Similar trends were also noted for the AEP observation water wells in 12-10-048-03 W5M. At this location, there are six observation water wells completed in aquifers from the Upper Surficial Deposits down to the Lower Scollard. The main difference in the water-level fluctuations between these observation water wells and the observation water wells in 14-04-048-02 W5M is only the observation water wells completed in the Upper Surficial Deposits and in the Upper Lacombe Aquifer appear to have a direct correlation with precipitation. This means that at the 12-10 location, the effects of precipitation cannot be observed below a depth of 25 metres while at the 14-04 site, the effects of precipitation are evident to a depth of 65 metres.

AEP Obs WW No. 156 in 08-36-050-26 W4M near Devon is completed at a depth of 10.7 metres in the Upper Surficial Deposits. The water levels in Obs WW No. 156 declined one metre from 1960 to 1970, rose three metres from 1970 to 1974, and rose another metre from 1974 to 1996 (see Appendix A). The water-level fluctuations in Obs WW No. 156 appear to be in response to groundwater users that stopped using groundwater in the mid-1970s.

AEP Obs WW No. 153 in 10-26-049-25 W4M is within the City of Leduc and is completed at a depth of 22.1 metres below ground level in the Middle Horseshoe Canyon Aquifer. The water levels in Obs WW No. 153 rose one metre from 1957 to 1972 (Appendix A). From 1972 to 1974, the water level sharply declined approximately two metres. The closest water well to this observation water well in the AEP groundwater database and drilled before 1972 is a domestic water well in NE 25-049-25 W4M. The domestic water well was drilled in 1968 and is completed in the Upper Horseshoe Canyon Aquifer. Whether this water well had an impact on the water level in the observation water well cannot be determined. However, the water-level decline between 1972 and 1973 does show the effects of groundwater diversion in the general vicinity of the observation water well.

6.2 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 bedrock aquifers can be summarized as follows:

Aquifer Designation	Transmissivity (m^2/day)	Gradient (m/m)	Width (km)	Main Direction of Flow	(m^3/day)	Flow (m^3/day)	Diversion (m^3/day)
Upper Lacombe						3,000	29
	34	0.008	6	Northwest	2,000		
	34	0.006	4	Southeast	1,000		
Lower Lacombe						3,000	514
	12	0.010	21	Northeast	3,000		
Haynes						1,000	502
	13	0.003	19	Northwest	1,000		
Upper Scollard						300	186
	5	0.003	27	Northwest	300		
Lower Scollard						600	162
	2	0.006	24	Northeast	300		
	2	0.006	24	Northwest	300		
Upper Horseshoe Canyon						600	413
	3	0.004	24	Northwest	300		
	3	0.003	35	North	300		
Middle Horseshoe Canyon						100	479
	1	0.003	29	Northwest	100		
Lower Horseshoe Canyon						100	0
	1	0.003	29	Northwest	100		

The data provided in the above table indicates there is more groundwater flowing through the individual bedrock aquifers than has been authorized to be diverted from each aquifer, except for the Middle Horseshoe Canyon 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. Because a significant aquifer cannot be delineated in the surficial deposits, no attempt has been made to calculate the flow through either the Upper Sand and Gravel or the Lower Sand and Gravel aquifers.

6.2.1 Quantity of Groundwater

An estimate of the volume of groundwater stored in the sand and gravel aquifers in the surficial deposits is 0.2 to 1 cubic kilometres. This volume is based on an areal extent of 800 square kilometres and a saturated sand and gravel thickness of five 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%, 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 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 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 Buried Warburg, Devon and Ellerslie valleys; in the extreme northwestern part of the County, the flow is toward the North Saskatchewan River.

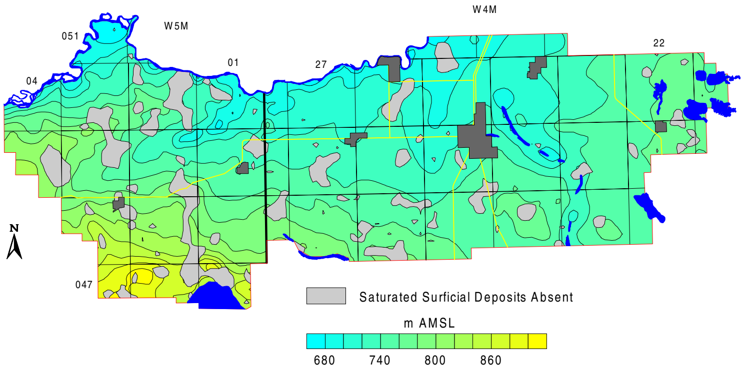

Figure 29. Non-Pumping Water-Level Surface in Surficial Deposits

6.2.2 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.

6.2.2.1 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 on the map below includes those areas 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.

The adjacent map shows that, in more than 50% 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 group of lakes that coincide with the Buried Ellerslie Valley. The remaining parts of the County are areas where there is a transition condition.

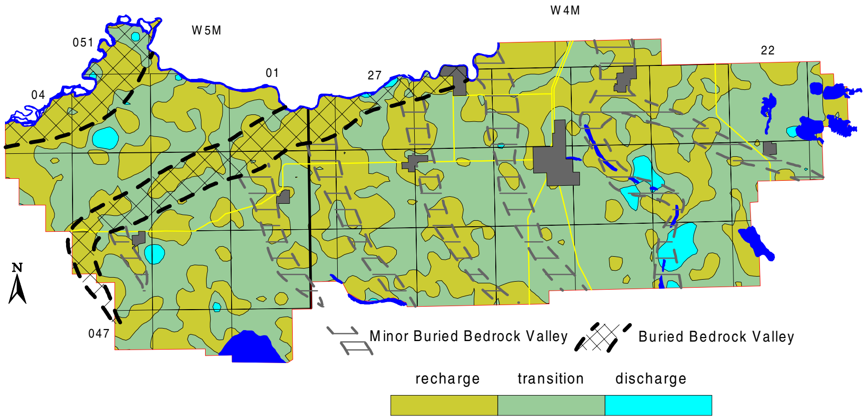

Figure 30. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)

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

6.2.2.2 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.

The hydraulic relationship between the surficial deposits and the Upper Horseshoe Canyon Aquifer indicates that in more than 60% 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 and the group of lakes that coincide with the Buried Ellerslie Valley. The hydraulic relationship between the surficial deposits and the remainder of the bedrock aquifers, with the exception of the Lacombe aquifers, indicates there is mainly a downward hydraulic gradient.

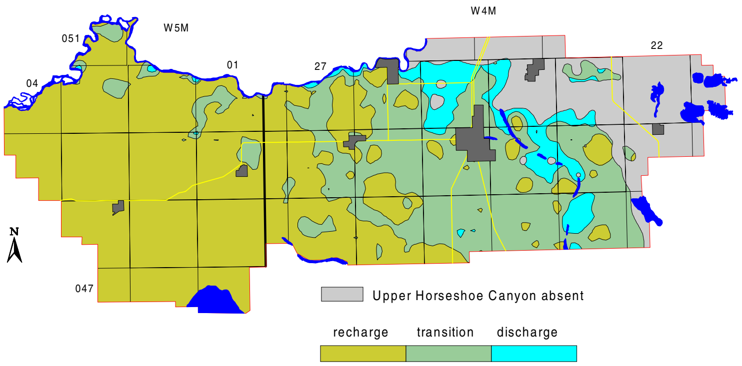

Figure 31. Recharge/Discharge Areas between Surficial Deposits and Upper Horseshoe Canyon Aquifer

7 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 3,498 records in the area of the County with lithological descriptions, 178 have sand and gravel within one metre of ground level. In the remaining 3,320 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.

7.1.1 Risk of Groundwater 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 - Top 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 4. Risk of Groundwater Contamination Criteria

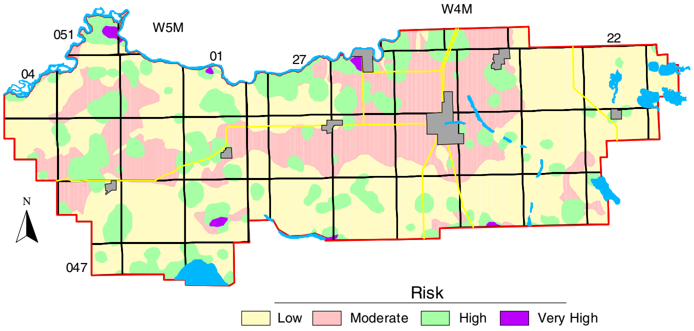

Figure 32. Risk of Groundwater Contamination

The Risk of Groundwater Contamination map shows that, in less than 25% of the County, there is a high or very high risk of the groundwater being contaminated. 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.

8 RECOMMENDATIONS

The present study has been based on information available from the groundwater database. The database has three problems:

1) the quality of the data;
2) the coordinate system used for the horizontal control; and
3) the distribution of the data.

The quality of the data in the groundwater database is affected by two factors: a) the technical training of the persons collecting the data, and b) the quality control of the data. The possible options to upgrade the database include the creation of a “super” database, which includes only verified data. The first step would be to field-verify the 16 existing water wells listed in Appendix E. These water well records indicate that a complete water well drilling report is available along with at least a partial chemical analysis. The level of verification would have to include identifying the water well in the field, obtaining meaningful horizontal coordinates for the water well and the verification of certain parameters such as water level and completed depth. An attempt to update the quality of the entire database is not recommended.

The results of the present study indicate that the only readily identifiable aquifers in the surficial deposits are the sand and gravel deposits associated with the lows in the bedrock surface. The most noteworthy bedrock lows include the Buried Warburg Valley and the minor buried bedrock valleys.

While there are a few areas where water-level data are available, on the overall, there are an insufficient number of water levels to set up a groundwater budget. One method to obtain additional water-level data is to solicit the assistance of the water well owners who are stakeholders in the groundwater resource. In the M.D. of Rocky View, water well owners are being provided with a tax credit if they accurately measure the water level in their water well once per week for a year. A pilot project indicated that approximately five years of records are required to obtain a reasonable data set. The cost of a five-year project involving 50 water wells would be less than the cost of one drilling program that may provide two or three observation water wells. Another municipality, Flagstaff County, is currently in the process of setting up a regional groundwater-monitoring program.

In general, for the next level of study, the database needs updating. It requires more information from existing water wells, and additional information from new ones.

Before an attempt is made to upgrade the level of interpretation provided in this report and the accompanying maps and groundwater query, it is recommended that all water wells for which water well drilling reports are available be subjected to the following actions (see also pages C-2 to C-4):

1. The horizontal location of the water well should be determined within 10 metres. The coordinates must be in 10TM NAD 27 or some other system that will allow conversion to 10TM NAD 27 coordinates.
2. A four-hour aquifer test (two hours of pumping and two hours of recovery) should be performed with the water well to obtain a realistic estimate for the transmissivity of the aquifer in which the water well is completed.
3. Water samples should be collected for chemical analysis after 5 and 115 minutes of pumping, and analyzed for major and minor ions.

A list of 16 water wells that could be considered for the above program is given in Appendix E.

In addition to the data collection associated with the existing water wells, all available geophysical logs should be interpreted to establish a more accurate spatial definition of individual aquifers.

There is also a need to provide the water well drillers with feedback on the reports they are submitting to the regulatory agencies. The feedback is necessary to allow for a greater degree of uniformity in the reporting process. This is particularly true when trying to identify the bedrock surface. The water well drilling reports should be submitted to the AEP Resource Data Division in an electronic form. The money presently being spent by AEP and PFRA to transpose the paper form to the electronic form should be used to allow for a technical review of the data and follow-up discussions with the drillers.

An effort should be made to form a partnership with the petroleum industry. The industry spends millions of dollars each year collecting information relative to water wells. Proper coordination of this effort could provide significantly better information from which future regional interpretations could be made. This could be accomplished by the County taking an active role in the activities associated with the construction of lease sites for the drilling of hydrocarbon wells and conducting of seismic programs.

Groundwater is a renewable resource and it must be managed.