5.3.12 Empress Aquifer – Unit 3

The Empress Aquifer – Unit 3 comprises the permeable parts of the Empress Formation – Unit 3. Structure contours have been prepared for the top of the Empress Formation – Unit 3. The structure contours show the Empress Formation – Unit 3 ranges in elevation from less than 470 to more than 550 metres AMSL and has a thickness of mainly less than 50 metres (see CD-ROM).

5.3.12.1 Depth to Top

The depth to the top of Unit 3 ranges from less than 50 metres below ground level to more than 100 metres in parts of the north-central, northwestern and southeastern areas of the M.D. (Page A-48).

5.3.12.2 Apparent Yield

The apparent yields for individual water wells completed through the Empress Aquifer - Unit 3 are mainly greater than 100 m³/day, with 31% of the values being less than 50 m³/day, 27% between 50 and 150 m³/day, and 42% of the values being more than 150 m³/day.

In the M.D., there are 21 licensed water wells that are completed in the Empress Aquifer - Unit 3, with a total authorized diversion of 9,266 m³/day. The highest allocation of 4,000 m³/day is for a water source well in 05-22-065-04 W4M used for industrial purposes. Seventeen of the 21 licensed water wells could be linked to a water well in the AENV groundwater database.

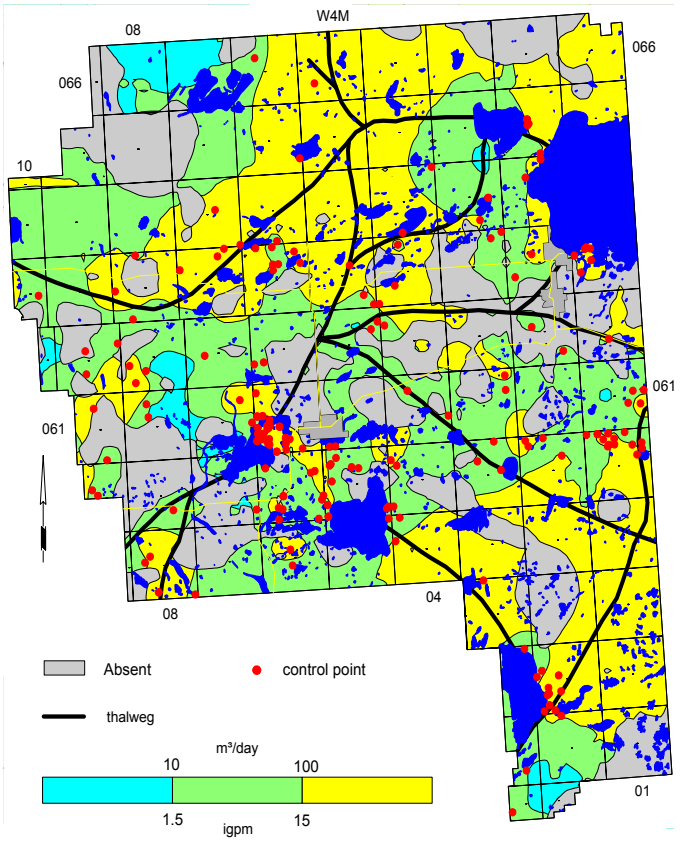

Figure 24. Apparent Yield for Water Wells Completed through Empress Aquifer – Unit 3

An extended aquifer test conducted with a water source well completed in the Empress Aquifer – Unit 3 in 04-33-061-04 W4M indicated a total long-term yield of 380 m³/day, based on an effective transmissivity of 130 m²/day (HCL, May 1985). This water source well is currently licensed to divert 500 m³/day for industrial purposes.

In 1982, BP Exploration was licensed to divert 470,000 m³/year (1,300 m³/day) for industrial purposes from a water source well completed in the Empress Aquifer - Unit 3 in 09-07-066-05 W4M. From 1978 to 1982, nearly 1,000,000 cubic metres were diverted from this water source well (HCL, 1983).

5.3.12.3 Quality

The groundwaters from the Empress Aquifer – Unit 3 are mainly a bicarbonate type, with calcium-magnesium or sodium as the main cation (see Piper diagram on CD-ROM). The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and nitrate + nitrite (as N) in the groundwaters from water wells completed in the Empress Aquifer - Unit 3 in the M.D. have been compared to the SGCDWQ and median concentrations from all surficial deposits in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines.

Constituent	No. of Analyses	Range for M.D. in mg/L Minimum	Maximum	Median	All Surficial Median	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	149	85	6846	894	748	500
Sodium	136	8	1650	214	112	200
Sulfate	150	0	3900	123	92	500
Chloride	151	0	1500	38	10	250
Nitrate + Nitrite (as N)	105	0	52	0.0	0.0	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Nitrate + Nitrite (as N), which is for Maximum Acceptable Concentration (MAC)
SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality Federal-Provincial Subcommittee on Drinking Water, March 2001

Table 12. Concentrations of Constituents in Groundwaters from Empress Aquifer – Unit 3

The median concentrations of TDS, sodium, sulfate and chloride from water wells completed in the Empress Aquifer – Unit 3 are greater than the median concentrations from water wells completed in all surficial deposits.

A groundwater sample from the water source well in 04-33-061-04 W4M has a TDS concentration of 868 mg/L, a sodium concentration of 323 mg/L, a sulfate concentration of 5 mg/L, a chloride concentration of 90 mg/L, and a nitrate + nitrite (as N) of less than 0.2 mg/L (HCL, May 1985).

A groundwater sample from the water source well in 09-07-066-05 W4M has a TDS concentration of 786 mg/L, a sodium concentration of 168 mg/L, a sulfate concentration of 121 mg/L, a chloride concentration of 8 mg/L, and a nitrate + nitrite (as N) of less than 0.2 mg/L (HCL, May 1983).

5.3.13 Lower Sand and Gravel Aquifer (Empress – Unit 1)

The Empress Aquifer – Unit 1 is a saturated sand and gravel deposit that occurs at or near the base of the surficial deposits in the deeper parts of the linear bedrock lows. Structure contours have been prepared for the top of the Empress Formation – Unit 1. The structure contours show the Empress Formation – Unit 1 ranges in elevation from less than 440 to more than 520 metres AMSL. The thickness of the Empress Formation – Unit 1 is mainly less than 15 metres but can be more than 15 metres in parts of the Buried Helena and Beverly valleys (see CD-ROM).

5.3.13.1 Depth to Top

The depth to the top of the Empress Formation – Unit 1 ranges from less than 50 metres below ground level to more than 150 metres in the north-central parts of the M.D. (Page A-51).

5.3.13.2 Apparent Yield

The apparent yields for individual water wells completed through the Empress Aquifer – Unit 1 are mainly greater than 100 m³/day, with 31% of the values being less than 50 m³/day, 27% between 50 and 150 m³/day, and 55% of the values being more than 150 m³/day.

In the M.D., there are four licensed water wells that are completed through the Empress Aquifer – Unit 1, with a total authorized diversion of 4,274 m^3/day, of which 4,000 m³/day is for a water source well in 05-22-065-04 W4M used for industrial purposes. Three of the four licensed water wells could be linked to a water well in the AENV groundwater database.

In 1987, Canadian Occidental Petroleum Ltd. were licensed to divert 534,000 m³/year (1,465 m³/day) for industrial purposes from three water source wells completed in the Empress Aquifer - Unit 1 in section 13, township 063, range 08, W4M. In 1987, 257,479 m³ were diverted from these water source wells (HCL, 1983).

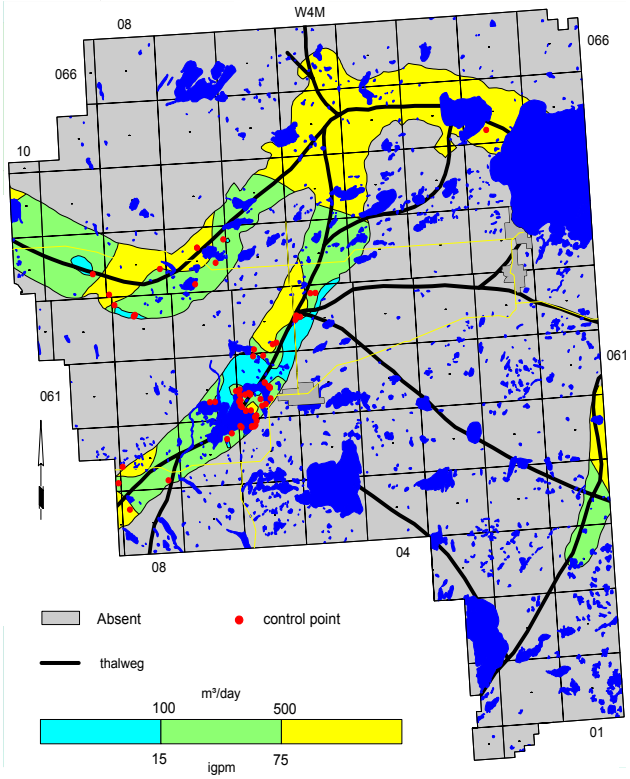

Figure 25. Apparent Yield for Water Wells Completed through Empress Aquifer – Unit 1

5.3.13.3 Quality

The groundwaters from the Empress Aquifer – Unit 1 are primarily a sodium-bicarbonate type (see Piper diagram on CD-ROM). The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and nitrate + nitrite (as N) in the groundwaters from water wells completed in the Empress Aquifer – Unit 1 in the M.D. have been compared to the SGCDWQ and median concentrations from all surficial deposits in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines.

Constituent	No. of Analyses	Range for M.D. in mg/L Minimum	Maximum	Median	All Surficial Median	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	29	270	2477	971	748	500
Sodium	29	11.4	609	280	112	200
Sulfate	30	3.36	1183	153	92	500
Chloride	30	0	495	56	10	250
Nitrate + Nitrite (as N)	26	0	2	0.0	0.0	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Nitrate + Nitrite (as N), which is for Maximum Acceptable Concentration (MAC)
SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality Federal-Provincial Subcommittee on Drinking Water, March 2001

Table 13. Concentrations of Constituents in Groundwaters from Empress Aquifer – Unit 1

The median concentrations of TDS, sodium, sulfate and chloride from water wells completed in the Empress Aquifer – Unit 1 are greater than the median concentrations from water wells completed in all surficial deposits.

A groundwater sample from the water source well in 06-13-063-08 W4M has a TDS concentration of 946 mg/L, a sodium concentration of 248 mg/L, a sulfate concentration of 40 mg/L, a chloride concentration of 42 mg/L, and a nitrate + nitrite (as N) of 1.02 mg/L (HCL, 1983).

5.4 Bedrock

5.4.1 Geological Characteristics

In the M.D., the uppermost bedrock is the Lea Park Formation, consisting mainly of dark grey shales of marine origin. At locations where deep bedrock valleys occur, the Lea Park Formation has been eroded, exposing the Milk River Formation and the *undivided* Colorado Group (Pages A-12 to A-17). The Milk River Formation and the *undivided* Colorado Group are marine shales of Upper Cretaceous Age, the base of the marine shales are at an elevation of approximately 300 metres AMSL. Neither the Lea Park Formation, the Milk River Formation or the *undivided* Colorado Group contain any aquifers that would be suitable for the development of groundwater supplies, since they are considered essentially impermeable.

There will be no direct review of the Lea Park Formation, the Milk River Formation or the *undivided* Colorado Group in the text of this report; the only maps associated with the Lea Park Formation and the *undivided* Colorado Group to be included on the CD-ROM will be structure-contour maps.

6. Groundwater Budget

6.1 Hydrographs

In the M.D., there are 26 observation water wells that are part of the AENV regional groundwater-monitoring network where water levels are being measured and recorded with time. These observation water wells are completed in surficial deposits near linear bedrock lows (Page A-55). Of the 26 observation water wells, eight have not been monitored since 1999. For the AENV observation water wells that have not been reclaimed, suspended or capped, the observation water wells are located in areas of industrial groundwater users. The AENV observation water wells are completed in the Marie Creek, Bonnyville, Muriel Lake, Bronson Lake, Empress – Unit 3 and Empress – Unit 1 aquifers, as shown below in Table 14.

AENV Obs WW No.	Well Name	Aquifer Name	Legal	Period of Monitoring Data	UID	Status - Recommendation*
188	AE Obs Well: Iron River 2078E (East)	Marie Creek	04-27-063-07 W4M	1985 - 2000	M35377.151707	Industrial area
243	AE Obs Well: Cushing Lake 2411E	Marie Creek	16-32-058-03 W4M	1987 - 2000	M35377.138927	Energy development in area
251	AE Obs Well: Esso Seismic Stn.5 2362	Marie Creek	04-17-065-03 W4M	1985 - 2001	M35377.149203	Industrial area
184	AE Obs Well: Bonnyville 1708EA (East)	Bonnyville	16-10-062-05 W4M	1977 - 1991	M35377.092553	Reclaimed
187	AE Obs Well: Iron River 2079E (West)	Bonnyville	13-31-063-07 W4M	1982 - 2000	M35377.148711	Industrial area
200	AE Obs Well: Wolfe Lake Grazing 2349E	Bonnyville	04-35-064-06 W4M	1985 - 2000	M35377.149040	Levels once per year
272	AE Obs Well: Soar Lake 89-1	Bonnyville	07-13-059-01 W4M	1989 - 1992	M35377.140834	Cap, retain for possible future use
183	AE Obs Well: Glendon 80-W1 (Suspended)	Muriel Lake	SE 26-060-08 W4M	1985 - 1986	M35377.145233	Suspended
189	AE Obs Well: Esso TH-1	Muriel Lake	13-30-064-03 W4M	1985 - 2000	M35377.148989	Cap, retain for possible future use
193	AE Obs Well: Marie Lake 82-2 (West)	Muriel Lake	SW 09-065-02 W4M	1985 - 2000	M35377.149092	Industrial area
195	AE Obs Well: Bourque Lake 1947E	Muriel Lake	04-26-065-04 W4M	1989 - 2000	M35377.149081	Regional, industrial area
197	AE Obs Well: BP-Triad 82-1	Muriel Lake	SW 28-066-05 W4M	1982 - 2000	M35377.128720	Regional, industrial area
245	AE Obs Well: Truman 84-1 (No. 2265E)	Muriel Lake	05-21-063-09 W4M	1984 - 1989	M35377.143153	Cap, retain for possible future use
250	AE Obs Well: Esso Seismic Stn.5 2361E	Muriel Lake	04-17-065-03 W4M	1985 - 2001	M35377.149202	Industrial area
248	AE Obs Well: Truman 84-4	Bronson Lake	05-21-063-09 W4M	1984 - 1989	M35377.143162	Cap, retain for possible future use
185	AE Obs Well: Bonnyville 1708EB (West)	Empress - Unit 3	16-10-062-05 W4M	1977 - 1989	M35377.092551	Reclaimed
198	AE Obs Well: BP-Triad 2346E (West)	Empress - Unit 3	04-28-066-05 W4M	1985 - 2000	M35377.150271	Regional, industrial groundwater use
199	AE Obs Well: Wolfe Lake Grazing 2348E	Empress - Unit 3	04-35-064-06 W4M	1988 - 2000	M35377.149037	Levels once per year
242	AE Obs Well: Cushing Lake 2406E (West)	Empress - Unit 3	16-32-058-03 W4M	1987 - 2000	M35377.138924	Energy development in area
244	AE Obs Well: Cushing Lake 2412E (East)	Empress - Unit 3	16-32-058-03 W4M	1987 - 1996	M35377.138929	Cap, retain for possible future use
246	AE Obs Well: Truman 84-2 (No. 2266E)	Empress - Unit 3	05-21-063-09 W4M	1984 - 2000	M35377.143155	Cold Lake Area
247	AE Obs Well: Truman 84-3 (No. 2267E)	Empress - Unit 3	05-21-063-09 W4M	1984 - 1989	M35377.143158	Cap, retain for possible future use
249	AE Obs Well: Esso Seismic Stn.5 2360E	Empress - Unit 3	04-17-065-03 W4M	1985 - 2000	M35377.149200	Industrial area
186	AE Obs Well: Lessard 2091E	Empress - Unit 1	14-25-063-05 W4M	1985 - 2001	M35377.087724	Esso Cold Lake Expansion
192	AE Obs Well: Marie Lake 82-1	Empress - Unit 1	SW 09-065-02 W4M	1982 - 2000	M35377.149090	Industrial area
194	AE Obs Well: Bourque Lake 1772E South	Empress - Unit 1	04-26-065-04 W4M	1978 - 2001	M35377.149075	Regional, industrial area

*AENV Fax Communication, 1998

Table 14. AENV Obs WW Summaries

Seventeen hydrographs were compared to determine if there were any water-level trends in the observation water wells. Four water-level trends were observed. There were water-level rises and declines in all four water-level trends but the fluctuations have occurred over different intervals of time. Examples of the four water-level trends are shown on the hydrographs for AENV Obs WW Nos. 188, 193, 194, 197 and 242 on Page A-55. These observation water wells are located in different areas of the M.D. and have been monitored for at least 14 years. The location of the observation water wells and the water-level trends are shown on Page A-56.

Licensed groundwater use for industrial purposes represents 68% of the total groundwater licensed. Almost all of the 68% is from water source wells in township 063 to 066, ranges 01 to 06, W4M. Groundwater production from 17 water source wells is available from the EUB database. Figure 26 on the following page shows the reported average daily groundwater production from 1985 to 2001.

In the last 30 years, there have been more than ten enhanced-oil-recovery projects in the M.D. that have used groundwater for at least part of the time. The larger projects include Esso Cold Lake and Amoco Wolf Lake. Some of the smaller projects include Norcen Primrose Lake, Koch Ardmore, Worldwide Energy Ardmore, Union Texas Ardmore, BP Marguerite Lake, and COPL Iron River.

In the time frame from 1985 to 2001, the Amoco Wolf Lake project started in 1985 and Esso used groundwater for 34 months starting at the end of 1991. The groundwater use at the Wolf Lake facility started to decrease in 1990, just before Esso started their main groundwater diversion. At the Wolf Lake facility, the groundwater use was limited throughout the 1990s.

The reported daily groundwater diversion from industrial users from 1977 to 1985 was less than 2,000 m^3/day. Since 1985, the total reported groundwater use has been more than 40 million cubic metres, an average of more than 7,000 cubic metres per day.

Three of the four water-level trends can be directly related to the groundwater diverted from two main enhanced-oil-recovery projects. The water-level fluctuations in AENV Obs WW No. 197 show the characteristics of Trend 1. The main characteristic of Trend 1 can be correlated to the start-up of the Amoco Wolf Lake project. From 1985 to 1990, the water level declined in response to the groundwater diversion from the Amoco Wolf Lake project. The reduced groundwater use at the Wolf Lake site beginning in the 1990s is reflected by the water-level rise in AENV Obs WW No. 197.

The water-level fluctuations in AENV Obs WW No 194 exhibit the characteristics of Trend 2. The main characteristic of Trend 2 can be correlated to the start-up of the Esso Cold Lake project. From 1978 to late 1991, the water level declined less than five metres. In late 1991, the water level declined more than 50 metres in response to the groundwater diversion from the Esso Cold Lake project.

The water-level fluctuations in AENV Obs WW No. 188 are an example of Trend 3. The main characteristic of Trend 3 is that the water-level fluctuations correlate to the combined groundwater diversion from the Amoco Wolf Lake and Esso Cold Lake projects. The hydrograph of AENV Obs WW No. 188 shows the water levels to decline from 1985 to 1990 in response to the groundwater diversion from Amoco Wolf Lake and again in 1992 in response to the groundwater diversion from Esso Cold Lake.

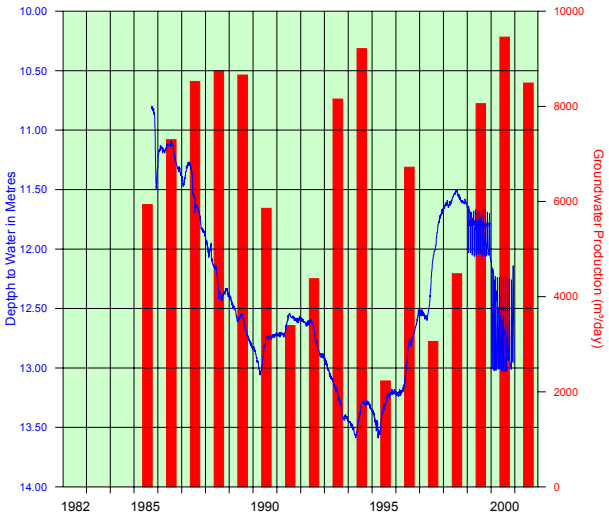

Figure 26. Annual Production vs Water Levels in AENV Obs WW No. 200

Another example illustrating the water-level characteristics of Trend 3 is AENV Obs WW No. 200. AENV Obs WW 200, in 04-35-064-06 W4M, is completed at a depth of 77.0 metres below ground level in the Bonnyville Aquifer. From 1985 to 1990, there was a net decline in the water level of approximately two metres in response to the groundwater production from the Amoco Wolf Lake project. From 1990 to 1991, the water level rose 0.5 metres. From 1991 to 1994, the water level declined about one metre in response to the groundwater production from the Esso Cold Lake project.

Even though there have been more than 40 million cubic metres of groundwater diverted from 1977 to 2001, the water levels in the observation water wells in various aquifers show that there has not been any negative impact on the aquifers.