6.2 Estimated Groundwater Use in Cardston County

An estimate of the quantity of groundwater removed from each geologic unit in Cardston County must include both the authorized non-exempt and the exempt groundwater diversions. As stated previously on page 6 of this report, the daily water requirement for livestock for the County based on the 2001 census is estimated to be 10,207 cubic metres. As of January 2003, AENV has licensed the use of 10,857 m³/day for livestock, which includes both surface water (based on consumptive use) and groundwater. Based on these figures, it would appear that there would not be any livestock watering from exempt groundwater use.

In the groundwater database for the County, there are records for 2,264 water wells that are used for domestic (1,454), domestic/stock (563) and stock (247) purposes.

Groundwater for household use requires a non-exempt authorization if the use is more than 1,250 m³/year. Under the *Water Act*, a residence is protected for up to 3.4 m³/day. However, the standard groundwater use for household purposes (a family of four) is 1.1 m³/day. Since there are 2,017 domestic water wells in Cardston County serving a population of 4,565, the domestic use per water well is 0.6 m³/day. Because it does not statistically appear that there any authorized non-exempt stock users, 0.6 m³/day was also assigned for domestic/stock water wells, and no value was assigned for stock water wells. Because of the limitations of the data, no attempt has been made to compensate for dugouts, springs or inactive water wells.

Based on using 0.6 m³/day for all available domestic or domestic/stock water wells, and the authorized amount for all non-exempt water wells, an estimate of the groundwater use from each geologic unit was prepared as shown below in Table 17. The data provided in Table 17 indicate that most of the 1,210 m³/day, estimated to be diverted from domestic or domestic/stock water wells, is from aquifers in the surficial deposits or the Disturbed Belt Aquifer. The total estimated groundwater use is mainly from the Lower Sand and Gravel Aquifer.

	Domestic and Domestic/Stock Diversions					***Authorized Non-Exempt Groundwater Diversions***	***Total Groundwater Diversions***
Aquifer Designation	Number of Domestic	Daily Use (0.6 m³/day)	Number of Domestic and Stock	Daily Use (0.6 m³/day)	Totals m³/day	Totals (m³/day)	Totals m³/day
Multiple Surficial Completions	329	197	106	64	261	0	261
Upper Sand/Gravel	78	47	27	16	63	43	106
Lower Sand/Gravel	226	136	103	62	197	26,940(1)	27,127
Multiple Bedrock Completions	101	61	59	35	96	0	96
Disturbed Belt	184	110	65	39	149	49	208
Upper Lacombe	3	2	3	2	4	0	4
Lower Lacombe	2	1	2	1	2	0.6	3
Haynes	5	3	0	0	3	4	7
Upper Scollard	43	26	9	5	31	22	53
Lower Scollard	138	83	18	11	94	49	143
Upper Horseshoe Canyon	84	50	12	7	58	127	185
Middle Horseshoe Canyon	46	28	26	16	43	276	319
Lower Horseshoe Canyon	6	4	7	4	8	87	95
Bearpaw	46	28	58	35	62	95	157
Oldman	58	35	43	26	61	27	88
Unknown	105	63	25	15	78	24	102
Totals (2)	1,454	872	563	338	1,210	27,744	28,954

(1) 18,587 m³/day of the 26,940 m³/day is licensed for dewatering purposes
(2) The values given in the table have been rounded and, therefore, the columns and rows may not add up equally

Table 17. Total Groundwater Diversions by Aquifer

By assigning 0.6 m³/day for domestic use or domestic/stock use, and using the total maximum authorized diversion associated with any non-exempt water well, a map has been prepared that shows the estimated groundwater use in terms of volume per section per day for the County (not including springs).

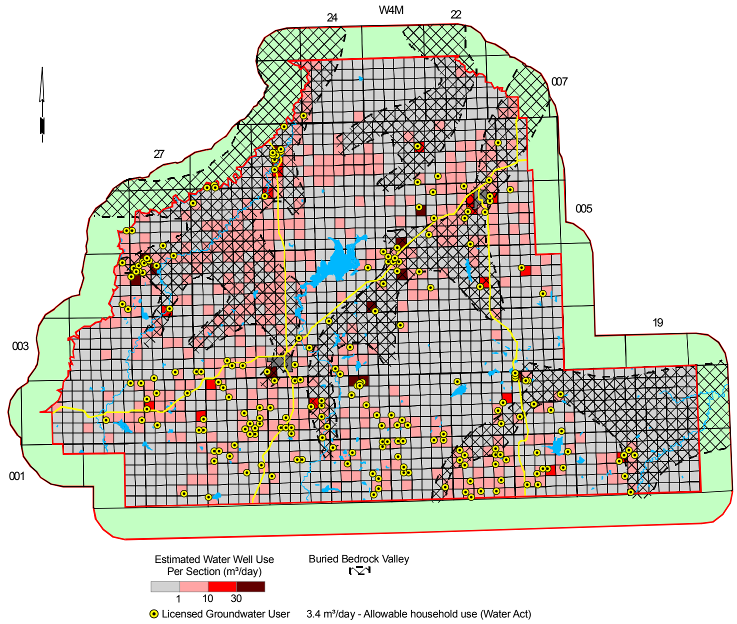

Figure 34. Estimated Water Well Use Per Section

There are 1,854 sections in the County. In 56% (1,043) of the sections in the County, there is no domestic, stock or authorized non-exempt groundwater user. The range in groundwater use for the remaining 811 sections is from 0.6 m³/day to nearly 22,000 m³/day (dewatering and fishery), with an average use per section of 16 m³/day (2.4 igpm). Without the inclusion of the dewatering wells in section 30, township 004, range 27, W4M, the average use per section is 3.8 m³/day (0.6 igpm). The estimated water well use per section can be more than 30 m³/day in 13 of the 811 sections. There are 49 of the total 265 authorized non-exempt groundwater users in areas of greater than 30 m³/day. The most notable areas where water well use of more than 30 m³/day is expected to occur is in the Buried Cochrane, Buried Cardston and Buried Whoop-Up valleys, as shown on Figure 34.

There are five dewatering water wells completed in the Lower Sand and Gravel Aquifer in section 30, township 004, range 27, W4M that are licensed by Alberta Environment to divert 14,800 m³/day. Rocky Mountain Broodstock Ltd. are licensed to divert 7,165 m³/day for fishery purposes from three water wells completed in the Lower Sand and Gravel Aquifer in 07-30-004-27 W4M. The combined authorized total of 21,965 m³/day from these eight water wells accounts for about 76% of the total groundwater use in the County.

Groundwater Use within Cardston County (m³/day)		%
Domestic/Stock (including agriculture and registrations)	2,114	7
Municipal (licensed)	1,085	4
Commercial/Dewatering/Fishery et al (licensed)	25,755	89
Total	28,954	100

Table 18. Total Groundwater Diversions

In summary, the estimated total groundwater use within Cardston County is 28,954 m³/day, with the breakdown as shown in the adjacent table. An estimated 28,852 m³/day is being withdrawn from a specific aquifer. The remaining 102 m³/day or 11% is being withdrawn from unknown aquifer units. Approximately 96% of the total estimated groundwater use is from authorized non-exempt water wells. Of the 28,954 m³/day, 97% is being diverted from surficial aquifers and 3% from bedrock aquifers.

6.3 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 various parts of individual 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; flow through the aquifers takes into consideration hydrogeological conditions outside the County border. Based on these assumptions, the estimated lateral groundwater flow through the individual aquifers has been summarized in Table 19.

Table 19 indicates that there is more groundwater flowing through the aquifers than has been authorized to be diverted from the individual aquifers, except for the Lower Sand and Gravel Aquifer. In some of the high-volume licensed water wells in the County (e.g. for dewatering or fisheries operations), it is suspected that the high groundwater use is a result of potential induced infiltration to the Lower Sand and Gravel Aquifer from the nearby rivers. However, even where use is less than the calculated aquifer flow, there can still be local impacts on water levels. The calculations of flow through individual aquifers as presented in the adjacent table are very approximate and are intended only as a guide; more detailed investigations are needed to better understand the groundwater flow.

Aquifer/Area	Trans (m^2/day)	Gradient (m/m)	Width (m)	Flow (m^3/day)	Aquifer Flow (m^3/day)	Authorized Non-Exempt Diversion (m^3/day)	Exempted Diversion (m^3/day)	Total (m^3/day)
Upper Surficial					10,100	43	0	43
east	15.3	0.0075	13,000	1492				
central - northeast	15.3	0.0125	8,000	1530				
northwest	15.3	0.0125	18,000	3443				
west - northeast	15.3	0.0067	36,000	3672				
Lower Surficial					3,700	26,940	0	26,940
Stand Off								
southwest to northeast	37.6	0.0029	10,000	1074				
Whoop Up								
south to north	37.6	0.0034	6,000	769				
Whiskey								
west to east	37.6	0.0050	10,000	1880				
Upper Lacombe					400	0	0	400
Northeast								
	5.6	0.007	11,000	411				
Lower Lacombe					400	0	0	0
Northern								
	4.1	0.007	15,000	410				
Haynes					1,000	4	0	4
Northern								
	12.8	0.004	20,000	960				
Upper Scollard					300	22	0	22
Northwest								
	2.2	0.010	15,000	330				
Lower Scollard					1,190	49	0	49
Northwest								
	13	0.004	22,000	1192				
Upper Horseshoe Canyon					430	127	0	127
Northwest								
	5.4	0.004	20,000	432				
Middle Horseshoe Canyon					750	276	0	276
Northwest								
	5.5	0.005	30,000	750				
Lower Horseshoe Canyon					1,380	87	0	87
Northwest								
	8.3	0.006	30,000	1383				
Bearpaw					1,120	95	0	95
Northwest								
	7	0.004	40,000	1120				
Oldman					3,380	27	0	27
Northwest								
	8.8	0.008	50,000	3385				
Disturbed Belt					3,700	49	0	49
South								
east	7.8	0.008	13,000	811				
West								
northeast	7.8	0.008	16,000	998				
northwest	7.8	0.011	8,000	672				
north-northeast	7.8	0.012	13,000	1217				

Table 19. Groundwater Budget

6.3.1 Quantity of Groundwater

An estimate of the volume of groundwater stored in the surficial deposits is 1.0 to 6.3 cubic kilometres. This volume is based on an areal extent of 4,150 square kilometres and a saturated thickness of five metres. The variation in the total volume is based on the value of porosity that is used for the surficial deposits. 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 to depths of less than 20 metres in aquifers in the surficial deposits. The water levels from these water wells 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 (indicated by grey areas on the map). The water-level map for the surficial deposits shows a flow direction north toward the Oldman River and southeast toward the Milk River.

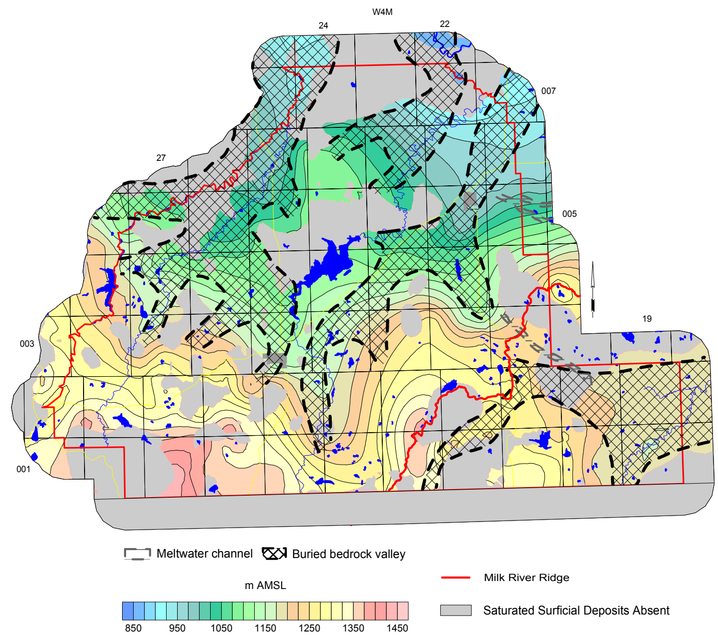

Figure 35. Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep

6.3.2 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 hydraulic unit. 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.

6.3.2.1 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. 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.

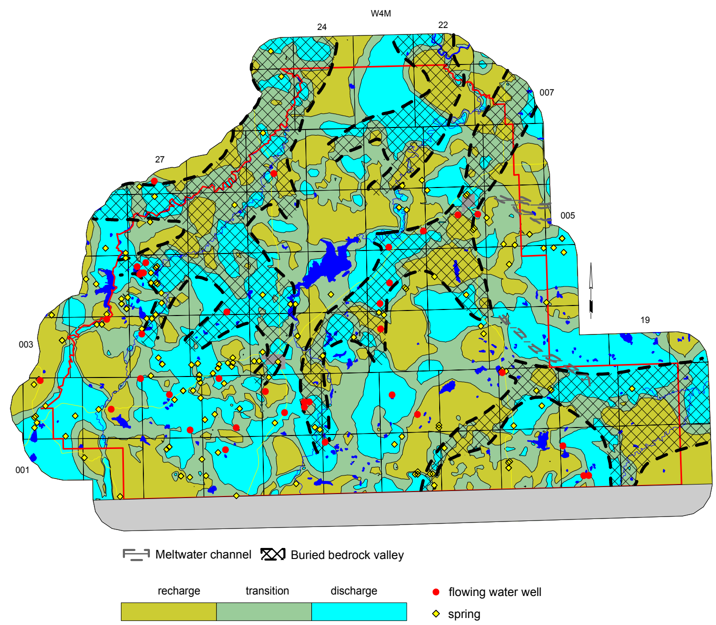

Figure 36. Recharge/Discharge Areas in Upper Bedrock Aquifer(s)

In the absence of sufficient water-level data in the surficial deposits, a reasonable hydraulic gradient between the surficial deposits and the upper bedrock aquifer(s) could not be determined. Therefore, an alternative approach has been used to establish approximate recharge and discharge areas. The first objective was to determine the location of springs, flowing shot holes and any water wells that had a water level measurement depth of less than 0.1 metres. These locations would reflect where there is an upward hydraulic gradient from the bedrock to the surficial deposits (i. e. discharge). The depth to water level for water wells completed in 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 bedrock surface. This resulting depth to water level grid was contoured to reflect the positioning of springs, flowing shot holes and flowing water wells (i. e. discharge). The recharge classification is used where the water level in the upper bedrock aquifer(s) is more than two metres below bedrock surface. The discharge areas are where the water level in the upper bedrock aquifer(s) is more than ten metres above the bedrock surface. When the depth to water level in the upper bedrock aquifer(s) is between two metres below and ten metres above the bedrock surface, the area is classified as a transition, that is, no recharge and no discharge.

Figure 36 shows that, in more than 30% of the County, there is a downward hydraulic gradient from the bedrock surface toward the upper bedrock aquifer(s) (i. e. recharge). Areas where there is an upward hydraulic gradient from the bedrock to the bedrock surface (i. e. discharge) are mainly in the vicinity of creeks and river valleys and major meltwater channels. The remaining parts of the County are areas where there is a transition condition.

Because of the paucity of data, recharge/discharge maps for the individual bedrock aquifers have not been attempted.

With 30% of the County land area being one of recharge to the bedrock, and the average precipitation being 568 mm per year, one percent of the annual precipitation is sufficient to provide the total calculated quantity of groundwater flowing through the upper bedrock aquifer(s).

6.4 Areas of Groundwater Decline

In order to determine the areas of possible water-level decline in the sand and gravel aquifer(s), the available non-pumping water-level elevation for each water well completed in the sand and gravel aquifer(s) was first sorted by location, and then by date of water-level measurement. The dates of measurements were required to differ by at least 365 days. Only the earliest and latest control points at a given location were used.

The areas of groundwater decline in the sand and gravel aquifer(s) have been calculated by determining the frequency of non-pumping water level control points per five-year period. Of the 369 surficial water wells with a non-pumping water level and date in the County, 158 are from water wells completed before 1975 and 88 are from water wells completed after 1984.

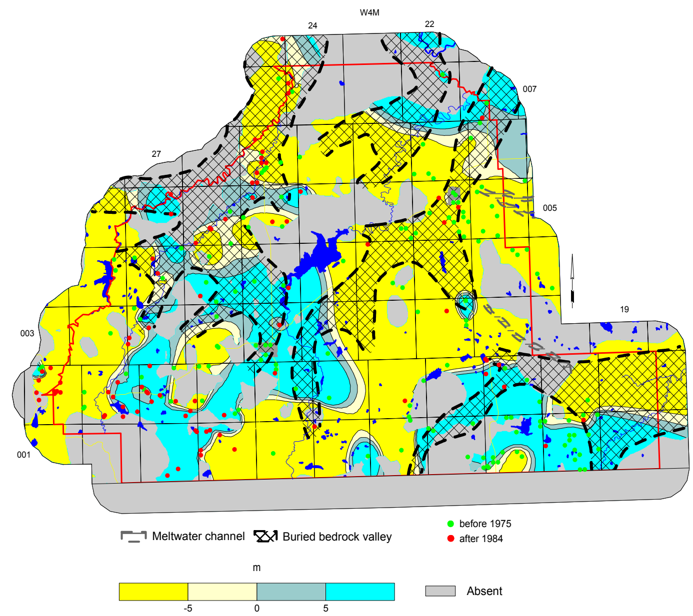

Figure 37. Changes in Water Levels in Surficial Deposits

Where the earliest water level (before 1975) is at a higher elevation than the latest water level (after 1984), there is the possibility that some groundwater decline has occurred. The interpretation of the adjacent map should be limited to areas where both earliest and latest water-level control points are present. Most of the areas in which the map suggests that there has been a decline in NPWL may reflect the nature of gridding a limited number of control points. The adjacent map, where sufficient control exists, indicates that there may have been a decline in the NPWL in parts of the Buried Stand Off, the Buried Cochrane, the Buried Mountain View, and the Buried Whoop-Up valleys.

Where the earliest water level is at a lower elevation than the latest water level, there is the possibility that the groundwater has risen at that location. The water level may have risen as a result of recharge in wetter years or may be a result of the water well being completed in a different surficial aquifer. Of the 16 groundwater users completed in surficial aquifers that are authorized to divert more than 50 m³/day, most occur in areas where a water-level decline exists.

Estimated Water Well Use Per Section (m³/day)	*% of Area with More than a 5-Metre Projected Decline*
<10	*62*
10 to 30	*1*
>30	*1*
no use	*36*

Table 20. Water-Level Decline of More than 5 Metres in Sand and Gravel Aquifer(s)

Figure 37 indicates that in 65% of the County where surficial deposits are present, it is possible that the non-pumping water level has declined. The areas of groundwater decline in the sand and gravel aquifer(s) where there is no estimated water well use suggest that groundwater diversion is not having an impact and that the decline may be due to variations in recharge to the aquifer.

In areas where a water-level decline of more than five metres is indicated on Figure 37, 36% of the areas has no estimated water well use; 62% of the use is less than ten m³/day; 1% of the use is between 10 and 30 m³/day per section; and the remaining 1% of the declines occurred where the estimated groundwater use per section is greater than 30 m³/day, as shown above in Table 20.

Of the 1,028 bedrock water wells with a NPWL and test date, 380 are from water wells completed before 1975 and 355 are from water wells completed after 1984. The adjacent map indicates that in more than 30% of the County, it is possible that the NPWL has declined. It appears that there has been a decline in the NPWL in areas of linear bedrock lows and near areas of discharge. Of the 165 groundwater users completed in upper bedrock aquifer(s), most occur in areas where a water-level rise exists.

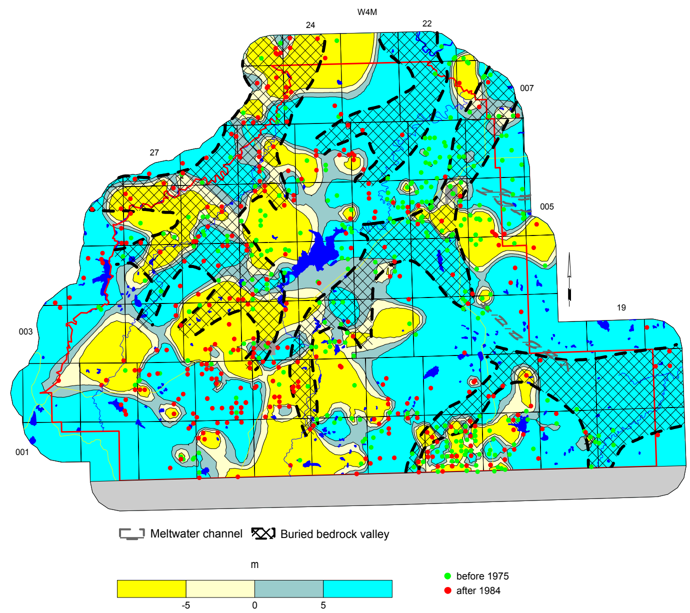

Figure 38. Areas of Potential Groundwater Depletion - Upper Bedrock Aquifer(s)

In areas where a water-level decline of more than five metres is indicated on Figure 38, 30% of the areas has no estimated water well use; 68% is less than ten m³/day; 1% is between 10 and 30 m³/day per section; the remaining 1% of the declines occurred where the estimated groundwater use per section is greater than 30 m³/day, as shown below in Table 21.

Estimated Water Well Use (m³/day)	*% of Area with More than a 5-Metre Decline*
<10	*68*
10 to 30	*1*
>30	*1*
no use	*30*

Table 21. Water-Level Decline of More than 5 Metres in Upper Bedrock Aquifer(s)

The areas of groundwater decline in the upper bedrock aquifer(s) where there is no estimated water well use suggest that groundwater production is not having an impact and that the decline may be due to variations in recharge to the aquifer.