5.2.4 Lower Sand and Gravel Aquifer

The Lower Sand and Gravel Aquifer is a saturated sand and gravel deposit that occurs at or near the base of the surficial deposits in the deeper part of the linear bedrock lows. The top of the lower surficial deposits is based on more than 1,000 control points across Alberta, including 22 in the County that are provided by Moran (1986) and Shetsen (1991).

5.2.4.1 Aquifer Thickness

The thickness of the Lower Sand and Gravel deposits is mainly less than five metres, but can be up to ten metres in the buried bedrock valleys (see CD-ROM).

5.2.4.2 Apparent Yield

Apparent yields for water wells completed in the Lower Sand and Gravel Aquifer range from less than 10 m³/day to more than 100 m³/day. The most notable areas where yields of more than 100 m³/day are expected are mainly in association with the Buried Stand Off Valley. In the County, the highest yielding water wells are completed in the Lower Sand and Gravel Aquifer, which tends to support a large proportion of the high consumption authorized non-exempt water wells.

In the County, there are 78 non-exempt authorizations for water wells that are completed through the Lower Sand and Gravel Aquifer, for a total authorized diversion of 26,940 m³/day, of which 96% is used for dewatering and fishery purposes.

Twenty-nine of the 78 authorized non-exempt water wells completed through the Lower Sand and Gravel Aquifer could be linked to a water well in the AENV groundwater database.

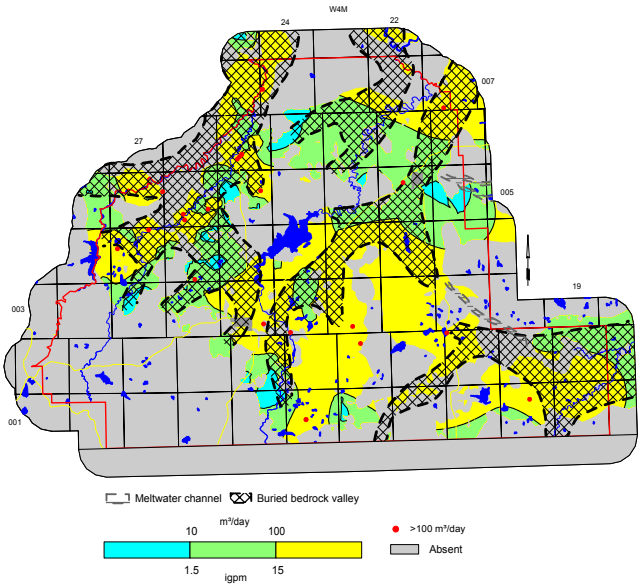


Figure 16. Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer

A groundwater study conducted for the Town of Cardston indicated a water supply well in 09-09-003-25 W4M, and completed in the Lower Sand and Gravel Aquifer in association with the Buried Cardston Valley, had a safe yield of 160 m³/day (HCL, July 1975). The Town of Cardston is currently licensed to divert 111 m³/day from a water supply well completed in the Lower Sand and Gravel Aquifer in 12-05-003-25 W4M.

A preliminary groundwater study was conducted for the Blood First Nation lands in 1997 with the existing St. Paul School Water Supply Well (Dash, November 1997). The St. Paul School WSW in NW 22-003-25 W4M is completed in the Lower Sand and Gravel Aquifer in association with the Buried Cardston Aquifer. The St. Paul WSW is used to divert groundwater to a pipeline, at a maximum pumping rate of 58 m³/day, which supplies the St. Paul School. The Blood First Nation wanted to determine if the groundwater diversion rate from the St. Paul School WSW could be increased to 190 m³/day in order to supply groundwater to a proposed rural pipeline. An extended aquifer test consisting of pumping the St. Paul School WSW for seven days at a rate of 1,020 lpm and a two-hour recovery period (at the request of the Blood First Nation) indicated a maximum long-term yield may be in the order of 525 m³/day; however, PFRA strongly recommended that the Blood First Nation initiate a conscientious groundwater monitoring program in order to determine the impact the increased groundwater diversion may have in the Lower Sand and Gravel Aquifer. Unfortunately, if a groundwater monitoring program was ever initiated, the monitoring data have not been made available to AAFC-PFRA.

5.3 Bedrock

5.3.1 Bedrock Aquifers

The upper bedrock includes formations that are less than 200 metres below the bedrock surface. In the County, the upper bedrock includes the Disturbed Belt, parts of the Paskapoo Formation, the Edmonton Group, the Bearpaw Formation, and the Belly River Group[19] as shown below on cross-section B-B' (see page A-13). Some of this bedrock contains saturated rocks that are permeable enough to transmit groundwater for a specific need. Water wells completed in bedrock aquifers usually do not require water well screens, although some of the sandstones may be friable[20] and water well screens are a necessity.

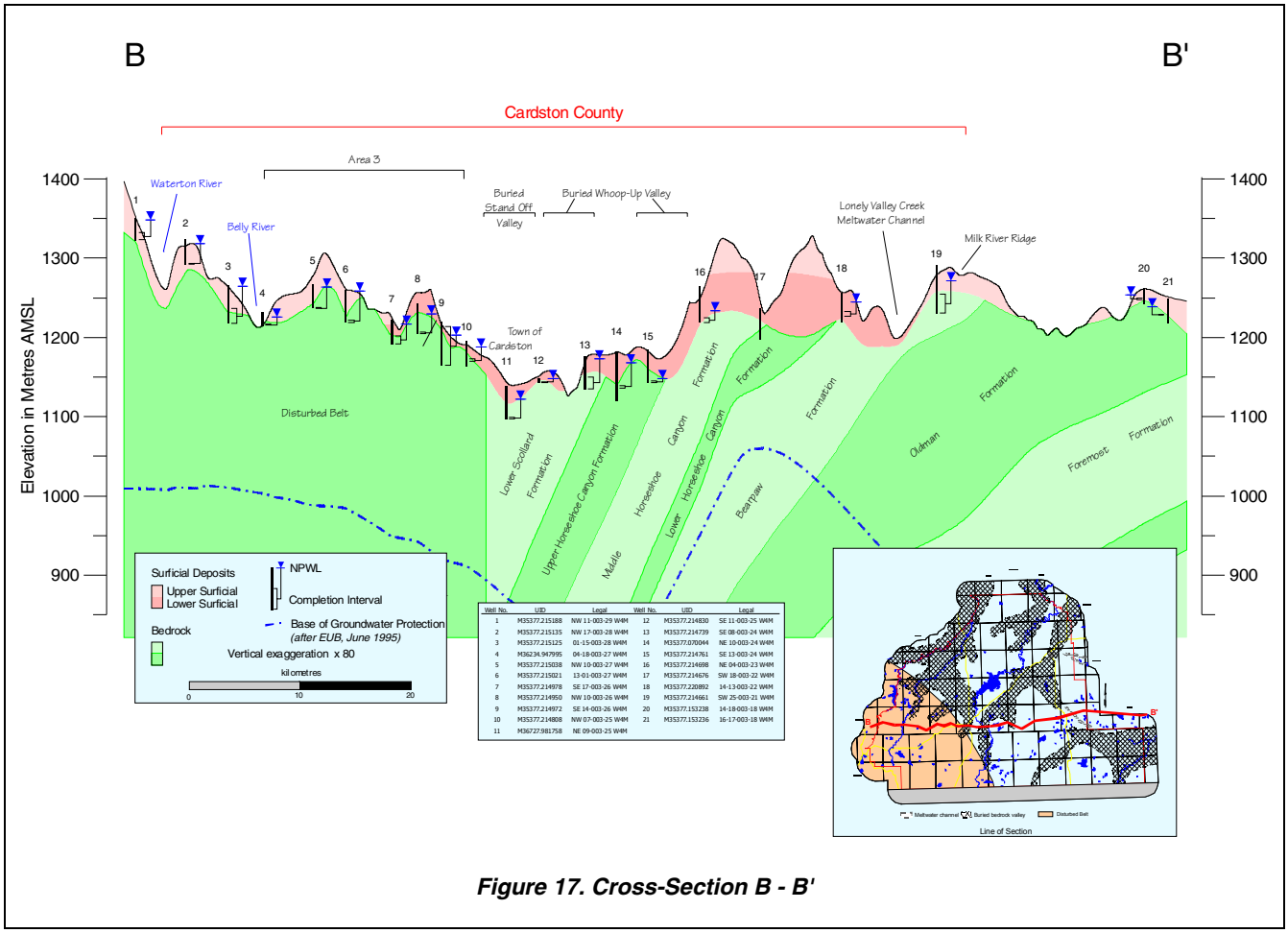


Figure 17. Cross-Section B - B'

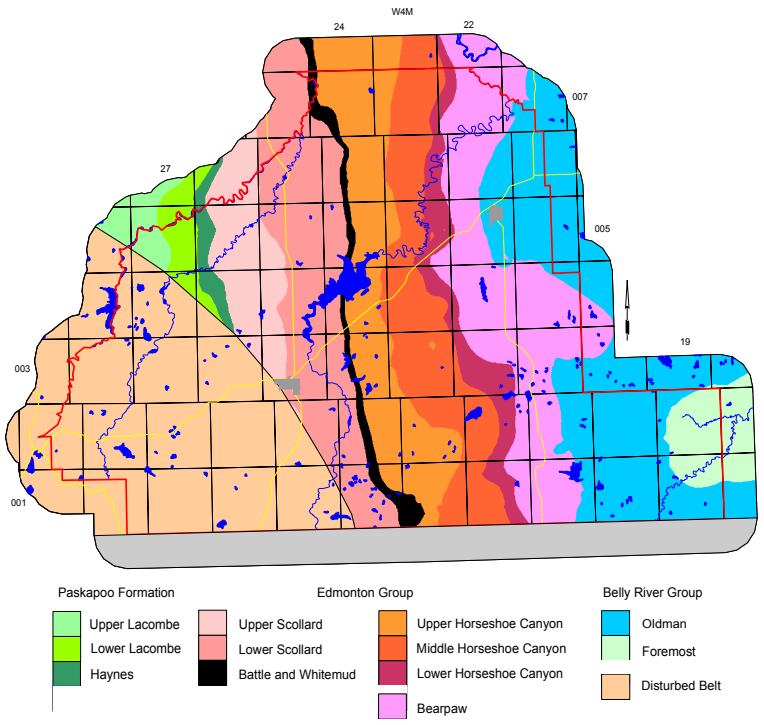
In the County, the Base of Groundwater Protection passes through parts of all the bedrock formations. A map showing the depth to the Base of Groundwater Protection is given on page 7 of this report, in Appendix A, and on the CD-ROM.

[19] The Scollard Formation is equivalent to the Willow Creek Formation, the Upper Horseshoe Canyon Formation is equivalent to the Upper St. Mary River Formation, the Middle Horseshoe Canyon Formation is equivalent to the Lower St. Mary River Formation, and the Lower Horseshoe Canyon Formation is equivalent to the Blood Reserve Formation.

[20] See glossary

5.3.2 Geological Characteristics

The Disturbed Belt is the upper bedrock in the western part of the County. The outline of the Disturbed Belt has been defined based on the Geological Map of Alberta (Hamilton et al, 1999, and Green, 1972). The Rocky Mountains and Foothills together form the Disturbed Belt in an area that has been deformed by folding and thrust faulting (Tokarsky, 1974). Water wells that were located within the Disturbed Belt boundary were defined as being completed in aquifers within the surficial deposits or in the Disturbed Belt Aquifer.



(for equivalent geological names, see footnote 19 on page 23)

Figure 18. Bedrock Geology

The Paskapoo Formation in central Alberta consists of the Dalehurst, Lacombe and Haynes members (Demchuk and Hills, 1991). The Edmonton Group, the Bearpaw Formation and the Belly River Group underlie the Paskapoo Formation. The Edmonton Group includes the Scollard, Battle, Whitemud and Horseshoe Canyon formations. The Belly River Group includes the Oldman and Foremost formations. A generalized geologic column is illustrated in Figure 6, in Appendix A, and on the CD-ROM.

The Paskapoo Formation consists of cycles of thick, tabular sandstone, siltstone and mudstone layers (Glass, 1990). The maximum thickness of the Paskapoo Formation is generally less than 800 metres. In the County, the Dalehurst Member is not present.

The Lacombe Member subcrops in parts of townships 004 to 006, ranges 26 to 28, W4M. The maximum thickness of the Lacombe Member is generally less than 320 metres. The upper part of the Lacombe Member is mostly composed of shale interbedded with sandstone and has a maximum thickness of 170 metres. The lower part of the Lacombe Member is composed of sandstone and coal layers. In the middle of the lower part of the Lacombe Member there is a coal zone, which can be up to five metres thick. In the County, the Lower Lacombe Member has a maximum thickness of 150 metres.

The Haynes Member underlies the Lacombe Member and is composed mainly of sandstone with some siltstone, shale and coal. In other parts of Alberta, the Haynes Member has a maximum thickness of 100 metres; in the County, the Haynes Member has a maximum thickness of 50 metres.

The Scollard Formation underlies the Haynes Member, generally has a maximum thickness of 160 metres and has two separate designations: Upper and Lower. The Upper Scollard consists mainly of sandstone, siltstone, shale and coal seams or zones. The Lower Scollard is composed mainly of shale and sandstone. In the County, the Scollard Formation has a maximum thickness of 500 metres.

Beneath the Scollard Formation are two formations having a maximum thickness of 30 metres; the two are the Battle and Whitemud formations. The Battle Formation is composed mainly of claystone, tuff, shale and

bentonite, and includes the Kneehills Member, a 2.5- to 30-cm thick tuff bed. The Whitemud Formation is composed mainly of shale, siltstone, sandstone and bentonite. The Battle and Whitemud formations are significant geologic markers, and were used in the preparation of various geological surfaces within the bedrock. Because of the ubiquitous nature of the bentonite in the Battle and Whitemud formations, there is very little significant permeability within these two formations.

The Horseshoe Canyon Formation is the lower part of the Edmonton Group and is the upper bedrock in the central parts of the County. The Horseshoe Canyon Formation has a maximum thickness of 500 metres and has three separate designations: Upper, Middle and Lower. The Upper Horseshoe Canyon, which can be up to 100 metres thick in other parts of Alberta, has a maximum thickness of 180 metres in Cardston County. The Middle Horseshoe Canyon, which can be up to 70 metres thick in other parts of Alberta, has an average thickness of 200 metres in the County. The Lower Horseshoe Canyon, which is up to 170 metres thick in other parts of Alberta, has an average thickness of 100 metres in the County.

The Horseshoe Canyon Formation consists of deltaic[21] and fluvial sandstone, siltstone and shale with interbedded coal seams, bentonite and thin nodular beds of limestone and ironstone. Because of the low-energy environment in which deposition occurred, the sandstones, when present, tend to be finer grained. The lower 60 to 70 metres and the upper 30 to 50 metres of the Horseshoe Canyon Formation can include coarser grained sandstone deposits.

The Bearpaw Formation underlies the Horseshoe Canyon Formation and is in the order of 200 metres thick within the County. The Bearpaw Formation consists of marine shale, siltstone and minor sandstone layers except in some areas where the thickness of the sandstone layers can be significant. The Bearpaw Formation "represents the final widespread marine unit in the Western Canada Foreland Basin" (Catuneanu et al, 1997).

The Belly River Group includes the Oldman and Foremost formations. The Oldman Formation is present as the upper bedrock in the southeastern part of the County, and is mainly less than 250 metres thick. The Oldman Formation is composed of continental deposits, sandstone, siltsone, shale and coal. The Oldman Formation is the upper part of the Belly River Group.

The Foremost Formation has been eroded in most of the County and subcrops along the Milk River. The Foremost Formation is mainly less than 200 metres thick and is between the overlying Oldman Formation and the underlying Lea Park Formation. The Foremost Formation includes both sandstone and shale units. Coal zones occur within the Foremost Formation, with the main ones referred to as the McKay and the Taber Coal zones. There are also minor amounts of ironstone, a chemical deposit.

The present identification of the Foremost Formation would not be possible without identifying a continuous top for the Lea Park Formation. The top of the Lea Park Formation represents a geologic time border between the marine environment of the Lea Park Formation and the mostly continental environment of the Foremost Formation.

The top of the Lea Park Formation is the bottom of the higher resistivity layer that occurs within a few metres below a regionally identifiable bentonite marker, as shown in the adjacent e-log. This marker occurs approximately 100 metres above the Milk River Shoulder.

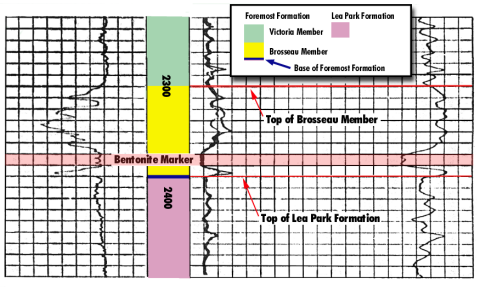


Figure 19. E-Log showing Base of Foremost Formation

[21] See glossary

There will be a limited review of the Lower Lacombe and Haynes members and the Foremost Formation in the text of this report because there are not sufficient hydrogeological data to create meaningful contour maps; the only maps associated with the Lower Lacombe and Haynes members and the Foremost Formation to be included on the CD-ROM will be structure-contour maps.

5.3.3 Upper Bedrock Completion Aquifer(s)

Of the 2,671 water wells in the database, 459 were defined as being completed below the top of bedrock, based on lithologic information and water well completion details. However, at least a reported completion depth is available for 1,394 water wells completed below the bedrock surface. Of these 1,394 water wells, eleven are completed below the upper bedrock, ten in saline formations and one in the Milk River Aquifer, giving a total of 1,383 water wells completed in upper bedrock aquifer(s). Assigning a water well to a specific geologic unit is possible only if the completion interval is identified. In order to make use of additional information within the groundwater database, it was assumed that the top of the completion interval was 80% of the total completed depth of a water well. With this assumption, it has been possible to designate the specific bedrock aquifer of completion for an additional 716 bedrock water wells, giving a total of 1,175 water wells. The remaining 208 of the total 1,383 bedrock water wells are identified as being completed in more than one bedrock aquifer as shown in Table 5. The bedrock water wells are mainly completed in the Disturbed Belt and the Lower Scollard aquifers.

Geologic Unit	No. of Bedrock Water Wells
Disturbed Belt	344
Upper Lacombe	9
Lower Lacombe	5
Haynes	6
Upper Scollard	61
Lower Scollard	194
Upper Horseshoe Canyon	124
Middle Horseshoe Canyon	98
Lower Horseshoe Canyon	28
Bearpaw	168
Oldman	136
Foremost	2
Multiple Completions	208
Total	1,383

Table 5. Completion Aquifer for Upper Bedrock Water Wells

There are 294 records for bedrock water wells that have apparent yield values, which is 21% of the 1,383 bedrock water wells. In the County, yields for water wells completed in the upper bedrock aquifer(s) are mainly between 10 and 100 m³/day. The areas where higher yields are expected may identify locations of increased permeability resulting from the weathering process. In addition to the 1,383 records for bedrock water wells, there are 201 records that indicate that the water well is dry, or abandoned with “insufficient water”. In order to depict a more accurate yield map, an apparent yield of 0.1 m³/day was assigned to the 201 dry water test holes prior to gridding. One hundred and twenty-nine (64%) of the 201 dry water test holes are within the Blood First Nation lands, of which 64 (50%) are completed in Lower Scollard Aquifer. In the County, 74 (37%) of the 201 dry water test holes are completed in the Upper and Lower Scollard aquifers.

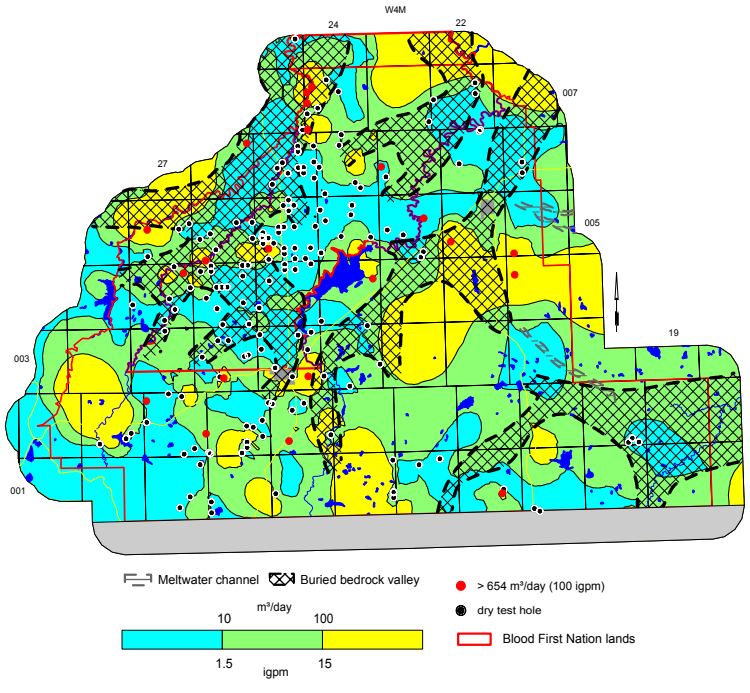


Figure 20. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

Of the 294 water well records with apparent yield values, 244 have been assigned to aquifers associated with specific geologic units. Thirty-three percent (99) of the 297 water wells completed in bedrock aquifers have apparent yields that are less than ten m³/day, 44% (128) have apparent yield values that range from 10 to 100 m³/day, and 23% (67) have apparent yields that are greater than 100 m³/day, as shown in Table 6. The water well records having higher apparent yield values are expected to be in areas of increased permeability resulting from the weathering process.

Aquifer	No. of Water Wells with Values for Apparent Yield (*)	Number of Water Wells with Apparent Yields <10 m³/day	10 to 100 m³/day	>100 m³/day
Disturbed Belt	90	32	37	21
Upper Lacombe	3	2	0	1
Lower Lacombe	1	0	0	1
Haynes	0	0	0	0
Upper Scollard	14	5	5	4
Lower Scollard	40	13	19	8
Upper Horseshoe Canyon	24	7	11	6
Middle Horseshoe Canyon	20	9	7	4
Lower Horseshoe Canyon	5	1	2	2
Bearpaw	29	5	16	8
Oldman	17	3	12	2
Foremost	0	0	0	0
Multiple Completions	51	22	19	10
Totals	294	99	128	67

* - does not include dry test holes

Table 6. Apparent Yields of Bedrock Aquifers

5.3.4 Chemical Quality of Groundwater

The Piper tri-linear diagram for bedrock aquifers (page A-28) shows that all chemical types of groundwater occur in the bedrock aquifers. However, the majority of the groundwaters are sodium-bicarbonate or sodium-sulfate types.

The TDS concentrations in the groundwaters from the upper bedrock aquifer(s) range from less than 500 mg/L to more than 2,000 mg/L, with the lower TDS values being in the Disturbed Belt Aquifer and the highest TDS values being in the central part of the County (page A-30). The relationship between TDS and sulfate concentrations shows that when TDS values in the groundwaters from the upper bedrock aquifer(s) exceed 1,200 mg/L, the sulfate concentrations exceed 400 mg/L.

In the County, 95% of the chloride concentrations in the groundwaters from the upper bedrock aquifer(s) are less than 100 mg/L. Chloride concentrations of greater than 100 mg/L are mainly associated with groundwaters from the Oldman Aquifer.

The nitrate + nitrite (as N) concentrations are less than 1.0 mg/L in 75% of the chemical analyses and greater than 10.0 mg/L in eight percent for upper bedrock water wells. Eighty percent of the total hardness values in the groundwaters from the upper bedrock aquifer(s) are less than 200 mg/L.

In the County, approximately 35% of the groundwater samples from upper bedrock aquifer(s) have fluoride concentrations that are too low (less than 0.5 mg/L) to meet the recommended daily needs of people. Approximately 35% of the groundwater samples from the entire County are between 0.5 and 1.5 mg/L and approximately 30% exceed the maximum acceptable concentration for fluoride of 1.5 mg/L.

A comparison was made of fluoride concentrations in the groundwaters from water wells in the County completed in different aquifers in the upper bedrock. The comparison was made to determine if there was a relationship between fluoride concentrations and the aquifer of completion. In addition, the comparisons were extended to compare the trends established within the County to trends throughout Alberta. The comparisons are summarized below in Table 7.

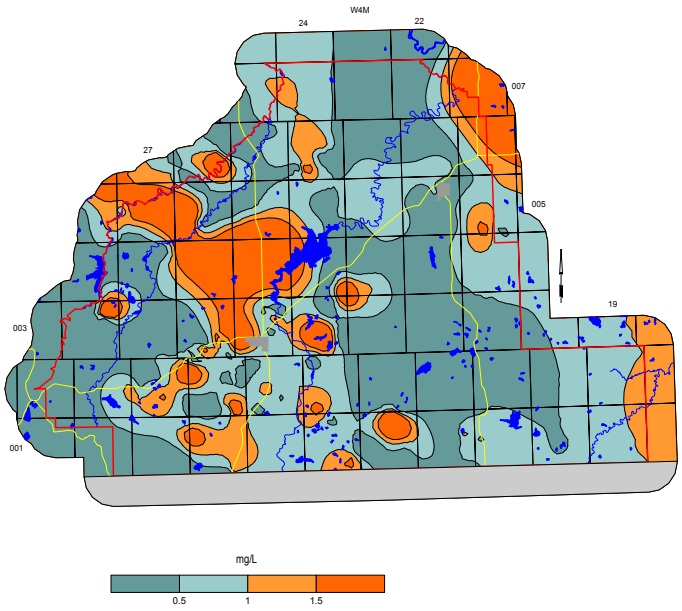


Figure 21. Fluoride in Groundwater from Upper Bedrock Aquifer(s)

Throughout Alberta, the median fluoride concentrations in groundwaters increase consistently in water wells completed in aquifers above the Upper Scollard Aquifer. In the County, there were insufficient data in the Lacombe and Haynes aquifers to determine if this trend would be replicated. In both the County and throughout Alberta, median fluoride concentrations decrease consistently in water wells completed below the Lower Scollard Aquifer, with the exception of the Oldman Aquifer. The percentages of analyses with fluoride concentrations of greater than 1.5 mg/L and greater than 2.5 mg/L exhibit a similar trend.

	Fluoride				Percentage of Analyses Greater than the SGCDWQ (1.5 mg/L)		Percentage of Analyses Greater than 2.5 mg/L	
	No. of Analyses		Median					
Aquifer Name	County	All Alberta	County	All Alberta	County	All Alberta	County	All Alberta
Disturbed Belt	100	616	0.4	0.27	11.0	8.0	6.0	3.7
Upper Lacombe	3	1,171	#N/A	0.42	#N/A	19.7	#N/A	10.1
Lower Lacombe	0	1,100	#N/A	0.43	#N/A	22.5	#N/A	12.0
Haynes	1	717	#N/A	0.53	#N/A	22.7	#N/A	13.8
Upper Scollard	7	695	2.4	0.47	57.1	20.1	42.9	6.6
Lower Scollard	37	861	0.8	0.56	13.5	16.7	5.4	3.1
Upper Horseshoe Canyon	37	4,546	0.8	0.65	13.5	24.4	13.5	6.0
Middle Horseshoe Canyon	22	2,179	0.6	0.50	4.5	16.0	4.5	2.2
Lower Horseshoe Canyon	6	6,350	0.5	0.43	0.0	7.0	0	0.8
Bearpaw	30	2,683	0.4	0.42	0.0	4.6	0	0.4
Oldman	31	3,793	0.5	0.70	12.9	16.8	9.7	2.3

SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality
Federal-Provincial Subcommittee on Drinking Water, March 2001
#N/A - fewer than five analyses

Table 7. Fluoride Concentrations in Groundwaters from Upper Bedrock Aquifer(s)