample and the reference material, respectively. The error in the reported values is ±2.0‰ for $\delta^{2}H$ and ±0.2‰ for $\delta^{18}O$.

APPENDIX III

UNIVERSITY OF OTTAWA RESULTS AND DATA INTERPRETATION FOR GROUNDWATER AGE DATING ANALYSES

Central B.C. $^3H/^3He$ Groundwater Dating

Two samples were analysed for ^4He, ^3He and ^{20}Ne. The objective of this analysis is to couple the concentration of ^3H with its decay product ^3He to determine a groundwater age. For this approach to work we assume that once water enters the saturated zone the concentration of helium and neon in the water are constant.

Calculations:

The decay of tritium in the subsurface produces ^3He. By measuring the ^3H and ^3He we can calculate how long groundwater has been underground. This method is generally effective for dating groundwater up to about 50 years of age.

To be able to calculate a groundwater age using this method we need to account for two other sources of ^3He in the water, the first is atmospheric and the second is crustal ^3He. We account for the atmospheric ^3He using how much ^3He is in air saturated water and with the neon concentration. We also need to account for crustal ^3He, which we do by using the concentration of ^4He (see sources of error)

The concentration of 3He from tritium is found using (Eq. 1).

Eq. 1: $^3He_{Tri} = {}^4He_m(R_m - R_{Ter}) - {}^4He_{eq}(R_{eq} - R_{Ter}) - L_{ex}(Ne_m - Ne_{eq})(R_{ex} - R_{ter})$
(Kipfer *et al.*, 2002)

The subscript "m" denotes measured, while "eq" equilibrium, and "ex" for excess. The R_{Ter} component is assumed to be 2 x 10^{-8}. We combine the amount of 3He with the amount of ^3H using Eq. 2 to calculate groundwater age:

Eq. 2 $$t = 12.3/\ln 2 \times \ln\left(1 + \frac{^3He}{^3H}\right)$$

Sources of Error:

Excess Air: The concentration of noble gases in groundwater is generally higher than is expected for water at a given temperature. This component is called excess air. This is interpreted to enter the water during recharge by bubbles being forces into the water during recharge. The concentration of neon does not change much with temperature, so we use neon to correct for the excess air.

Crustal Helium Production: In calculating groundwater ages using noble gas $^{3}H/^{3}He$ concentration there are various sources of error. The terrogenic component is calculated using the amount ^{4}He excess and a literature value for the $^{3}He/^{4}He$ ratio of excess. The correction is generally made using a literature value for the $^{3}He/^{4}He$ of the crustal production. The error from this calculation increases with the amount of ^{4}He.

Sampler Location: It is assumed that the sampler was sampling formation gas concentrations when it was in place. This is valid if the sampler is at or close to the screened interval with water a confining water column above the sampler location.

Results and Interpretation

The two samplers which were analysed have similar neon concentrations and similar $^{3}He/^{4}He$ ratios; however the amounts of helium are very different.

Table 1 Concentrations of ^{4}He, ^{3}He and Neon

	^{4}He (cc/g)	^{3}He (cc/g)	$^{3}He/^{4}He$	Ne (cc/g)	^{3}H (TU)
Gibbs	2.83E-7	2.41E-13	8.50E-7	2.03E-7	6.8
Faulder	6.74E-8	5.20E-14	7.71E-7	1.69E-7	Not Analyzed

The Faulder sample has much lower total helium than the Gibbs sample. We expect these two wells to have very similar helium concentrations as they are very close to each other and are believed to be in hydraulic connections. The low gas concentrations in Faulder may be the result of degassing in the well. If the sampler was not deep enough below the water level the water may have been degas
sing. Due to a flux of helium up from the formation it maintains the helium ratio of the groundwater, however it doe not hold the true concentration of helium. Because of the differences in helium concentrations it is interpreted that the Gibbs sampler represents the formation.

The Gibbs well is characterized by ^{4}He which is from crustal sources. In the subsurface ^{4}He is produced from the decay uranium and thorium, in association with this decay there is production of ^{3}He. Because of the high ^{4}He the correction for crustal sources may have a significant affect on the age calculated for the sample. A standard value for the crustal $^{3}He/^{4}He$ correction is $2x10^{-8}$ and this returns a groundwater age of 43 years.

The age of 43 years is much older than the expected groundwater age and this result should interpreted with caution. Because of the high helium changing the correction value will have a significant effect on the result. Because of the techtonic setting of central BC a higher value for the correction is likely. The correction factor can sometimes be calculated from the $^{3}He/^{4}He$ ratios of thermal springs.

Conclusion

The helium isotope data does not provide a clear answer as to the age of the groundwater in the Gibbs well. There is significant crustal helium and this may be an indicator that the water is from a deeper source than previously thought, or there may be a high flux of helium from the sediments.

References:

Clark I. and Fritz P. (1997) *Enviromental Isotopes in Hydrogeology*. Lewis Publishing.

Kipfer, R., Aeschback-Hertig, W., Peeters, F., and Stute, M., 2002. Noble Gases in Lakes and Groundwaters. In: Porcelli, D., Ballentine, C. J., and Wieler, R. Eds.), *Noble Gases in Geochemistry and Cosmochemistry*. Mineralogical Society of America, Washington D.C.