4.3.5 Upper Horseshoe Canyon Aquifer

The Upper Horseshoe Canyon Aquifer comprises the porous and permeable parts of the Upper Horseshoe Canyon Formation. The Upper Horseshoe Canyon Formation subcrops under the surficial deposits in the majority of the County and underlies the Scollard Formation, where present. The Upper Horseshoe Canyon Formation varies from less than 20 metres thick at the eastern edge of the subcrop to more than 200 metres thick in Tp 050, R 14, W4M. Higher local permeability can be expected when the depth of burial is less than 100 metres and fracturing or weathering has occurred.

4.3.5.1 Depth to Top

The depth to the top of the Upper Horseshoe Canyon Formation is variable, ranging from less than 20 metres in areas of subcrop to more than 140 metres in townships 029 and 030, range 17, W4M where the Scollard Formation is present.

4.3.5.2 Apparent Yield

The apparent yields for individual water wells completed in the Upper Horseshoe Canyon Aquifer are mainly between 10 and 100 m³/day. The adjacent map indicates that apparent yields of more than 100 m³/day mainly are expected in the northwestern part of the County.

A water supply well for the Village of Morrin in NW 15-031-20 W4M (AEP, 1980) is reported to have a 20-year safe yield of more than 100 m³/day. The water supply well is completed in the Upper Horseshoe Canyon Aquifer in an area of the County where water wells yields are expected to be between 10 and 100 m³/day. This situation helps to illustrate that the maps are regional in nature and that the hydrogeological conditions at a given location must be determined by an appropriate groundwater investigation.

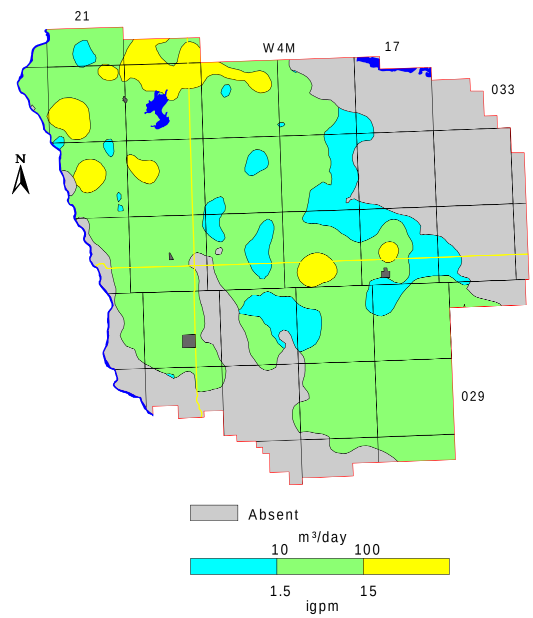

Figure 18. Apparent Yield for Water Wells Completed through Upper Horseshoe Canyon Aquifer

4.3.5.3 Quality

The groundwaters from the Upper Horseshoe Canyon Aquifer are mainly sodium-bicarbonate or sodium-sulfate types (see CD-ROM). The TDS concentrations are expected to be mainly less than 2,000 mg/L. The higher values are mostly in the western part of the County. The sulfate concentrations are usually less than 500 mg/L. Chloride concentrations in the groundwaters from the Upper Horseshoe Canyon are mainly less than 100 mg/L.

Groundwater from the Village of Morrin water supply well (AEP, 1980), that is completed in the Upper Horseshoe Canyon Formation, has a TDS concentration of 1,260 mg/L, a sulfate concentration of 20 mg/L and a chloride concentration of 64 mg/L.

4.3.6 Middle Horseshoe Canyon Aquifer

The Middle Horseshoe Canyon Aquifer comprises the porous and permeable parts of the Middle Horseshoe Canyon Formation that underlies the Upper Horseshoe Canyon Formation, and subcrops under the surficial deposits in a third of the southwestern and northeastern parts of the County. The thickness of the Middle Horseshoe Canyon Formation is mainly between 50 and 60 metres but varies from less than 10 metres at the northeastern and southwestern edges to more than 60 metres in the northwestern part of the County.

4.3.6.1 Depth to Top

The depth to the top of the Middle Horseshoe Canyon Formation is mainly less than 20 metres below ground level, but can be more than 220 metres in the southeastern part of the County in townships 029 and 030, range 17, W4M.

4.3.6.2 Apparent Yield

There are 54 control points used to prepare the map for apparent yield through the Middle Horseshoe Canyon Aquifer. Of 54 apparent yield values, 48% are less than 10 m³/day, 41% are between 10 and 100 m³/day and 11% are greater than 100 m³/day. The adjacent map shows that approximately 65% of the County is underlain by the Middle Horseshoe Canyon Formation where apparent yields are expected to be between 10 and 100 m²/day. This discrepancy occurs because of the distribution of the control points. The map shows the control points are concentrated in the eastern and southwestern parts of the County. There is a 15-kilometre-wide swath through the County, from the southeast to the northwest, where no data are available. The areas where water wells with higher yields are expected are in parts of township 033, ranges 18 and 19, W4M.

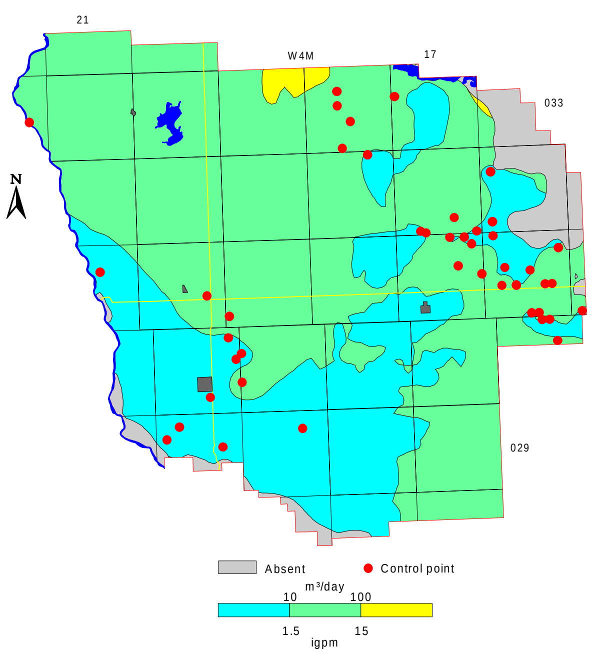

Figure 19. Apparent Yield for Water Wells Completed through Middle Horseshoe Canyon Aquifer

4.3.6.3 Quality

The groundwaters from the Middle Horseshoe Canyon Aquifer are mainly sodium-bicarbonate or sodium-sulfate types (see CD-ROM). The TDS concentrations are expected to be mostly less than 1,500 mg/L with higher values in the southwestern and northeastern parts of the County. The sulfate concentrations are mainly less than 500 mg/L. Chloride concentrations in the groundwaters from the Middle Horseshoe Canyon Aquifer are mainly less than 100 mg/L.

4.3.7 Lower Horseshoe Canyon Aquifer

The Lower Horseshoe Canyon Aquifer comprises the porous and permeable parts of the Lower Horseshoe Canyon Formation that underlies the Middle Horseshoe Canyon Formation, and either outcrops or subcrops along the southwestern edge of the County and subcrops in parts of townships 031 to 033, ranges 15 and 16, W4M. The thickness of the Lower Horseshoe Canyon Formation is mainly between 120 and 140 metres but varies from less than 60 metres at the southwestern edge to more than 160 metres along the northwestern edge of the County.

4.3.7.1 Depth to Top

The depth to the top of the Lower Horseshoe Canyon Formation varies from less than 20 metres to more than 280 metres below ground level. The greatest depth is in the southeastern part of the County in townships 029 and 030, range 17, W4M.

4.3.7.2 Apparent Yield

There are 35 control points used to prepare the map for apparent yield from the Lower Horseshoe Canyon Formation. Of 35 apparent yield values, 14% are less than 10 m³/day, 46% are between 10 and 100 m³/day and 40% are greater than 100 m³/day. The adjacent map shows that approximately 10% of the County is underlain by the Lower Horseshoe Canyon Formation where apparent yields are expected to be greater than 100 m³/day. This discrepancy between percent of actual values vs. area of distribution occurs because of the location of the control points. The map shows the control points are concentrated in the eastern and southwestern parts of the County. The areas where water wells with higher yields are expected are in parts of townships 031 and 032, ranges 15 and 16, W4M. This would be the area where the Lower Horseshoe Canyon Formation would be most subjected to weathering processes.

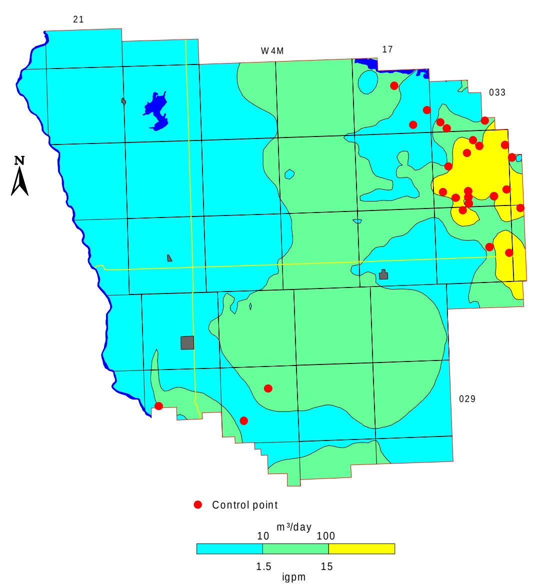

Figure 20. Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer

4.3.7.3 Quality

The groundwaters from the Lower Horseshoe Canyon Aquifer are mainly sodium-bicarbonate or sodium-sulfate types (see CD-ROM). The TDS concentrations are mostly less than 2,000 mg/L. The higher values are in the northern and northwestern parts of the County. The sulfate concentrations are usually less than 500 mg/L, with higher values in parts of townships 032 and 033, ranges 16 and 17, W4M. Chloride concentrations in the groundwaters from the Lower Horseshoe Canyon Aquifer range from less than 10 to more than 250 mg/L. The higher values are in most of the northwestern half of the County.

Oldman Aquifer

The Oldman Aquifer comprises the porous and permeable parts of the Oldman Formation that underlies the Bearpaw Formation. The depth to the top of the Oldman Formation is mainly greater than 200 metres throughout the County. The shallower locations are in the northeastern and southwestern parts of the County. There are 247 records in the database for holes that have been drilled to depths of greater than 200 metres. However, most of the holes were structure test holes or core holes. While these records provide lithologic information, they do not provide details for the aquifer parameters or the chemical quality of the groundwater. There are three records in the database for water wells used for stock and/or domestic purposes that are more than 200 metres deep. A projected long-term yield has been calculated from the data included with one record and a second record includes the results of a chemical analysis. The projected long-term yield is 0.2 cubic metres per day. The chemical analysis results indicate the TDS is 3,721 mg/L and the chloride ion concentration is 2,182 mg/L. The chemical analysis results are similar to the results of a groundwater sample obtained from a water test hole completed in the Foremost Formation east of the County (Hydrogeological Consultants Ltd., 1997). In the eastern half of the County, the Oldman Formation is above the Base of Groundwater Protection and in the western half of the County the Formation is below the Base of Groundwater Protection.

The projected long-term yield for the water test hole east of the County is 70 m³/day, significantly more than the yield of the water well completed in the County. The difference in yield is undoubtedly related to the presence of natural gas in the Oldman Aquifer.

In addition to the data available from the groundwater database, the summary results of drill stem tests are available from the EUB database. The DST summaries often provide a description of fluid obtained during the DST. Therefore, the DST summaries can be used to determine an apparent yield and the quality of fluid available from the Aquifer.

There are 162 DSTs that have a completion interval that includes at least a part of the Oldman Aquifer. The fluids from the 162 DSTs have been grouped as water, gas and water, and oil.

Of the 162 DSTs, 75 have sufficient information to allow for the calculation of an apparent long-term yield. The projected long-term yield values vary from less than 1 m³/day to a maximum of 383 m³/day, with the mean being 26 m³/day and the median 12 m³/day.

The data from the DSTs have been used to prepare the adjacent map. The contours outline the different fluids expected at various locations and the posting shows the expected long-term yield at individual locations.

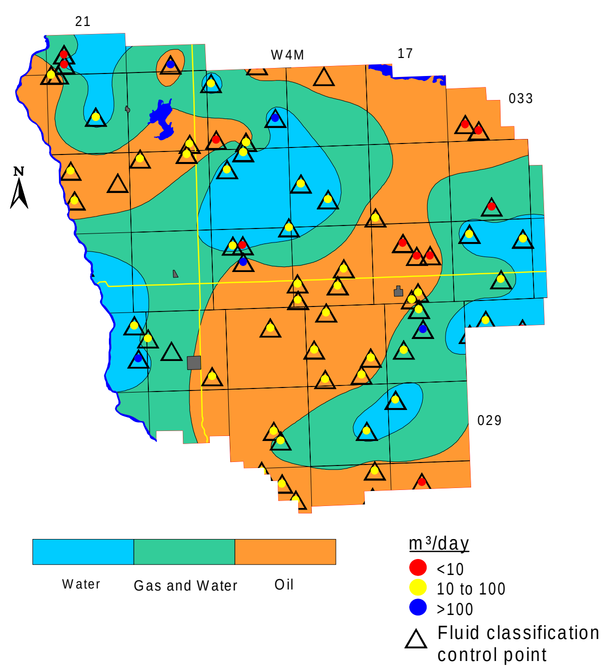

Figure 21. Type of Fluid Encountered in Oldman Aquifer

5 GROUNDWATER BUDGET

5.1 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. 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 those parts of the various aquifers within the County.

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. Based on these assumptions, the estimated lateral groundwater flow through the individual aquifers can be summarized as follows:

Aquifer Designation	Transmissivity (m^2/day)	Gradient (m/m)	Width (km)	Main Direction of Flow	Quantity (m^3/day)	Authorized Diversion (m^3/day)
Upper Horseshoe Canyon	7.6	0.0025	18	West	340	662.8
Middle Horseshoe Canyon					780	179.0
	4.6	0.00278	50	West	640	
	4.6	0.00125	24	East	140	
Lower Horseshoe Canyon					1,750	57.5
	7.5	0.00347	50	West	1,300	
	7.5	0.00208	29	East	450	

The above table indicates there is more groundwater flowing through two of the aquifers than has been authorized to be diverted by AEP. However, the unlicensed groundwater diversion for livestock is five times greater than the licensed diversion; therefore, it is possible that the groundwater use is greater than the quantity flowing through the aquifers. From the third aquifer, the Upper Horseshoe Canyon Aquifer, the authorized diversion is more than the quantity of groundwater flowing through the Aquifer. However, because of the very approximate nature of the calculation of the quantity of groundwater flowing through the individual aquifers, more detailed work is required to establish the flow through the aquifers. Also, it should be noted that the quantity of groundwater being used could be less than the amount of groundwater authorized.

In the case of the Upper Sand and Gravel Aquifer, no value has been calculated for the flow through the Aquifer because of the difficulty in obtaining a reasonable value for hydraulic gradient in the Upper Sand and Gravel Aquifer.

5.2 Quantity of Groundwater

An estimate of the volume of groundwater stored in the sand and gravel aquifers in the surficial deposits is 2 to 11 cubic kilometres. This volume is based on an areal extent of 3,000 square kilometres and a saturated sand and gravel thickness of four metres. The variation in the total volume is based on the value of porosity that is used for the sand and gravel. One estimate of porosity is 5% (Sonderegger et al., 1989), which gives the low value of the total volume. The high estimate is based on a porosity of 30% (Ozoray, Dubord and Cowen, 1990).

The adjacent water-level map has been prepared by considering water wells completed in surficial deposits. These water levels were used for the calculation of saturated surficial deposits and for the calculation of recharge/discharge areas.

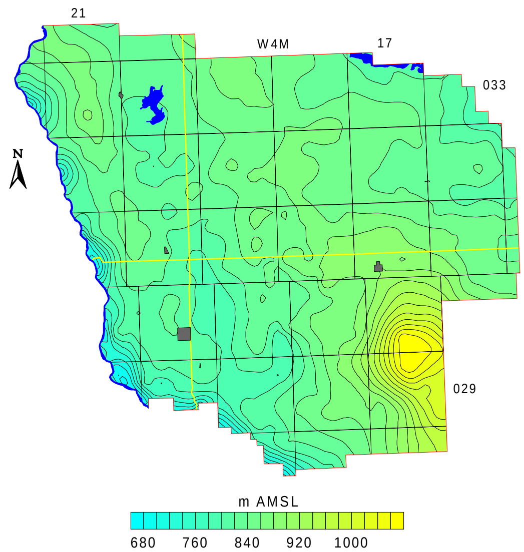

Figure 22. Non-Pumping Water-Level Surface in Surficial Deposits

5.3 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.

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.

5.3.1.1 Surficial Deposits/Upper Bedrock Aquifer(s)

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 on the map in Figure 23 includes those areas where the elevation of the water level in the surficial deposits is more than five metres above the elevation of the water level in the upper bedrock aquifer(s). The discharge areas are where the elevation of the water level in the surficial deposits is more than five metres lower than the elevation of the water level in the bedrock. When the elevation of the water level in the surficial deposits is between five metres above and five metres below the elevation of the water level in the bedrock, the area is classified as a transition.

The adjacent map shows that, in more than 70% of the County, there is a downward hydraulic gradient 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 the Red Deer River Valley. The remaining parts of the County are areas where there is a transition condition.

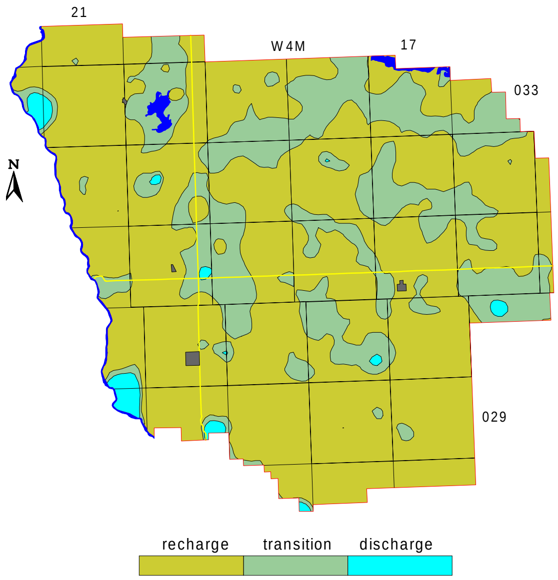

Figure 23. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)

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

5.3.1.2 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.

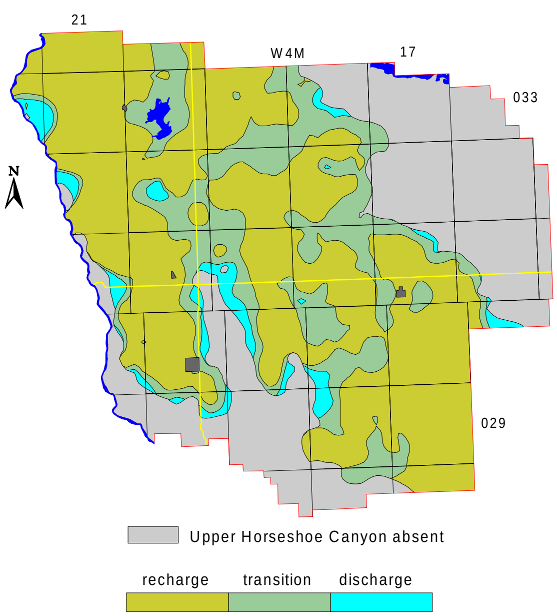

Figure 24. Recharge/Discharge Areas between Surficial Deposits and Upper Horseshoe Canyon Aquifer

The hydraulic relationship between the surficial deposits and the Upper Horseshoe Canyon Aquifer indicates that in more than 70% of the County where the Upper Horseshoe Canyon Aquifer is present, there is a downward hydraulic gradient. Discharge areas for the Upper Horseshoe Canyon Aquifer are associated with the edge of the Aquifer. The hydraulic relationship between the surficial deposits and the remainder of the bedrock aquifers present in the County indicates there is mainly a downward hydraulic gradient.

6 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. The agricultural activities that generate contaminants include the 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 which 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 surficial geology map prepared by the Alberta Research Council (Shetsen, 1990) 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; and
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 1,018 records in the area of the County with lithological descriptions, 77 have sand and gravel within one metre of ground level. In the remaining 941 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.

6.1.1 Risk of Contamination Map

The information from the reclassification of the surficial geology map is the basis for preparing the initial risk map. The depth to the first sand and gravel is then used to modify the initial map and to prepare the final map. The criteria used for preparing the final Risk of Groundwater Contamination map are outlined in the adjacent table.

Surface Permeability	Sand or Gravel Present To Within One Metre Of Ground Surface	Groundwater Contamination Risk
Low	No	Low
Moderate	No	Moderate
High	No	High
Low	Yes	High
Moderate	Yes	High
High	Yes	Very High

Table 5. Risk of Groundwater Contamination Criteria

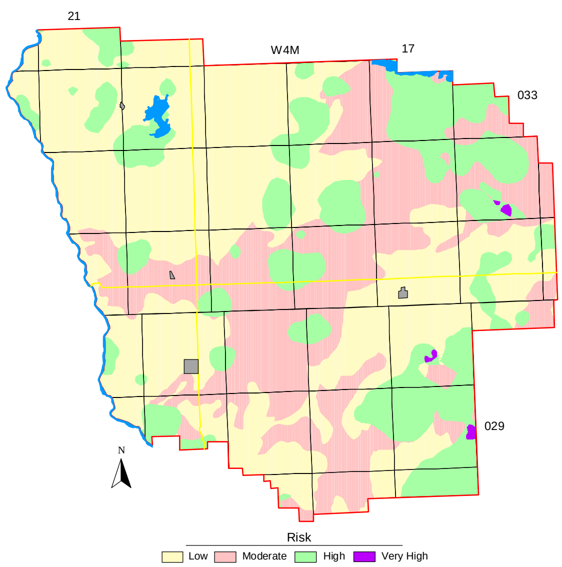

Figure 25. Risk of Groundwater Contamination

The Risk of Groundwater Contamination map shows that there is a high or very high risk of the groundwater being contaminated, in less than 25% of the County. These areas would be considered the least desirable ones for a development that has a product or by-product that could cause groundwater contamination. However, because the map has been prepared as part of a regional study, the designations are a guide only; detailed hydrogeological studies must be completed at any proposed development site to ensure the groundwater is protected from possible contamination. At all locations, good environmental practices should be exercised in order to ensure that groundwater contamination would not affect groundwater quality.