largest total licensed allocations are in the Lower Sand and Gravel Aquifer. Of the 20,709 m³/day licensed groundwater use in the Lower Sand and Gravel Aquifer, 95% of the groundwater use is from a dewatering water well in SE 08-022-28 W4M.

Aquifer **	No. of Diversions	Licensed Groundwater Users* (m³/day) Agricultural	Municipal	Commercial	Dewatering	Recreation	Industrial	Exploration	Management	Total	Percentage
Upper Sand and Gravel	1	3	0	0	0	0	0	0	0	3	0
Lower Sand and Gravel	25	224	3	828	19,614	40	0	0	0	20,709	71
Bedrock	5	83	10	0	0	0	0	0	0	93	0
Disturbed Belt	64	319	101	0	0	12	0	35	0	467	2
Dalehurst	176	1,095	1,580	78	0	76	20	507	0	3,356	12
Lacombe	83	651	1,081	86	0	7	0	0	0	1,825	6
Haynes	25	147	872	1	0	0	0	0	0	1,020	4
Upper Scollard	9	47	17	68	0	0	0	0	0	132	0
Unknown	10	13	217	24	0	1	0	0	1,179	1,434	5
Total	398	2,582	3,881	1,085	19,614	136	20	542	1,179	29,039	100
Percentage		9	13	4	68	0	0	2	4	100	

* - data from AENV ** - Aquifer identified by HCL

Table 1. Licensed Groundwater Diversions

Based on the 1996 Agriculture Census, the calculated water requirement for 534,237 livestock for the M.D. is in the order of 14,855 m³/day. This value includes intensive livestock use but not domestic animals. Of the 14,855 m³/day average calculated livestock use, AENV has licensed a groundwater diversion of 2,582 m³/day (17%) and licensed a surface-water diversion of 6,808 m³/day (46%). The remaining 37% of the calculated livestock use would have to be from unlicensed sources. A census of the animals conducted by the M.D. in 1999 estimated the number to be 434,351 animals; this includes domestic animals but not intensive livestock operations.

2.3.6 Groundwater Chemistry and Base of Groundwater Protection

Groundwaters from the surficial deposits can be expected to be chemically hard, with a high dissolved iron content. Of the available chemical data for the surficial aquifers, there were no nitrate + nitrite (as N) concentrations that exceeded 10 mg/L; a plot of nitrate + nitrite (as N) in surficial aquifers is on the accompanying CD-ROM. The TDS concentrations in the groundwaters from the upper bedrock in the M.D. range from less than 500 to more than 3,000 mg/L (page A-34). Elevated nitrate + nitrite (as N) concentrations were evident in 2% of the available chemical data for the upper bedrock aquifer(s). Groundwaters from the bedrock aquifers frequently are chemically soft, with generally low concentrations of dissolved iron. The chemically soft groundwater is high in concentrations of sodium. Less than ten percent of the chemical analyses indicate a fluoride concentration above 1.5 mg/L, with most of the exceedances occurring in the southern and east-central part of the M.D. (see CD-ROM).

The minimum, maximum and median[8] 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 Summary of Guidelines for Canadian Drinking Water Quality (SGCDWQ) in Table 2. Of the five constituents compared to the SGCDWQ, median values of TDS and sodium concentrations exceed the guidelines; maximum values of all five constituents exceed the guidelines.

The maximum TDS and sulfate values shown in the adjacent table are from a domestic water well tap sample drilled in SW 07-024-28 W4M and completed 45 metres below ground surface in the Lacombe Aquifer.

Constituent	Range for M.D. in mg/L Minimum	Maximum	Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	186	7,949	1019	500
Sodium	2	1,500	294	200
Sulfate	0	5,248	407	500
Chloride	0	354	10	250
Fluoride	0	10	0.8	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, March 2001

Table 2. Concentrations of Constituents in Groundwaters from Upper Bedrock Aquifer(s)

8 see glossary

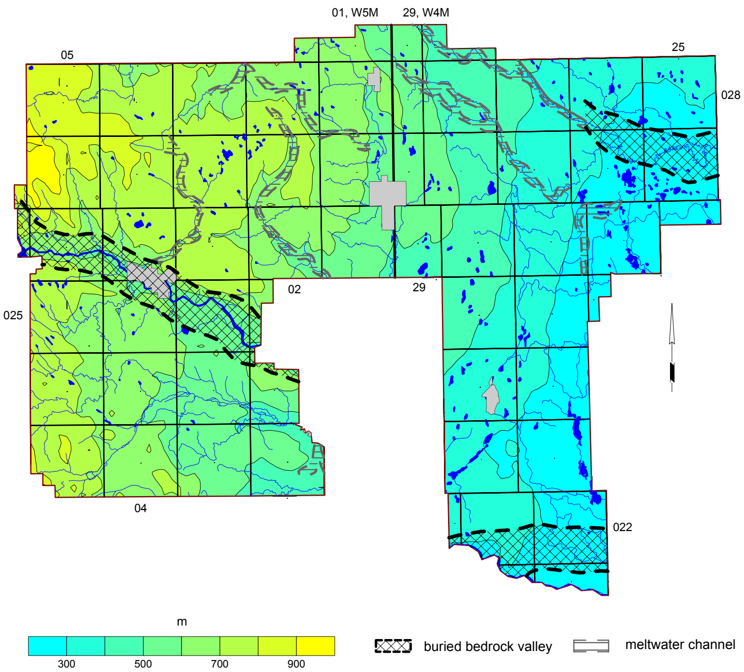

Figure 4. Depth to Base of Groundwater Protection (after EUB, 1995)

In general, Alberta Environment defines the Base of Groundwater Protection as the elevation below which the groundwater will have more than 4,000 mg/L of total dissolved solids. By using the ground elevation, formation elevations, and Alberta Energy and Utilities Board (EUB) information indicating the formations containing the deepest useable water for agricultural needs, a value for the depth to the Base of Groundwater Protection can be determined. These values are gridded using the Kriging[9] method to prepare a depth to the Base of Groundwater Protection surface. This depth, for the most part, would be the maximum drilling depth for a water well for agricultural purposes or for a potable water supply. If a water well has total dissolved solids exceeding 4,000 mg/L, the groundwater use does not require licensing by AENV. In the M.D., the depth to Base of Groundwater Protection ranges from less than 300 metres in the eastern part of the M.D. to more than 800 metres below ground level in the western part of the M.D., as shown on Figure 4 and on some cross-sections presented in Appendix A and on the CD-ROM.

There are 10,975 water wells with completed depth data, of which none are completed below the Base of Groundwater Protection. In the M.D., the Base of Groundwater Protection is below the Upper Scollard Formation (see Figures A-14, A-15, A-19 and A-20).

Proper management of the groundwater resource requires water-level data. These data are often collected from observation water wells. At the present time, there is one AENV-operated observation water well within the M.D. Additional data can be obtained from some of the licensed groundwater diversions. In the past, the data for licensed diversions have been difficult to obtain from AENV, in part because of the failure of the licensee to provide the data.

Even with the available sources of data, the number of water-level data points relative to the size of the M.D. is too few to provide a reliable groundwater budget (see section 6.0 of this report). The most cost-efficient method to collect additional groundwater monitoring data would be to have the water well owners measuring the water level in their own water well on a regular basis, as has been the case in the Wildrose Country Ground Water Monitoring Association.

[9] See glossary

3. Terms

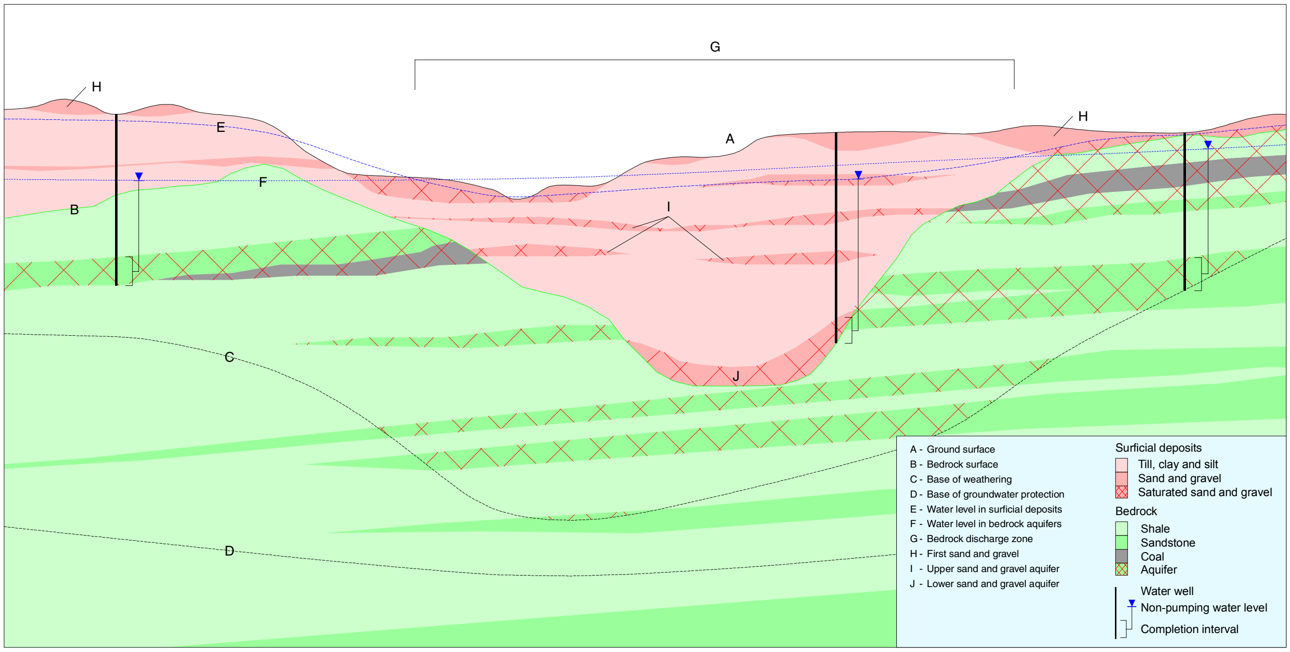

Figure 5. Generalized Cross-Section (for terminology only)

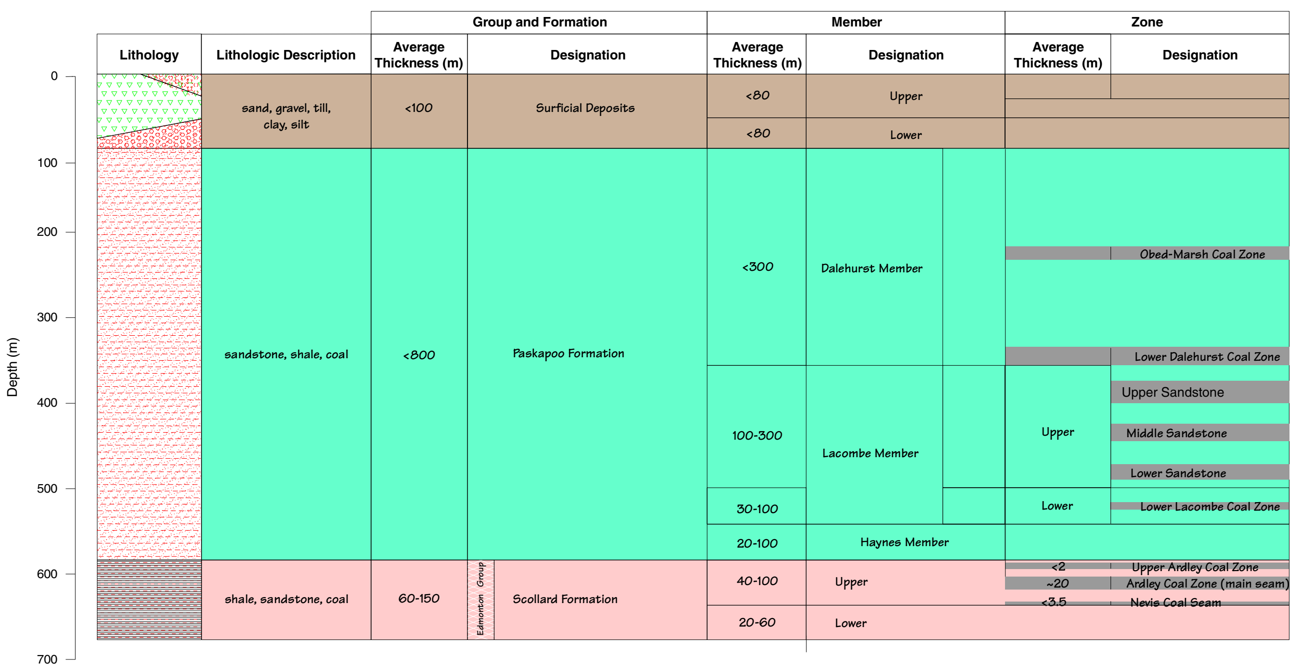

Figure 6. Geologic Column

4. Methodology

4.1 Data Collection and Synthesis

The AENV groundwater database is the main source of groundwater data. The database includes the following:

1) water well drilling reports
2) aquifer test results from some water wells
3) location of some springs
4) locations for some water wells determined during water well surveys
6) chemical analyses for some groundwaters
7) location of some flowing shot holes
8) location of some structure test holes
9) a variety of data related to the groundwater resource.

The main disadvantage to the database is the absence of quality control. Very little can be done to overcome this lack of quality control in the data collection, other than to assess the usefulness of control points relative to other data during the interpretation. Another disadvantage to the database is the lack of adequate spatial information. Any duplicate water wells that have been identified within the M.D. have been removed from the database used in this regional groundwater assessment.

The AENV groundwater database uses a land-based system with only a limited number of records having a value for ground elevation. The locations for records usually include a quarter section description; a few records also have a land description that includes a Legal Subdivision (Lsd). For digital processing, a record location requires a horizontal coordinate system. In the absence of an actual location for a record, the record is given the coordinates for the centre of the land description.

The present project uses the 10TM coordinate system based on the NAD27 datum. This means that a record for the NE ¼ of section 30, township 025, range 28, W4M, would have a horizontal coordinate with an Easting of 77,332 metres and a Northing of 5,666,287 metres, the centre of the quarter section. If the water well has been repositioned by AAFC-PFRA using orthorectified aerial photos, the location will be more accurate, possibly within several tens of metres of the actual location. Once the horizontal coordinates are determined for a record, a ground elevation for that record is obtained from the 1:20,000 Digital Elevation Model (DEM); AltaLis Ltd. provides the DEM.

At many locations within the M.D., more than one water well is completed at one legal location. Digitally processing this information is difficult. To obtain a better understanding of the completed depths of water wells, a digital surface was prepared representing the minimum depth for water wells and a second digital surface was prepared for the maximum depth. Both of these surfaces are used in the groundwater query on the CD-ROM. When the maximum and minimum water well depths are similar, there is only one aquifer that is being used at a given location.

After assigning spatial control for the ground location for the records in the groundwater database, the data are processed to determine values for hydrogeological parameters**.** As part of the processing, obvious keying errors in the database are corrected.

Where possible, determinations are made from individual records in order to assign water wells to aquifers and identify surficial aquifers for the following:

1) depth to bedrock
2) total thickness of sand and gravel below 15 metres
3) total thickness of saturated sand and gravel
4) depth to the top and bottom of completion intervals[10].

Also, where sufficient information is available, values for apparent transmissivity[11] and apparent yield[12] are calculated, based on the aquifer test summary data supplied on the water well drilling reports. Where valid detailed aquifer test results exist, the interpreted data provide values for aquifer transmissivity and effective transmissivity. Since the last regional hydrogeological map covering at least a part of the M.D. was published in 1978 (Ozoray and Barnes, 1978)-see CD-ROM, 3,989 values for apparent transmissivity and 3,280 values for apparent yield have been added to the groundwater database. With the addition of the apparent yield values, including a 0.1-m³/day value assigned to dry water wells and water test holes, a hydrogeological map has been prepared to help illustrate the general groundwater availability across the M.D (Figure 7). The map is based on groundwater being obtained from all aquifers and has been prepared to allow direct comparison with the results provided on the Alberta Research Council hydrogeological maps.

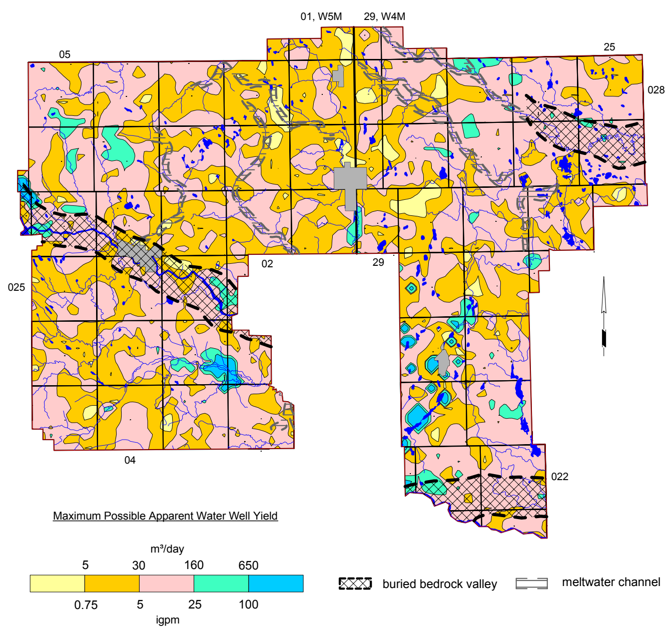

Figure 7. Hydrogeological Map

The EUB well database includes records for all of the wells drilled by the oil and gas industry. The information from this source includes:

1) spatial control for each well site
2) depth to the top of various geologic units
3) type and intervals for various down-hole geophysical logs
4) drill stem test (DST) summaries.

Values for apparent transmissivity, apparent yield and hydraulic conductivity are calculated from the DST summaries.

Published and unpublished reports and maps provide the final source of information to be included in the new groundwater database. The reference section of this report lists the available reports. The only digital data from publications are from the Geological Atlas of the Western Canada Sedimentary Basin (Mossop and Shetsen, 1994). These data are used to support the geological interpretation of geophysical logs but cannot be distributed because of a licensing agreement.

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10 See glossary
11 For definitions of Transmissivity, see glossary
12 For definitions of Yield, see glossary

4.2 Spatial Distribution of Aquifers

Determination of the spatial distribution of the aquifers is based on:

1) lithologs provided by the water well drillers
2) geophysical logs from structure test holes
3) geophysical logs for wells drilled by the oil and gas industry
4) data from existing cross-sections.

The aquifers are defined by mapping the tops and bottoms of individual geologic units. The values for the elevation of the top and bottom of individual geologic units at specific locations help to determine the spatial distribution of the individual surfaces. Establishment of a surface distribution digitally requires preparation of a grid. The inconsistent quality of the data necessitates creating a representative sample set obtained from the entire data set. If the data set is large enough, it can be treated as a normal population and the removal of extreme values can be done statistically. When data sets are small, the process of data reduction involves a more direct assessment of the quality of individual points. Because of the uneven distribution of the data, all data sets are gridded using the Kriging method.

The final definition of the individual surfaces becomes an iterative process involving the plotting of the surfaces on cross-sections and the adjusting of control points to fit with the surrounding data.

4.3 Hydrogeological Parameters

Water well records that indicate the depths to the top and bottom of their completion interval are compared digitally to the spatial distribution of the various geological surfaces. This procedure allows for the determination of the aquifer in which individual water wells are completed. When the completion interval of a water well cannot be established unequivocally, the data from that water well are not used in determining the distribution of hydraulic parameters.

After the water wells are assigned to a specific aquifer, the parameters from the water well records are assigned to the individual aquifers. The parameters include non-pumping (static) water level (NPWL), apparent transmissivity, and apparent water well yield. The total dissolved solids, sulfate and chloride concentrations from the chemical analysis of the groundwater are also assigned to applicable aquifers. In addition, chemical parameters of nitrate + nitrite (as N) are assigned to surficial aquifers and fluoride is assigned to upper bedrock aquifer(s). **Since 1986, Alberta Health and Wellness has restricted access to chemical analysis data, and hence the database includes only limited amounts of chemical data since 1986.**

Once the values for the various parameters of the individual aquifers are established, the spatial distribution of these parameters must be determined. The distribution of individual parameters involves the same process as the distribution of geological surfaces. This means establishing a representative data set and then preparing a grid. The representative data set included using the available data from townships 021 to 029, ranges 25 to 29, W4M and townships 023 to 029, ranges 01 to 06, W5M, plus a buffer area of at least one township. Even when only limited data are available, grids are prepared. However, the grids prepared from the limited data must be used with extreme caution because the gridding process can be unreliable.