# III. TERMS

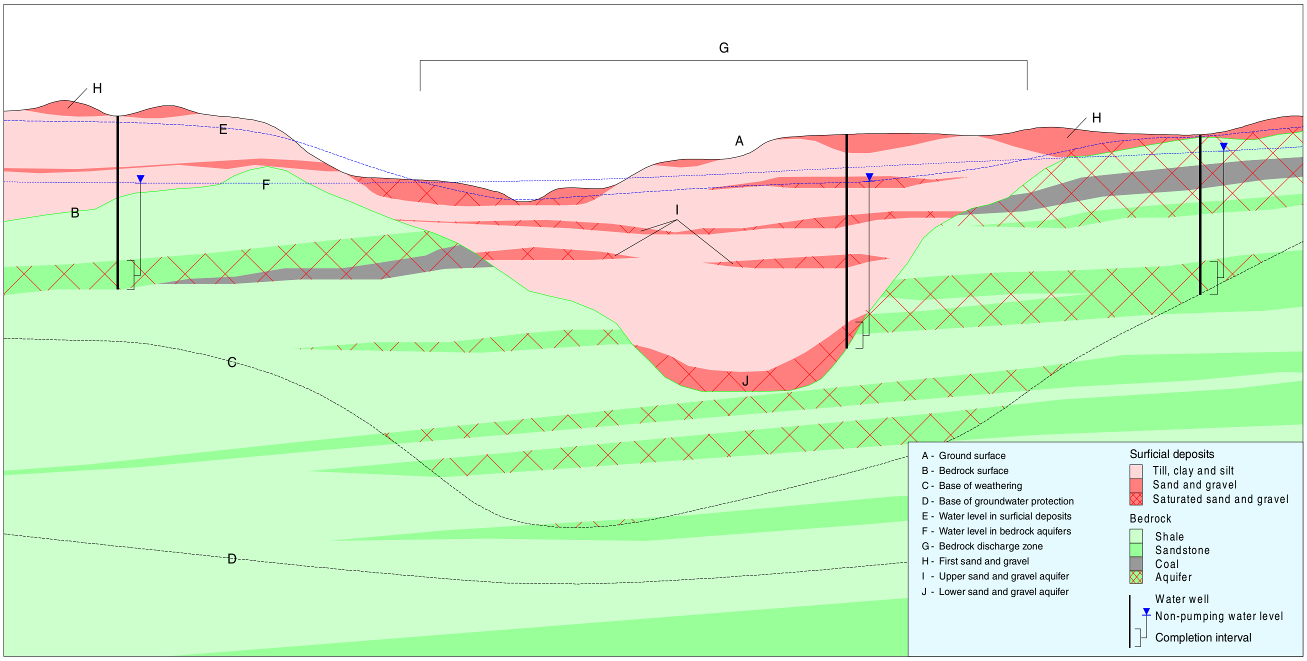
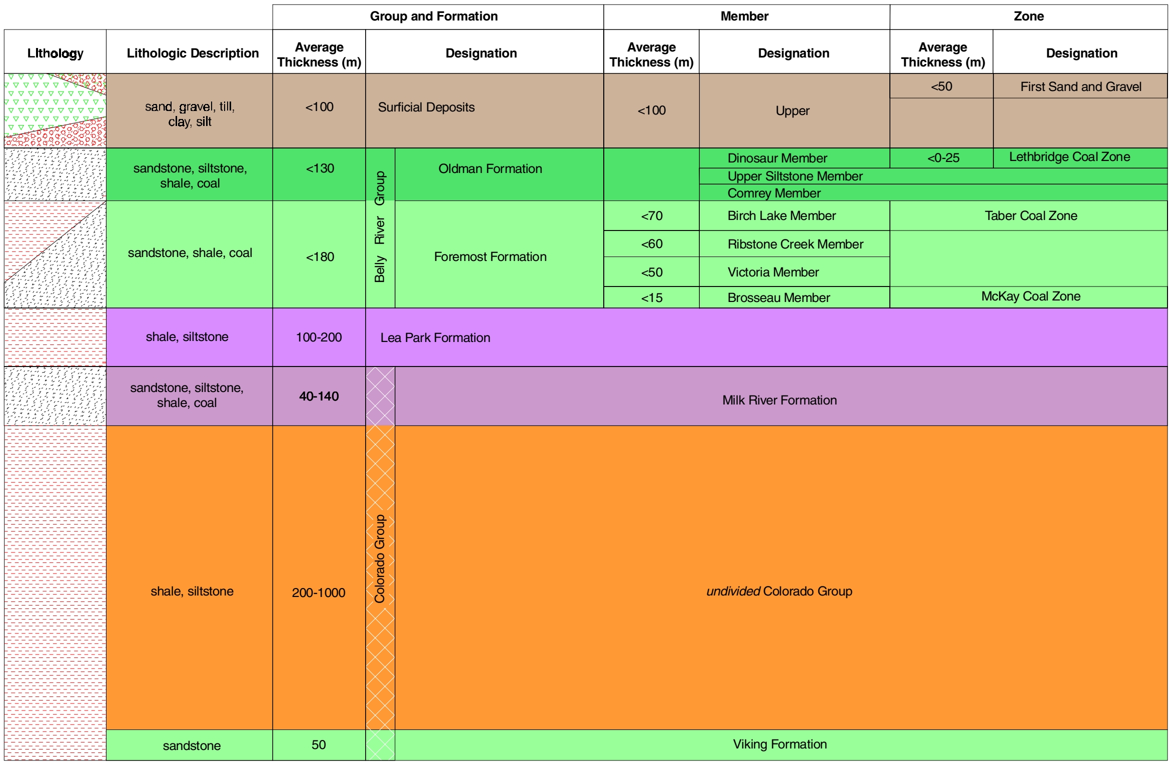


*Figure 5. Generalized Cross-Section (for terminology only)*



| | | Group and Formation | | | Member | | Zone | |
|---|---|---|---|---|---|---|---|---|
| Lithology | Lithologic Description | Average Thickness (m) | | Designation | Average Thickness (m) | Designation | Average Thickness (m) | Designation |
| | sand, gravel, till, clay, silt | <100 | Surficial Deposits | | <100 | Upper | <50 | First Sand and Gravel |
| | sandstone, siltstone, shale, coal | <130 | Belly River Group | Oldman Formation | | Dinosaur Member | <0-25 | Lethbridge Coal Zone |
| | | | | | | Upper Siltstone Member | | |
| | | | | | | Comrey Member | | |
| | sandstone, shale, coal | <180 | | Foremost Formation | <70 | Birch Lake Member | Taber Coal Zone | |
| | | | | | <60 | Ribstone Creek Member | | |
| | | | | | <50 | Victoria Member | | |
| | | | | | <15 | Brosseau Member | McKay Coal Zone | |
| | shale, siltstone | 100-200 | Lea Park Formation | | | | | |
| | sandstone, siltstone, shale, coal | 40-140 | | Milk River Formation | | | | |
| | shale, siltstone | 200-1000 | Colorado Group | *undivided* Colorado Group | | | | |
| | sandstone | 50 | | Viking Formation | | | | |

*Figure 6. Geologic Column*

# IV. METHODOLOGY

## A. Data Collection and Synthesis

The AE 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) water well locations determined during water well surveys
5) chemical analyses for some groundwaters
6) location of flowing shot holes
7) location of structure test holes
8) 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. However, unlike other areas in the Province where there are numerous duplicate records, the present database for the County contains approximately 175 duplicate water well IDs.

The AE 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. This means that a record for the SE ¼ of section 31, township 064, range 24, W4M, would have a horizontal coordinate with an Easting of 89,825 metres and a Northing of 6,045,858 metres, the centre of the quarter section. If the water well has been positioned by PFRA as a result of field verification, the location will be more accurate, possibly within several 10s 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) from the Resource Data Division of AE.

At many locations within the County, 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.

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 for the following:

1) depth to bedrock
2) total thickness of sand and gravel
3) thickness of first sand and gravel when present within one metre of ground surface
4) total thickness of saturated sand and gravel
5) depth to the top and bottom of completion intervals.

Also, where sufficient information is available, values for apparent transmissivity[8] and apparent yield[9] 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 regional hydrogeology map was published in 1973 (Borneuf, 1973), 212 values for effective transmissivity have been added to the groundwater database.

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 geological 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 (pages 35-36). 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 verify the geological interpretation of geophysical logs but cannot be distributed because of a licensing agreement.

## B. 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) wells drilled by the oil and gas industry
4) data from existing cross-sections.

The identification of aquifers becomes a two-step process: first, mapping the tops and bottoms of individual geological units; and second, identifying the porous and permeable parts of each geological unit in which the aquifer is present.

The values for the elevation of the top and bottom of individual geological units at specific locations help to determine the spatial distribution of the individual surfaces. Establishment of a surface distribution digitally requires preparating 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

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[8] For definitions of Transmissivity, see glossary

[9] For definitions of Yield, see glossary

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.

The porous and permeable parts of the individual geological units have been mainly determined from geophysical logs.

## C. 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), transmissivity and projected water well yield. The total dissolved solids, chloride and sulfate concentrations from the chemical analysis of the groundwater are also assigned to applicable aquifers.

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. Even when only limited data are available, grids are prepared. However, the data from these grids must be used with extreme caution because the gridding process can be unreliable.

### 1) Risk Criteria

The main source of groundwater contamination involves activities on or near the land surface. The risk of groundwater contamination is high when the near-surface materials are porous and permeable and low when the materials are less porous and less permeable. The two sources of data for the risk analysis include (a) a determination of when sand and gravel is or is not present within one metre of the ground surface, and (b) the surficial geology map. The presence or absence of sand and gravel within one metre of the land surface is based on a geological surface prepared from the data supplied on the water well drilling reports. The information available on the surficial geology map is categorized based on relative permeability. The information from these two sources is combined to form the risk assessment map. The criteria used in the classification of risk are given in the above table.

| Surface Permeability | Sand or Gravel Present - Top Within One Metre Of Ground Surface | Groundwater Contamination Risk |
|---|---|---|
| Low | No | Low |
| Moderate | No | Moderate |
| High | No | High |
| Low | Yes | High |
| Moderate | Yes | High |
| High | Yes | Very High |

***Table 3. Risk of Groundwater Contamination Criteria***

## D. Maps and Cross-Sections

Once grids for geological surfaces have been prepared, various grids need to be combined to establish the extent and thickness of individual geological units. For example, the relationship between an upper bedrock unit and the bedrock surface must be determined. This process provides both the outline and the thickness of the geological unit.

Grids must also be combined to allow the calculation of projected long-term yields for individual water wells. The grids related to the elevation of the NPWL and the elevation of the top of the aquifer are combined to determine the available drawdown[10]. The available drawdown data and the transmissivity values are used to calculate values for projected long-term yields for individual water wells, completed in a specific aquifer.

Once the appropriate grids are available, the maps are prepared by contouring the grids. The areal extent of individual parameters is outlined by “masks” to delineate individual aquifers. Appendix A includes page-size maps from the text, plus additional page-size maps and figures that support the discussion in the text. A list of maps and figures that are included on the CD-ROM is given in Appendix B.

The grids for the geological surfaces are used to prepare a three-dimensional stratigraphic model. The stratigraphic model has been prepared from the USGS 3-D MODFLOW model that was prepared for the County to estimate flow through various aquifers. Cross-sections are prepared by selecting specific rows or columns from the stratigraphic model grid and exporting the data to AutoCAD for finalizing for presentation. If a cross-section is required along a line that is at an angle to the model grid, the grid can be rotated. Once the cross-section has been selected, water wells that are within 400 metres of the line of section are added to the cross-section.

Once the technical details of a cross-section are correct, the drawing file is moved to the software package CorelDRAW! for simplification and presentation in a hard-copy form. These cross-sections are presented in this report and as poster-size drawings forwarded with this report. The cross-sections also are in Appendix A, and are included on the CD-ROM; page-size maps of the poster-size cross-sections are included in Appendix D of this report.

## E. Software

The files on the CD-ROM have been generated from the following software:

- Acrobat 4.0
- ArcView 3.1
- AutoCAD 14.01
- CorelDRAW! 8.0
- Environmental Systems
- Microsoft Professional Office 2000
- Surfer 6.04
- Tecplot 8.0
- USGS 3-D MODFLOW

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[10] See glossary

# V. AQUIFERS

## A. Background

An aquifer is a porous and permeable rock that is saturated. If the NPWL is above the top of the rock unit, this type of aquifer is an artesian aquifer. If the rock unit is not entirely saturated and the water level is below the top of the unit, this type of aquifer is a water-table aquifer. These types of aquifers occur in one of two general geological settings in the County. The first geological setting includes the sediments that overlie the bedrock surface. In this report, these are referred to as the surficial deposits. The second geological setting includes aquifers in the upper bedrock. The geological settings, the nature of the deposits making up the aquifers within each setting, the expected yield of water wells completed in aquifer(s) within different geological units, and the general chemical quality of the groundwater associated with each setting are reviewed separately.

### 1) Surficial Aquifers

Surficial deposits in the County are mainly less than 50 metres thick, except in areas of linear bedrock lows where the thickness of the surficial deposits can exceed 100 metres. The Buried Amber Valley is the main linear bedrock low in the County. The Buried Amber Valley is present in the southwest corner of the County and trends northeast to township 069, range 17, W4M where it joins the Buried Helena Valley. The Buried Helena Valley, a major linear bedrock low east of the County, is not well defined within the County of Athabasca. Cross-section A-A' passes through parts of the Buried Amber Valley, and shows the thickness of the surficial deposits varying from less than ten to more than 100 metres.

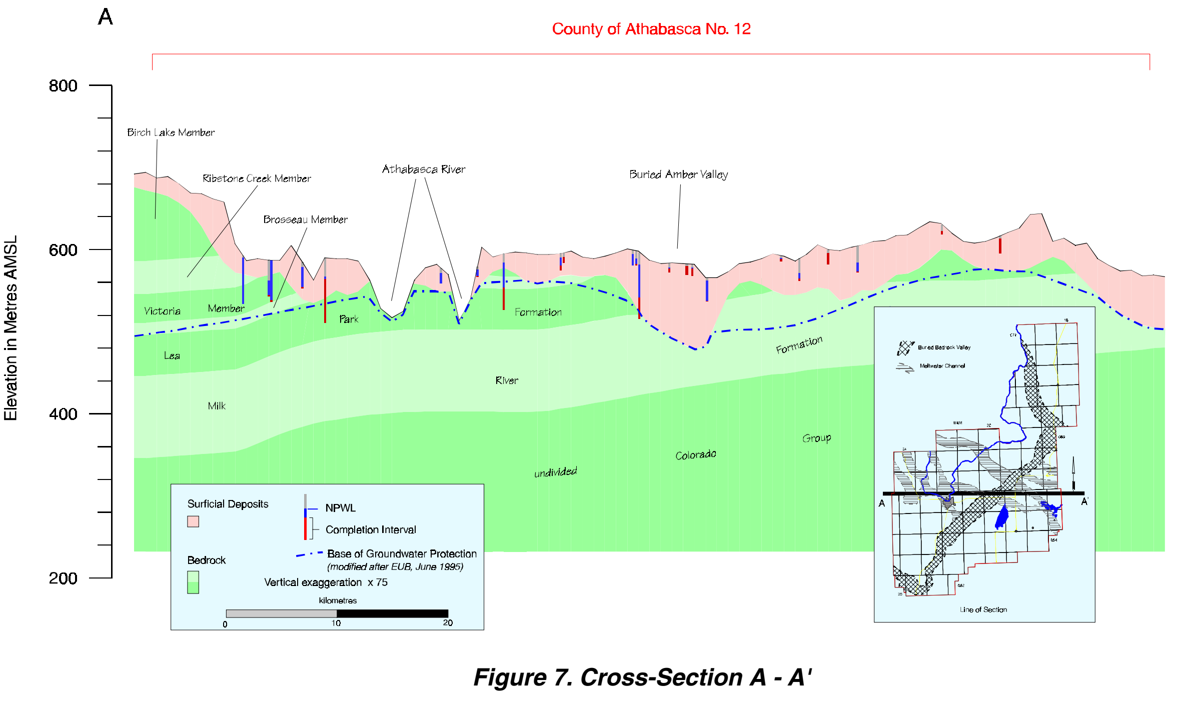

*Figure 7. Cross-Section A - A'*

The main aquifers in the surficial materials are sand and gravel deposits. In order for a sand and gravel deposit to be an aquifer, it must be saturated; if not saturated, a sand and gravel deposit is not an aquifer. The top of the surficial aquifers has been determined from the NPWL in water wells that are less than 15 metres deep. The base of the surficial deposits is the bedrock surface.

For a water well with a small-diameter casing to be effective in surficial deposits and to provide sand-free groundwater, the water well must be completed with a water well screen. Some water wells completed in the surficial deposits are completed in low-permeability aquifers and have a large-diameter casing. The large-diameter water wells may have been hand dug or bored and because they are completed in very low permeability aquifers, most of these water wells would not benefit from water well screens. The groundwater from an aquifer in the surficial deposits usually has a chemical hardness of at least a few hundred mg/L and a dissolved iron concentration such that the groundwater must be treated before being used for domestic needs. Within the County, casing-diameter information is available for 1,553 of the 2,226 water wells completed in the surficial deposits; 45% of these have a casing diameter of more than 300 millimetres, and are assumed to be bored or dug water wells.

### 2) Bedrock Aquifers

The upper bedrock includes rocks that are less than 200 metres below the bedrock surface and above the Mannville Group. Some of this bedrock contains porous, permeable and 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 are friable[11] and water well screens are a necessity. The groundwater from the bedrock aquifers is usually chemically soft.

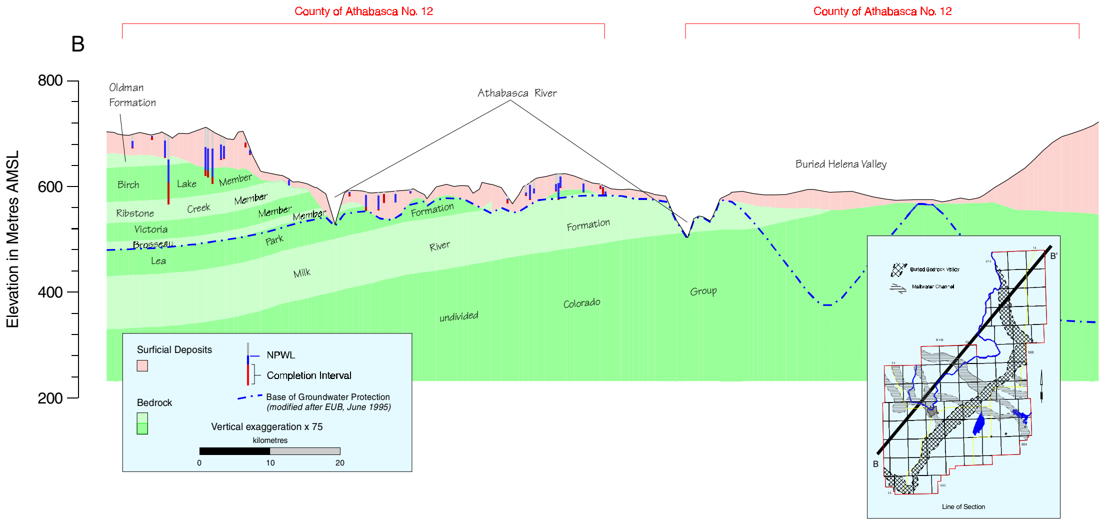

*Figure 8. Cross-Section B - B'*

The data for 599 water wells show that the top of the water well completion interval is below the top of bedrock, indicating that the water wells are completed in at least one bedrock aquifer. Within the County, casing-diameter information is available for 447 of the 599 water wells completed below the top of bedrock. Of these 447 water wells, 84% have surface-casing diameters of less than 300 mm and these bedrock water wells have been mainly completed nearly equally with either a screen, open hole, or with a perforated liner.

The upper bedrock includes a part of the Belly River Group, the Lea Park Formation, the Milk River Formation and the *undivided* Colorado Group (page A-7). In the County, the Lea Park and the Milk River formations and the *undivided* Colorado Group are regional aquitards[12]. The Mannville Group underlies the Colorado Group.

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[11] See glossary
[12] See glossary

## B. Aquifers in Surficial Deposits

The surficial deposits are the sediments above the bedrock surface. This includes pre-glacial materials, which were deposited before glaciation, and materials deposited directly or indirectly by glaciation. The *lower surficial deposits* include pre-glacial fluvial[13] and lacustrine[14] deposits. The lacustrine deposits include clay, silt and fine-grained sand. The *upper surficial deposits* include the more traditional glacial deposits of till[15] and meltwater deposits. In the County, no lower surficial deposits have been defined to date and the upper surficial deposits include mainly till.

### 1) Geological Characteristics of Surficial Deposits

While the surficial deposits are treated as one hydrogeological unit, they consist of three hydraulic units. The first unit is the sand and gravel deposits of the lower surficial deposits when present. These deposits are mainly saturated, where present. The second and third hydraulic units are associated with the sand and gravel deposits in the upper surficial deposits. The sand and gravel deposits in the upper surficial deposits occur mainly as pockets. The second hydraulic unit is the saturated part of these sand and gravel deposits; the third hydraulic unit is the unsaturated part of these deposits. See Figure 5 for a graphical depiction of the above description. While the unsaturated deposits are not technically an aquifer, they are significant as they provide a pathway for liquid contaminants to move downward into the groundwater. Because of the significance of the shallow sand and gravel deposits, they have been mapped where the tops of these deposits are present within one metre of the ground surface; these shallow deposits are referred to as the “first sand and gravel”.

The base of the surficial deposits is the bedrock surface, represented by the bedrock topography as shown on the adjacent map. Over the majority of the County, the upper surficial deposits are less than 50 metres thick (page A-11). The exceptions are mainly in association with areas where linear bedrock lows are present, where the deposits can have a thickness of up to 100 metres.

The main linear bedrock low in the County is designated as the Buried Amber Valley, as shown on Figure 9. This Valley trends north-northeast while occupying the present-day Tawatinaw River Valley, then turns northeast occupying the present-day Pine Creek and joins the Buried Helena Valley in township 069, range 17, W4M. The Buried Amber Valley is approximately four to ten kilometres wide, with local relief being up to 100 metres.

The Buried Helena Valley is present in the northeastern part of the County but is not well defined based on the bedrock topography contours; for purposes of illustration, the Buried Helena Valley was digitized from the Bedrock Topography of Alberta (Pawlowicz and Fenton, 1995). There are several connecting linear bedrock lows in the County. These lows trend mainly northwest to

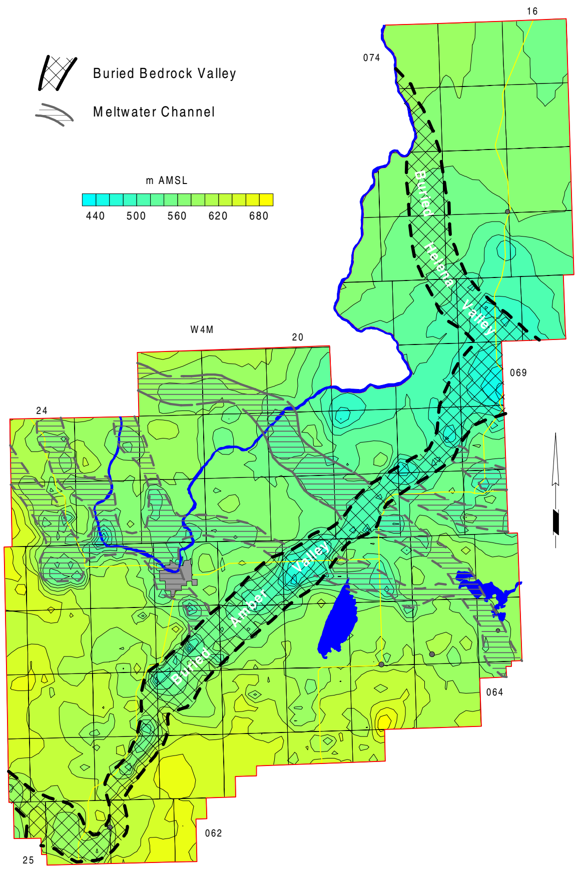

*Figure 9. Bedrock Topography*

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[13] See glossary
[14] See glossary
[15] See glossary

southeast in the County and are indicated as being of meltwater origin.

Sand and gravel deposits can occur throughout the surficial deposits. The total thickness of sand and gravel deposits is generally less than ten metres but can be more than 15 metres.

The upper surficial deposits are either directly or indirectly a result of glacial activity. The deposits include till, with minor sand and gravel deposits, which are expected to occur mainly as isolated pockets. The greatest thickness of the upper surficial deposits is mainly in association with the linear bedrock lows; there are several areas where the upper surficial deposits are very thin or not present.

The combined thickness of all sand and gravel deposits has been determined as a function of the total thickness of the surficial deposits. Over approximately 5% of the County, the sand and gravel deposits are more than 30% of the total thickness of the surficial deposits (page A-13). The areas where sand and gravel deposits constitute more than 30% of the total thickness of the surficial deposits may be in areas of buried bedrock valleys or meltwater channels or areas where linear bedrock lows exist but have not been identified due to a shortage of accurate bedrock control points.

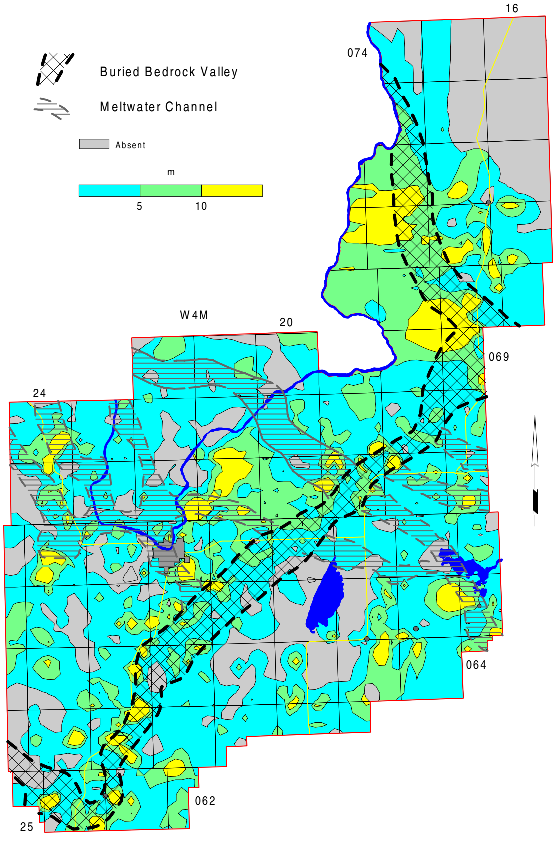

*Figure 10. Thickness of Sand and Gravel Deposits*

### 2) Sand and Gravel Aquifer(s)

One source of groundwater in the County includes aquifers in the surficial deposits. Since the sand and gravel aquifer(s) are not everywhere, the actual aquifer that is developed at a given location is usually dictated by the aquifer that is present. The thickness of saturated sand and gravel deposits (aquifer(s)) is mainly less than five metres, but can be more than ten metres.

From the present hydrogeological analysis, 4,938 water wells are completed in aquifers in the upper surficial deposits. This number of water wells is more than two times the number determined to be completed in aquifers in the surficial deposits, based on lithologies given on the water well drilling reports. The larger number is obtained by comparing the elevation of the reported depth of a water well to the elevation of the bedrock surface at the same location. For example, if only the depth of a water well is known, the elevation of the completed depth can be calculated. If the elevation of the completed depth is above the expected elevation of the bedrock surface at the same location, then the water well is determined to be completed in an aquifer in the surficial deposits.

Water wells completed in the upper surficial deposits occur throughout the project area. North of township 065 and east of range 23, W4M, there are no water wells completed in bedrock aquifers. This is the area where the upper bedrock is the Lea Park Formation or the Colorado Group.