3) Chemical Quality of Groundwater

The TDS concentrations in the groundwaters from the upper bedrock aquifer(s) range from less than 500 to more than 2,500 mg/L.

The relationship between TDS and sulfate concentrations shows that when TDS values in the groundwater from the upper bedrock aquifer(s) exceed 1,200 mg/L, the sulfate concentrations exceed 400 mg/L. The chloride concentrations in the groundwaters from the upper bedrock aquifer(s) are less than 100 mg/L in more than 75% of the County. The higher chloride values can be expected in the southeastern part of the County, with 65% of the bedrock water wells having completion depths of less than 70 metres.

In 95% of the County, the fluoride ion concentrations in the groundwaters from the upper bedrock aquifer(s) are less than 1 mg/L.

The Piper tri-linear diagrams[18] (see Appendix A) show that all chemical types of groundwater occur in the bedrock aquifers. However, the majority of the groundwaters are sodium-bicarbonate or sodium-sulfate types.

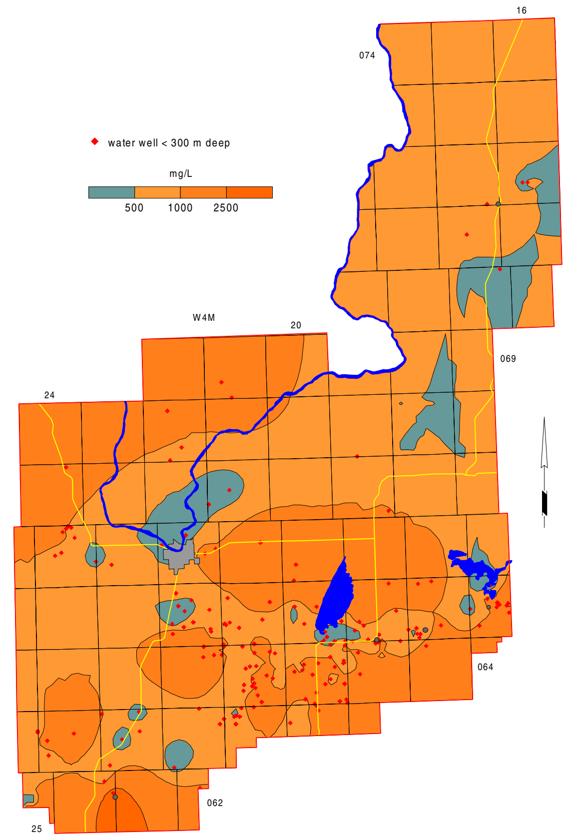

Figure 16. Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

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[18] See glossary

4) Birch Lake Aquifer

The Birch Lake Aquifer comprises the porous and permeable parts of the Birch Lake Member, as defined for the present program. Structure contours have been prepared for the top and bottom of the Member, which underlies the southwestern part of the County. The structure contours show the Member has a maximum thickness of 65 metres.

a) Depth to Top

The depth to the top of the Birch Lake Member is mainly less than 30 metres below ground level and is a reflection of the thickness of the surficial deposits.

b) Apparent Yield

The apparent yields for individual water wells completed through the Birch Lake Aquifer are mainly in the range of ten to 100 m³/day. The areas where water wells with higher yields are expected are mainly associated with the edge of the Aquifer.

c) Quality

The groundwaters from the Birch Lake Aquifer are mainly a sodium-bicarbonate type (see CD-ROM), with the TDS concentrations ranging mainly from 500 to 750 mg/L. The lower values of TDS occur mainly in townships 063 and 064, ranges 19, 20 and 21, W4M. When TDS values in the groundwaters from the Birch Lake Aquifer exceed 1,200 mg/L, the sulfate concentrations exceed 400 mg/L.

The chloride concentrations of the groundwaters from the Birch Lake Aquifer can be expected to be mainly less than 50 mg/L.

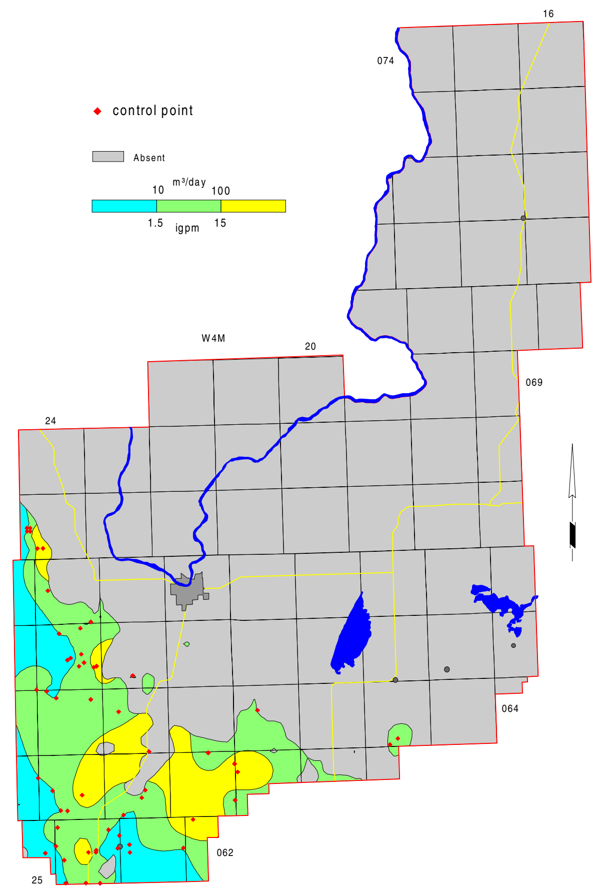

Figure 17. Apparent Yield for Water Wells Completed through Birch Lake Aquifer

5) Ribstone Creek Aquifer

The Ribstone Creek Aquifer comprises the porous and permeable parts of the Ribstone Creek Member. Structure contours have been prepared for the top and bottom of the Member, which underlies most of the southwestern one-third of the County. The structure contours show the Member having a maximum thickness of 50 metres.

a) Depth to Top

The depth to the top of the Ribstone Creek Member is mainly less than 80 metres below ground level but can be more than 120 metres where the Oldman Formation is the upper bedrock.

b) Apparent Yield

The apparent yields for individual water wells completed through the Ribstone Creek Aquifer are mainly in the range of ten to 50 m³/day, with 25% of the values being more than 50 m³/day. The areas where water wells with higher yields are expected are mainly in the western and eastern parts of the County where the Aquifer is present.

c) Quality

The groundwaters from the Ribstone Creek Aquifer are mainly calcium-bicarbonate or sodium-bicarbonate types (see Piper diagram on CD-ROM). The TDS concentrations range from less than 1,000 to more than 1,500 mg/L. The sulfate concentrations are mainly less than 500 mg/L. Chloride concentrations in the groundwaters from the Ribstone Creek Aquifer are mainly less than 100 mg/L, with concentrations increasing with depth of burial of the Aquifer.

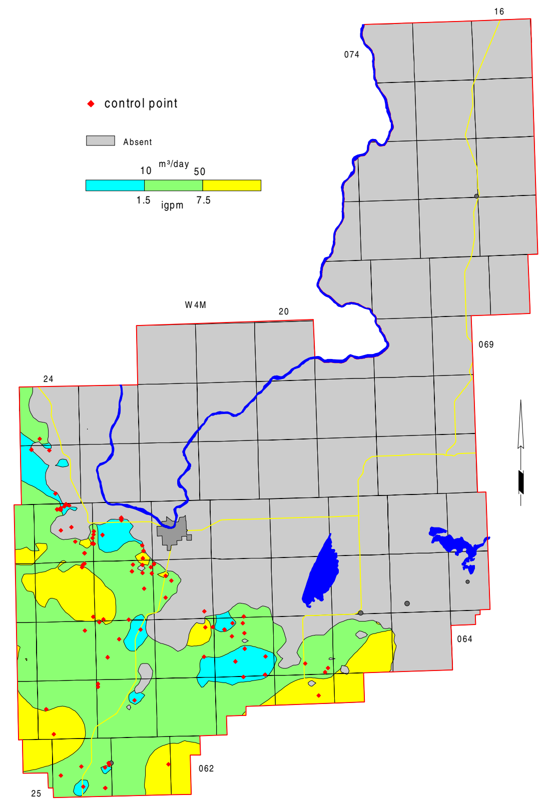

Figure 18. Apparent Yield for Water Wells Completed through Ribstone Creek Aquifer

6) Victoria Aquifer

The Victoria Aquifer comprises the porous and permeable parts of the Victoria Member. Structure contours have been prepared for the top of the Member, which underlies the southwestern third of the County. The structure contours show the Member having a maximum thickness of 35 metres.

a) Depth to Top

The depth to the top of the Victoria Member is mainly less than 120 metres below ground level but can be more than 160 metres in parts of the southwestern part of the County, where the Oldman Formation is the upper bedrock.

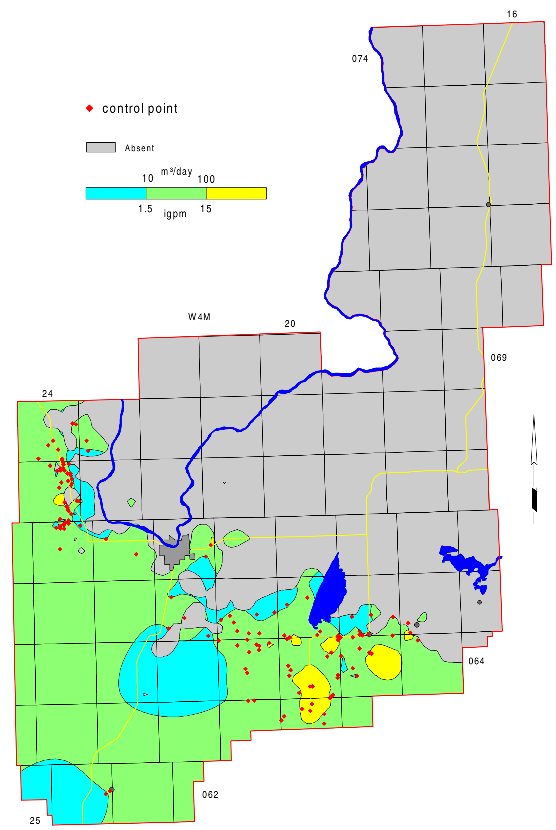

Figure 19. Apparent Yield for Water Wells through Victoria Aquifer

b) Apparent Yield

The apparent yields for individual water wells completed through the Victoria Aquifer range mainly from ten to 100 m³/day. However, the control points are mainly limited to where the Member is the upper bedrock. The adjacent map indicates that water wells with apparent yields of more than 100 m³/day are expected mainly in townships 063 and 064, ranges 19 and 20, W4M. There are little or no data for the Aquifer in the southwestern part of the County. In this area, the Victoria Aquifer would be at a depth of more than 120 metres.

c) Quality

The groundwaters from the Victoria Aquifer are mainly calcium-bicarbonate or sodium-bicarbonate types (see Piper diagram on CD-ROM). Total dissolved solids concentrations are expected to range mainly from 750 to 1,500 mg/L, although there is a paucity of data where the depth of burial is greater than 100 metres. However, since most of the Victoria Member is above the Base of Groundwater Protection, the TDS would still be expected to be less than 4,000 mg/L.

Sulfate concentrations of less than 100 mg/L in the groundwaters from the Victoria Aquifer can be expected where the Victoria Member is the upper bedrock, and sulfate concentrations ranging mainly from 100 to 500 mg/L can be expected in the rest of the County where the Member is present. The indications are that chloride concentrations are expected to be less than 50 mg/L.

7) Brosseau Aquifer

The Brosseau Aquifer comprises the porous and permeable parts of the Brosseau Member. Structure contours have been prepared for the top of the Member, which underlies the southwestern third of the County. The structure contours show the Member having an average thickness of 15 metres.

a) Depth to Top

The depth to the top of the Brosseau Member is variable, ranging from less than 20 metres near the Athabasca River to more than 220 metres in the southwestern part of the County.

b) Apparent Yield

The apparent yields for individual water wells completed through the Brosseau Aquifer range mainly from ten to 100 m³/day. However, the control points are mainly limited to where the Member is the upper bedrock. The adjacent map indicates that water wells with apparent yields of more than 300 m³/day are expected mainly in townships 063 and 064, ranges 18 to 20, W4M. There are little or no data for the Aquifer in the southwestern part of the County. In this area, the Brosseau Aquifer would be at a depth of more than 140 metres.

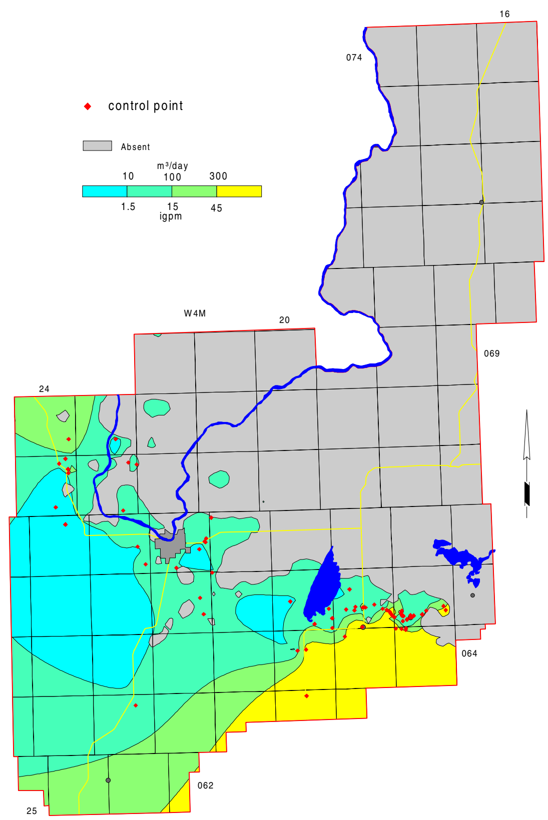

Figure 20. Apparent Yield for Water Wells Completed through Brosseau Member

c) Quality

There are nine water well records in the groundwater database with sufficient information to determine the chemical type of groundwaters from the Brosseau Aquifer in the County of Athabasca. The groundwaters are bicarbonate-type waters with no dominant cation.

There are eight water well records in the database for the County with TDS, sulfate and chloride concentrations; the TDS values are mainly between 500 and 1,000 mg/L, the sulfate values are mainly less than 250 mg/L, and the chloride values are less than 100 mg/L.

VI. GROUNDWATER BUDGET

A. Hydrographs

There is one location in the County where water levels are being measured and recorded with time. This site is an observation water well (Obs WW) that is part of the AE regional groundwater-monitoring network. The hydrograph for AE Obs WW No. 252 in 13-06-065-24 W4M is shown on the adjacent figure, in Appendix A, and included on the CD-ROM.

The water-level fluctuations in AE Obs WW No. 252 in 13-06-065-24 W4M have been compared to the summer precipitation measured at the Cross Lake weather station from 1986 to 1998; the comparison is shown in the adjacent figure. The observation water well is completed at a depth of 26.8 metres below ground level in the Upper Surficial Deposits. The summer precipitation includes the total precipitation measured in May, June, July and August of each year. The comparison shows that, in general, the water-level fluctuation does not reflect the changes in summer precipitation.

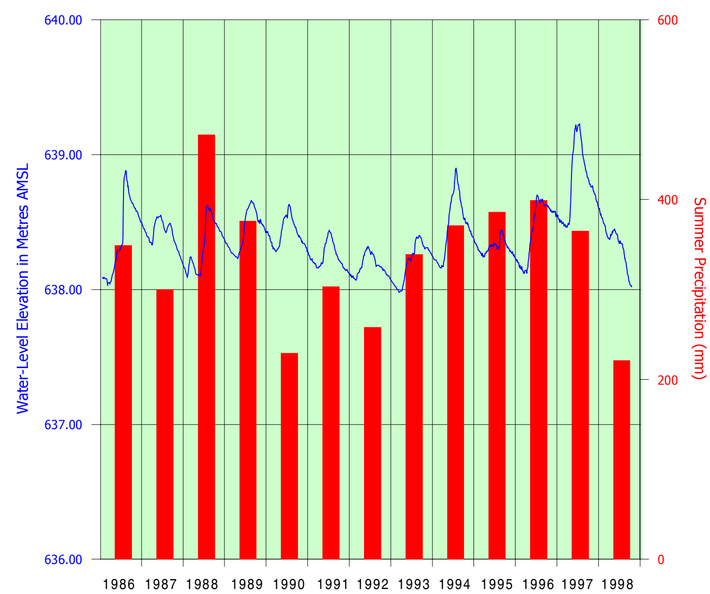

Figure 21. Annual Precipitation vs Water Levels in AE Obs WW No. 252

The water-level graph does show a "typical" yearly fluctuation in the water levels in aquifers in Alberta. The water level rises in late spring/early summer and declines until late spring/early summer of the next year. In 1995, there is no pronounced late spring/early summer water-level rise but a slight rise late in the summer. This would suggest that there was insufficient moisture available for recharge as the frost was leaving the ground but sufficient precipitation later in the year to overcome any soil moisture deficiency to allow for some groundwater recharge.

B. Groundwater Flow

A direct measurement of groundwater recharge or discharge is not possible from the data that are available for the County. One indirect method of measuring recharge is to determine the quantity of groundwater flowing laterally through each individual aquifer. This method assumes that there is sufficient recharge to the aquifer to maintain the flow through the aquifer and the discharge is equal to the recharge. However, even the data that can be used to calculate the quantity of flow through an aquifer must be averaged and estimated.

1) Quantity of Groundwater

The adjacent water-level map has been prepared from water levels associated with water wells completed in aquifers in the surficial deposits. These water levels were used for the calculation of the saturated thickness of the surficial deposits. In areas where the elevation of the water-level surface is below the bedrock surface, the surficial deposits are not saturated. The water-level map for the surficial deposits shows a general flow direction toward the Athabasca River.

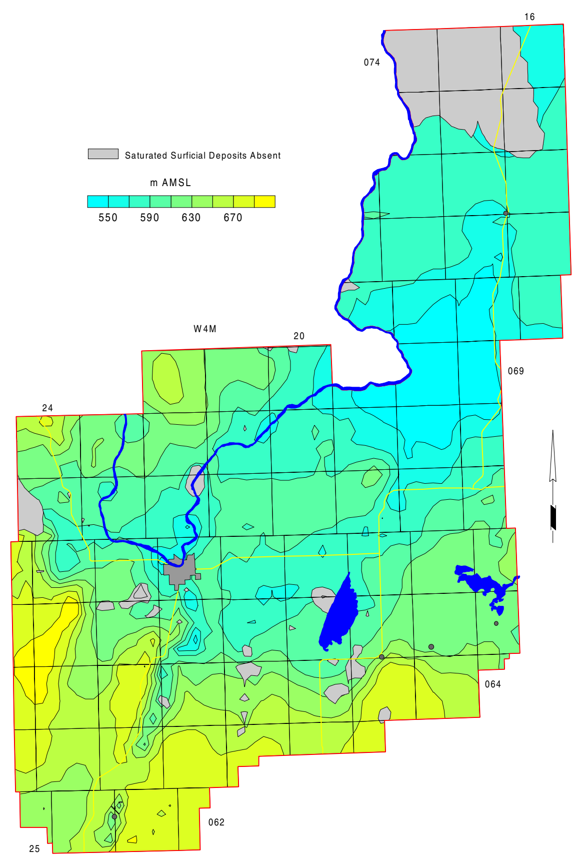

Figure 22. Non-Pumping Water-Level Surface in Surficial Deposits

2) Recharge/Discharge

The hydraulic relationship between the groundwater in the surficial deposits and the groundwater in the bedrock aquifers is given by the non-pumping water-level surface associated with each of the hydraulic units. Where the water level in the surficial deposits is at a higher elevation than the water level in the bedrock aquifers, there is the opportunity for groundwater to move from the surficial deposits into the bedrock aquifers. This condition would be considered as an area of recharge to the bedrock aquifers and an area of discharge from the surficial deposits. The amount of groundwater that would move from the surficial deposits to the bedrock aquifers is directly related to the vertical permeability of the sediments separating the two aquifers. In areas where the surficial deposits are unsaturated, the extrapolated water level for the surficial deposits is used.

When the hydraulic gradient is from the bedrock aquifers to the surficial deposits, the condition is a discharge area from the bedrock aquifers, and a recharge area to the surficial deposits.

a) Surficial Deposits/Bedrock Aquifers

The hydraulic gradient between the surficial deposits and the upper bedrock aquifer(s) has been determined by subtracting the non-pumping water-level surface associated with all water wells completed in the upper bedrock aquifer(s) from the non-pumping water-level surface determined for all water wells in the surficial deposits. The recharge classification is used where the water level in the surficial deposits is more than five metres above the water level in the upper bedrock aquifer(s). The discharge areas are where the water level in the surficial deposits is more than five metres lower than the water level in the bedrock. When the water level in the surficial deposits is between five metres above and five metres below the water level in the bedrock, the area is classified as a transition, that is, no recharge and no discharge.

The adjacent map shows that, in more than 75% of the County, there is a downward hydraulic gradient (i.e. recharge) from the surficial deposits toward the upper bedrock aquifer(s). Areas where there is an upward hydraulic gradient from the bedrock to the surficial deposits are mainly in the vicinity of linear bedrock lows. The remaining parts of the County are areas where there is a transition condition.

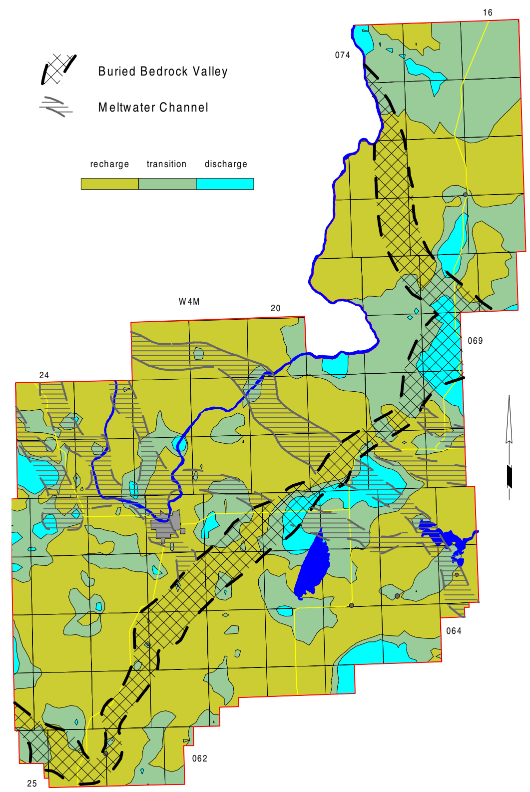

Figure 23. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)

Because of the paucity of data, a calculation of the volumes of groundwater entering and leaving the surficial deposits has not been attempted.

b) Bedrock Aquifers

Recharge to the bedrock aquifers within the County takes place from the overlying surficial deposits and from flow in the aquifer from outside the County. The recharge/discharge maps show that generally for most of the County, there is a downward hydraulic gradient from the surficial deposits to the bedrock, i.e. recharge to the bedrock aquifers. On a regional basis, calculating the quantity of water involved is not possible because of the complexity of the geological setting and the limited amount of data. However, because of the generally low permeability of the upper bedrock materials, the volume of water is expected to be small.

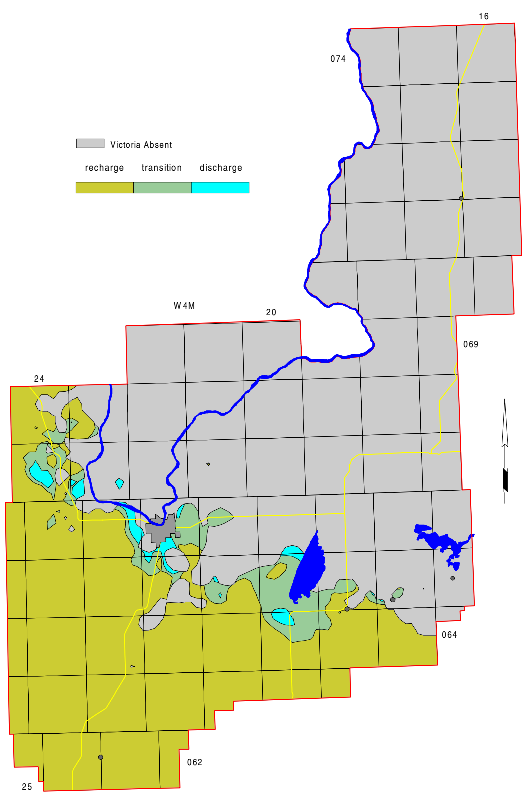

Figure 24. Recharge/Discharge Areas between Surficial Deposits and Victoria Aquifer

The hydraulic relationship between the surficial deposits and the Victoria Aquifer indicates that in more than 95% of the County where the Victoria Aquifer is present, there is a downward hydraulic gradient (i.e. recharge). Discharge areas for the Victoria Aquifer are mainly associated with the edge of the Aquifer. The hydraulic relationship between the surficial deposits and the remainder of the bedrock aquifers indicates there is also mainly a downward hydraulic gradient.

C. Groundwater Flow Model

A USGS 3-D Modflow groundwater model was prepared for the County. A simulation was completed using the model. The model has five layers, one layer for each geological unit. The values for the transmissivity distribution for each geological unit were determined using an automated calibration method. The main criterion for the calibration is the water level in the surficial deposits. The initial values for transmissivity distribution were the values determined from the present study. The model results are considered very approximate and are meant to support the regional study. The model needs considerably more data before it could be used for management of the groundwater resource in the County.

The adjacent figure shows the water-level surface for the surficial deposits for the model. There are five main groundwater recharge areas; the main discharge points are the Athabasca River and Tawatinaw River.

The results of the model were used to prepare the following table:

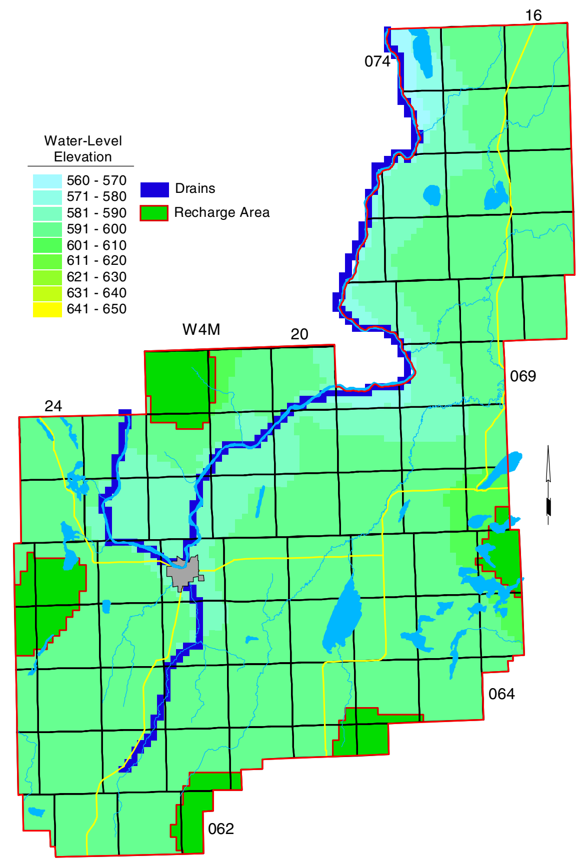

Figure 25. Modelled Non-Pumping Water-Level Surface in Surficial Deposits

Aquifer/Area	Horizontal Volume (m^3/day)	Vertical Volume (m^3/day)	General Horizontal Direction of Flow	Volume (m^3/day)	Aquifer Volume (m^3/day)	Authorized Diversion (m^3/day)
Upper Surficial					10,700	2,956
Southeastern area	5160	2300	northwest	7460		
Southwestern area	975	1785	northeast	2760		
Northern area	511	0	south	511		
Birch Lake					4,500	54
Southeastern area	1340	1000	northwest	2340		
Southwestern area	1450	700	northeast	2150		
Ribstone Creek					3,300	90
Southeastern area	850	900	northwest	1750		
Southwestern area	980	600	northeast	1580		
Victoria					2,900	87
Southeastern area	480	500	northwest	980		
Southwestern area	1480	400	northeast	1880		
Brosseau					1,600	14
Southeastern area	565	565	northwest	1130		
Southwestern area	250	250	northeast	500		

Table 7. Groundwater Budget

The data provided in the adjacent table indicate there is more groundwater flowing through the individual bedrock aquifers than has been authorized to be diverted from each aquifer. The calculations of flow through individual aquifers as presented in the above table are very approximate and are intended as a guide for future investigations.

VII. POTENTIAL FOR GROUNDWATER CONTAMINATION

The most common sources of contaminants that can impact groundwater originate on or near the ground surface. The contaminant sources can include leachate from landfills, effluent from leaking lagoons or from septic fields, and petroleum products from storage tanks or pipeline breaks. Additional agricultural activities that generate contaminants include the improper spreading of fertilizers, pesticides, herbicides and manure. The spreading of highway salt can also degrade groundwater quality.

When activities occur that can or do produce a liquid that could contaminate groundwater, it is prudent (from a hydrogeological point of view) to locate the activities where the risk of groundwater contamination is minimal. Alternatively, if the activities must be located in an area where groundwater can be more easily contaminated, the necessary action must be taken to minimize the risk of groundwater contamination.

The potential for groundwater contamination is based on the concept that the easier it is for a liquid contaminant to move downward, the easier it is for the groundwater to become contaminated. In areas where there is groundwater discharge, liquid contaminants cannot enter the groundwater flow systems to be distributed throughout the area. In groundwater recharge areas, low-permeability materials impede the movement of liquid contaminants downward. Therefore, if the soils develop on a low-permeability parent material of till or clay, the downward migration of a contaminant is slower relative to a high-permeability parent material such as sand and gravel of fluvial origin. Once a liquid contaminant enters the subsurface, the possibility for groundwater contamination increases if it coincides with a higher permeability material within one metre of the land surface.

To determine the nature of the materials on the land surface, the Agricultural Region of Alberta Soil Inventory Database (AGRASID) (CAESA, 1998) has been reclassified based on the relative permeability. The classification of materials is as follows:

1) high permeability - sand and gravel
2) moderate permeability - silt, sand with clay, gravel with clay, and bedrock
3) low permeability - clay and till.

To identify the areas where sand and gravel can be expected within one metre of the ground surface, all groundwater database records with lithologies were reviewed. From a total of 4,529 records with lithological descriptions in the area of the County, 936 have the top of a sand and gravel deposit present within one metre of ground level. In the remaining 3,593 records, the first sand and gravel is deeper or not present. This information was gridded to prepare a distribution of where the first sand and gravel deposit could be expected within one metre of ground level.