

The Milk River Formation underlies the entire M.D. but subcrops in the northwestern part of the M.D., has a thickness of approximately 50 metres, is composed mostly of shale, with minor amounts of coal, and underlies the Lea Park Formation. In the M.D., the Milk River Formation has limited importance and there will be no direct review in the text of this report; there are insufficient or no hydrogeological data within the study area to prepare meaningful maps. Structure-contour maps of the Milk River Formation are included in Appendix A and on the CD-ROM.

The Colorado Group, present under the entire M.D., includes mainly shale units between the Milk River Formation and the Mannville Group. The Viking Formation, a 50-metre-thick sandstone unit that sometimes can be distinguished near the base of the Colorado Group, is composed of well-washed and variable shaly, fine- to coarse-grained sandstone, with subordinate conglomerate and pebbly sandstone. In the southern part of the province, the Viking Formation is developed as a source of groundwater, and in many central and northern parts of the province as a source of gas. However, even the Viking Formation would not be expected to have yields of greater than 20 m³/day (HCL, Revised May 15, 1991).

The Mannville Group underlies the Colorado Group and contains several porous and permeable zones toward its base, which include the Grand Rapids and Clearwater formations.

5.3.3 Upper Bedrock Completion Aquifer(s)

Of the 1,110 water wells in the database, 147 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 402 water wells completed below the bedrock surface. 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 234 bedrock water wells, giving a total of 381 water wells. The remaining 21 of the total 402 upper bedrock water wells are identified as being completed in more than one bedrock aquifer, as shown in Table 7. The bedrock water wells are mainly completed in the Foremost Aquifer.

The water wells shown to be completed in the Lea Park and Milk River formations have been determined mainly based on completed depth only and without the benefit of lithologic description or any other supporting documentation, and therefore the completion formations are suspect.

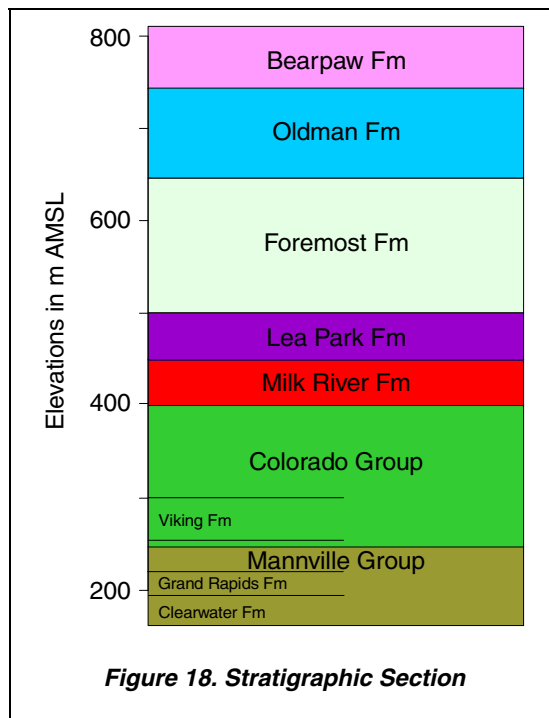


Figure 18. Stratigraphic Section

Geologic Unit	No. of Bedrock Water Wells
Bearpaw	0
Oldman	7
Foremost	340
Lea Park	25
Milk River	9
Multiple Completions	21
Total	402

Table 6. Completion Aquifer for Upper Bedrock Water Wells

There are 125 records for bedrock water wells that have apparent yield values, which is 31% of the 402 bedrock water wells in the M.D.

The main areas where bedrock water wells are largely absent are where the Lea Park and Milk River formations are the upper bedrock. In these areas, water wells are mainly completed in surficial deposits. Yields for water wells completed in the upper bedrock aquifer(s) are mainly between 10 and 100 m³/day and have a median apparent yield of 25 m³/day. The areas in the northwestern part of the M.D. where apparent yields of more than 100 m³/day are shown and the areas in the northeastern part of the M.D. where apparent yields are between ten and 100 m³/day are a result of the gridding process using limited data control. The bedrock water wells in the southern part of the County having apparent yields of less than ten m³/day are mainly where the upper bedrock is the Oldman Formation.

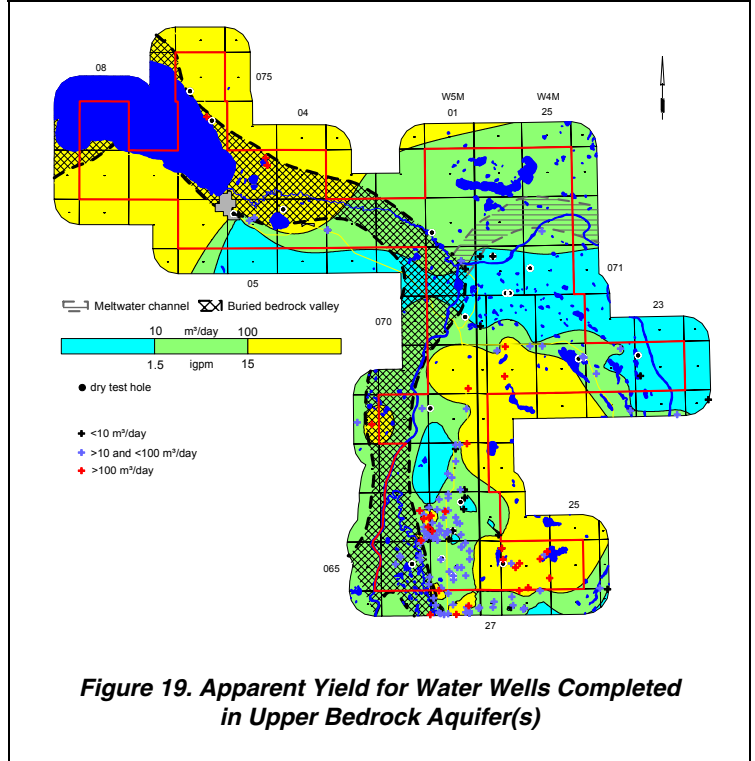


Figure 19. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

In addition to the 125 records for bedrock water wells with apparent yield values, there are 28 records that indicate that the water well/water test hole 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 28 dry water test holes prior to gridding.

Aquifer	No. of Water Wells with Values for Apparent Yield (*)	Number of Water Wells with Apparent Yields		
		<10 m ³ /day	10 to 100 m ³ /day	>100 m ³ /day
Bearpaw	0	0	0	0
Oldman	3	0	3	0
Foremost	108	17	71	20
Lea Park	2	2	0	0
Milk River	0	0	0	0
Multiple Completions	12	2	5	5
Totals	125	21	79	25

* - does not include dry test holes

Table 7. Apparent Yields of Bedrock Aquifers

Of the 125 water well records with apparent yield values, 108 have been assigned to the Foremost Aquifer. Seventeen percent (21) of the 125 water wells completed in bedrock aquifers have apparent yields that are less than ten m³/day, 63% (79) have apparent yield values that range from 10 to 100 m³/day, and 20% (25) have apparent yield values that are greater than 100 m³/day, as shown in Table 7. In the Foremost Aquifer, nearly 45% of the apparent yield values are greater than 100 m³/day.

5.3.4 Chemical Quality of Groundwater

The Piper tri-linear diagram for bedrock aquifers (page A-27) shows that groundwaters from bedrock aquifers are mainly sodium-bicarbonate or calcium-magnesium-type waters.

The TDS concentrations in the groundwaters from the upper bedrock aquifer(s) range from less than 500 mg/L to more than 1,500 mg/L, with most of the groundwaters with higher TDS concentrations occurring where the Oldman Formation is the upper bedrock in the southern part of the M.D.

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 M.D., more than 85% of the chloride concentrations in the groundwaters from the upper bedrock aquifer(s) are less than 50 mg/L.

In the M.D., there were 11 groundwater samples that had Nitrate + Nitrite (as N) concentrations that were greater than the SGCDWQ for the upper bedrock aquifer(s). Approximately 55% of the total hardness values in the groundwaters from the upper bedrock aquifer(s) are less than 200 mg/L.

In the M.D., approximately 75% 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 23% of the groundwater samples from the entire M.D. are between 0.5 and 1.5 mg/L and approximately 2% exceed the MAC for fluoride of 1.5 mg/L, with most of the exceedances occurring in the southern part of the M.D. (see CD-ROM).

The minimum, maximum and median²⁰ concentrations of TDS, sodium, sulfate, chloride and fluoride in the groundwaters from water wells completed in the upper bedrock in the M.D. have been compared to the SGCDWQ in Table 8. Of the five constituents compared to the SGCDWQ, median concentrations of **TDS** exceed the guidelines.

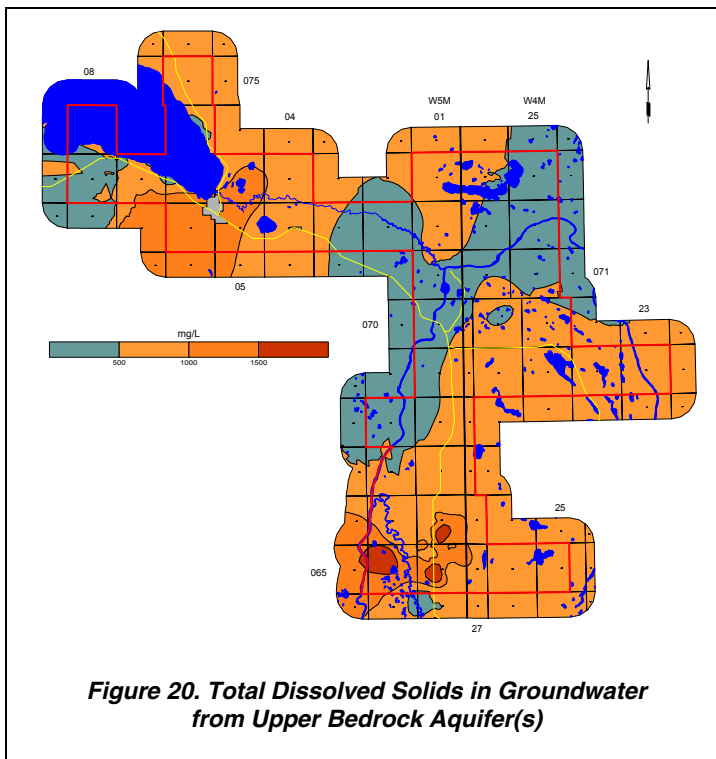


Figure 20. Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

Constituent	No. of Analyses	Range for County in mg/L			Recommended Maximum Concentration SGCDWQ
		Minimum	Maximum	Median	
Total Dissolved Solids	250	0	8,559	679	500
Sodium	213	0	1,091	80	200
Sulfate	250	0	1,345	48	500
Chloride	250	0	1,450	7	250
Fluoride	220	0	2.2	0.3	1.5

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Fluoride, which is for Maximum Acceptable Concentration (MAC)
SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality
 Federal-Provincial-Territorial Committee on Drinking Water, April 2003

Table 8. Concentrations of Constituents in Groundwaters from Upper Bedrock Aquifer(s)

²⁰ see glossary

5.3.5 Oldman Aquifer

The Oldman Aquifer comprises the permeable parts of the Oldman Formation, as defined for the present program. The structure contours show that the Oldman Formation ranges in elevation from less than 590 to more than 790 metres AMSL and has a maximum thickness of 110 metres. The regional groundwater flow direction in the Oldman Aquifer is downgradient to the west toward the Pembina River (see CD-ROM).

5.3.5.1 Depth to Top

The depth to the top of the Oldman Formation is mainly less than 50 metres and is a reflection of the thickness of the surficial deposits (page A-30).

5.3.5.2 Apparent Yield

The apparent yield values for individual water wells completed through the Oldman Aquifer range from less than five to more than 30 m³/day, and have a median apparent yield of 25 m³/day. The areas where data control points are present show that water wells with yields of greater than 30 m³/day are expected to be in the southwestern part of the M.D., as shown on Figure 21.

There are three registered groundwater users that have water wells completed through the Oldman Aquifer, for a total groundwater diversion of five m³/day. Of the three registered groundwater users, one could be linked to a water well in the AENV groundwater database.

5.3.5.3 Quality

There were insufficient chemistry data to determine the groundwater type in the Oldman Aquifer. The TDS concentrations range from less than 500 to more than 1,000 mg/L, with the highest TDS concentration being 1,346 mg/L (page A-32). More than 70% of the sulfate concentrations in groundwaters from the Oldman Aquifer are less than 500 mg/L. All of the chloride concentrations from the Oldman Aquifer are less than or equal to two mg/L and all of the fluoride concentrations are less than 2.5 mg/L.

Of the five constituents that have been compared to the SGCDWQ, the median values of **TDS** and **sodium** exceed the guidelines. The median concentrations of TDS, sodium and sulfate from water wells completed in the Oldman Aquifer are greater than the median concentrations from water wells completed in all upper bedrock aquifer(s).

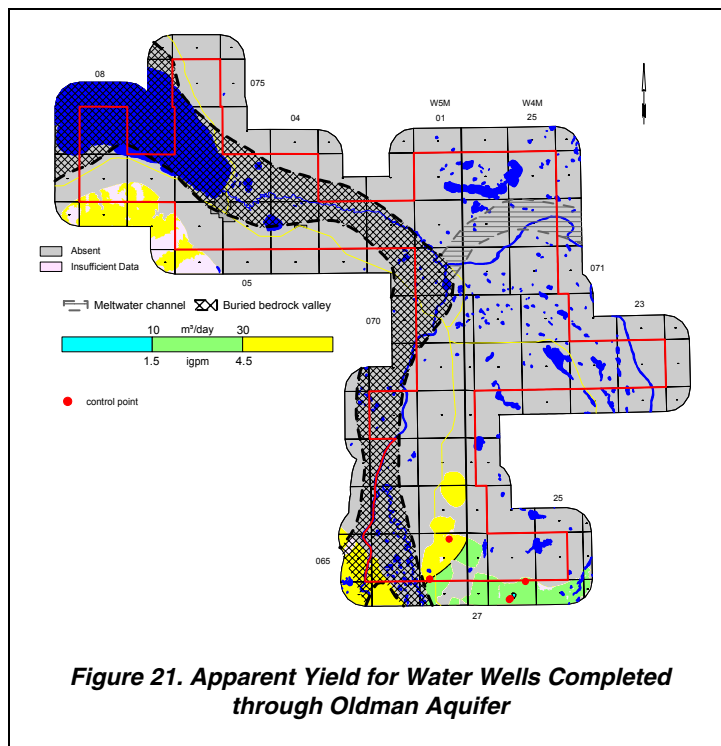


Figure 21. Apparent Yield for Water Wells Completed through Oldman Aquifer

Constituent	No. of Analyses	Range for County in mg/L			All Bedrock Median	Recommended Maximum Concentration SGCDWQ
		Minimum	Maximum	Median		
Total Dissolved Solids	7	430	1,346	982	679	500
Sodium	5	33	228	202	80	200
Sulfate	7	16	623	316	48	500
Chloride	7	0	2	1	7	250
Fluoride	5	0	0	0.2	0.3	1.5

Concentration in milligrams per litre unless otherwise stated
 Note: indicated concentrations are for Aesthetic Objectives except for Fluoride, which is for Maximum Acceptable Concentration (MAC)
 SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality
 Federal-Provincial Subcommittee on Drinking Water, April 2002

Table 9. Apparent Concentrations of Constituents in Groundwaters from Oldman Aquifer

5.3.6 Foremost Aquifer

The Foremost Aquifer comprises the permeable parts of the Foremost Formation, as defined for the present program. The Foremost Formation subcrops under the surficial deposits in most of the M.D. The structure contours show that the Foremost Formation ranges in elevation from less than 520 to more than 680 metres AMSL and has a maximum thickness of 180 metres. The regional groundwater flow direction in the Foremost Aquifer is downgradient to the northeast toward the Lesser Slave River and west toward the Pembina River (see CD-ROM).

5.3.6.1 Depth to Top

The depth to the top of the Foremost Formation ranges from less than 25 metres to more than 350 metres in the areas north and south of Lesser Slave Lake (page A-33).

5.3.6.2 Apparent Yield

The apparent yields for individual water wells completed through the Foremost Aquifer range from less than ten to more than 100 m³/day, as shown on Figure 22. The areas showing water wells with yields of greater than 100 m³/day are expected to be in the southern parts of the M.D.

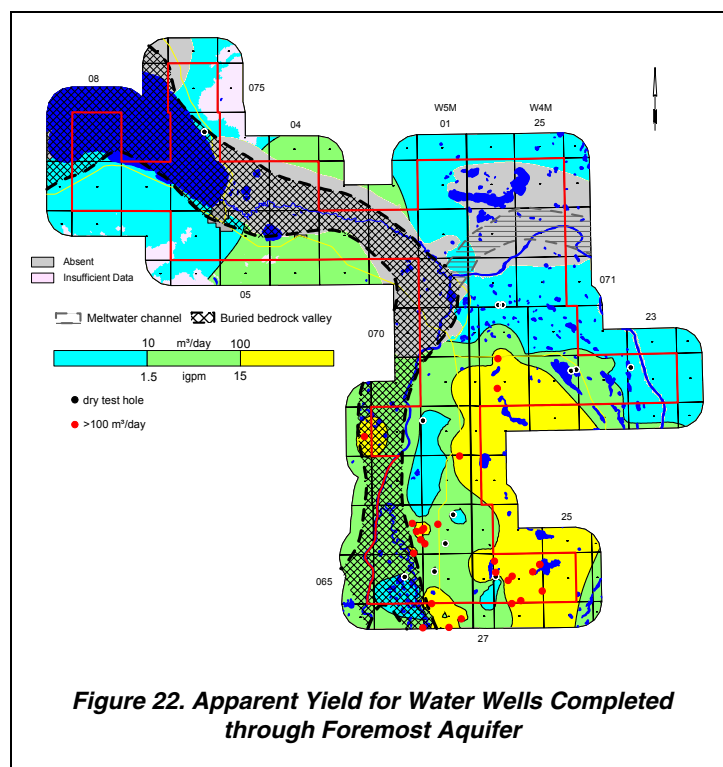
Shown on the adjacent map are the locations of 14 dry water test holes.

There are 45 licensed and registered groundwater users that have water wells completed through the Foremost Aquifer, for a total authorized groundwater diversion of 173 m³/day.

Of the 45 licensed and registered groundwater users, 28 could be linked to water wells in the AENV groundwater database.

The highest authorized groundwater use is for a water well in 13-16-066-01 W5M completed for the Town of Flatbush in July 1991, licensed to Alberta Municipal Affairs to divert 37.2 m³/day for municipal purposes.

An extended aquifer test conducted with a Town of Flatbush Highway Maintenance Yard water supply well in 04-09-066-01 W5M completed in the Foremost Aquifer in October 1973 indicated a long-term yield of 14.4 m³/day (HCL, Nov-1973).



5.3.6.3 Quality

The groundwaters from the Foremost Aquifer are mainly a calcium-magnesium-bicarbonate type (see Piper diagram on CD-ROM), with 85% of the groundwater samples having TDS concentrations of less than 1,000 mg/L (page A-35). Seventy percent of the sulfate concentrations in groundwaters from the Foremost Aquifer are less than 100 mg/L. Eighty-five percent of the chloride concentrations from the Foremost Aquifer are less than 50 mg/L, and 75% of the fluoride concentrations from the Foremost Aquifer are less than 0.5 mg/L.

A chemical analysis of a groundwater sample collected in October 1973 from the Town of Flatbush Highway Maintenance Yard water supply well in 04-09-066-01 W5M indicates the groundwater is a sodium-bicarbonate type, with a TDS concentration of 1,706 mg/L, a sulfate concentration of 570 mg/L, a chloride concentration of 4 mg/L, and a fluoride concentration of 0.46 mg/L (HCL, Nov-1973).

Of the five constituents that have been compared to the SGCDWQ, the median value of **TDS** exceeds the guidelines. The median concentrations of TDS, sulfate and chloride from water wells completed in the Foremost Aquifer are greater than the median concentrations from water wells completed in all upper bedrock aquifer(s).

Constituent	No. of Analyses	Range for County in mg/L			All Bedrock Median	Recommended Maximum Concentration SGCDWQ
		Minimum	Maximum	Median		
Total Dissolved Solids	216	0	2,820	702	679	500
Sodium	192	0	1,091	80	80	200
Sulfate	217	0	1345	50	48	500
Chloride	217	0	1450	9	7	250
Fluoride	199	0	2	0.3	0.3	1.5

Concentration in milligrams per litre unless otherwise stated
 Note: indicated concentrations are for Aesthetic Objectives except for Fluoride, which is for Maximum Acceptable Concentration (MAC)
 SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality
 Federal-Provincial Subcommittee on Drinking Water, April 2002

Table 10. Apparent Concentrations of Constituents in Groundwaters from Foremost Aquifer

5.3.7 Mannville Group

5.3.7.1 Grand Rapids Formation

A Norwich Resources water source well in 12-35-074-06 W5M is completed from 530 to 534 metres below ground surface in the Grand Rapids Formation of the Mannville Group (see Figure 18 on Page 23 showing a graphical stratigraphic section of the Mannville Group). Water Source Well 12-35 was completed in August 1987 and was licensed to divert 340 m³/day for oil industrial (injection) purposes.

An extended aquifer test conducted with WSW 12-35 in September 1988 indicated a long-term yield of in excess of 305 m³/day, based on an effective transmissivity of 34 m²/day and a corresponding storativity of 8.7×10^{-5} (HCL, April-1989).

Groundwater production data are available from 1988 to 2001. Water Source Well No. 12-35 diverted an annual maximum of 67,840 cubic metres (185 m³/day) in 1994 (HCL, Dec-1995). The groundwaters from WSW No. 12-35 are a sodium-chloride-type with TDS concentrations in excess of 10,000 mg/L.

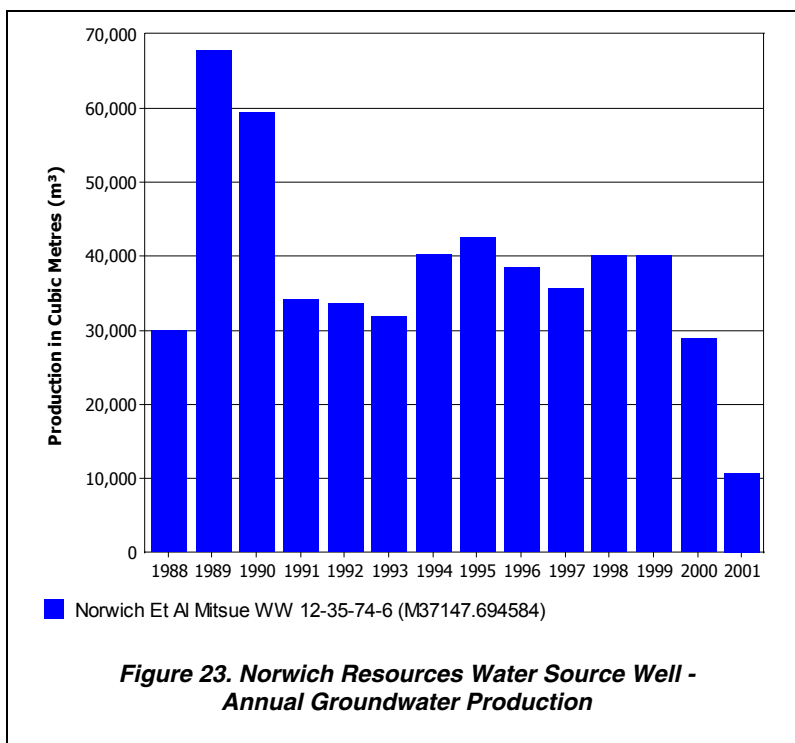


Figure 23. Norwich Resources Water Source Well - Annual Groundwater Production

5.3.7.2 Clearwater Formation

A Glen Isle Exploration Ltd. hydrocarbon well in 03-05-074-04 W5M was recompleted as a water source well by perforating the depth interval from 500 to 505 metres below Kelly Bushing (KB) in a sandstone layer within the Clearwater Formation, approximately 75 metres below the Grand Rapids Formation of the Mannville Group; KB elevation is 601.5 metres AMSL. The 03-05-074-04 W5M was the target location for the hydrocarbon well; the surface location is 06-05-074-04 W5M. Water Source Well No. 06-05, completed from 101.5 to 96.5 metres AMSL, is completed approximately 95 metres below the Norwich Resources water source well in 12-35-074-06 W5M. An extended aquifer test conducted with WSW No. 06-05 in March 1991 indicated a long-term yield of 165 m³/day, based on an effective transmissivity of 3.8 m²/day and a corresponding storativity of 8.7×10^{-5} (HCL, Revised May 15, 1991).

The chemical quality of the groundwater from the Norwich Resources water source well and the Glen Isle Exploration Ltd. water source well is similar, with TDS concentrations ranging from 8,000 to 12,000 mg/L.