# Groundwater Supply at Gull Lake

Gull Lake Area

Tp 041 to 043, R 28, W4M and Tp 041 to 043, R 01 and 02, W5M

Prepared for
Ponoka County

Prepared by
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May 2010

Our File No.: 10-136.00

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HYDROGEOLOGICAL CONSULTANTS LTD.

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**PERMIT NUMBER P 385**
The Association of Professional Engineers,
Geologists and Geophysicists of Alberta

# TABLE OF CONTENTS

# Executive Summary

Ponoka County retained the services of HCL to determine if sufficient groundwater is available for a proposed development in land west of Gull Lake; the proposed development comprises approximately 146 square kilometres ($km^2$), and will include up to 1,400 residential lots. The present review considered the groundwater supply, aquifers present and the possible impact on Gull Lake.

The proposed development includes the parts of three basins: the Gull Lake Basin, the Blindman River Basin, and the Lloyd Creek Basin.

From the perspective of groundwater supply for the area of the proposed development, groundwater availability is based on flow through individual aquifers. In the area of proposed development, the only aquifers that have been identified are in the bedrock.

The amount of water required for 1,400 lots depends on the utilization of the lots. If the lots are for full-time residences, the water requirement would be expected to be in the order of 2,000 $m^3$/day; if the lots are all parking spots for recreational vehicles, the water requirements would be 70 $m^3$/day. While the *Water Act* protects up to 3.4 $m^3$/day per lot, this amount far exceeds any normal use of water for domestic needs; all other needs must be licensed.

The groundwater flow through the four geounits that underlie the AOI is estimated to be 15,745 $m^3$/day. The proposed development of 1,400 lots on land west of Gull Lake will require water supplies in the range of 70 to 2,000 $m^3$/day. The estimated value of 2,000 $m^3$/day plus the current groundwater use of 2,650 $m^3$/day totals 4,650 $m^3$/day. The total current and proposed groundwater use of 4,650 $m^3$/day represents 30% of the estimated aquifer flow of 15,745 $m^3$/day in the AOI, meaning that a supply of 2,000 $m^3$/day is available for the development of 1,400 lots.

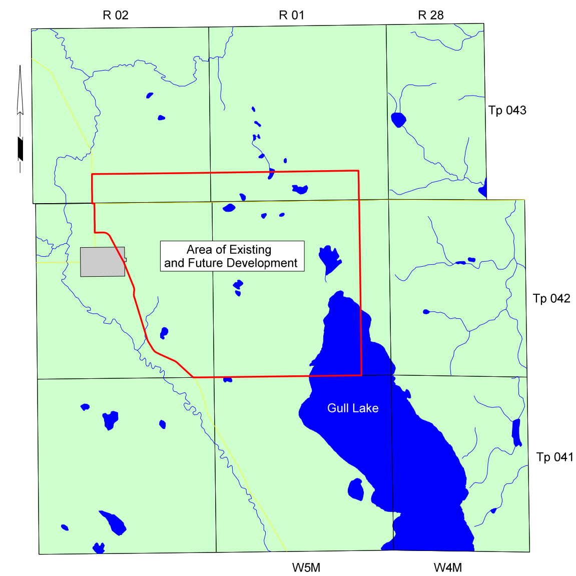
The two main water bodies that would be affected by groundwater diversion would be Gull Lake and the Blindman River. In the Gull Lake Basin, the groundwater development should focus on Geounit 3 and Geounit 1 to minimize the effects on water levels in Gull Lake. In the Blindman River Basin, the groundwater development should focus on Geounit 2 and Geounit 1 to minimize the effects on the Blindman River water levels.

The remaining geounit, Geounit 4, is only present west of Gull Lake in the topographically higher areas between Gull Lake and the Blindman River. The groundwater in Geounit 4 would reach Gull Lake and the Blindman River only after the groundwater has been discharged to the land surface. Because wetlands away from Gull Lake would be maintained by discharge from Geounit 4 and because there has not been significant development of aquifers in Geounit 4, the expectation is that future development will not include aquifers within Geounit 4. If Geounit 4 is not developed for additional groundwater supplies, the wetlands away from the Lake will not be impacted; wetlands near the Lake would not be expected to be affected by groundwater use.

# 1. Introduction

## 1.1. Purpose

The first multiple-lot subdivision at Gull Lake in Ponoka County (County) was Parkland Beach in 1975, located on the northwestern side of Gull Lake. Since that time, approximately 800 cottage and acreage lots have been created, and landowners have expressed interest in further development. The County has identified an area on the west side of Gull Lake where further development will be considered, and this area is shown on the adjacent figure. The County anticipates that 1,400 lots could be created. The main purpose of this study as defined by the County is to determine that a sufficient quantity of groundwater is available for future development on the west side of Gull Lake.




***Area of Existing and Future Development***

A total supply of 1,250 cubic metres per year (3.4 cubic metres per day) of groundwater is protected for each lot under section 23(3) of the *Water Act* (Province of Alberta, 2000). While this quantity of water, 1,750,000 $m^3$/year for the proposed 1,400 lots (4,790 $m^3$/day), is protected under the *Water Act* for household use, a typical permanent residence with four people would use approximately 1.4 $m^3$/day[1], 2,000 $m^3$/day for 1,400 permanent residences, or as low as 0.05 $m^3$/day[2] if all lots were parking spots for RVs.

## 1.2. Scope

Hydrogeological Consultants Ltd. (HCL) were retained by the County to use the readily available hydrogeological data to answer the following questions, and to include the information in a covering report:

a) How much groundwater is available on a sustainable basis, to supply residential development in the study area, without depleting the supply to existing households, licensees, and traditional agricultural users?

b) Will the extraction of this much groundwater affect natural systems such as the state of wetlands, and the quality and quantity of overflows to the lake?

c) Will the change from agricultural to residential use affect the infiltration rates, either positively or negatively, and is it possible or desirable to increase infiltration through surface engineering measures, or by control of land cover?

HCL has defined the area of study (AOS) of the present program as a 3x3 township area around township 042, range 01, W5M, and the area of interest (AOI) as the area of existing and future development on the west side of Gull Lake, which includes parts of townships 042 and 043, ranges 01 and 02, W5M.

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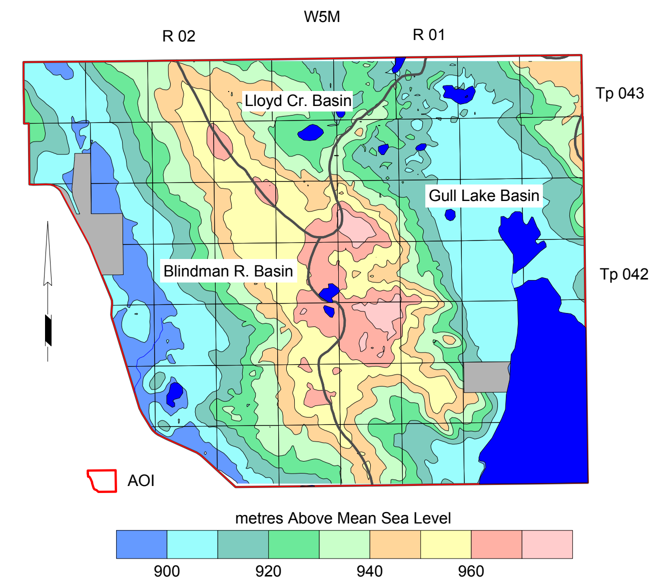
1 Alberta Environment indicates average daily water consumption is 343 litres per day per person; for a household of four, this would be about 1.4 $m^3$/day. http://www3.gov.ab.ca/env/water/Conservation/residential.cfm

2 Alberta Environment guidelines indicate that the expected volume of sewage for an RV park is 180 litres per day per lot. Based on this information, if an RV lot were used for 3 months per year, 16.2 $m^3$, or about 0.05 $m^3$/day of groundwater, would be used.

## 2. Background

### 2.1. Drainage Basins

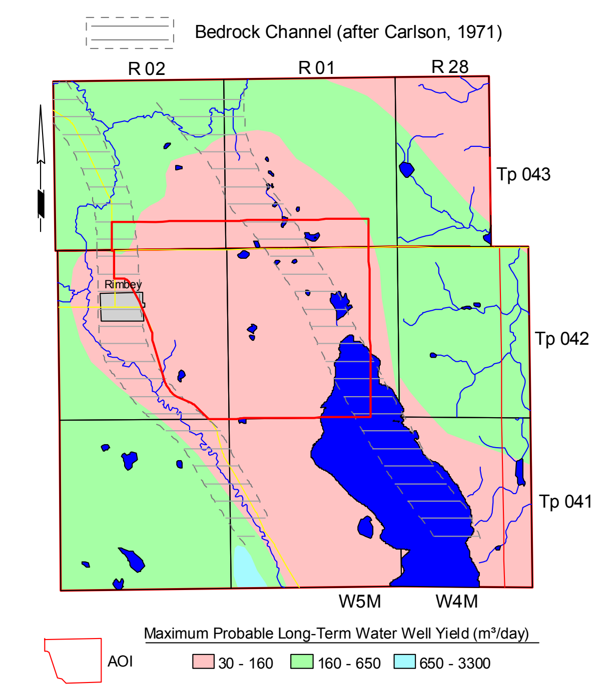
For the present report, the AOI is located within three drainage basins: Gull Lake, Blindman River, and Lloyd Creek as shown on the adjacent surface topography map. The three basins are sub-basins of the Red Deer River Drainage Basin (AAFC, Mar-2008). Ground elevations in the AOI range from 890 to 980 metres above mean sea level (AMSL).




***Surface Topography and Drainage Basins in AOI***

### 2.2. General Hydrogeology

The upper bedrock in the AOS is the Dalehurst Member of the Paskapoo Formation (HCL, 2003). The Paskapoo Formation is comprised primarily of non-marine sandstone and shale deposits. The Paskapoo Formation is subdivided into three Members; from youngest to oldest they are: the Dalehurst, Lacombe and Haynes members; the Lacombe Member is often divided into the upper and lower parts by HCL. The total thickness of the Paskapoo Formation underlying the AOI is in the order of 250 metres.




***Combined Hydrogeological Map (after Tokarsky, 1971 and LeBreton, 1971)***

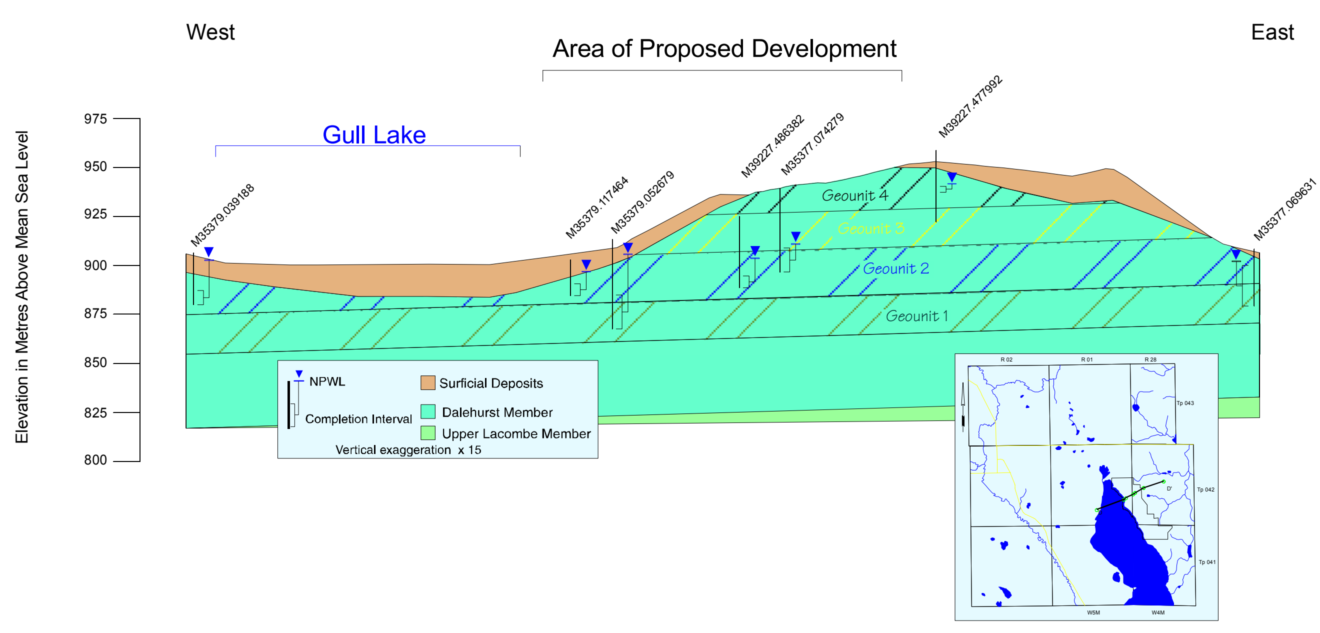
The regional hydrogeological maps prepared by the Alberta Geological Survey (Tokarsky, 1971; LeBreton, 1971) indicate that water wells completed in aquifers within 300 metres of surface in the AOS are expected to mainly have long-term yields that are between 30 and 650 $m^3$/day, as shown in the adjacent figure. Water wells completed in aquifers in the AOI, are expected to have long-term yields that are mainly between 30 and 160 $m^3$/day. The Gull Lake Bedrock Channel, a linear bedrock low, trends northwest to southeast beneath Gull Lake. Associated with the linear bedrock low are sand and gravel deposits that are expected to be mainly less than five metres thick (HCL, 2003).

Groundwater from upper bedrock aquifer(s) in the AOI would be expected to be sodium-bicarbonate-type waters with a total dissolved solids (TDS) content of less than 1,000 milligrams per litre (mg/L) (HCL, 2003).

## 2.3. Previous Work

### 2.3.1. Groundwater Supply – East Side of Gull Lake

In August 2009, HCL completed a desktop groundwater supply study on the east side of Gull Lake for Ponoka County. The area of interest for the 2009 study lies entirely within the Gull Lake Basin. An analysis of bedrock non-pumping water levels (NPWLs) determined the presence of four geounits within the Dalehurst Member within the area of interest, as shown in the cross-section below. Two of the four geounits are present beneath most of the 22 square kilometres that are to be developed on the east side of Gull Lake. Groundwater in the deepest geounit (Geounit 1) is flowing out of the Gull Lake Basin under Gull Lake; the volume of groundwater estimated to be flowing through this geounit is 800 m³/day. Groundwater flowing through the geounit overlying the deepest geounit (Geounit 2) is expected to be discharging into Gull Lake. The quantity of groundwater flowing through this geounit is estimated to be 7,000 m³/day.




***Southwest - Northeast Cross-Section***

Because groundwater flowing through Geounit 1 is leaving the Gull Lake Basin, development of groundwater from this geounit would have little or no effect on the water level in Gull Lake. The depth to the bottom of this geologic unit varies from 50 to 100 metres below ground level. The groundwater from this geounit is expected to be a sodium-bicarbonate-type water with total dissolved solids of less than 500 mg/L.

The remaining two geounits, Geounits 3 and 4, are only present in the topographically higher areas away from Gull Lake. The total groundwater flow in these two geounits is estimated to be 350 m³/day. The groundwater in these geologic units would reach Gull Lake only after the groundwater has been discharged to the land surface. Because wetlands away from Gull Lake would be maintained by discharge from Geounits 3 or 4 and because there has not been significant development of aquifers in these geounits, the expectation is that future development will not include aquifers within Geounits 3 and 4. Without development of these aquifers, the wetlands away from the Lake will not be impacted; wetlands near the Lake would not be expected to be affected by groundwater use.

### 2.3.2. Groundwater Query

The Groundwater Query for Ponoka County is based on the regional groundwater assessment (HCL, 2003). The results of the Query for the development in 16-17-042-01 W5M are provided in the adjacent table. The geological information in the table indicates that the upper bedrock below the proposed development is the Dalehurst Member of the Paskapoo Formation. The Query shows that the Dalehurst Member forms the bedrock surface in the area of proposed development; the base of the Dalehurst Member is at a depth of 168 metres below ground level (BGL), an elevation of 810 metres above mean sea level (AMSL). Beneath the Dalehurst Member is the Upper Lacombe Member.

**Ponoka County**

**16-17-042-01 W5M**

| **General Results** Depth(s) | **Top** metre | **Yield** $m^3$/day | **NPWL** metre | **TDS** mg/L | **Sulfate** mg/L | **Chloride** mg/L | **Fluid** Expected |
|---|---|---|---|---|---|---|---|
| gwQuery Determined Minimum | 56 | 231[2] | 63 | 649 | 123 | -- | -- |
| gwQuery Determined Maximum | 65 | 231[2] | 63 | 649 | 123 | -- | -- |

| **Detailed Results** Geologic Unit Encountered | **Top** metre | **Yield*** $m^3$/day | **NPWL** metre | **TDS** mg/L | **Sulfate** mg/L | **Chloride** mg/L | **Fluid** Expected |
|---|---|---|---|---|---|---|---|
| Lower Surficial Deposits | 0 | -- | -- | -- | -- | -- | -- |
| Bedrock Surface | 37 | | | | | | |
| Dalehurst Member | 37 | 231[2] | 63 | 649 | 123 | -- | -- |
| Upper Lacombe Member | 168 | 93[2] | 88 | 788 | 136 | 16 | -- |

| Parameter | metre |
|---|---|
| Base of Groundwater Protection (Depth) [4] | 441 |
| Ground Elevation (AMSL) | 978 |

**Legend/Notes**

'--' indicates information not available.

Base of Groundwater Protection (BGP; TDS > 4,000 mg/L).

* Yield based on the 'Fluid Encountered' being water.

[2] Results are based on a regional groundwater study by hydrogeological consultants ltd. (HCL)

[3] Results are based on a summary of Drill Stem Test (DST) results.

[4] https://www3.eub.gov.ab.ca/Eub/

The information calculated with the MOW-TECH LTD. gwQuery is meant only as a guide. Actual drilling conditions may vary. MOW-TECH LTD. is not liable for drilling or groundwater problems as a result of using this data.

***Mow-Tech Ltd. gwQuery Results***

The groundwater component of the Groundwater Query indicates that the expected approximate yield from a water well completed in the Dalehurst Member is 230 $m^3$/day. The table also shows that water wells completed in the Upper Lacombe Member have expected yields that are in the order of 90 $m^3$/day.

Groundwaters from the Dalehurst Member are expected to have a TDS concentration of approximately 650 mg/L. Groundwaters from the upper part of the Lacombe Member are expected to have a TDS concentration that is approximately 790 mg/L.

The base of groundwater protection is at a depth of 441 metres. This is the depth below which groundwater is expected to have a TDS concentration of more than 4,000 mg/L.

Because the Groundwater Query is based on regional data, local conditions may vary. The Mow-Tech Ltd. gwQuery is available on the internet: http://www.gwquery.com.

# 3. Present Program

## 3.1. Maps, Aerial Photographs

The proposed development is situated within the 1:50,000 National Topographic Series (NTS) 83A12 and 83B9 map sheets. Digital topographic control has been obtained from the 1:20,000 digital elevation model (DEM) prepared by AltaLIS Ltd.

Digital ortho-imagery has been obtained from Ponoka County for the present program. Otho-imagery is created for a digital image of an aerial photograph when displacements caused by the camera and the terrain have been removed. It combines the image characteristics of a photograph with the geometric qualities of a map. The ortho-imagery was provided at a 30-centimetre resolution.

## 3.2. Groundwater Database – Area of Study

The Groundwater Centre database, an enhanced version of the Alberta Environment (AENV) groundwater database, includes 3,446 records for the AOS. Of the 3,446 groundwater records, 2,523 are classified as water wells. Water well classification includes the ten categories for "Type of Work" as shown in the adjacent table. The "new well" category, although new at the time the information was filed with AENV, may now be many years old. Information relating to the records in the groundwater database has been used in the preparation of cross-sections, and to determine aquifer parameters.

Spatial information on groundwater records may be limited to the quarter section. Unless more detailed information is available, the coordinates assigned to groundwater records are the centres of their legal location.

| Type of Work | No. of Records |
|---|---|
| Chemistry | 365 |
| Deepened | 26 |
| Federal Well Survey | 151 |
| New Well | 1887 |
| Old Well - Test | 2 |
| Reconditioned | 3 |
| Reconstructed | 2 |
| Test Hole | 2 |
| Water Test Hole | 24 |
| Well Inventory | 61 |
| Cathodic Protection | 2 |
| Coal Test Hole | 3 |
| Core Hole | 2 |
| Drill Stem Test Hole | 1 |
| Dry Hole - Abandoned | 2 |
| Flowing Shot Hole | 528 |
| New Well - Abandoned | 49 |
| Old Well - Abandoned | 14 |
| Spring | 28 |
| Structure Test Hole | 235 |
| Test Hole - Abandoned | 3 |
| Water Test Hole - Abandoned | 29 |
| Well - Abandoned | 8 |
| [unknown] | 19 |
| ***Total Water Well Records*** | ***2523*** |
| ***Groundwater-Related Records*** | ***923*** |
| ***Total*** | ***3446*** |

***Groundwater Database Records - Area of Study***

## 3.3. Groundwater Database – Area of Interest

In the AOI, there are 926 groundwater records. Of these 926 records, 760 are classified as being records that are for water wells.

| Type of Work | No. of Records |
|---|---|
| Chemistry | 95 |
| Deepened | 5 |
| Federal Well Survey | 2 |
| New Well | 637 |
| Old Well - Test | 1 |
| Reconditioned | 1 |
| Test Hole | 1 |
| Water Test Hole | 10 |
| Well Inventory | 8 |
| Cathodic Protection | 2 |
| Core Hole | 1 |
| Dry Hole - Abandoned | 2 |
| Flowing Shot Hole | 101 |
| New Well - Abandoned | 3 |
| Old Well - Abandoned | 1 |
| Spring | 2 |
| Structure Test Hole | 43 |
| Water Test Hole - Abandoned | 3 |
| Well - Abandoned | 1 |
| [unknown] | 7 |
| ***Total Water Well Records*** | ***760*** |
| ***Groundwater-Related Records*** | ***166*** |
| ***Total*** | ***926*** |

***Groundwater Database Records - Area of Interest***

## 3.4. Existing Lots and Licences

There are approximately 850 existing lots located in the AOI[3]. Currently, there are 93 authorized groundwater diversions in the AOI, for a total annual diversion of 366,097 m³. Of the 93 authorizations, two are for commercial purposes (62,312 m³/year), three are for recreation purposes (4,870 m³/year), two are for municipal purposes (146,920 m³/year), 24 are for agriculture purposes (91,202 m³/year), and 62 are registrations (60,793 m³/year).

## 3.5. Published and Unpublished Reports

A list of sources provided in the Bibliography section of this report provides data that pertain to the work completed for this project. The soils maps were reviewed to identify possible wetlands areas.

## 3.6. Data Processing

The horizontal coordinates in this report are based on a 10-degree Transverse Mercator (10TM) projection, referenced to 115 degrees west longitude and using the NAD83 datum.

Transmissivity values from the aquifer test data from pumped water wells' records within the Groundwater Centre database have been calculated using the following approximation of the Theis non-equilibrium equation:

$$T = \frac{2.3 \cdot Q}{4 \cdot \pi \cdot \Delta s}$$

Where:

T = Transmissivity
Q = Discharge
$\Delta$s = Drawdown per log cycle

Transmissivity from specific capacity is calculated based on the following equation:

$$\frac{Q}{s} = \frac{4 \cdot \pi \cdot T}{2.3 \cdot \log_{10}\left(\frac{2.25 \cdot T \cdot t}{S \cdot r^2}\right)}$$

[3] As per a phone conversation with Charlie Cutforth of Ponoka County in December 2009.

Where:

S = Storativity and is assumed to be 0.0001
t = time since discharge started
r = effective radius of the water well

Drawdowns at various times and distances from the groundwater discharge point are calculated from the following equation:

$$s = \frac{Q \cdot W(u)}{4 \cdot \pi \cdot T}$$

Where:

W(u) is the well function of u

And

$$u = \frac{r^2 \cdot S}{4 \cdot T \cdot t}$$

When multiple groundwater discharge points are involved, the principle of superposition is used. The multiple discharge points can be at various locations or at one location.

Drawdowns at various times and distances are calculated based on approximations of W(u). For values of u greater than 0 and less than one, the following approximation is used:

$$W(u) = -\ln u + (-0.57721556) + (0.99999193)*u + (-0.24991055)*u^2 + (0.05519968)*u^3 + (-0.000976004)*u^4 + (0.00107857)*u^5$$

Where:

ln = natural logarithm

For values of 1 < u < infinity, the following approximation is used:

$$W(u) = (1/(u*e^u))*(((0.250621)+(2.334733*u)+u^2))/((1.681534)+(3.330657*u)+u^2))$$

Theoretical long-term yield is calculated from the Moell Method[4], using the following equation:

$$Q_{20} = \frac{Q(H_A)}{s_{100} + 5\Delta s} \times 0.7$$

Where

| | |
|---|---|
| $H_A$ | = available drawdown |
| $S_{100}$ | = the drawdown after 100 minutes of pumping |
| Q | = pumping rate during the aquifer tests |
| Q20 | = sustainable yield for 20 years |
| $\Delta s$ | = drawdown per log cycle |
| 0.7 | = safety factor |

All gridding uses the Kriging method with a linear variogram model as provided in Golden software Surfer V9.

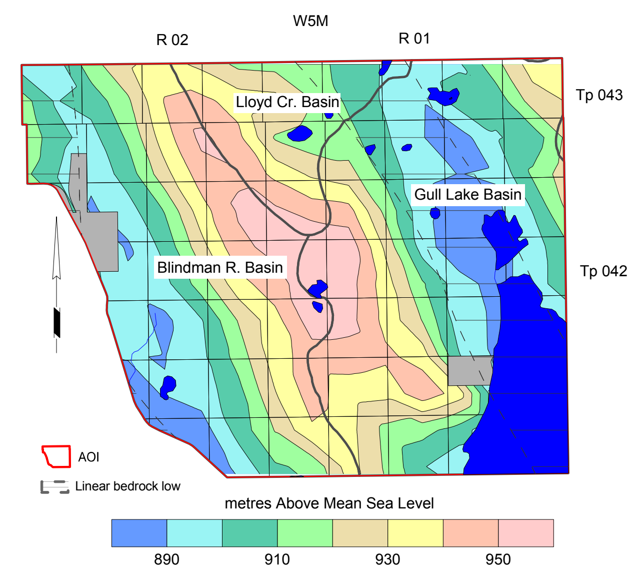
[4] Groundwater Evaluation Guideline, 05 December 2002. Alberta Environment.

# 4. Results

## 4.1. Groundwater Database

### 4.1.1. Bedrock Surface

The surficial deposits are the sediments above the bedrock surface. The base of the surficial deposits is the bedrock surface, represented by the adjacent bedrock topography map. In the AOI, there are more than 600 water well records with sufficient data to prepare a bedrock topography map. The bedrock surface varies between 880 and 970 metres AMSL. The lowest elevations occur in the bedrock linear low that passes beneath Gull Lake from the north-northwest. Saturated sand or gravel deposits are largely absent in the AOI; the exceptions are mainly in association with the linear bedrock lows, where the deposits may be more than five metres thick (HCL, 2003).




**_Bedrock Surface Topograpy_**

### 4.1.2. Bedrock Geology

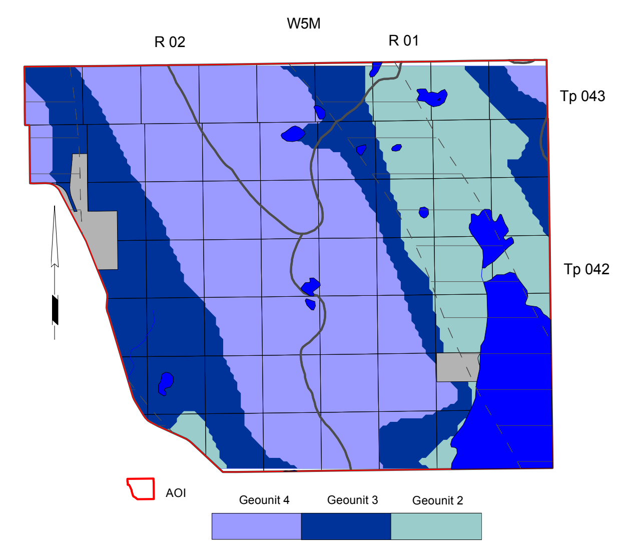
For the present report, there are four geologic units of interest, and in the AOI the four geologic units occur within the Dalehurst Member. The bedrock geology map and the two cross-sections shown in this report have been prepared based on geologic unit tops determined from the August 2009 study.

Geounit 4 is the uppermost bedrock unit in the central part of the AOI, and has a maximum thickness of 45 metres. The top of Geounit 4, the bedrock surface, ranges in elevation from 900 to 960 metres AMSL.

Structure contours prepared for the top of Geounit 3 show that the top of Geounit 3 ranges in elevation from 900 to 930 metres AMSL; Geounit 3 has a thickness of 19 metres.

Structure contours prepared for the top of Geounit 2 show that Geounit 2 is present throughout the AOI; Geounit 2 ranges in elevation from 880 to 910 metres AMSL, and has a thickness of 24 metres.

The lowest geologic unit, Geounit 1, underlies Geounit 2 and is present throughout the AOI. Structure contours prepared for the top of Geounit 1 show that the top of Geounit 1 ranges in elevation from 855 to 885 metres AMSL; Geounit 1 has a thickness of 20 metres.




**_Bedrock Geology_**

### 4.1.3. Water Well Summary

In the AOI, there are records for 434 water wells with hydrogeological data where the bedrock geounit of water well completion was determined. The water wells selected for hydrogeological analysis required that the record had the following minimum requirements: a non-pumping water level (NPWL), completion interval top and bottom, and a legal location of at least a quarter section. Of the 434 water wells, 32 (7%) are completed in Geounit 4, 66 (15%) are completed in Geounit 3, 190 (44%) are completed in Geounit 2, and 146 (34%) are completed in Geounit 1, as shown in the table below. Of these 434 water wells, 418 water wells had at least one value for the elevation of NPWL. A non-pumping water level surface map was created for each geounit.

Water wells completed in the four geounits are expected to have average apparent long-term yields that range from 150 to 220 m$^3$/day, and the groundwaters from these water wells are expected to have TDS concentrations that range from 475 to 650 mg/L.

| Geologic Unit | No. Water Wells Completed | Average Elevation of Completed Depth of Water Wells (m AMSL) | Average Elevation of NPWL (m AMSL) | Average Apparent Yield (m$^3$/day) | Average TDS (mg/L) |
|---|---|---|---|---|---|
| Geounit 4 | 32 | 920 | 935 | 154 | 476 |
| Geounit 3 | 66 | 901 | 917 | 165 | 649 |
| Geounit 2 | 190 | 883 | 904 | 217 | 566 |
| Geounit 1 | 146 | 861 | 891 | 202 | 552 |

***Summary of Water Wells in the Area of Interest***

In addition to the water wells completed in bedrock geounits, there are 19 water wells completed in surficial deposits; however, because there were insufficient aquifer test data to calculate long-term yield values, and due to the limited areal extent of sand or gravel deposits in the AOI, aquifers in the surficial deposits have been considered insignificant in the AOI and have not been discussed further.

### 4.1.4. Groundwater Use

Of the 366,097 m³/year (1,008 m³/day) of licensed groundwater use, 35 m³/day has been determined to be from water wells completed in Geounit 4, 84 m³/day from water wells completed in Geounit 3, 280 m³/day from water wells completed in Geounit 2, and 245 m³/day from water wells completed in Geounit 1; 346 m³/day is from water wells completed in multiple bedrock aquifer(s), and the remaining 19 m³/day is from an unknown aquifer as a result of lack of completion interval data.

| Aquifer ** | Licences and/or Registrations | Registrations (m³/day) | Licensed Groundwater Users* (m³/day) Agricultural | Municipal | Commericial | Recreation | Total Groundwater Diversion | Percentage |
|---|---|---|---|---|---|---|---|---|
| Geounit 4 | 7 | 12 | 22 | 0 | 0 | 0 | 35 | 3.5 |
| Geounit 3 | 15 | 33 | 47 | 0 | 0 | 3 | 84 | 8.3 |
| Geounit 2 | 33 | 60 | 49 | 0 | 171 | 0 | 280 | 27.8 |
| Geounit 1 | 15 | 40 | 1 | 203 | 0 | 0 | 245 | 24.3 |
| Multiple bedrock | 18 | 11 | 130 | 200 | 0 | 5 | 346 | 34.3 |
| Unknown | 5 | 10 | 10 | 0 | 0 | 0 | 19 | 1.9 |
| Total(1) | 93 | 167 | 259 | 403 | 171 | 8 | 1,008 | 100.0 |
| Percentage | | 16.5 | 25.7 | 40.0 | 16.9 | 0.8 | 100 | |

* - data from AENV ** - Aquifer identified by HCL

(1) The values given in the table have been rounded and, therefore, the columns and rows may not add up equally

***Total Groundwater Use by Aquifer in the Area of Interest***

In the AOI, there are 575 domestic water wells, 52 domestic and stock water wells, and 76 stock only water wells. Forty-three of the 703 domestic/stock water wells were matched to either a licensed or a registered water well. In order to identify the geounit of completion for these 660 unregistered and/or unlicensed domestic/stock water wells, the water well record had to have at least a completed depth. Of the 660 domestic/stock water wells with a completed depth, 36 are completed in Geounit 4, 100 are completed in Geounit 3, 241 are completed in Geounit 2, 188 are completed in Geounit 1, and 83 water wells are completed in multiple bedrock aquifer(s); the completion geounit could not be determined for the remaining 12 water wells. To determine the groundwater use from domestic water wells, diversion is set to 0.4 m³/day; for stock-only use, a diversion of 14.3 m³/day is used; and for domestic and stock use, a diversion of 14.7 m³/day is used[5].

The groundwater use has been determined by taking into consideration all known licensed and registered groundwater use, and all known domestic/stock groundwater use. It has been assumed that the 660 domestic/stock water wells and 93 licensed and registered water wells are active. The data provided in the table below indicate that 2,650 m³/day is being diverted in the AOI, of which 13% is from Geounit 4, 19% is from Geounit 3, 28% is from Geounit 2, 15% is from Geounit 1, 23% is from multiple bedrock aquifer(s), and the remaining 2% is from unknown aquifer(s).

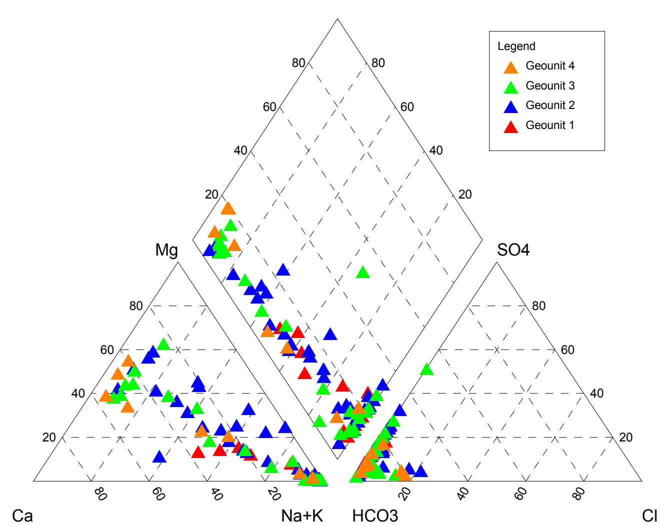
| | ***Domestic/Stock Diversions*** | | ***Licensed and/or Registered Groundwater Diversions*** | ***Total Groundwater Diversions*** | |
|---|---|---|---|---|---|
| Aquifer Designation | Number of Domestic/Stock Diversions | Daily Use m³/day | Totals (m³/day) | Totals m³/day | Percentage |
| Geounit 4 | 36 | 310 | 35 | 345 | 13 |
| Geounit 3 | 100 | 417 | 84 | 501 | 19 |
| Geounit 2 | 241 | 450 | 280 | 729 | 28 |
| Geounit 1 | 188 | 160 | 245 | 405 | 15 |
| Multiple Bedrock Completions | 83 | 272 | 346 | 617 | 23 |
| Unknown | 12 | 33 | 19 | 52 | 2 |
| Totals | 660 | 1,642 | 1,008 | 2,650 | 100 |

***Licensed and Registered Groundwater Use by Aquifer in the Area of Interest***

## 4.2. Groundwater Quality

A total of 80 chemical analyses are available in the groundwater database associated with groundwater samples collected from 67 water wells that are completed in geounits within the AOI. Of the 80 chemical analyses, eight are associated with six water wells that are completed in Geounit 4, 22 are associated with 17 water wells that are completed in Geounit 3, 38 are associated with 32 water wells that are completed in Geounit 2, and 12 are associated with 12 water wells that are completed in Geounit 1.

The adjacent Piper tri-linear diagram shows that, chemically, the groundwaters from Geounit 4, Geounit 3, and Geounit 2 are classified mainly as bicarbonate-type waters with no dominant cation. The groundwaters from Geounit 1, the deepest aquifer, are sodium-bicarbonate-type groundwaters.




***Piper Tri-Linear Diagram***

[5] HCL, August 2009.

## 4.3. Wetlands

For regulatory purposes under the Clean Water Act in the USA, the term “wetlands” means "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas." Aerial photographs provided by the County were reviewed and there is evidence of “wetlands” in the Blindman River Basin.

To determine the nature of the materials on the land surface, the Agricultural Region of Alberta Soil Inventory Database (AGRASID) (Alberta Soil Information Centre, 2001) was reviewed. The maps showed two areas that were identified as “peatlands” in the AOI.

## 4.4. Infiltration Rates

The amount of water that infiltrates into the groundwater flow system is dependent on many variables such as soil moisture, type of soil, and slope of the land surface. Soils such as clay and silt will encourage runoff and minimize recharge while larger-grained soils such as sorted sand or gravel will encourage infiltration[6]. On the surface, the type of land use is also important. When considering agriculture, it is necessary to consider whether land use will be for livestock or crops. As many crops are planted in rows, this can create channels in the soil that will increase surface runoff during heavy rainfall events. If the land is developed for domestic use, the area that is used for house, garage and driveways will prevent infiltration into the soil. With industrial developments, the building and parking lot will prevent infiltration. To increase infiltration in domestic and industrial areas, gardens can be created and green space should be maximized. Homeowners and businesses should be encouraged to plant trees and flowers, as the root systems and trunks/stems will increase the likelihood that infiltration will occur. In the case of confined feedlot operations, direct groundwater recharge is unlikely and undesirable. The responsible spreading of mammal wastes will not adversely affect groundwater recharge rates.

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[6] http://ga.water.usgs.gov/edu/watercycleinfiltration.html

# 5. Interpretation

## 5.1. Geometry of Aquifers

From an analysis of the elevation of non-pumping water levels conducted in August 2009 (HCL, 2009), it was determined that there are four separate geologic units. The trend of each geounit is based on the trend of the top of the Lacombe Member. The lowest geounit passes under Gull Lake and the Blindman River, and is referred to as Geounit 1; the top of Geounit 1 is 64 metres above the top of the Upper Lacombe Member; the top of Geounit 2 is 88 metres above the top of the Upper Lacombe Member; the top of Geounit 3 is 107 metres above the top of the Upper Lacombe Member; and the top of Geounit 4 is 116 metres above the top of the Upper Lacombe Member. The four geounits are shown on the cross-section below. Also shown on the cross-section are the three drainage sub-basins present in the AOI: Gull Lake, Blindman River and Lloyd Creek.

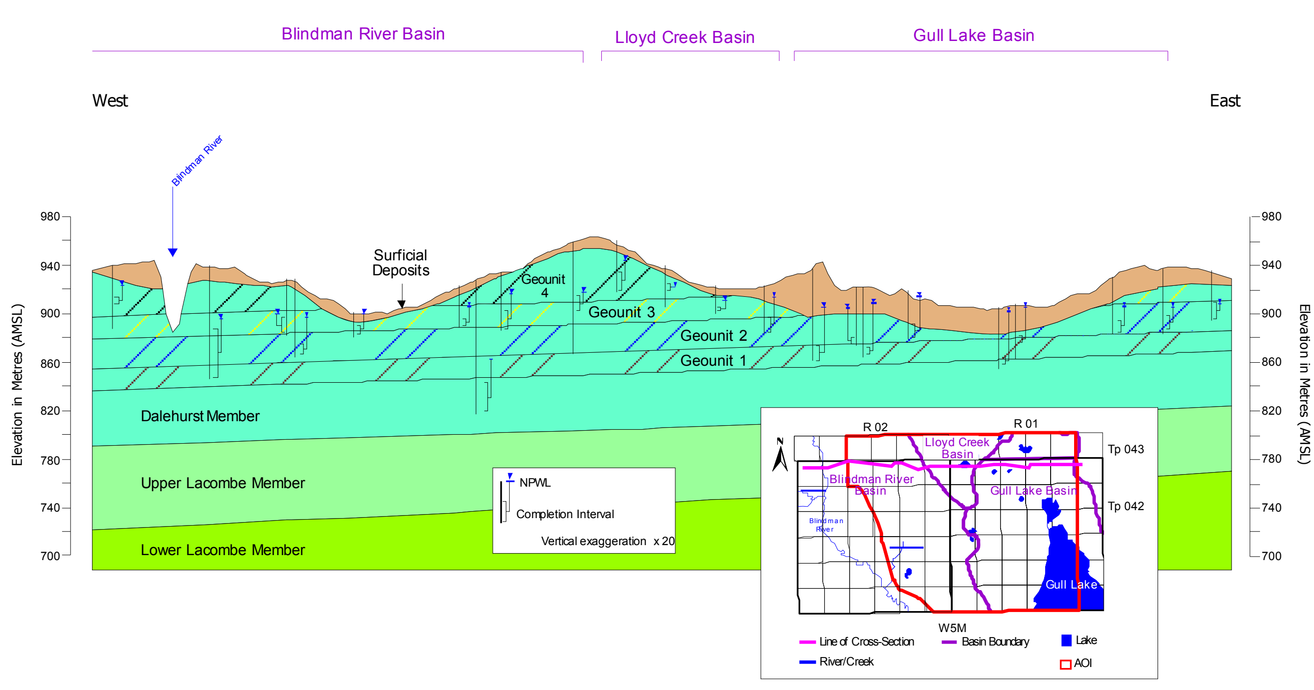



***Figure 1. Southwest - Northeast Cross-Section***

The geounit overlying Geounit 1 contains aquifers that discharge directly into Gull Lake and is referred to as Geounit 2. At least part of Geounit 2 passes below the Blindman River; on the cross-section above, the Blindman River does not intercept Geounit 2. However, if the bedrock surface is more than four metres below the ground elevation of the River bottom, then Geounit 2 would be expected to be impacted by the Blindman River. The similarity between the water levels associated with the water wells completed in both Geounits 2 and 3 suggests that the Blindman River does intersect Geounit 2.

Geounits 3 and 4 are at elevations above Geounit 2 and the groundwater from aquifers associated with these geounits will discharge on to the ground surface, and therefore, indirectly to Gull Lake. Groundwater from aquifers associated with Geounit 3 will discharge directly into the Blindman River.

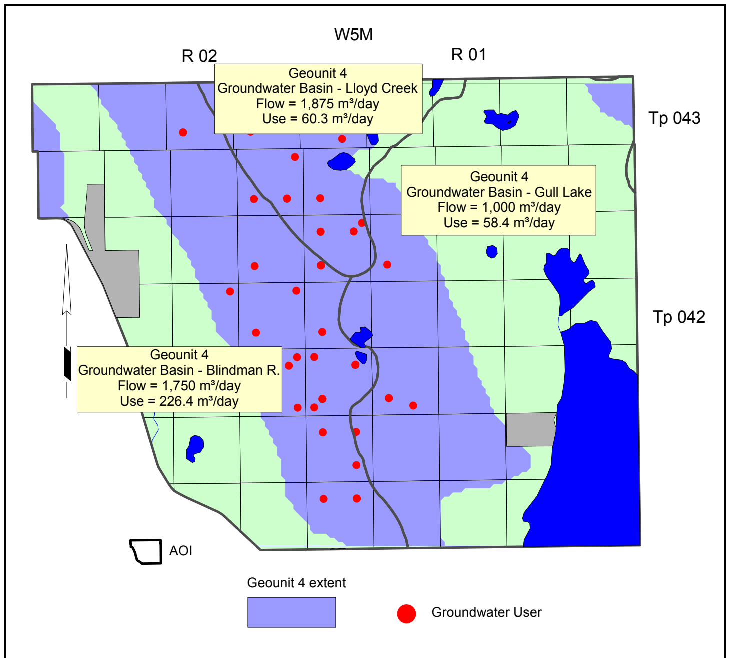
## 5.2. Groundwater Flow

A direct measurement of groundwater recharge or discharge is not possible from the data that are available for the AOI. One approach is to estimate the quantity of groundwater flowing laterally through each individual geounit. This method assumes that there is sufficient recharge to the aquifer to maintain the flow through the aquifer. However, even the data that can be used to calculate the quantity of flow through an aquifer must be averaged and estimated. To determine the flow requires a value for the average transmissivity of the aquifer, an average hydraulic gradient and an estimate for the width of the aquifer. For the present program, the flow has been estimated for the four geounits in the AOI.

The flow through each aquifer assumes that by taking a large enough area, an aquifer can be considered as homogeneous, the average gradient can be estimated from the non-pumping water-level surface, and flow takes place through the entire width of the aquifer; flow through the aquifers takes into consideration hydrogeological conditions outside the AOI. Based on these assumptions, the estimated lateral groundwater flow through the individual geounits has been calculated. The calculations of flow through individual geounits as presented in the following figures are very approximate and are intended only as a guide; more detailed investigations are needed to better understand the groundwater flow.

### 5.2.1. Geounit 4

The adjacent figure indicates that there are three areas where groundwater flow has been estimated in Geounit 4. The non-pumping water-level surface determined in Geounit 4 indicated that the groundwater divides roughly corresponded to the surface-water divides; i.e., the three surface-water basins. The groundwater from Geounit 4, where Geounit 4 is present, which flows downgradient to the east toward Gull Lake, has an estimated aquifer flow of 1,000 $m^3$/day. The current groundwater diversion in this area from licensed and registered groundwater users, and domestic/stock water well use in Geounit 4, is estimated to be 58 $m^3$/day. A groundwater diversion of 58 $m^3$/day represents 6% of the estimated aquifer flow of 1,000 $m^3$/day in Geounit 4 in this area.




***Geounit 4 – Groundwater Flow and Groundwater Use***

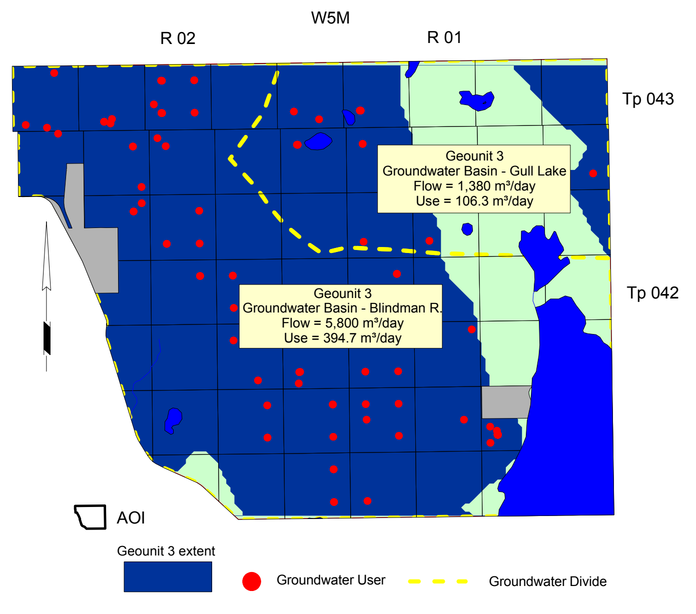
The groundwater from Geounit 4, where Geounit 4 is present, which flows downgradient to the west toward Lloyd Creek, has an estimated aquifer flow of 1,875 $m^3$/day. The current groundwater diversion in this area from licensed and registered groundwater users, and domestic/stock water well use in Geounit 4, is estimated to be 60 $m^3$/day. A groundwater diversion of 60 $m^3$/day represents 3% of the estimated aquifer flow of 1,875 $m^3$/day in Geounit 4 in this area.

The groundwater from Geounit 4, where Geounit 4 is present, which flows downgradient to the west toward the Blindman River, has an estimated aquifer flow of 1,750 $m^3$/day. The current groundwater diversion in this area from licensed and registered groundwater users, and domestic/stock water well use in Geounit 4, is estimated to be 226 $m^3$/day. A groundwater diversion of 226 $m^3$/day represents 13% of the estimated aquifer flow of 1,750 $m^3$/day in Geounit 4 in this area.

However, even though the groundwater use is less than the calculated aquifer flow, there can still be local impacts on water levels.

### 5.2.2. Geounit 3

The adjacent figure indicates that there are two areas where groundwater flow has been estimated in Geounit 3. The non-pumping water-level surface determined in Geounit 3 indicated that there is one groundwater divide as depicted by the dashed yellow line. The groundwater from Geounit 3, where Geounit 3 is present, which flows downgradient mainly northeasterly in the Gull Lake groundwater basin, has an estimated aquifer flow of 1,380 m³/day. The current groundwater diversion in the area from licensed and registered groundwater users, and domestic/stock water well use in Geounit 3, is estimated to be 106 m³/day. A groundwater diversion of 106 m³/day represents 8% of the estimated aquifer flow of 1,380 m³/day in Geounit 3 in this area.



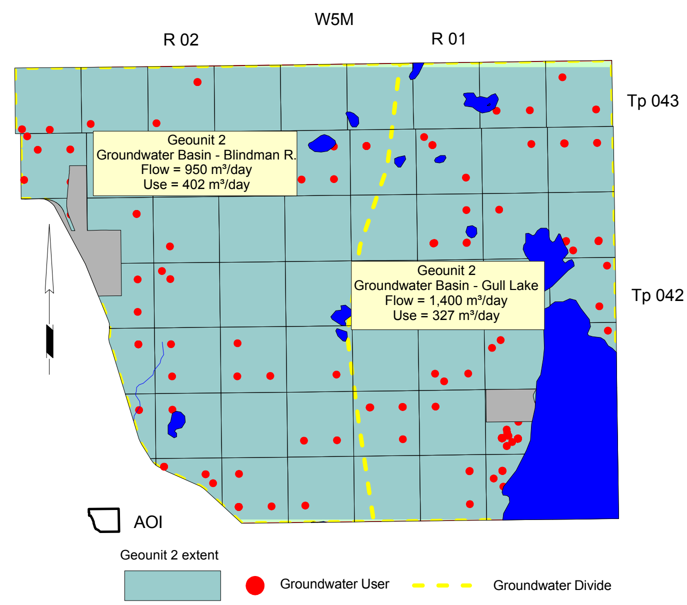

***Geounit 3 – Groundwater Flow and Groundwater Use***

The groundwater from Geounit 3, where Geounit 3 is present, which flows downgradient to the west toward the Blindman River, has an estimated aquifer flow of 5,800 m³/day. The current groundwater diversion in this area from licensed and registered groundwater users, and domestic/stock water well use in Geounit 3, is estimated to be 395 m³/day. A groundwater diversion of 395 m³/day represents 6.8 % of the estimated aquifer flow of 5,800 m³/day in Geounit 3 in this area.

However, even though the groundwater use is less than the calculated aquifer flow, there can still be local impacts on water levels.

### 5.2.3. Geounit 2

The adjacent figure indicates that there are two areas where groundwater flow has been estimated in Geounit 2. The non-pumping water-level surface determined in Geounit 2 indicated that there is one groundwater divide as depicted by the dashed yellow line. The groundwater flowing through Geounit 2, which flows downgradient to the east toward Gull Lake, has an estimated volume of 1,400 m³/day. The current groundwater diversion in this area from licensed and registered groundwater users, and domestic/stock water well use in Geounit 2, is estimated to be 327 m³/day. A groundwater diversion of 327 m³/day represents 23% of the estimated aquifer flow of 1,400 m³/day in Geounit 2 in this area.



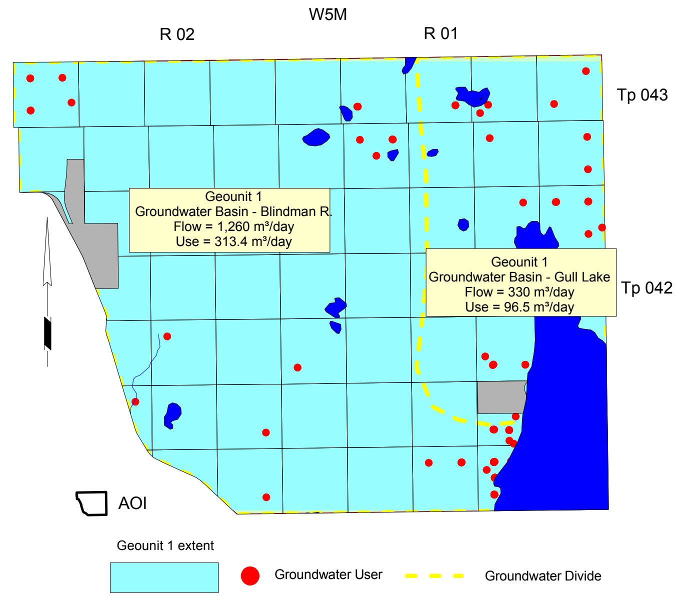

***Geounit 2 – Groundwater Flow and Groundwater Use***

The groundwater from Geounit 2, which flows downgradient to the west toward the Blindman River, has an estimated aquifer flow of 950 m³/day. The current groundwater diversion in this area from licensed and registered groundwater users, and domestic/stock water well use in Geounit 2, is estimated to be 400 m³/day. A groundwater diversion of 400 m³/day represents 42% of the estimated aquifer flow of 950 m³/day in Geounit 2 in this area.

However, even though the groundwater use is less than the calculated aquifer flow, there can still be local impacts on water levels.

### 5.2.4. Geounit 1

The adjacent figure indicates that there are two areas where groundwater flow has been estimated in Geounit 1. The non-pumping water-level surface determined in Geounit 1 indicated that there is one groundwater divide as depicted by the dashed yellow line; the groundwater divide also partially corresponds to the bedrock surface. The groundwater flow through Geounit 1, which flows downgradient to the east toward Gull Lake, has an estimated volume of 330 m³/day. The current groundwater diversion in this area from licensed and registered groundwater users, and domestic/stock water well use in Geounit 1, is estimated to be 97 m³/day. A groundwater diversion of 97 m³/day represents 29% of the estimated aquifer flow of 330 m³/day in Geounit 1 in this area.




***Geounit 1 – Groundwater Flow and Groundwater Use***

The groundwater from Geounit 1, which flows downgradient to the west toward Blindman River, has an estimated aquifer flow of 1,260 m³/day. The current groundwater diversion in this area from licensed and registered groundwater users, and domestic/stock water well use in Geounit 1, is estimated to be 313 m³/day. A groundwater diversion of 313 m³/day represents 25% of the estimated aquifer flow of 1,260 m³/day in Geounit 1 in this area.

However, even though the groundwater use is less than the calculated aquifer flow, there can still be local impacts on water levels.

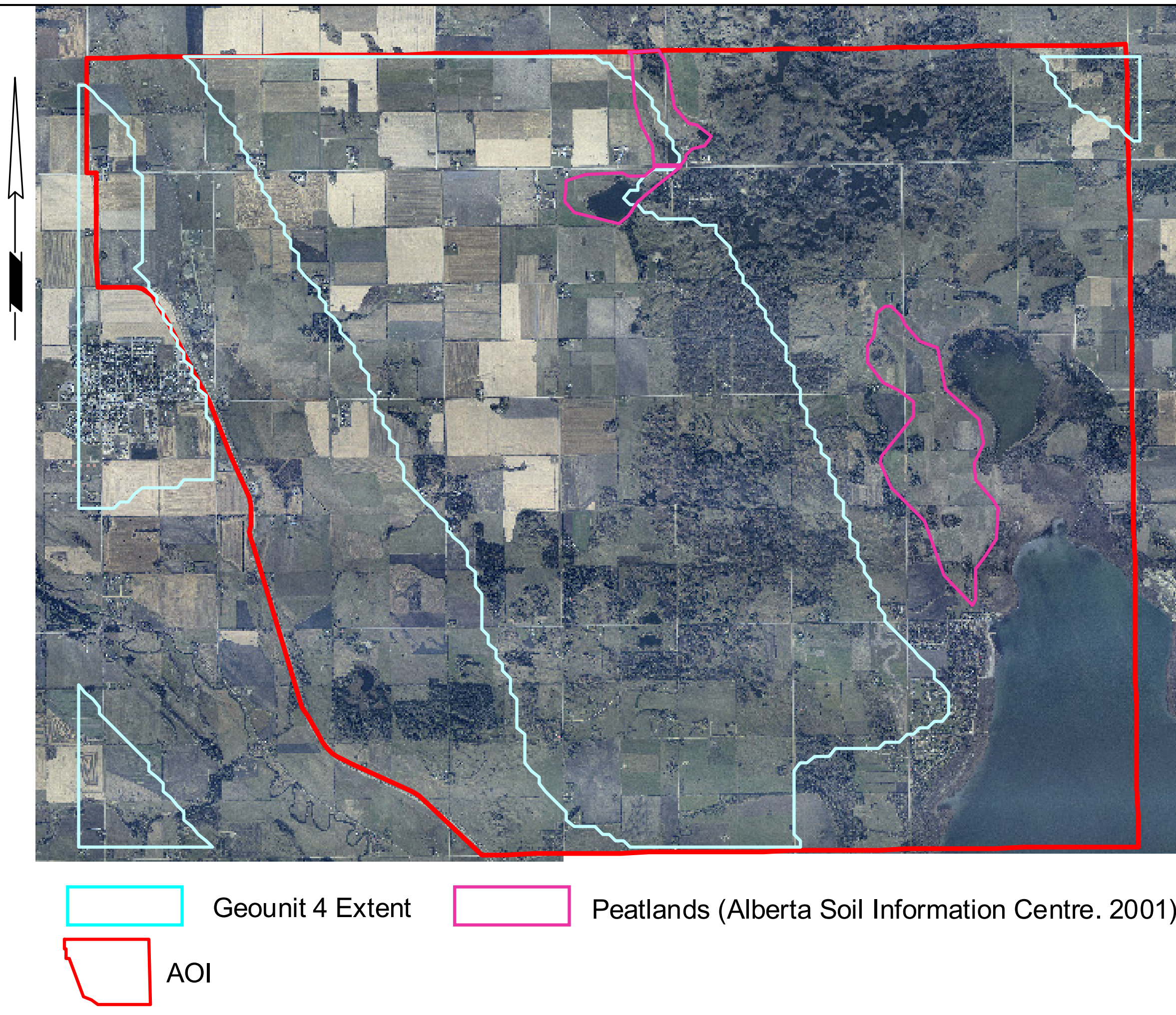
## 5.3. Wetlands

There are no data readily available for wetlands in the AOI, and in particular away from the immediate area of Gull Lake. If there are wetlands away from Gull Lake, it was anticipated that the wetlands would be maintained by discharge from Geounit 4. In order to support this theory, the geologic extent of Geounit 4 was added to the aerial photograph of the AOI, as shown in the figure on the next page. Also shown on the aerial photograph are “peatland” areas.

The figure on the following page indicates that the largest of the two shown peatlands occurs in the low area that is an extension of Gull Lake. The second peatland area occurs at the eastern limit of Geounit 4 at the north end of the AOI. This peatland is believed to be receiving groundwater discharge from Geounit 4.

Along the western limit of the main area where Geounit 4 is present, there is evidence from the aerial photograph that there are indications of excess moisture. The excess moisture conditions have not resulted in the formation of peatlands, but clearly the conditions have limited cultivation of the land. The excess moisture condition appears to be resulting from the discharge of groundwater from Geounit 4.

The wetlands associated with Geounit 4 may be impacted if there is significant discharge from water wells completed in Geounit 4.




***Aerial Photograph indicating Areas of Potential Wetlands in Association with Geounit 4***

## 5.4. Infiltration Rates

There are very little quantitative data available with respect to land-use changes. However, the proposed changes in land use would not be expected to have a significant impact on groundwater infiltration rates.

## 6. Conclusions

The groundwater flow through the four geounits that underlie the AOI is estimated to be 15,745 $m^3$/day. The current groundwater use from the four units is estimated to be 1,984 $m^3$/day. The total current estimated groundwater use from the four geounits, multiple bedrock aquifer(s), and unknown aquifers is 2,650 $m^3$/day, which represents 17% of the estimated aquifer flow of 15,745 $m^3$/day in the four geounits in the AOI.

The proposed development of 1,400 lots on land west of Gull Lake will require water supplies in the range of 70 to 2,000 $m^3$/day. The estimated value of 2,000 $m^3$/day plus the current groundwater use of 2,650 $m^3$/day totals 4,650 $m^3$/day. The total current and proposed groundwater use of 4,650 $m^3$/day represents 30% of the estimated aquifer flow of 15,745 $m^3$/day in the AOI, meaning that a supply of 2,000 $m^3$/day is available for the development of 1,400 lots.

The aquifers present in the area of interest are expected to be able to provide groundwater supplies to satisfy the water needs. The two main water bodies that would be affected by groundwater diversion would be Gull Lake and the Blindman River. In the Gull Lake Basin, the groundwater development should focus on Geounit 3 and Geounit 1 to minimize the effects on water levels in Gull Lake. In the Blindman River Basin, the groundwater development should focus on Geounit 2 and Geounit 1 to minimize the effects on the Blindman River water levels.

The remaining geounit, Geounit 4, is only present west of Gull Lake in the topographically higher areas between Gull Lake and the Blindman River. The total groundwater flow through Geounit 4 is estimated to be 4,625 $m^3$/day. The groundwater in Geounit 4 would reach Gull Lake and the Blindman River only after the groundwater has been discharged to the land surface. Because wetlands away from Gull Lake would be maintained by discharge from Geounit 4 and because there has not been significant development of aquifers in Geounit 4, the expectation is that future development will not include aquifers within Geounit 4. If Geounit 4 is not developed for additional groundwater supplies, the wetlands away from the Lake will not be impacted; wetlands near the Lake would not be expected to be affected by groundwater use.

There are very little quantitative data available with respect to land-use changes. However, the proposed changes in land use would not be expected to have a significant impact on groundwater infiltration rates in the AOI.

# 7. Recommendations

Because local hydrogeological conditions may vary significantly within the AOI, it is recommended that background information be collected. One type of background data that is required is the spatial position of area water wells. The second type of data includes the frequent measuring of water levels in selected water wells. Therefore, it is recommended that the following work be undertaken:

- A field-verified water well survey in the area of the proposed development. The horizontal coordinates of the water wells should be determined within ten metres; a consumer-grade GPS is adequate for this purpose.
- It is recommended that the County initiate a groundwater monitoring program within the AOI. To that end, the County has suggested that the following three water well owners might be receptive to having their water wells utilized in the groundwater monitoring program: the Gull Lake Golf Course, the Herman Wegman Water Well (WW) in Polsens Estates, and the Bruce Phillips WW at Sunnyside.

HCL would be pleased to assist the County in establishing a program to collect the baseline information.

Gill Poulter, P.Geol.
Hydrogeologist

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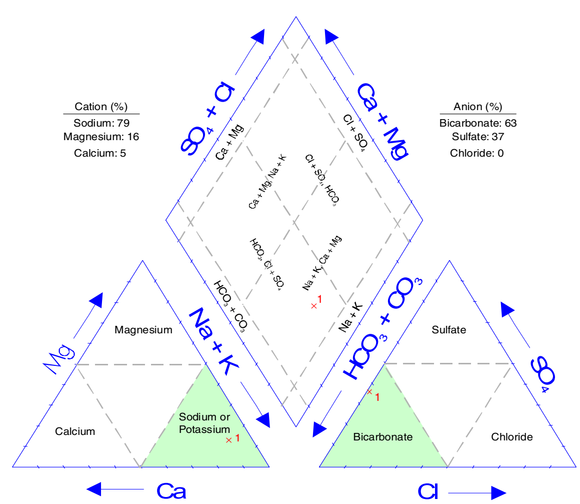
# 9. Glossary

| | |
|---|---|
| AENV | Alberta Environment |
| AMSL | above mean sea level |
| AOI | Area of Interest |
| AOS | Area of Study |
| Aquifer | a formation, group of formations, or part of a formation that contains saturated permeable rocks capable of transmitting groundwater to water wells or springs in economical quantities |
| BGL | Below Ground Level |
| DEM | Digital Elevation Model |
| km | kilometre |
| Kriging | a geo-statistical method for gridding irregularly-spaced data (Cressie, 1990) |
| $m^3$ | cubic metres |
| $m^3$/day | cubic metres per day |
| mg/L | milligrams per litre |
| NPWL | non-pumping water level |
| PFRA | Prairie Farm Rehabilitation Administration |
| Piper tri-linear diagram | a method that permits the major cation and anion compositions of single or multiple samples to be represented on a single graph. This presentation allows groupings or trends in the data to be identified. From the Piper tri-linear diagram, it can be seen that the groundwater from this sample water well is a sodium-bicarbonate-type. The chemical type has been determined by graphically calculating the dominant cation and anion. For a more detailed explanation, please refer to Freeze and Cherry, 1979 |
| Surficial Deposits | includes all sediments above the bedrock |
| TDS | Total Dissolved Solids |




***Piper tri-linear diagram***

| | |
|---|---|
| Transmissivity | the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient: a measure of the ease with which groundwater can move through the aquifer<br><br>Apparent Transmissivity: the value determined from a summary of aquifer test data, usually involving only two water-level readings<br><br>Effective Transmissivity: the value determined from late pumping and/or late recovery water-level data from an aquifer test<br><br>Aquifer Transmissivity: the value determined by multiplying the hydraulic conductivity of an aquifer by the thickness of the aquifer |
| VE | Vertical Exaggeration |
| Yield | a regional analysis term referring to the rate a properly completed water well could be pumped, if fully penetrating the aquifer<br><br>Apparent Yield: based mainly on apparent transmissivity<br><br>Long-Term Yield: based on effective transmissivity |

# Stratigraphy of the “Undisturbed” Geology of Alberta as used by Hydrogeological Consultants Ltd.

- upper surficial
- lower surficial
- Cypress Hills Fm
- Dalehurst Member
- upper part of Lacombe Member
- lower part of Lacombe Member
- Haynes Member
- upper part of Scollard Fm
- lower part of Scollard Fm
- Battle/Whitemud Fms
- upper part of Horseshoe Canyon Fm
- middle part of Horseshoe Canyon Fm
- lower part of Horseshoe Canyon Fm
- Bearpaw Fm
- Oldman Fm
- Foremost Fm
- Lea Park Fm
- Milk River Fm
- Colorado Shale
- Cardium Fm
- Kaskapau Fm
- Dunvegan Fm
- Shaftesbury Fm
- Viking Fm
- Joli Fou Fm
- upper part of Mannville Grp
- middle part of Mannville Grp
- lower part of Mannville Grp
- Jurassic
- Triassic
- upper part of Paleozoic
- Banff Fm
- Wabamun Group
- Winterburn Group
- Woodbend Group
- Beaverhill Lake Group
- Elk Point Group
- Precambrian

## 10. Conversions

| Multiply | by | To Obtain |
|---|---|---|
| **Length/Area** | | |
| feet | 0.304 785 | metres |
| metres | 3.281 000 | feet |
| hectares | 2.471 054 | acres |
| centimetre | 0.032 808 | feet |
| centimetre | 0.393 701 | inches |
| acres | 0.404 686 | hectares |
| inches | 25.400 000 | millimetres |
| miles (statute) | 1.609 344 | kilometres |
| kilometres | 0.621 370 | miles (statute) |
| square feet ($ft^2$) | 0.092 903 | square metres ($m^2$) |
| square metres ($m^2$) | 10.763 910 | square feet ($ft^2$) |
| square metres ($m^2$) | 0.000 001 | square kilometres ($km^2$) |
| **Concentration** | | |
| grains/gallon (UK) | 14.270 050 | parts per million (ppm) |
| parts per million (ppm) | 0.998 859 | milligrams per litre (mg/L) |
| milligrams per litre (mg/L) | 1.001 142 | parts per million (ppm) |
| **Volume (capacity)** | | |
| acre feet | 1233.481 838 | cubic metres |
| cubic feet | 0.028 317 | cubic metres |
| cubic metres | 35.314 667 | cubic feet |
| cubic metres | 219.969 248 | imperial gallons (UK) |
| cubic metres | 264.172 050 | gallons (US liquid) |
| cubic metres | 1000.000 000 | litres |
| imperial gallons (UK) | 0.004 546 | cubic metres |
| imperial gallons (UK) | 4.546 000 | litres |
| **Rate** | | |
| litres per minute | 0.219 974 | imperial gallons per minute (ipgm) |
| litres per minute | 1.440 000 | cubic metres/day ($m^3$/day) |
| imperial gallons per minute (igpm) | 6.546 300 | cubic metres/day ($m^3$/day) |
| cubic metres/day ($m^3$/day) | 0.152 759 | imperial gallons per minute (ipgm) |
| **Pressure** | | |
| pound per square inch (psi) | 6.894 757 | kilopascal (kpa) |
| kilopascal (kpa) | 0.145 038 | pound per square inch (psi) |
| **Miscellaneous** | | |
| Celsius | $F^\circ = 9/5\ (C^\circ + 32)$ | Fahrenheit |
| Fahrenheit | $C^\circ = (F^\circ - 32) * 5/9$ | Celsius |
| degrees | 0.017 453 | radians |