County of Stettler No. 6

Part of the Red Deer River and Battle River Basins
Parts of Tp 033 to 042, R 14 to 22, W4M
Regional Groundwater Assessment

Prepared for

In conjunction with

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Prairie Farm Rehabilitation Administration | Administration du rétablisseme agricole des Prairies

Canada

Prepared by
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The Association of Professional Engineers, Geologists and Geophysicists of Alberta

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"Water is the lifeblood of the earth." - Anonymous

How a county takes care of one of its most precious resources - groundwater - reflects the future wealth and health of its people. Good environmental practices are not an accident. They must include genuine foresight with knowledgeable planning. Implementation of strong practices not only commits to a better quality of life for future generations, but creates a solid base for increased economic activity. **This report, even though it is regional in nature, is the first step in fulfilling a commitment by the County toward the management of the groundwater resource, which is a key component of the well-being of the County, and is a guide for future groundwater-related projects.**

1.1 About This Report

This report provides an overview of (a) the groundwater resources of the County of Stettler No. 6, (b) the processes used for the present project and (c) the groundwater characteristics in the County.

Additional technical details are available from files on the CD-ROM provided with this report. The files include the geo-referenced electronic groundwater database, grid files used to prepare distribution of various hydrogeological parameters, the groundwater query, and ArcView files. Likewise, all of the illustrations and maps from the present report, plus additional maps, figures and cross-sections, are available on the CD-ROM. For convenience, poster-size maps and cross-sections have been prepared as a visual summary of the results presented in this report. Copies of these poster-size drawings have been forwarded with this report, and are included as page-size drawings in Appendix D.

Appendix A features page-size copies of the figures within the report plus additional maps and cross-sections. An index of the page-size maps and figures is given at the beginning of Appendix A.

Appendix B provides a complete list of maps and figures included on the CD-ROM.

Appendix C includes the following:

1) a procedure for conducting aquifer tests with water wells;
2) a table of contents for the Water Well Regulation under the Environmental Protection and Enhancement Act; and
3) additional information.

The Water Well Regulation deals with the wellhead completion requirement (no more water-well pits), the proper procedure for abandoning unused water wells and the correct procedure for installing a pump in a water well.

1.2 The Project

It must be noted that the present project is a regional study and as such the results are to be used only as a guide. Detailed local studies are required to verify hydrogeological conditions at given locations.

The present project is made up of five parts as follows:

Module 1 - Data Collection and Synthesis
Module 2 - Hydrogeological Maps
Module 3 - Covering Report
Module 4 - Groundwater Query
Module 5 - Training Session

This report represents Modules 2 and 3.

1.3 Purpose

This project is a regional groundwater assessment of the County of Stettler No. 6. The regional groundwater assessment provides the information to assist in the management of the groundwater resource within the County. Groundwater resource management involves determining the suitability of various areas in the County for particular activities. These activities can vary from the development of groundwater for agricultural or industrial purposes, to the siting of waste storage. **Proper management ensures protection and utilization of the groundwater resource for the maximum benefit of the people of the County.**

The regional groundwater assessment includes:

- identification of the aquifers[1] within the surficial deposits[2] and the upper bedrock;
- spatial definition of the main aquifers;
- quantity and quality of the groundwater associated with each aquifer;
- hydraulic relationship between aquifers; and
- identification of the first sand and gravel deposits below ground level.

Under the present program, the groundwater-related data for the County of Stettler No. 6 have been assembled. Where practical, the data have been digitized. These data are then being used in the regional groundwater assessment for the County.

[1] See glossary
[2] See glossary

2 INTRODUCTION

2.1 Setting

The County of Stettler No. 6 is situated in east-central Alberta. This area is part of the Alberta Plains region. The County exists within the Red Deer River and Battle River basins. The southwestern boundary of the County is the Red Deer River and the northeastern boundary is the Battle River. The other boundaries follow township or section lines. The area includes some or all of townships 033 to 042, ranges 14 to 22, west of the 4th Meridian.

The ground elevation varies between 680 and 930 metres above mean sea level (AMSL). The topographic surface generally decreases toward the Battle River in the northeastern part of the County.

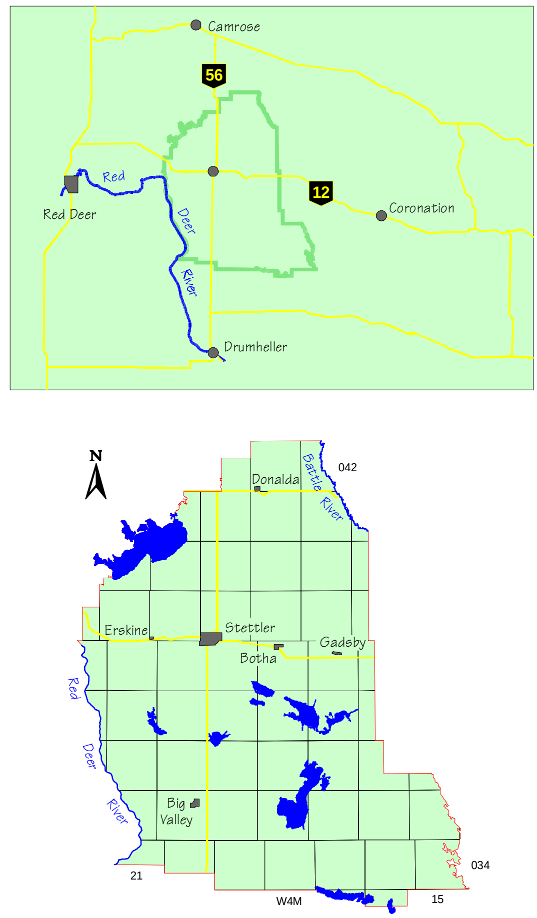

Figure 1. Index Map

2.2 Climate

The County of Stettler lies within the transition zone between a humid, continental Dfb climate and a semiarid Bsk climate. This classification is based on potential evapotranspiration values determined using the Thornthwaite method (Thornthwaite and Mather, 1957), combined with the distribution of natural ecoregions in the area. The ecoregions map (Strong and Legatt, 1981) shows that the County is located in the Aspen Parkland region, a transition between boreal forest and grassland environments.

A Dfb climate consists of long, cool summers and severe winters. The mean monthly temperature drops below –3 °C in the coolest month, and exceeds 10 °C in the warmest month. A Bsk climate is characterized by its moisture deficiency, where mean annual potential evapotranspiration exceeds the mean annual precipitation.

The mean annual precipitation averaged from two meteorological stations within the County measured 425 millimetres (mm), based on data from 1961 to 1990. The mean annual temperature averaged 2.7 °C, with the mean monthly temperature reaching a high of 16.6 °C in July, and dropping to a low of -13.4 °C in January. The calculated annual potential evapotranspiration is 522 millimetres.

2.3 Background Information

There are currently records for 4,625 water wells in the groundwater database for the County of Stettler. Of the 4,625 water wells, 4,161 are for domestic/stock purposes. The remaining 464 water wells were completed for a variety of uses, including municipal, observation and industrial purposes. Based on a rural population of 5,278, there are 3.2 domestic/stock water wells per family of four. The domestic or stock water wells vary in depth from less than 2 metres to 360 metres below ground level. Lithologic details are available for 2,694 water wells.

Data for completion depths are available for 4,435 water wells, with 4,088 indicated as having a completion depth of less than 80 metres. Of the remaining 347 water wells with completion depths, the completion ranges are as follows:

Water Wells	
Total Depth (m)	Number
80 to 99	212
100 to 119	67
>119	68

From the adjacent map, it can be seen that water wells that are more than 120 metres deep, mainly occur in the western part of the County, to the north of the Town of Stettler, and in the eastern part of the County.

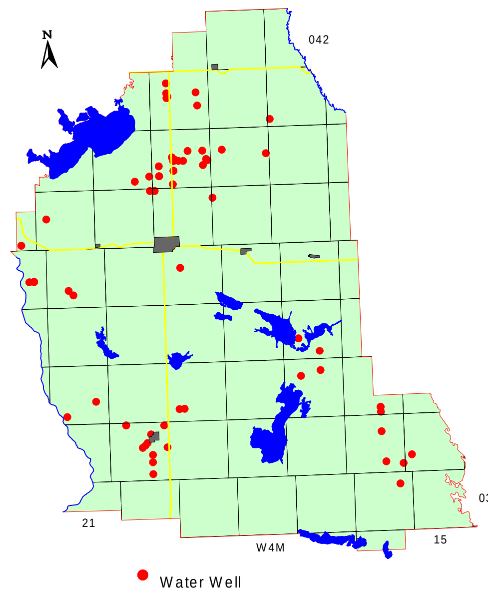

Figure 2. Water Wells Deeper than 120 metres

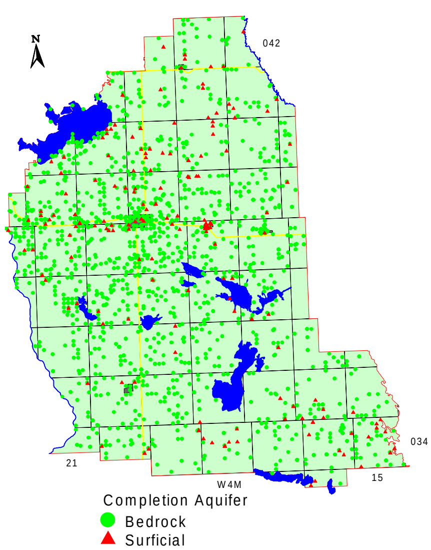

Figure 3. Location of Water Wells

There are 2,091 water well records with sufficient information to identify the aquifer in which the water wells are completed. The water wells that were not drilled deep enough to encounter the bedrock plus water wells that have the bottom of their completion interval above the bedrock surface are water wells completed in surficial aquifers. The number of water wells completed in aquifers in the surficial deposits is 199. The adjacent map shows that these water wells are mainly in the north-central and southeastern parts of the County.

The remaining 1,892 water wells have the top of their completion interval deeper than the depth to the bedrock surface. From the adjacent map it can be seen that water wells completed in bedrock aquifers occur over most of the County.

Water wells not used for domestic needs must be licensed. At the end of 1996, 172 groundwater diversions were licensed in the County. The total maximum authorized diversion from these 172 water wells is 4,583 cubic metres per day (m³/day); 70% of the authorized groundwater diversion is allotted for industrial use. The largest licensed industrial groundwater diversion within the County is 1200 m³/day, for a PanCanadian Petroleum Limited saline water source well in 14-06-038-16 W4M. This saline water source well is completed at a depth of more than 1,500 metres below ground surface in the Leduc Formation. Seven other authorized industrial groundwater users in the County have water well completion depths ranging from 625 to 1,315 metres below ground surface and are located in townships 037 and 038, range 17, W4M. The water well completed at a depth of 625 metres is completed in the Basal Belly River Formation and the remaining six water wells are completed in the Glauconitic Formation, at a depth of approximately 1,300 metres. Although chemistry data were not available for the groundwater from the eight licensed water wells completed below a depth of 600 metres, the Alberta Energy and Uitlities Board (EUB) chemical database does have data for the groundwaters from the different formations. All of the groundwaters are a sodium-chloride-type. The total dissolved solids (TDS) in the groundwaters from the Leduc Formation are in the order of 100,000 milligrams per litre (mg/L); from the Glauconitic Formation the TDS are approximately 25,000 mg/L; and from the Basal Belly River Formation the TDS are in the order of 5,500 mg/L.

The largest licensed groundwater diversion within the County not used for industrial purposes is for the Village of Donalda, having a diversion of 71 m³/day.

The adjacent table shows a breakdown of the 172 licensed groundwater diversions by the aquifer in which the water well is completed. Even though ten saline water source wells are licensed, these supplies no longer need to be licensed. The next highest diversions are for licensed water wells completed in the Upper and Lower Horseshoe Canyon aquifers, of which most of the groundwater is used for agricultural purposes.

	Licensed Groundwater Diversions (m³/day)					
Aquifer	Agricultural	Domestic	Industrial	Municipal	Other	Total
Surficial	39	0	3	264	0	306
Scollard	129	0	0	0	0	129
Upper Horseshoe Canyon	404	30	31	132	10	607
Lower Horseshoe Canyon	324	0	0	173	0	497
Saline Source Wells	2	0	3043	0	0	3044
Total	898	30	3077	568	10	4,583

Table 1. Licensed Groundwater Diversions

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 surface was prepared representing the minimum depth for water wells and a second 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, the impression is that there is only one aquifer that is being used. Over approximately 75% of the County, the difference between the maximum and minimum depth is less than 15 metres. The areas where the greatest differences occur most often are in the eastern and north-central parts of the County. In these areas, aquifers in the surficial deposits and aquifers in the bedrock are developed.

Groundwaters from the surficial deposits can be expected to be chemically hard with a high dissolved iron content. The TDS concentrations in the groundwaters from the upper bedrock in the County are generally less than 2,000 mg/L. Groundwaters from the bedrock aquifers frequently are chemically soft with generally low concentrations of dissolved iron. The chemically soft groundwater is high in sodium concentration. Approximately 30% of the chemical analyses indicate a fluoride concentration above 1.0 mg/L.

Alberta Environmental Protection (AEP) defines the Base of Groundwater Protection as the elevation below which the groundwater is expected to have more than 4,000 mg/L of total dissolved solids. By using the ground elevation, the bedrock surface and the Base of Groundwater Protection, a depth to the Base of Groundwater Protection can be determined. This depth, for the most part, would be the maximum drilling depth for a water supply well. In the County, the depth to the Base of Groundwater Protection generally increases from north to south. Over approximately 20% of the County, the depth to the Base of Groundwater Protection is less than 200 metres, which mainly includes townships 041 and 042, and areas close to the Red Deer and Battle river valleys.

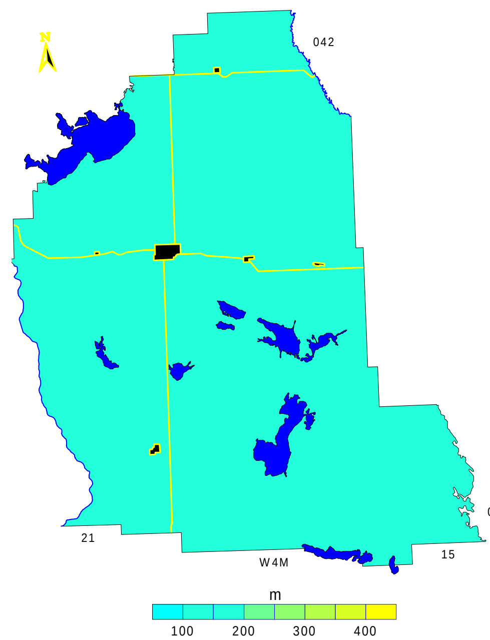

Figure 4. Depth to Base of Groundwater Protection

Proper management of the groundwater resource requires water-level data. These data are often collected from observation water wells. At the present time, data are available from four AEP-operated observation water wells within the County of Stettler. Additional data can be obtained from some of the licensed groundwater diversions. In the past, these data have been difficult to obtain from AEP, in part because of the failure of the licensee to provide the data.

However, even with the available sources of data, the number of water-level data points relative to the size of the County is too few to provide a reliable groundwater budget. 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.

3 TERMS

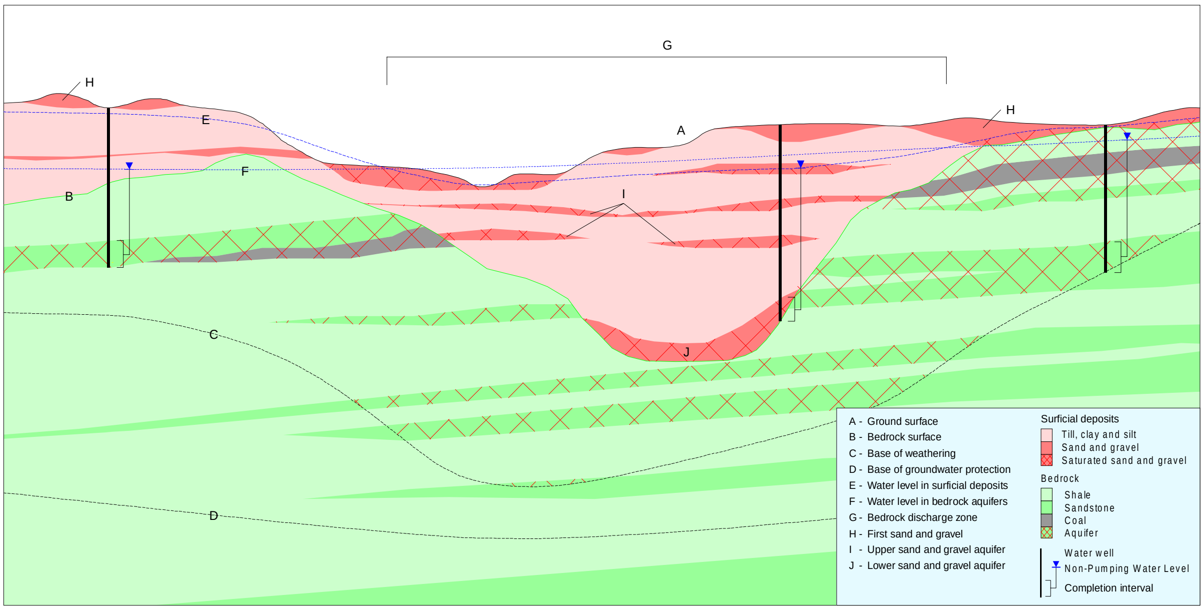

Figure 5. Generalized Cross-Section (for terminology only)

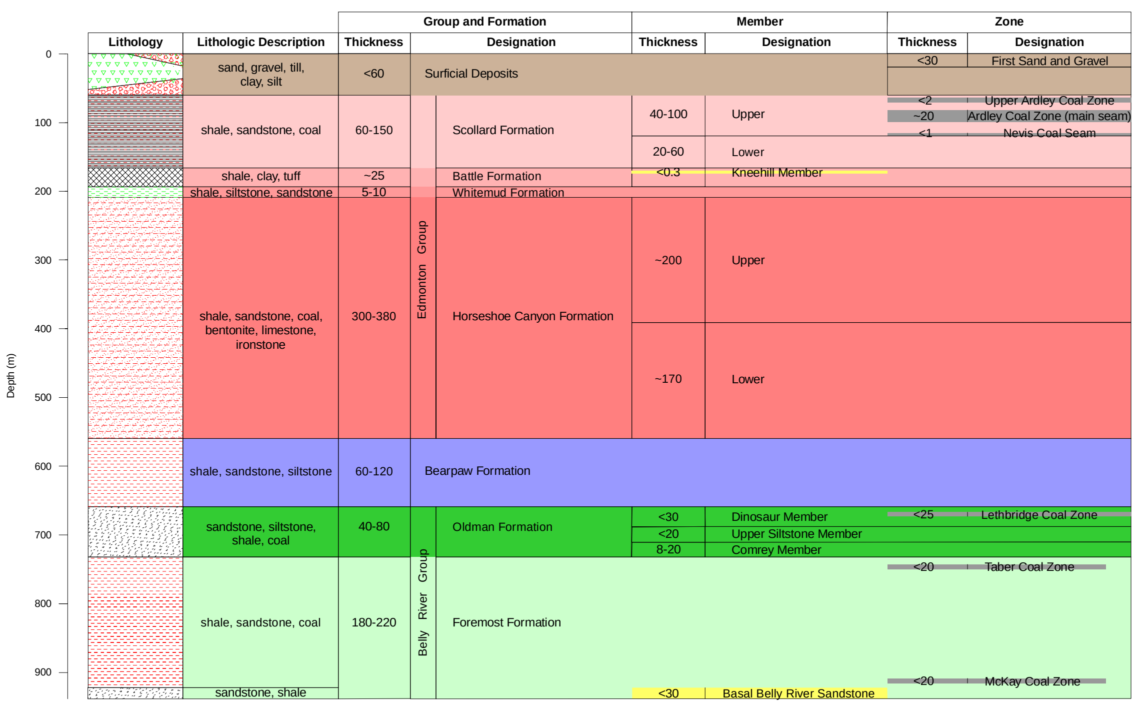

Figure 6. Geologic Column

4 METHODOLOGY

4.1 Data Collection and Synthesis

The AEP groundwater database is the main source of groundwater data available. 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; and
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.

The AEP 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 SW ¼ of section 01, township 039, range 20, W4M, would have a horizontal coordinate with an Easting of 152,819 metres and a Northing of 5,796,604 metres, the centre of the quarter section. Once the horizontal coordinates are determined, a ground elevation is obtained from the 1:20,000 Digital Elevation Model (DEM) from the Resource Data Division of AEP.

After assigning spatial control to 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; and
5) depth to the top and bottom of completion intervals.

Also, where sufficient information is available, values for apparent transmissivity[3] and apparent yield[4] are calculated, based on the aquifer test summary data supplied on the water well drilling reports. The apparent transmissivity results are then used to estimate a value for hydraulic conductivity[5]. The conductivity values are obtained by dividing the apparent transmissivity by the completion interval. To obtain a value for regional transmissivity of the aquifer, the hydraulic conductivity is multiplied by the effective thickness of the aquifer based on nearby e-log information. Where valid detailed aquifer test results exist, the interpreted data provide values for aquifer transmissivity and effective transmissivity.

The Alberta Energy and Utilities Board (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; and
4) drill stem test (DST) summaries.

Unfortunately, the EUB database contains very little information from above the base of groundwater protection. Because the main interest for a groundwater study comes from data above the base of groundwater protection, the data from the EUB database have limited use.

Values for apparent transmissivity 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 verify the geological interpretation of geophysical logs but cannot be distributed because of a licensing agreement.

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) wells drilled by the oil and gas industry; and
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.

After obtaining values for the elevation of the top and bottom of individual geological units at specific locations, the spatial distribution of the individual surfaces can be determined. Digitally, establishment of the distribution of a surface requires the preparation of a grid. The inconsistent quality of the data

[3] For definitions of Transmissivity, see glossary
[4] For definitions of Yield, see glossary
[5] See glossary

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[6] 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.

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), 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 the various 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.

4.3.1 Risk Criteria

The main source of groundwater contamination involves activities on or near the land surface. The risk 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 table above.

Surface Permeability	Sand or Gravel Present To 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 2. Risk of Groundwater Contamination Criteria

[6] See glossary

4.4 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 aquifer outline and the aquifer thickness. The aquifer thickness is used to determine the aquifer transmissivity by multiplying the hydraulic conductivity by the thickness.

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 non-pumping water level and the elevation of the top of the aquifer are combined to determine the available drawdown. 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, wherever the aquifer is present.

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.

Cross-sections are prepared by first choosing control points from the database along preferred lines of section. Data from these control points are then obtained from the database and placed in an AutoCAD drawing with an appropriate vertical exaggeration. The data placed in the AutoCAD drawing include the geo-referenced lithology, completion intervals and non-pumping water levels. Data from individual geological units are then transferred to the cross-section from the digitally prepared surfaces.

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 in Appendix A, are included on the CD-ROM, and are in Appendix D in a page-size format.

4.5 Software

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

- Microsoft Professional Office 97
- Surfer 6.04
- ArcView 3.0a
- AutoCAD 14.01
- CorelDRAW! 8.0
- Acrobat 3.0

5 AQUIFERS

5.1 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 is 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 different aquifers, and the general chemical quality of the groundwater associated with each setting are reviewed separately.

5.1.1 Surficial Aquifers

Surficial deposits in the County are mainly less than 20 metres thick, except in areas of linear bedrock lows where the thickness of surficial deposits can exceed 60 metres. The Buried Buffalo Lake Valley is one of the main linear bedrock lows. This linear low is present in the northern part of the County. Cross-section A-A' passes south of Buffalo Lake and shows the thickness of the surficial deposits being approximately 90 metres.

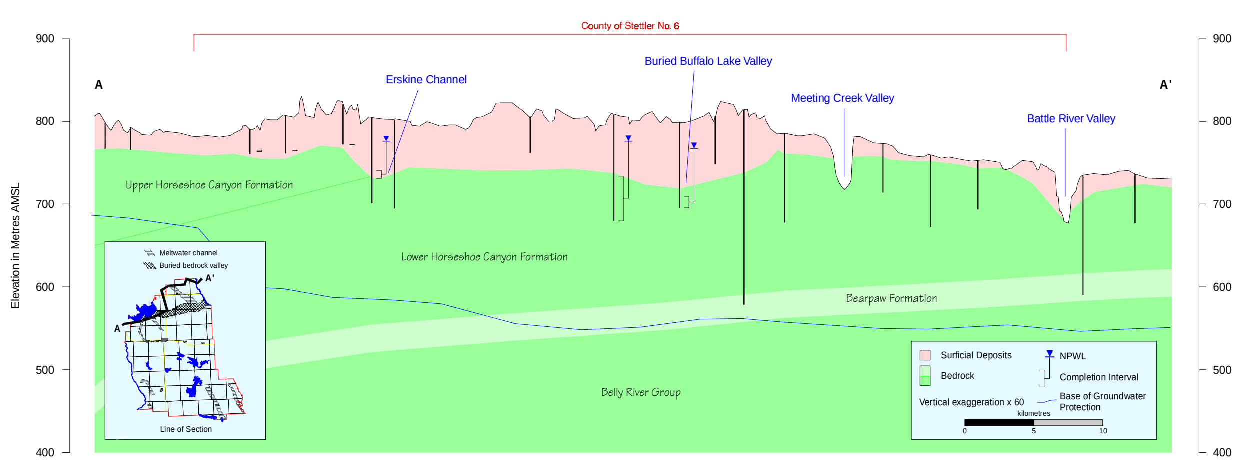

Figure 7. Cross-Section A - A'

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 less than 15 metres deep. The base of the surficial aquifers 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. Many of the 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, 27% of the water wells completed in the surficial deposits have a casing diameter of greater than 300 millimetres or no reported diameter for the surface casing, and are assumed to be dug or bored water wells.

5.1.2 Bedrock Aquifers

The upper bedrock includes rocks that are less than 200 metres below the bedrock surface. Some of this bedrock contains porous, permeable and saturated rocks that have a structure that is permeable enough for the rock to be an aquifer. Water wells completed in bedrock aquifers usually do not require water well screens and the groundwater is usually chemically soft. The data for 1,892 water wells indicate that the top of the water well completion interval is below the bedrock surface, indicating that the water wells are completed in at least one bedrock aquifer. Of these 1,892 water wells in the database, 1,781 have values for surface casing diameter. Of the 1,781 water wells, 98% have casing diameters of less than 300 millimetres.

The upper bedrock includes parts of the Scollard, Horseshoe Canyon and Bearpaw formations. The Belly River Group is not considered part of the upper bedrock in the Stettler area, even though in some areas it is less than 200 metres below the bedrock surface. The present-day Red Deer River has eroded down almost to the base of the Upper Horseshoe Canyon Formation along the southwestern part of the County.

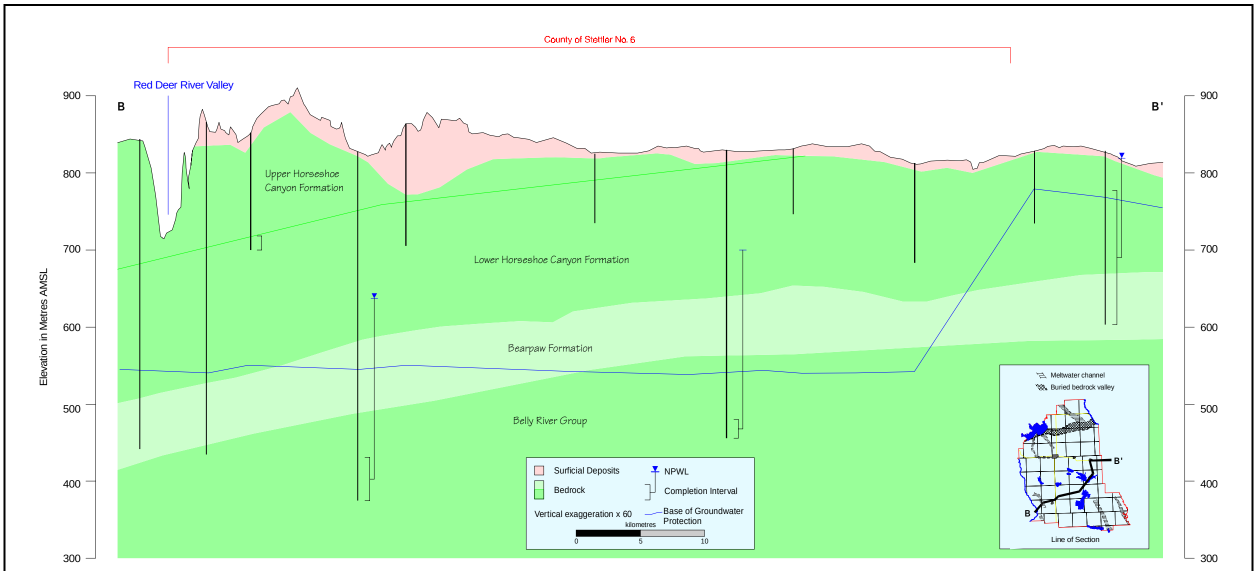

Figure 8. Cross-Section B - B'

5.2 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 drift, materials deposited directly by or indirectly during glaciation. The lower surficial deposits include the pre-glacial and some transitional sediments deposited as the glaciers advanced. The upper surficial deposits include the more traditional glacial deposits of till and meltwater deposits. In the County of Stettler, pre-glacial materials may be present in association with the Buried Buffalo Lake Valley, but none have been designated for the present study.

5.2.1 Geological Characteristics of Surficial Deposits

While the surficial deposits are treated as one hydrogeological unit, they consist of three hydraulic parts. The first is the sand and gravel deposits of the lower surficial deposits, the second is the saturated sand and gravel deposits of the upper surficial deposits and the third is the sand and gravel close to ground level, which is usually unsaturated. The sand and gravel deposits in the upper part of the surficial deposits can extend above the upper limit of the saturation zone and because they are not saturated, they are not an aquifer. However, these sand and gravel deposits are significant since 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 they are present within one metre of the ground surface and are referred to as the "first sand and gravel".

Over the majority of the County, the surficial deposits are less than 20 metres thick. The exceptions are mainly in association with the main linear low in the bedrock surface, which occurs in the northern part of the County. This linear bedrock low has been designated as the Buried Buffalo Lake Valley, and is approximately 15 kilometres north of the Town of Stettler and is shown on the adjacent map. The Buried Buffalo Lake Valley trends from the southwest to the northeast and is a tributary valley to the Buried Wainwright Valley located in the County of Flagstaff.

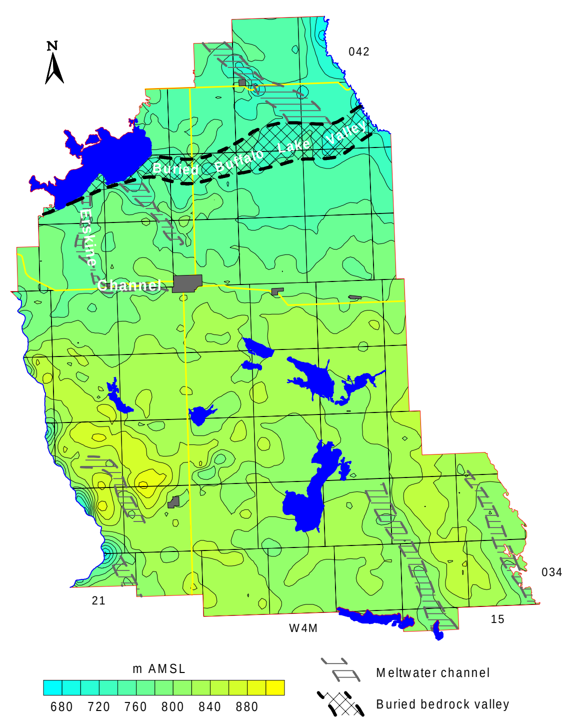

Figure 9. Bedrock Topography

The Buried Buffalo Lake Valley is approximately three to five kilometres wide with local relief being less than 40 metres. Sand and gravel deposits can be expected to be present in association with this bedrock low, but the thickness of the deposits is expected to be less than 10 metres.

Minor linear bedrock lows that are believed to be associated with meltwater channels also occur in the County. Seven are noted on the adjacent map. The linear bedrock low west of Stettler may be of meltwater origin or a tributary to the Buried Buffalo Lake Valley. This channel has been designated as the Erskine Channel (AEP Observation Well Network). The Town of Stettler developed the sand and gravel aquifer associated with the linear bedrock low for its water supply up until 1985. The four channels in the southern part of the County are of meltwater origin; the two channels north of Stettler may be tributaries to the Buried Buffalo Lake Valley.

Sand and gravel deposits can occur throughout the entire unconsolidated section. 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 50% of the total thickness of the surficial deposits. These areas tend to highlight the location of the minor linear bedrock lows where the surficial deposits are thinner. In the case of the Buried Buffalo Lake Valley, the surficial deposits include thick accumulations of till, and therefore, the percentage of sand and gravel deposits is less, when given as a function of the total thickness of surficial deposits.

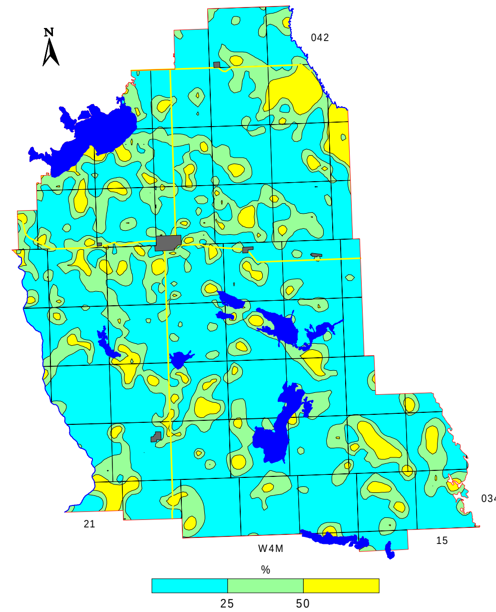

Figure 10. Amount of Sand and Gravel in Surficial Deposits

5.2.2 Sand and Gravel Aquifer(s)

One source of groundwater in the County includes aquifers in the surficial deposits. The actual aquifer that is developed is usually dictated by which aquifer is present.

The adjacent map shows water well yields that are expected in the County, based on the aquifers that have been developed by existing water wells. Based on these data, water wells with yields of more than 100 m³/day from sand and gravel aquifer(s) can be expected in less than 10% of the County. Over approximately 25% of the County, the sand and gravel deposits are not present or if present, are not saturated.

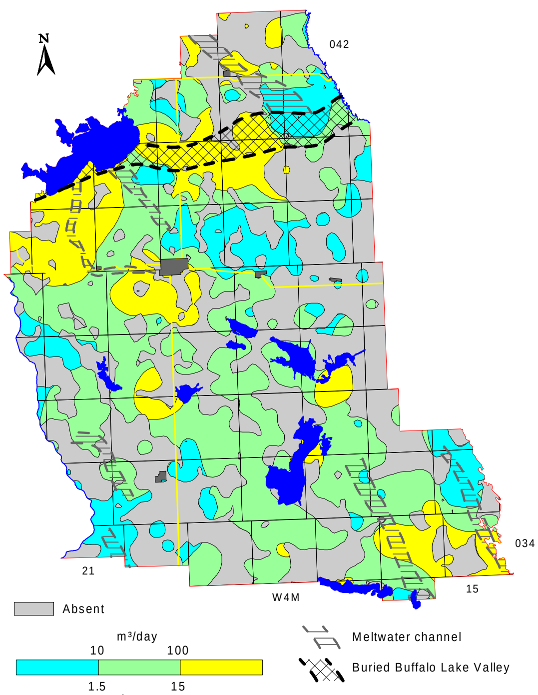

Figure 11. Apparent Yield for Water Wells Completed through Sand and Gravel Aquifer(s)

The main groundwater supply from surficial deposits that has been developed in the County was for the Town of Stettler. The Town used a sand and gravel aquifer associated with the Erskine Channel. Extensive studies of this aquifer indicate that a long-term supply of 3,000 m³/day of groundwater is available from this aquifer (AEP, 1980).

5.2.3 Chemical Quality of Groundwater from Surficial Deposits

The Piper tri-linear diagrams show that the majority of the groundwaters are sodium-bicarbonate-type waters; however, there are groundwaters from the surficial deposits that are calcium-magnesium-bicarbonate or sodium-sulfate-type waters.

Two-thirds of the groundwaters from the surficial aquifers have a chemical hardness of more than 50 mg/L. The TDS concentrations in the groundwaters from the surficial deposits range from less than 500 to over 2,000 mg/L, with 60% of the groundwaters having a TDS of less than 1,000 mg/L. The groundwaters with a TDS of more than 2,000 mg/L occur mainly in the eastern part of the County. The groundwaters with elevated levels of sulfate occur in areas where there are elevated levels of total dissolved solids. When TDS values exceed 1,100 mg/L, sulfate concentrations exceed 400 mg/L.

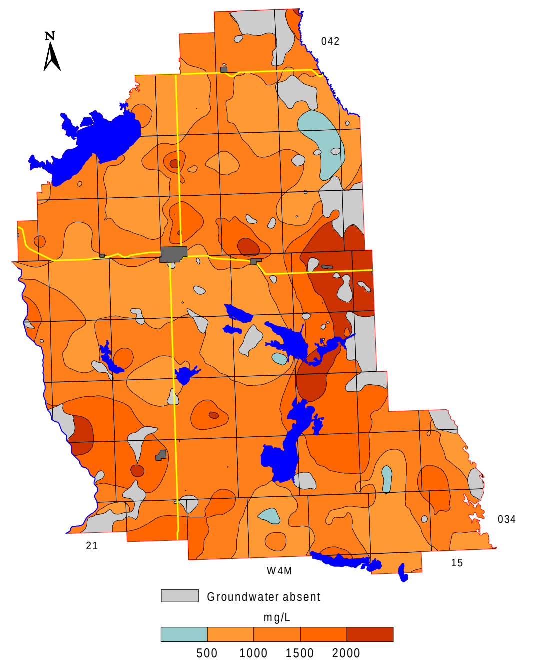

Figure 12. Total Dissolved Solids in Groundwater from Surficial Deposits

There are very few groundwaters with appreciable concentrations of the chloride ion. All of the groundwaters from the surficial deposits are expected to have concentrations of dissolved iron of greater than 1 mg/L.

5.3 Bedrock

5.3.1 Geological Characteristics

The upper bedrock in the County is the Edmonton Group. This Formation consists of fresh and brackish-water deposits of fine-grained sandstone and silty shale, thick coal seams, and numerous bentonite beds (Carrigy, 1971). The thickness of the Edmonton Group varies from 300 to 500 metres, and is underlain by the Bearpaw Formation. The Edmonton Group in the County includes the Scollard, Battle, Whitemud and Horseshoe Canyon formations.

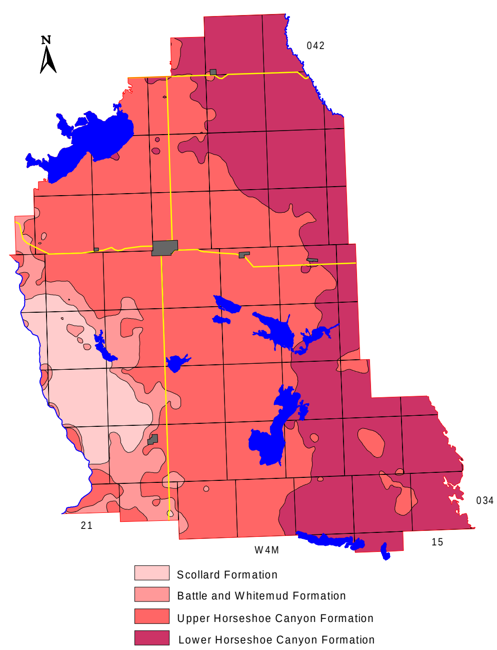

Figure 13. Bedrock Geology

The Scollard Formation is the upper bedrock and subcrops in the southwestern part of the County, mainly in townships 036 and 037, ranges 20 and 21, W4M. The Scollard Formation has a maximum thickness of 70 metres within the County and consists mainly of sandstone, siltstone, shale and coal seams or zones.

Beneath the Scollard Formation are two formations having a maximum thickness of 30 metres: the two are the Battle and Whitemud formations. The Battle and Whitemud formations are also present only in the southwestern part of the County. 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 considered to be significant geologic markers, and were used to prepare the structural maps and hydrostratigraphy classifications. Because of the ubiquitousness 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 remainder of the County. The Horseshoe Canyon Formation has a maximum thickness of 380 metres and within the County includes the Upper and Lower Horseshoe Canyon Formation. The Middle Horseshoe Canyon Formation is absent within the County. The Upper Horseshoe Canyon, which can be up to 170 metres thick, is the upper bedrock in the western three-quarters of the County where the Scollard Formation is absent. The Lower Horseshoe Canyon, which is up to 200 metres thick, is the upper bedrock in the eastern one-quarter of the County. There are subcrops of the Upper Horseshoe Canyon that occur as outliers within the area of the Lower Horseshoe Canyon in the eastern part of the County.

The Horseshoe Canyon Formation consists of deltaic[7] and fluvial[8] sandstone, siltstone and shale with interbedded coal seams, bentonite and thin nodular beds of 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 of the Horseshoe Canyon can include coarser grained sandstone deposits.

The Bearpaw Formation underlies the Horseshoe Canyon Formation and is in the order of 80 metres thick within the County. The Bearpaw Formation includes transgressive, shallow marine (shoreface) and open marine facies[9] deposits. In the County of Stettler, the Bearpaw Formation is composed mainly of shale and as such is a regional aquitard[10]. The border between the bottom of the Bearpaw Formation and the uppermost part of the Belly River Group was used as a geological marker in the e-log interpretation.

The Belly River Group includes the Foremost and Oldman formations. The main areas of higher permeability occur near the base of the Belly River Group at a depth of approximately 600 plus metres below ground level. The porous and permeable zones may be developed for hydrocarbons and limited quantities of groundwater, with total dissolved solids of in the order of 20,000 mg/L.

[7] See glossary
[8] See glossary
[9] See glossary
[10] See glossary

5.3.2 Aquifers

In general, water wells in the bedrock aquifer(s) in the County of Stettler can be expected to provide only limited quantities of groundwater. The adjacent map shows water well yields that are expected based on the bedrock aquifer(s) that have been developed. For approximately 50% of the County, water wells completed in the bedrock aquifer(s) have apparent yields of more than 10 m³/day.

Of the 1,892 bedrock water wells, there were 1,666 water well records with sufficient information to classify the aquifer in which the water well is completed. Of the 1,666 water wells, 1,142 are completed in the Upper Horseshoe Canyon Aquifer, 471 are completed in the Lower Horseshoe Canyon Aquifer and 53 are completed in the Scollard Aquifer. The classification for the remaining 226 is unknown. The producing water wells mainly occur within the area where the Upper Horseshoe Canyon Aquifer is present.

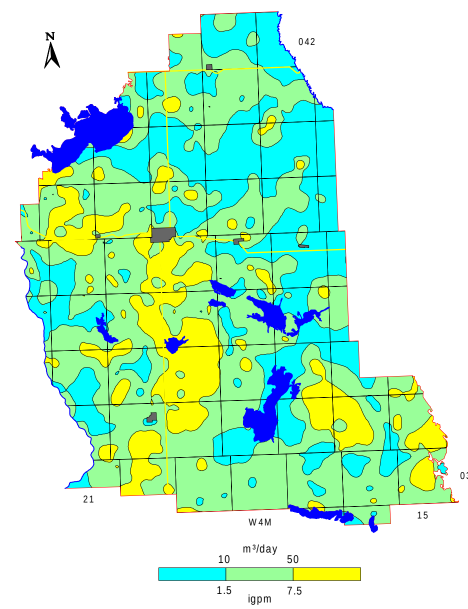

Figure 14. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

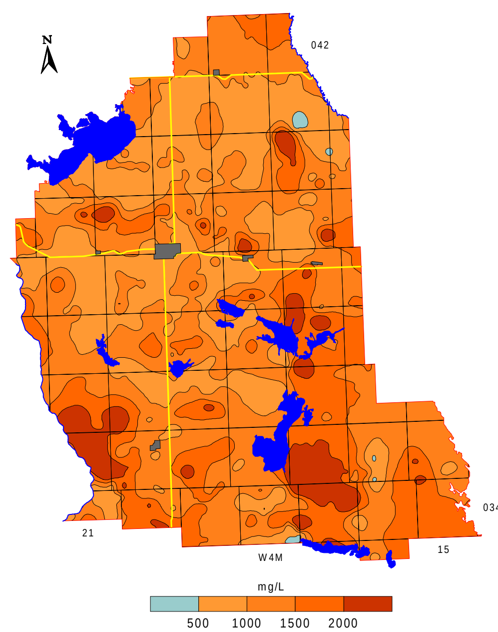

Figure 15. Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

5.3.3 Chemical Quality of Groundwater

The TDS concentrations in the groundwaters from the upper bedrock aquifer(s) range from less than 500 to more than 2,000 mg/L. In more than 70% of the area, TDS values are more than 1,000 mg/L.

A relationship between TDS and sulfate concentrations shows that when TDS values in the upper bedrock aquifer(s) exceed 1,200 mg/L, the sulfate concentration exceeds 400 mg/L.

The Piper tri-linear diagrams show that all chemical types of groundwater occur in the bedrock aquifer(s). However, the majority of the groundwaters are sodium-bicarbonate or sodium-sulfate types.

In 60% of the County, the fluoride ion concentration in the groundwater from the upper bedrock aquifer(s) is less than 1.0 mg/L.

5.3.4 Scollard Aquifer

The Scollard Aquifer is part of the Scollard Formation that underlies 200 square kilometres in the southwestern part of the County. The thickness of the Scollard Formation is generally less than 70 metres; in most of the County, the Scollard Formation has been eroded.

5.3.4.1 Depth to Top

The depth to the top of the Scollard Formation is mainly less than 30 metres below ground level. The greatest depth is in the central part of the area where the Formation is present.

5.3.4.2 Apparent Yield

The projected long-term yield for individual water wells completed through the Scollard Aquifer is mainly 10 to 50 m³/day. Adjacent to the Red Deer River Valley in townships 035 to 038, ranges 21 and 22, W4M the Scollard Formation is expected to be drained. The areas where water wells with higher yields are expected are mainly in the middle part of the area where the Scollard Aquifer is present.

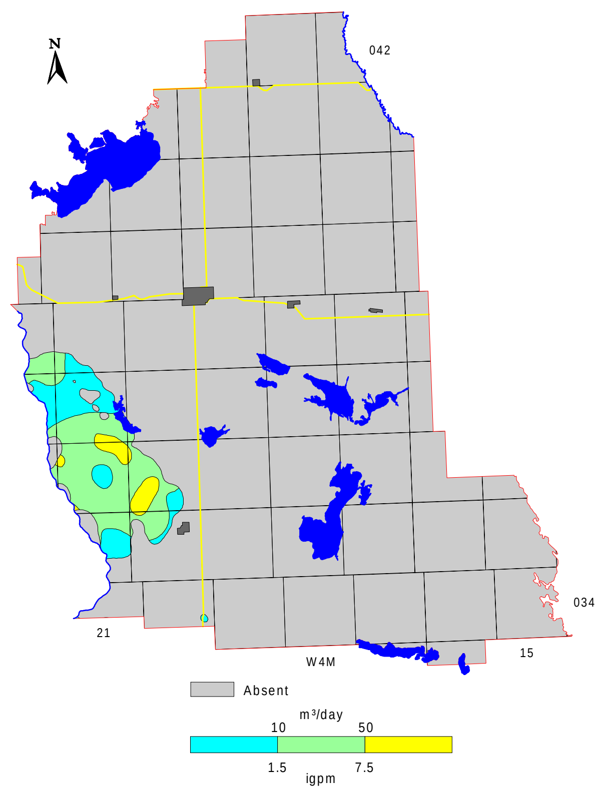

Figure 16. Apparent Yield for Water Wells Completed through Scollard Aquifer

5.3.4.3 Quality

The TDS concentrations for groundwater from the Scollard Aquifer range from less than 1,000 to more than 2,000 mg/L. The higher values of TDS occur in the southwestern part of the area where the Aquifer is present. When TDS values in the groundwater from the Scollard Aquifer exceed 1,100 mg/L, the sulfate concentrations exceed 400 mg/L.

The chloride concentration of the groundwater from the Scollard Aquifer can be expected to be less than 10 mg/L.

5.3.5 Upper Horseshoe Canyon Aquifer

The Upper Horseshoe Canyon Aquifer is the upper part of the Horseshoe Canyon Formation and subcrops under the central and western parts of the County. The thickness of the Upper Horseshoe Canyon Aquifer increases to the southwest and can reach 200 metres in the western part of the County. In general terms, the permeability of the Upper Horseshoe Canyon Aquifer is very low. Higher local permeability can be expected when the depth of burial is less than 100 metres and fracturing or weathering has occurred.

5.3.5.1 Depth to Top

The depth to the top of the Upper Horseshoe Canyon Aquifer is variable, ranging from less than 10 to more than 30 metres. The largest area where the top of the Upper Horseshoe Canyon Aquifer is more than 30 metres below ground level is in the western part of the County, where the Upper Horseshoe Canyon Aquifer underlies the Scollard Aquifer.

5.3.5.2 Apparent Yield

The projected long-term yields for water wells completed through the Upper Horseshoe Canyon Aquifer are mainly less the 50 m³/day. The higher yields trend along a north-south area in the central part of the County. The main part of the area is south of the Town of Stettler in close proximity to Highway 56. These higher yields may be related to a shallow depth of burial, fracturing or weathering. Higher water well yields may also be expected in the northwestern part of the County.

A groundwater study conducted on the north side of Buffalo Lake at Braseth Beach, SW 18-041-21 W4M (Hydrogeological Consultants Ltd., 1997), just outside the County limits, determined a long-term yield of more than 185 m³/day for a water well completed in the Upper Horseshoe Canyon Aquifer. West of Stettler, a lineament analysis was used to identify a higher permeability zone in the Upper Horseshoe Canyon Aquifer (Hydrogeological Consultants Ltd., 1996).

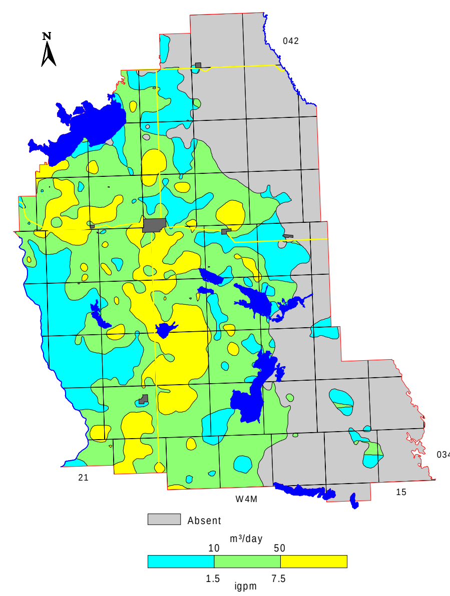

Figure 17. Apparent Yield for Water Wells Completed through Upper Horseshoe Canyon Aquifer

5.3.5.3 Quality

The Piper tri-linear diagrams show that sodium-bicarbonate and sodium-sulfate are the dominant types of groundwater that occur in the Upper Horseshoe Canyon Aquifer. The TDS concentrations in groundwater from the Upper Horseshoe Canyon Aquifer range from less than 1,000 to more than 2,000 mg/L. The lower TDS values tend to be in the central part of the County. When TDS values exceed 1,200 mg/L, the sulfate concentrations exceed 400 mg/L.

Chloride concentrations in the groundwater from the Upper Horseshoe Canyon Aquifer are mainly less than 100 mg/L. The exceptions occur along the western part of the County. In this area, chloride concentrations can exceed 250 mg/L.

5.3.6 Lower Horseshoe Canyon Aquifer

The Lower Horseshoe Canyon Aquifer is part of the Lower Horseshoe Canyon Formation and subcrops under the eastern part of the County. The thickness of the Lower Horseshoe Canyon Aquifer is generally 170 metres, but can reach a thickness of 200 metres. Higher local permeability can be expected in the lowest part of the Lower Horseshoe Canyon Formation than in the Upper Horseshoe Canyon Aquifer.

5.3.6.1 Depth to Top

The depth to the top of the Lower Horseshoe Canyon Aquifer ranges from less than 20 metres in the northeastern part of the County where the Aquifer subcrops, to more than 230 metres in the western part of the County where the Scollard Aquifer is present.

5.3.6.2 Apparent Yield

The projected long-term yields for individual water wells completed in the Lower Horseshoe Canyon Aquifer are mainly less than 10 m³/day. The adjacent map indicates that apparent yields of more than 50 m³/day are expected mainly in the southeastern corner of the County. There is little or no data for the Aquifer in the southern and western parts of the County. In these areas, the main aquifer would be expected at a depth of more than 300 metres.

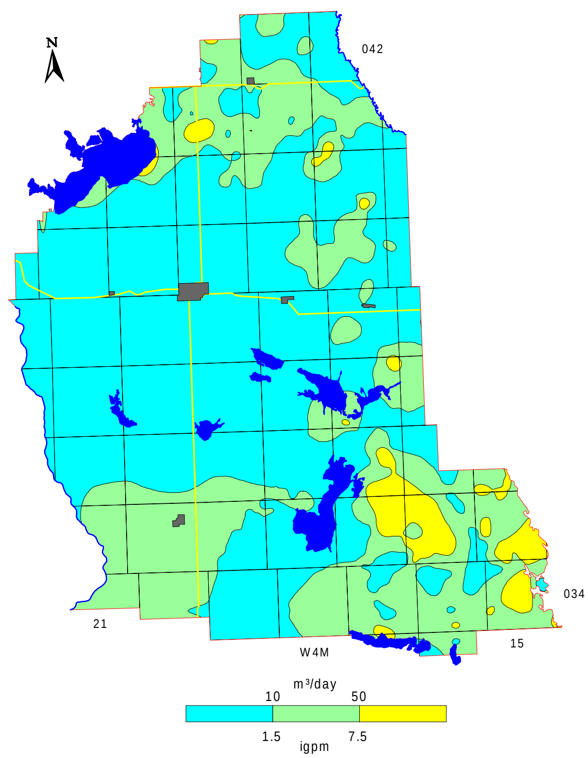

Figure 18. Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer

5.3.6.3 Quality

Groundwaters from the Lower Horseshoe Canyon Aquifer are mainly sodium-bicarbonate or sodium-sulfate type waters. TDS concentrations are expected to be in the order of 500 to 1,500 mg/L where the Aquifer is present, although there is a paucity of data from the western part of the County.

Chloride concentrations in the groundwater from the Lower Horseshoe Canyon Aquifer are mainly less than 100 mg/L.

6 GROUNDWATER BUDGET

6.1 Hydrographs

There are four observation water wells in the County where water levels are being measured and recorded with time. These observation water wells are part of the AEP groundwater-monitoring network. Three of the observation water wells are located west of the Town of Stettler in the Erskine Channel area. One of the three observation water wells, Obs WW No. 135, is completed near the base of the channel deposits, in the sand and gravel aquifer. Two observation water wells, Obs WW Nos. 136 and 137, are completed in the Upper Horseshoe Canyon Aquifer. The fourth observation well, Obs WW No. 232, is located south of Buffalo Lake, (12-10-040-21 W4M), and is completed in an aquifer associated with the Buried Buffalo Lake Valley. Water-level measurements are available from this observation water well from 1963 to 1996. However, the data from Obs WW No. 232 are of limited use because of the quality of the records.

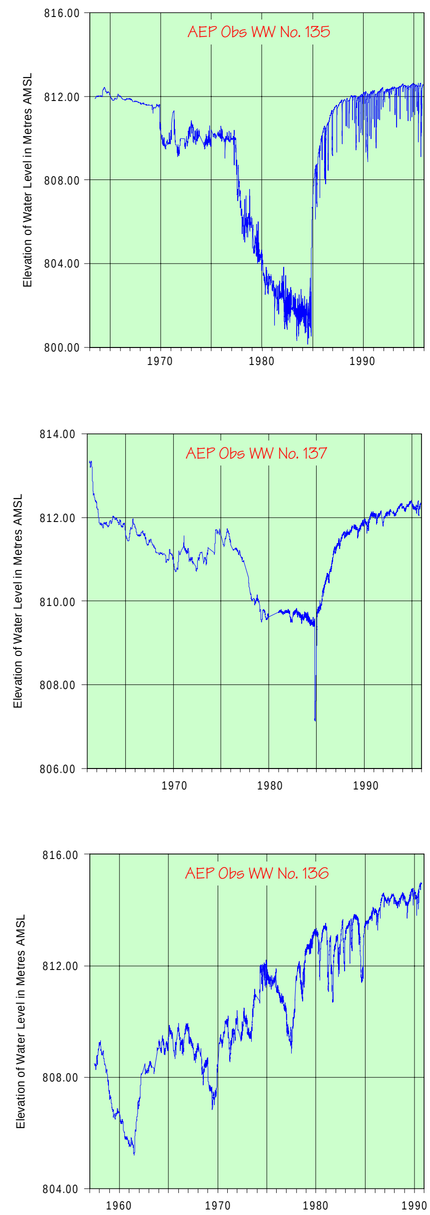

Figure 19. Hydrographs - AEP Observation Water Wells

Obs WW No. 135 is completed in the Erskine Aquifer. The water-level decline in the Obs WW from 1977 to 1985 is a result of increased groundwater production from the Erskine Aquifer for the Town of Stettler. Obs WW No. 137 is completed in a bedrock aquifer near the Erskine Aquifer. The increased decline in the water levels from 1977 to 1985 and the water-level rise from 1985 to 1990 in Obs WW No. 137 indicates a direct hydraulic relationship exists between the sand and gravel aquifer of the Erskine Aquifer and the Upper Horseshoe Canyon bedrock aquifer in which Obs WW No. 137 is completed.

The water-level measurements in Obs WW No. 136 rose more than eight metres between 1962 and 1991. The rise may have been the result of the Town of Stettler having taken a bedrock water well out of service.

In general, all hydrographs show local hydraulic conditions, and are not used for regional budget analysis. The hydrograph for Obs WW No. 135 indicates that approximately five years after the groundwater diversion from the Erskine Aquifer was stopped by the Town of Stettler, the water level had returned to the same level as in 1963, when the monitoring began.

6.2 Groundwater Flow

A direct measurement of groundwater recharge or discharge is not possible from the data that are presently available for the County. One indirect method of measuring recharge is to determine the quantity of groundwater flowing through each individual aquifer. This method assumes that there is sufficient recharge to the aquifer to maintain the flow through the aquifer and the discharge is equal to the recharge. However, even the data that can be used to calculate the quantity of flow must be averaged and estimated. To determine the flow requires a value for the average transmissivity of the aquifer, an average hydraulic gradient and an estimate for the width of the aquifer. For the present program, the flow has been estimated for those parts of the various aquifers within the County. The aquifers include the surficial deposits as one hydraulic unit, the Buried Buffalo Lake Valley, the Scollard Aquifer, the Upper Horseshoe Canyon Aquifer, and the Lower Horseshoe Canyon Aquifer.

The flow through each aquifer assumes that by taking a large enough area, an aquifer can be considered as homogeneous, the average gradient can be estimated from the non-pumping water-level surface, and flow takes place through the entire width of the aquifer. Based on these assumptions, the estimated groundwater flow through the individual aquifers can be summarized as follows:

Aquifer Designation	Transmissivity (m^2/day)	Gradient (m/m)	Width (km)	Main Direction of Flow	Quantity (m^3/day)	Authorized Diversion (m^3/day)
Surficial Deposits	5	0.0025	50	Northeast	600	300
Buried Buffalo Lake Valley	10	0.015	5	East	750	
Buried Buffalo Lake Valley	10	0.013	5	West	600	
Scollard	6	0.006	15	West/North	600	129
Upper Horseshoe Canyon	6	0.002	60	Southeast/Northeast	700	610
Lower Horseshoe Canyon	2	0.003	70	West/Northeast	500	497

The above table indicates that there is more groundwater flowing through the aquifers than has been authorized to be diverted from the individual aquifers. The authorized diversion for the surficial deposits includes the authorized diversion from the Buried Buffalo Lake Valley. However, because of the very approximate nature of the calculation of the quantity of groundwater flowing through the individual aquifers, more detailed work is required to establish the flow through the aquifers.

6.2.1 Quantity of Groundwater

An estimate of the volume of groundwater stored in the sand and gravel aquifers in the surficial deposits is 0.4 to 2.5 cubic kilometres. This volume is based on an areal extent of 4,300 square kilometres and a saturated sand and gravel thickness of two metres. The variation in the total volume is based on the value of porosity that is used for the sand and gravel. One estimate of porosity is 5%, which gives the low value of the total volume. The high estimate is based on a porosity of 30% (Ozoray, Dubord and Cowen, 1990).

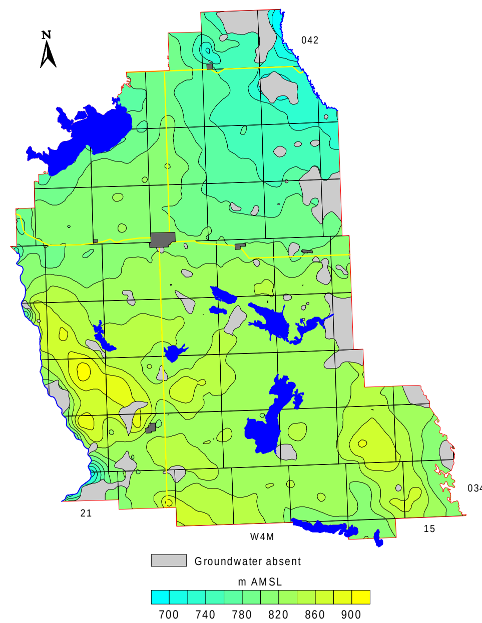

Figure 20. Non-Pumping Water-Level Surface in Water Wells Shallower than 15 metres

The adjacent water-level map has been prepared by considering all water wells completed in aquifers in the surficial deposits. The map shows the highest level of groundwater in surficial deposits, and this level was used for calculation of saturated surficial deposits and for calculations of recharge/discharge areas.

6.2.2 Recharge/Discharge

The hydraulic relationship between the groundwater in the surficial deposits and the groundwater in the bedrock aquifers is given by the non-pumping water-level surface associated with each of the hydraulic units. Where the water level in the surficial deposits is at a higher elevation than the water level in the bedrock aquifers, there is the opportunity for groundwater to move from the surficial deposits into the bedrock aquifers. This condition would be considered as an area of recharge to the bedrock aquifers and an area of discharge from the surficial deposits. The amount of groundwater that would move from the surficial deposits to the bedrock aquifers is directly related to the vertical permeability of the sediments separating the two aquifers.

When the hydraulic gradient is from the bedrock aquifers to the surficial deposits, the condition is a discharge area, relative to the bedrock aquifers.

6.2.2.1 Surficial Deposits/Bedrock Aquifers

The hydraulic gradient between the surficial deposits and the bedrock aquifers has been determined by subtracting the non-pumping water-level surface, determined for all water wells in the surficial deposits, from the non-pumping water-level surface associated with all water wells completed in bedrock aquifers. The recharge classification on the adjacent map includes those areas where the water level in the surficial deposits is more than five metres above the water level in the upper bedrock aquifer(s). The discharge areas are where the water level in the surficial deposits is more than five metres lower than the water level in the bedrock. When the water level in the surficial deposits is between five metres above and five metres below the water level in the bedrock, the area is classified as a transition.

The adjacent map shows that in more than 50% of the County there is a downward hydraulic gradient between the surficial deposits and the upper bedrock aquifer(s). Areas where there is an upward hydraulic gradient, discharge from the bedrock, are very few. The areas of discharge from the bedrock are mainly along the Red Deer River Valley and in the southwestern part of the County, south of the subcrop of the Scollard Formation. The remaining parts of the County are areas where there is a transition condition. The extensive areas of transition conditions may be a result of limited topographic relief and/or limited data for both aquifer conditions.

Because of the paucity of data, a calculation of the volumes of groundwater entering and leaving the surficial deposits has not been attempted.

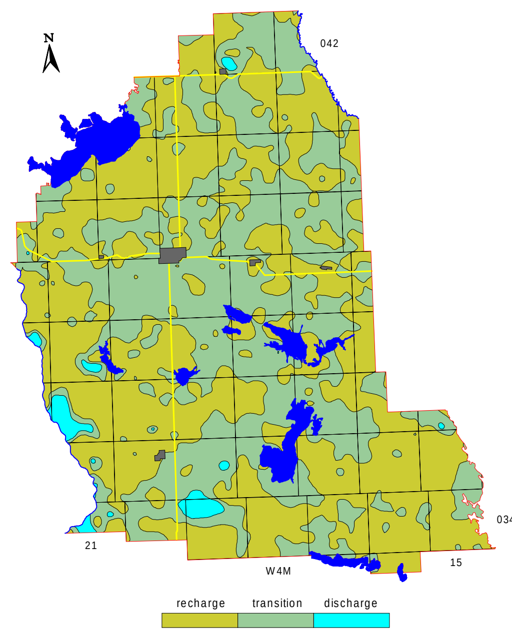

Figure 21. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)

6.3 Bedrock Aquifers

Recharge to the bedrock aquifers within the County takes place from the overlying surficial deposits and from flow in the aquifer from outside the County. The recharge/discharge maps show that generally for most of the County, there is a downward hydraulic gradient from the surficial deposits to the bedrock. On a regional basis, calculating the quantity of water involved is not possible because of the complexity of the geological setting and the limited amount of data. However, because of the generally low permeability of the upper bedrock materials, the volume of water is expected to be small.

The hydraulic relationship between the surficial deposits and the Scollard Aquifer indicates that in 90% of the County where the Scollard is present, there is a downward hydraulic gradient. Discharge areas are present at the edges of the Scollard Formation.

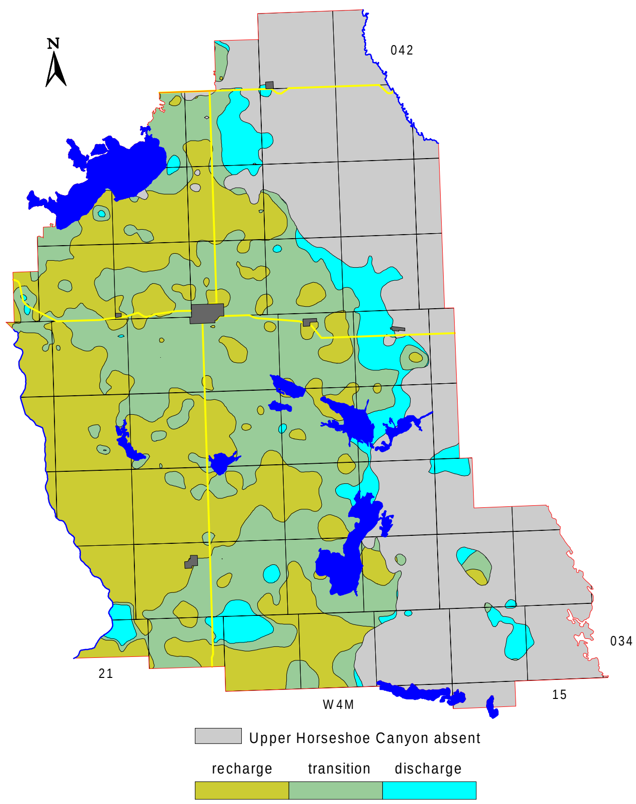

Figure 22. Recharge/Discharge Areas between Surficial Deposits and Upper Horseshoe Canyon Aquifer

The recharge/discharge configuration for the Upper Horseshoe Canyon Formation and the surficial deposits shows discharge from the bedrock in the eastern and the southern parts of the County. The discharge in the eastern parts of the County is associated with the edge of the Aquifer. The high TDS concentrations in the surficial deposits and upper bedrock aquifer(s) in Tps 036 to 039, ranges 16 and 17, W4M, correlates with an area of discharge between the surficial deposits and the Upper Horseshoe Canyon Aquifer. The extensive area of transitional flow may be indicative of the low relief, limited data and the broad range used for the definition of transitional flow.

It would be expected that there would be discharge from the Upper Horseshoe Canyon Formation along the Red Deer River Valley, but there are no data to confirm this. Discharge from the bedrock would also be expected in areas of linear bedrock lows. Again, the limited data do not show this to be happening.

The available data indicate that there is an upward hydraulic gradient from the Lower Horseshoe Canyon Aquifer to the Upper Horseshoe Canyon Aquifer in several areas in the County. The areas tend to be concentrated in a five- to ten-kilometre-wide band extending from Buffalo Lake in the northwest to Gough Lake in the south-central part of the County.

7 POTENTIAL FOR GROUNDWATER CONTAMINATION

The most common sources of contaminants that can impact groundwater originate on or near the ground surface. The contaminant sources can include leachate from landfills, effluent from leaking lagoons or from septic fields, and petroleum products from storage tanks or pipeline breaks. The agricultural activities that generate contaminants include spreading of fertilizers, pesticides, herbicides and manure. The spreading of highway salt can also degrade groundwater quality.

When activities occur that do or can produce a liquid which could contaminate groundwater, it is prudent (from a hydrogeological point of view) to locate the activities where the risk of groundwater contamination is minimal. Alternatively, if the activities must be located in an area where groundwater can be more easily contaminated, the necessary action must be taken to minimize the risk of groundwater contamination.

The potential for groundwater contamination is based on the concept that the easier it is for a liquid contaminant to move downward, the easier it is for the groundwater to become contaminated. In areas where there is groundwater discharge, liquid contaminants cannot enter the groundwater flow systems to be distributed throughout the area. When there are groundwater recharge areas, low-permeability materials impede the movement of liquid contaminants downward. Therefore, if the soils develop on a low-permeability parent material of till or clay, the downward migration of a contaminant is slower relative to a high-permeability parent material such as sand and gravel of fluvial origin. Once a liquid contaminant enters the subsurface, the possibility for groundwater contamination increases if it coincides with a higher permeability material within one metre of the land surface.

To determine the nature of the materials on the land surface, the surficial geology map prepared by the Alberta Research Council (Shetsen, 1990) has been reclassified based on the relative permeability. The classification of materials is as follows:

1. high permeability - sand and gravel;
2. moderate permeability - silt, sand with clay, gravel with clay, and bedrock; and
3. low permeability - clay and till.

To identify the areas where sand and gravel can be expected within one metre of the ground surface, all groundwater database records with lithologies were reviewed. From a total of 2,999 records in the area of the County with lithology descriptions, 721 have sand and gravel within one metre of ground level. In the remaining 2,278 records, the first sand and gravel is deeper or not present. This information was gridded to prepare a distribution of where the first sand and gravel deposit could be expected within one metre of ground level.

7.1.1 Risk of Contamination Map

The information from the reclassification of the surficial geology map is the basis for preparing the initial risk map. The depth to the first sand and gravel is then used to modify the initial map and to prepare the final map. The criteria used for preparing the final Risk of Groundwater Contamination map are outlined in the adjacent table.

Surface Permeability	Sand or Gravel Present To 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

The Risk of Groundwater Contamination map shows that, in less than 35% of the County, there is a high or very high risk of the groundwater being contaminated. These areas would be considered the least desirable ones for a development that has a product or by-product that could cause groundwater contamination. However, because the map has been prepared as part of a regional study, the designations are a guide only; detailed hydrogeological studies must be completed at any proposed development site to ensure the groundwater is protected from possible contamination. At all locations, good environmental practices should be exercised in order to ensure that groundwater contamination would not affect groundwater quality.

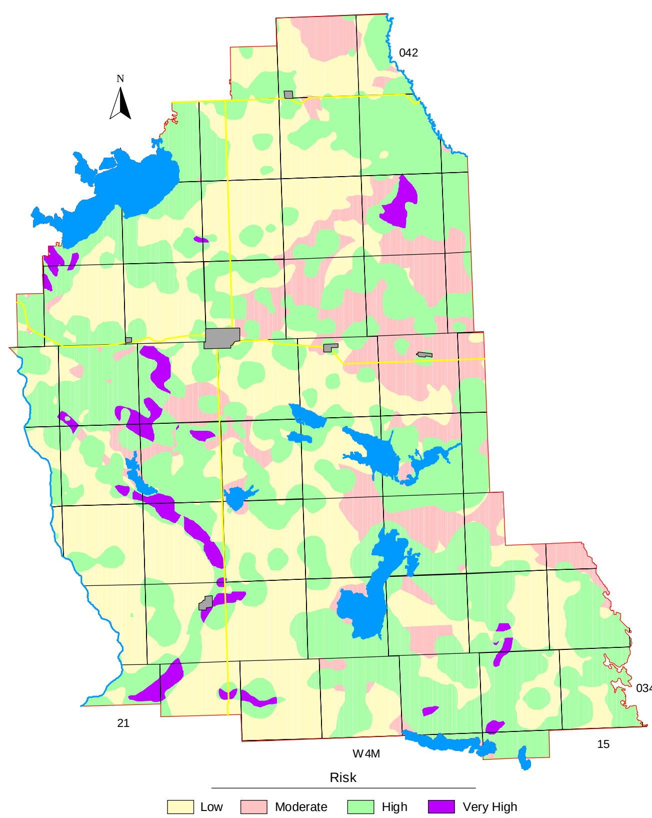

Figure 23. Risk of Groundwater Contamination

8 RECOMMENDATIONS

The present study has been based on information available from the groundwater database. The database has three problems:

1) the quality of the data;
2) the coordinate system used for the horizontal control; and
3) the distribution of the data.

The quality of the data in the groundwater database is affected by two factors: a) the technical training of the persons collecting the data; and b) the quality control of the data. The possible options to upgrade the database include the creation of a "super" database, which includes only verified data. The level of verification would have to include identifying the water well in the field, obtaining meaningful horizontal coordinates for the water well and the verification of certain parameters such as water level and completed depth. An attempt to update the quality of the entire database is not recommended.

The results of the present study indicate that the only readily identifiable aquifers in the surficial deposits are the sand and gravel deposits associated with the Erskine Channel and the Buried Buffalo Lake Valley. In the bedrock, there are indications that in the lower 70 metres of the Lower Horseshoe Canyon Formation a useable aquifer may be present

In the western part of the County, the base of the Lower Horseshoe Canyon Formation can be at depths approaching 400 metres. Because of the depth, no water wells have been completed through the Aquifer. Therefore, it is recommended that a test-drilling program be completed to evaluate the Lower Horseshoe Canyon Aquifer in the County of Stettler. The program could involve the drilling of water test holes in areas where only limited groundwater supplies are available from shallower aquifers; one such area could be in the western part of the County where less than 10 m^3/day of groundwater is available from the Upper Horseshoe Canyon Aquifer. The purpose of the program would be to determine the parameters of the Aquifer at depth and the quality of the groundwater from the Aquifer. This Aquifer would represent the maximum depth that can be considered for the development of groundwater supplies for traditional agricultural purposes.

Another area where insufficient data are available is for the determination of a groundwater budget. There are only three observation water-well data sources in the County from which to obtain water levels for the groundwater budget. One method to obtain additional water-level data is to solicit the assistance of the water well owners who are stakeholders in the groundwater resource. In the M.D. of Rocky View, water well owners are being provided with a tax credit if they accurately measure the water level in their water well once per week for a year. A pilot project indicated that approximately five years of records are required to obtain a reasonable data set. The cost of a five-year project involving 50 water wells would be less than the cost of one drilling program that may provide two or three observation water wells.

In general, for the next level of study, the database needs updating. It requires more information from existing water wells, and additional information from new ones.

Before an attempt is made to upgrade the level of interpretation provided in this report and the accompanying maps and groundwater query, it is recommended that all water wells for which water well drilling reports are available be subjected to the following actions:

1. The horizontal location of the water well should be determined within 10 metres. The coordinates must be in 10TM NAD 27 or some other system that will allow conversion to 10TM NAD 27 coordinates.
2. A four-hour aquifer test (two hours of pumping and two hours of recovery) should be performed with the water well to obtain a realistic estimate for the transmissivity of the aquifer in which the water well is completed.
3. Water samples should be collected for chemical analysis after 5 and 115 minutes of pumping, and analyzed for major and minor ions.

In addition to the data collection associated with the existing water wells, all available geophysical logs should be interpreted to establish a more accurate spatial definition of individual aquifers.

There is also a need to provide the water well drillers with feedback on the reports they are submitting to the regulatory agencies. The feedback is necessary to allow for a greater degree of uniformity in the reporting process. This is particularly true when trying to identify the bedrock surface. The water well drilling reports should be submitted to the AEP Resource Data Division in an electronic form. The money presently being spent by AEP and Prairie Farm Rehabilitation Administration (PFRA) to transpose the paper form to the electronic form should be used to allow for a technical review of the data and follow-up discussions with the drillers.

An effort should be made to form a partnership with the petroleum industry. The industry spends millions of dollars each year collecting information relative to water wells. Proper coordination of this effort could provide significantly better information from which future regional interpretations could be made. This could be accomplished by the County taking an active role in the activities associated with the construction of lease sites for the drilling of hydrocarbon wells and conducting of seismic programs.

Groundwater is a renewable resource and it must be managed.

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10 GLOSSARY

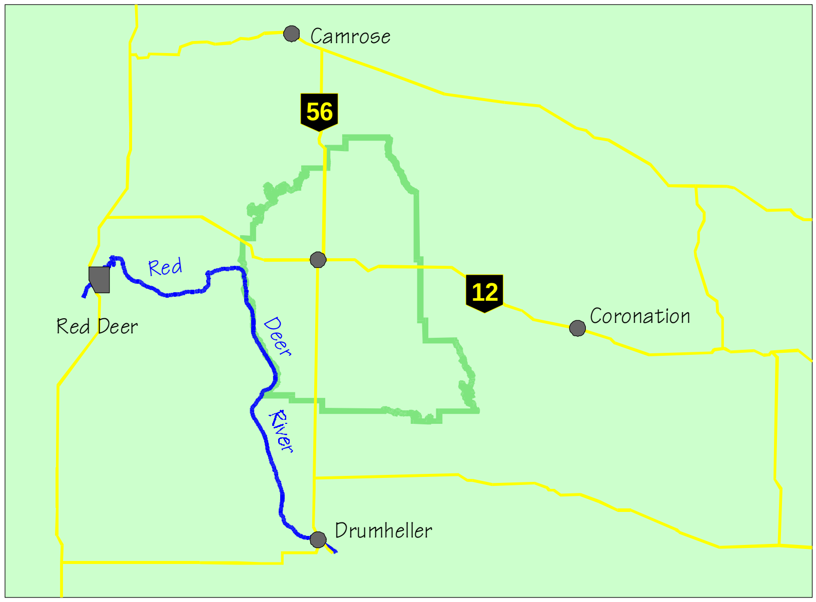
Aquifer	a formation, group of formations, or part of a formation that contains saturated permeable rocks capable of transmitting groundwater to water wells or springs in economical quantities.
Aquitard	a confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer.
Available Drawdown	in a confined aquifer, the distance between the non-pumping water level and the top of the aquifer.
	in an unconfined aquifer (water table aquifer), two thirds of the saturated thickness of the aquifer.
Deltaic	a depositional environment in standing water near the mouth of a river.
Facies	the aspect or character of the sediment within beds of one and the same age (Pettijohn, 1957).
Fluvial	produced by the action of a stream or river.
Hydraulic Conductivity	the rate of flow of water through a unit cross-section under a unit hydraulic gradient; units are length/time.
Kriging	a geo-statistical method for gridding irregularly-spaced data.
Lacustrine	fine-grained sedimentary deposits associated with a lake environment and not including shore-line deposits.
Surficial Deposits	includes all sediments above the bedrock.
Transmissivity	the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient: a measure of the ease with which groundwater can move through the aquifer.
	Apparent Transmissivity: the value determined from a summary of aquifer test data, usually involving only two water-level readings.
	Effective Transmissivity: the value determined from late pumping and/or late recovery water-level data from an aquifer test.
	Aquifer Transmissivity: the value determined by multiplying the hydraulic conductivity of an aquifer by the thickness of the aquifer.
Yield	a regional analysis term referring to the rate a properly completed water well could be pumped, if fully penetrating the aquifer.
	Apparent Yield: based mainly on apparent transmissivity.
	Long-Term Yield: based on effective transmissivity.

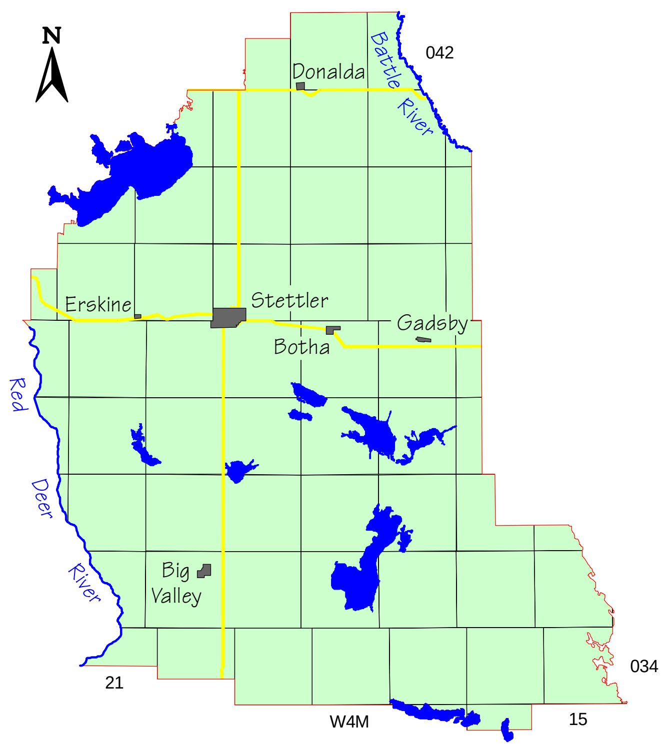
COUNTY OF STETTLER NO. 6

Appendix A

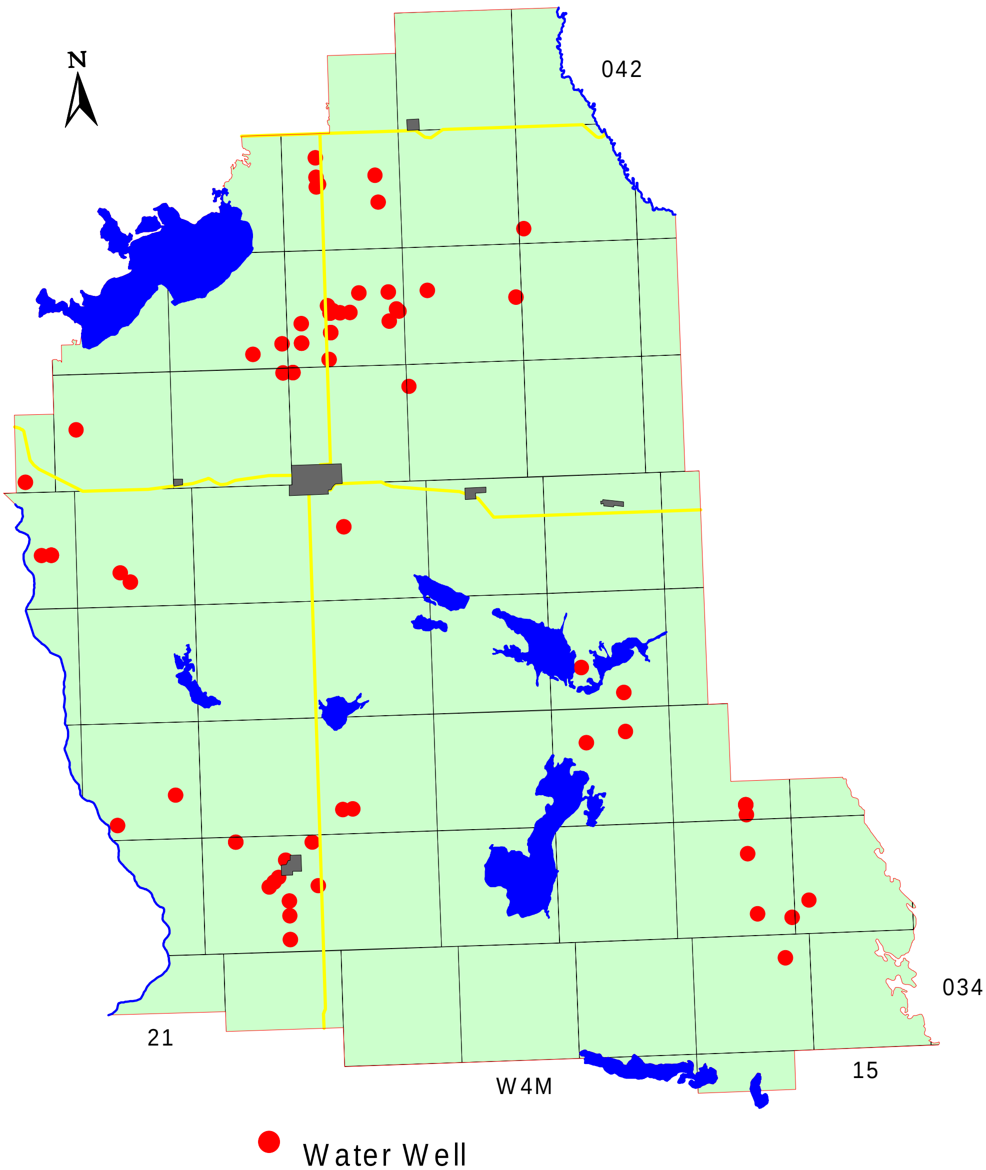
HYDROGEOLOGICAL MAPS AND FIGURES

Index Map

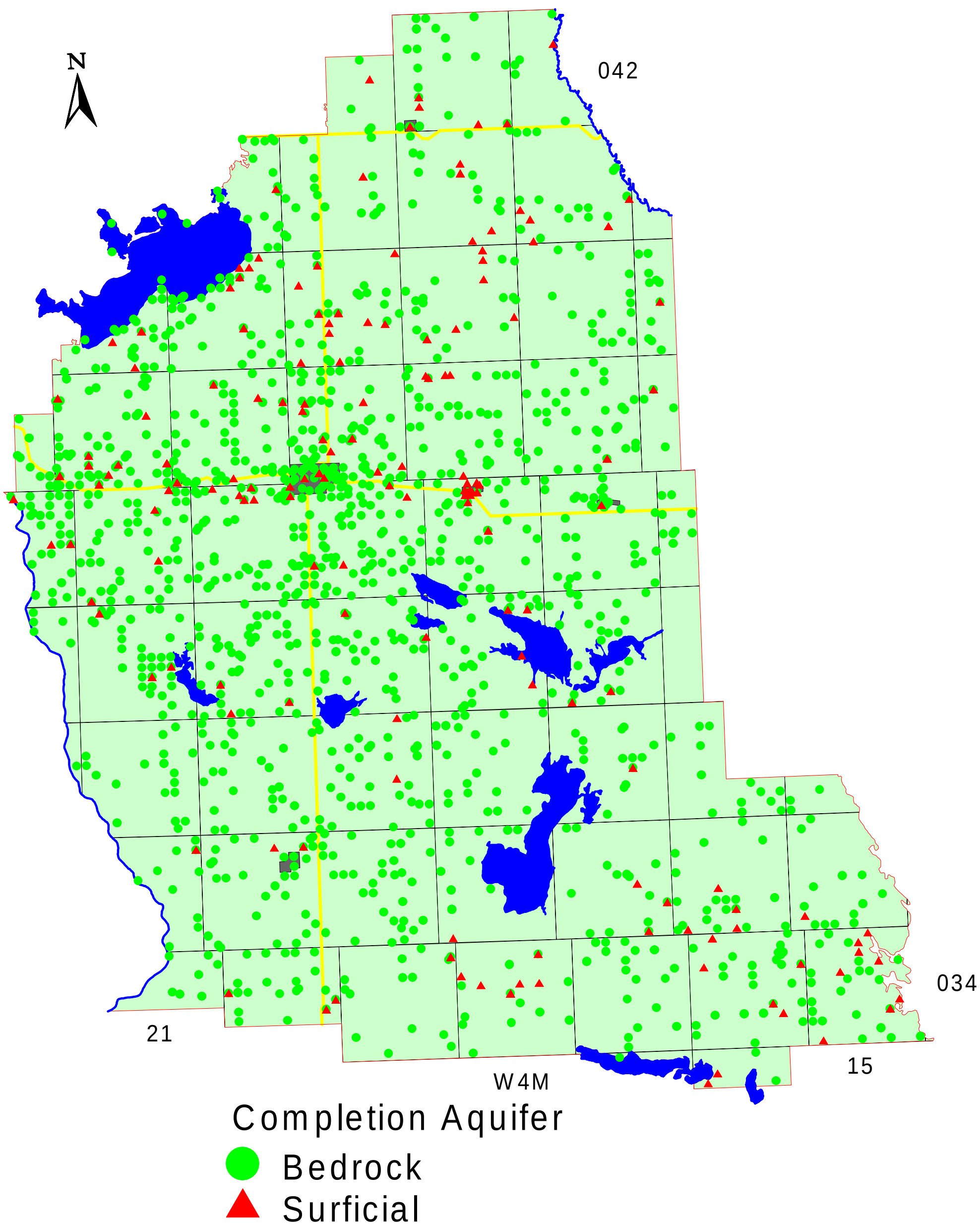

Camrose
56
Red
Red Deer
Deer
River
12
Coronation
Drumheller


N
042
Donalda
Battle
River
Erskine
Stettler
Gadsby
Botha
Red
Deer
River
Big
Valley
034
21
W4M
15

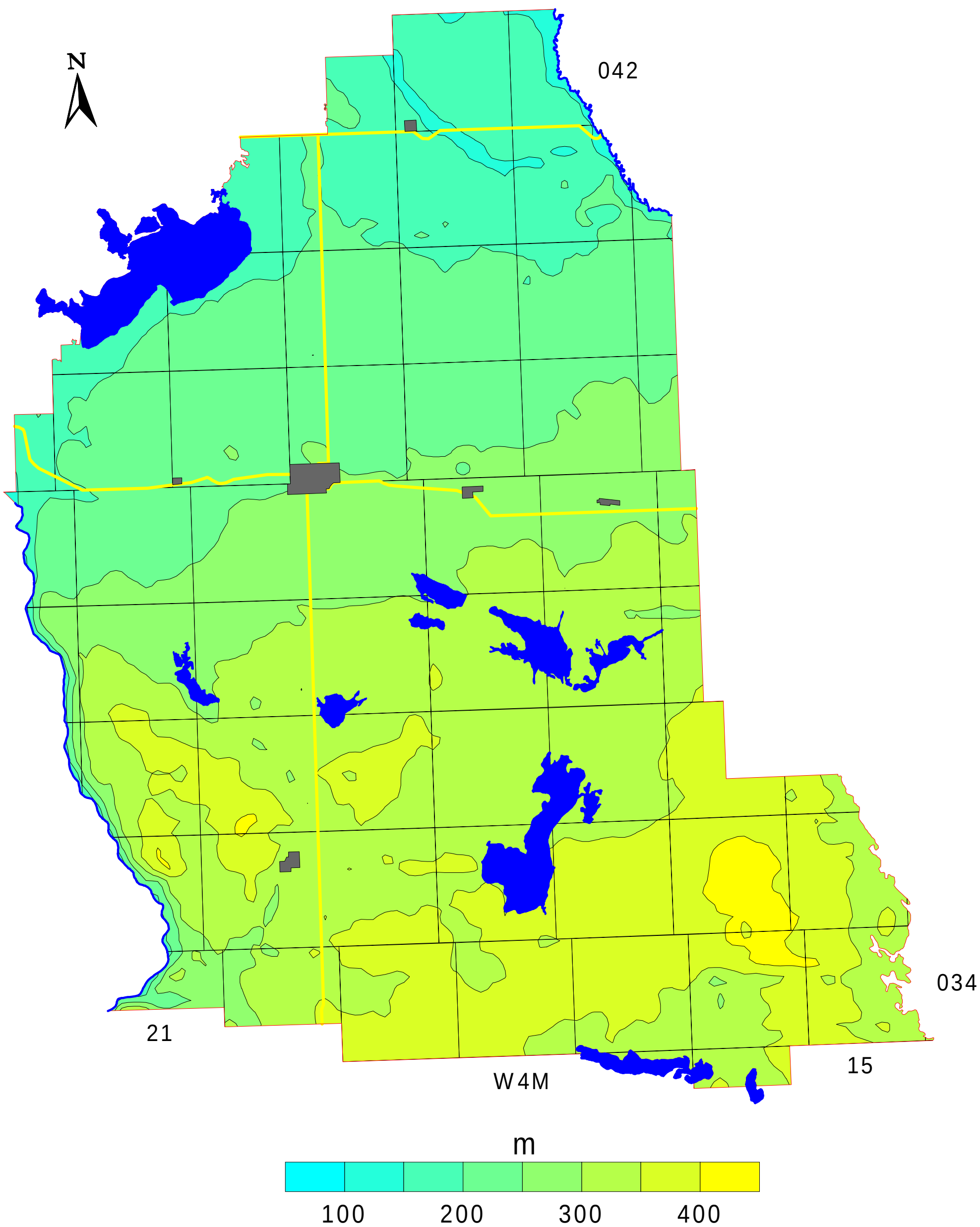
Water Wells Deeper than 120 metres

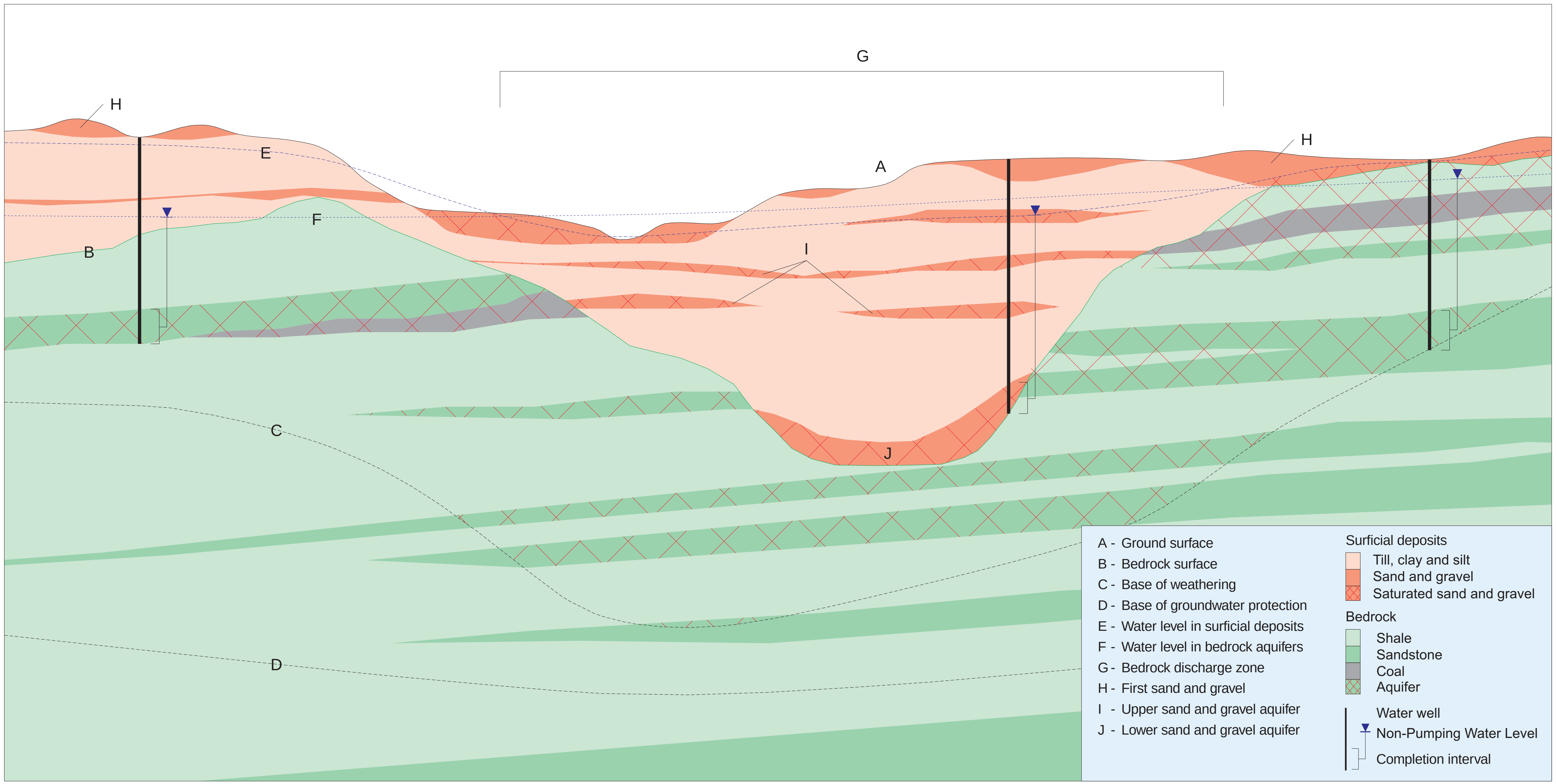


Location of Water Wells



Depth to Base of Groundwater Protection





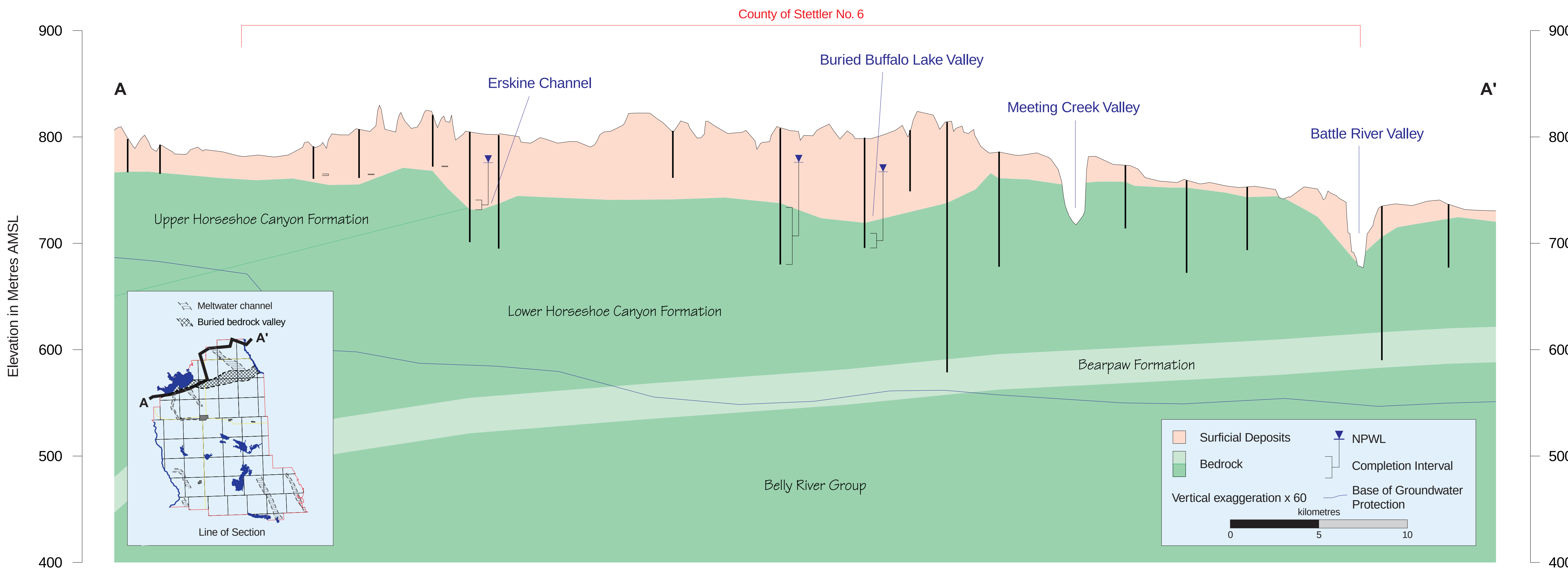
Generalized Cross-Section

(For terminology only)

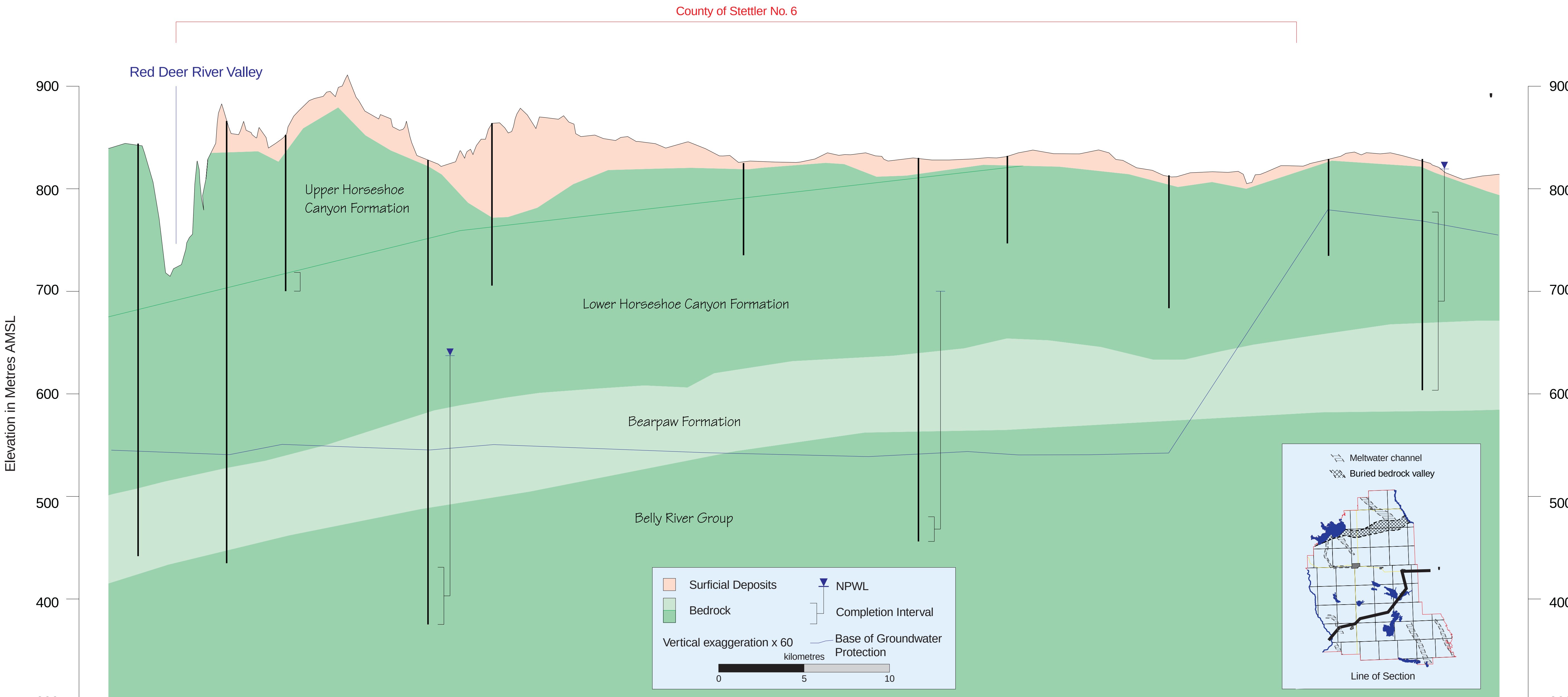
Lithology	Lithologic Description	Group and Formation: Thickness	Group	Group and Formation: Designation	Member: Thickness	Member: Designation	Zone: Thickness	Zone: Designation
	sand, gravel, till, clay, silt	<60		Surficial Deposits			<30	First Sand and Gravel
	shale, sandstone, coal	60-150	Edmonton Group	Scollard Formation	40-100	Upper	<2	Upper Ardley Coal Zone
							~20	Ardley Coal Zone (main seam)
							<1	Nevis Coal Seam
					20-60	Lower		
	shale, clay, tuff	~25	Edmonton Group	Battle Formation	<0.3	Kneehill Member		
	shale, siltstone, sandstone	5-10	Edmonton Group	Whitemud Formation				
	shale, sandstone, coal, bentonite, limestone, ironstone	300-380	Edmonton Group	Horseshoe Canyon Formation	~200	Upper		
					~170	Lower		
	shale, sandstone, siltstone	60-120		Bearpaw Formation				
	sandstone, siltstone, shale, coal	40-80	Belly River Group	Oldman Formation	<30	Dinosaur Member	<25	Lethbridge Coal Zone
					<20	Upper Siltstone Member		
					8-20	Comrey Member		
	shale, sandstone, coal	180-220	Belly River Group	Foremost Formation			<20	Taber Coal Zone
							<20	McKay Coal Zone
	sandstone, shale				<30	Basal Belly River Sandstone		

Depth (m): 0, 100, 200, 300, 400, 500, 600, 700, 800, 900

Geologic Column

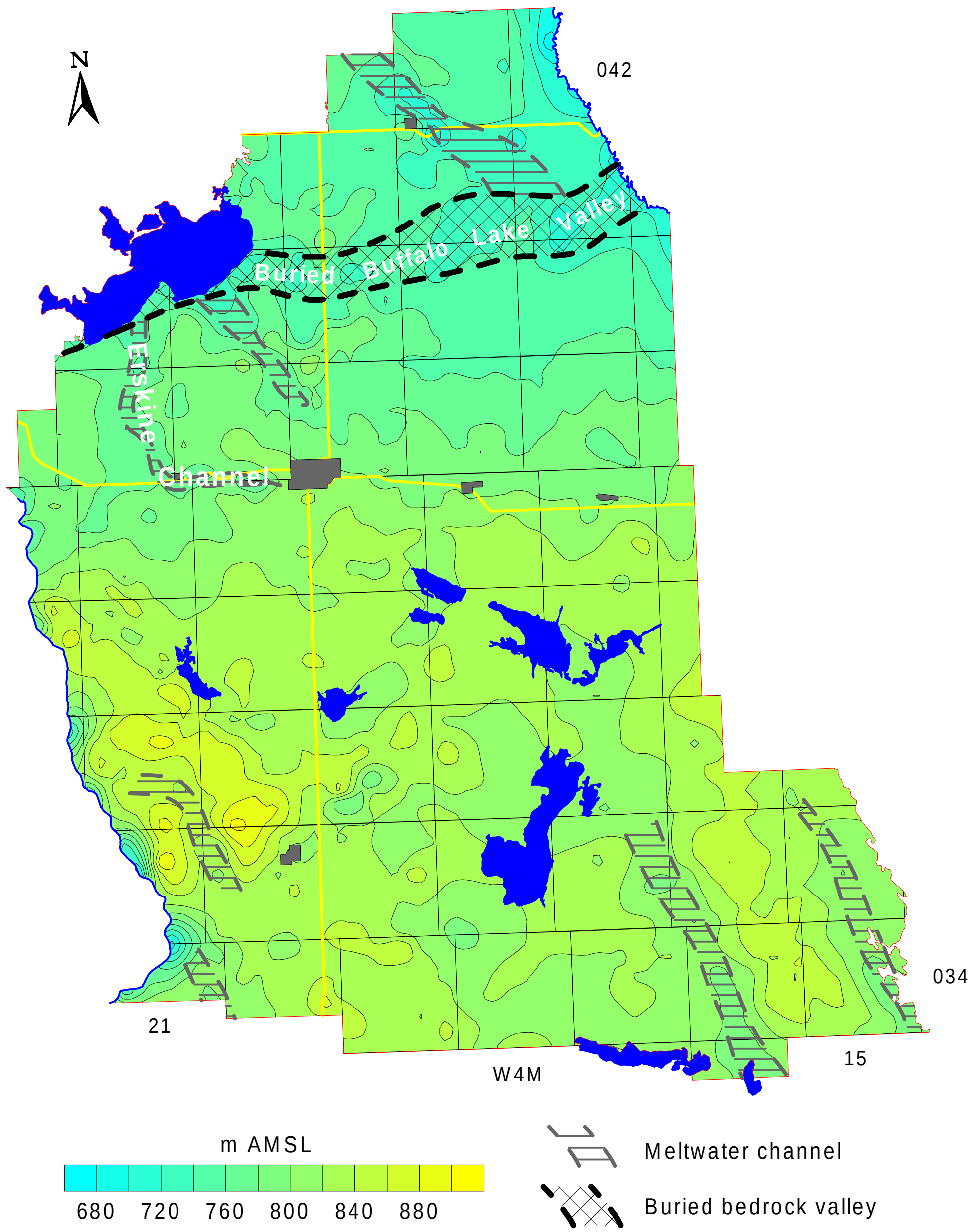


Cross-Section A - A'

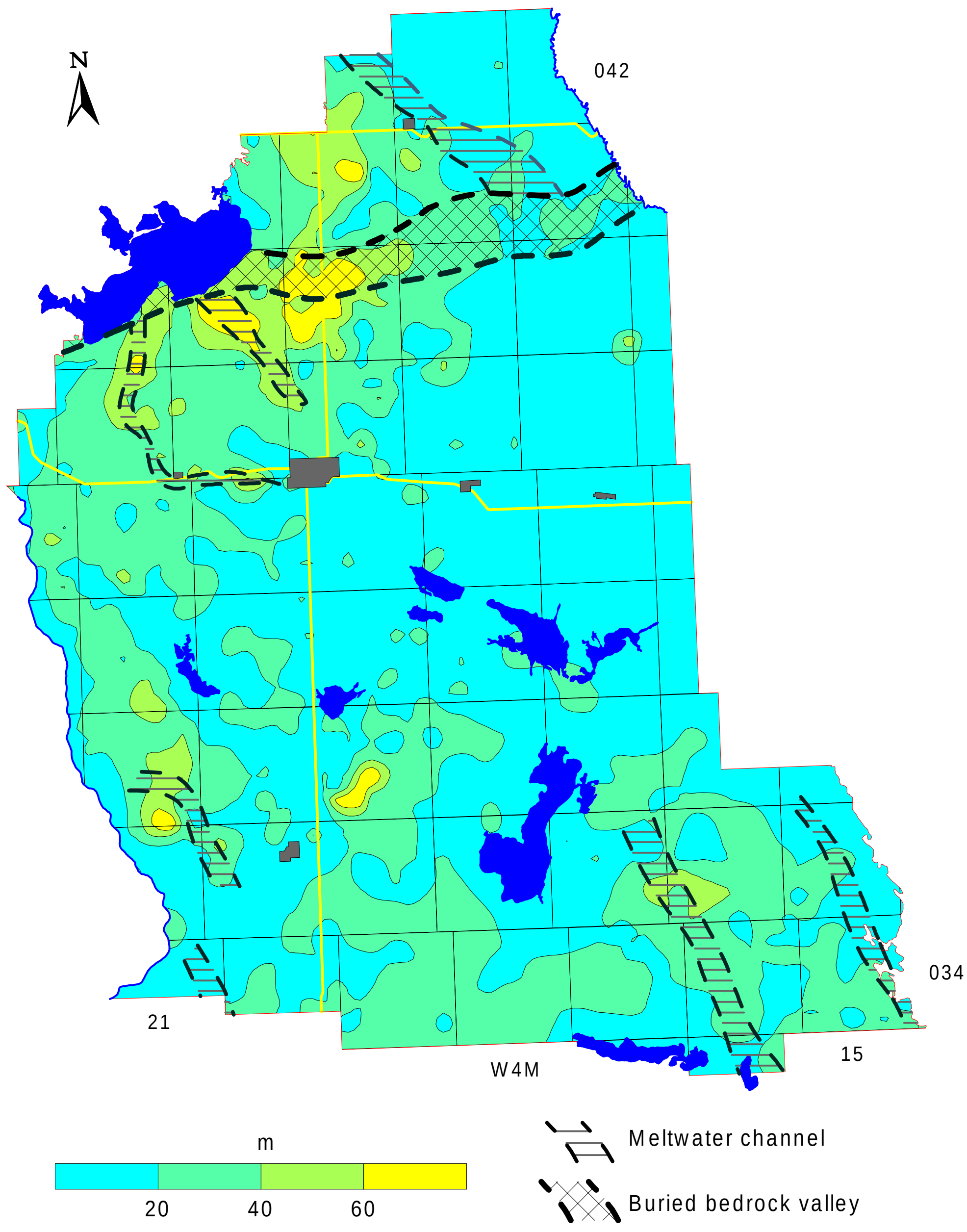


Cross-Section B - B'

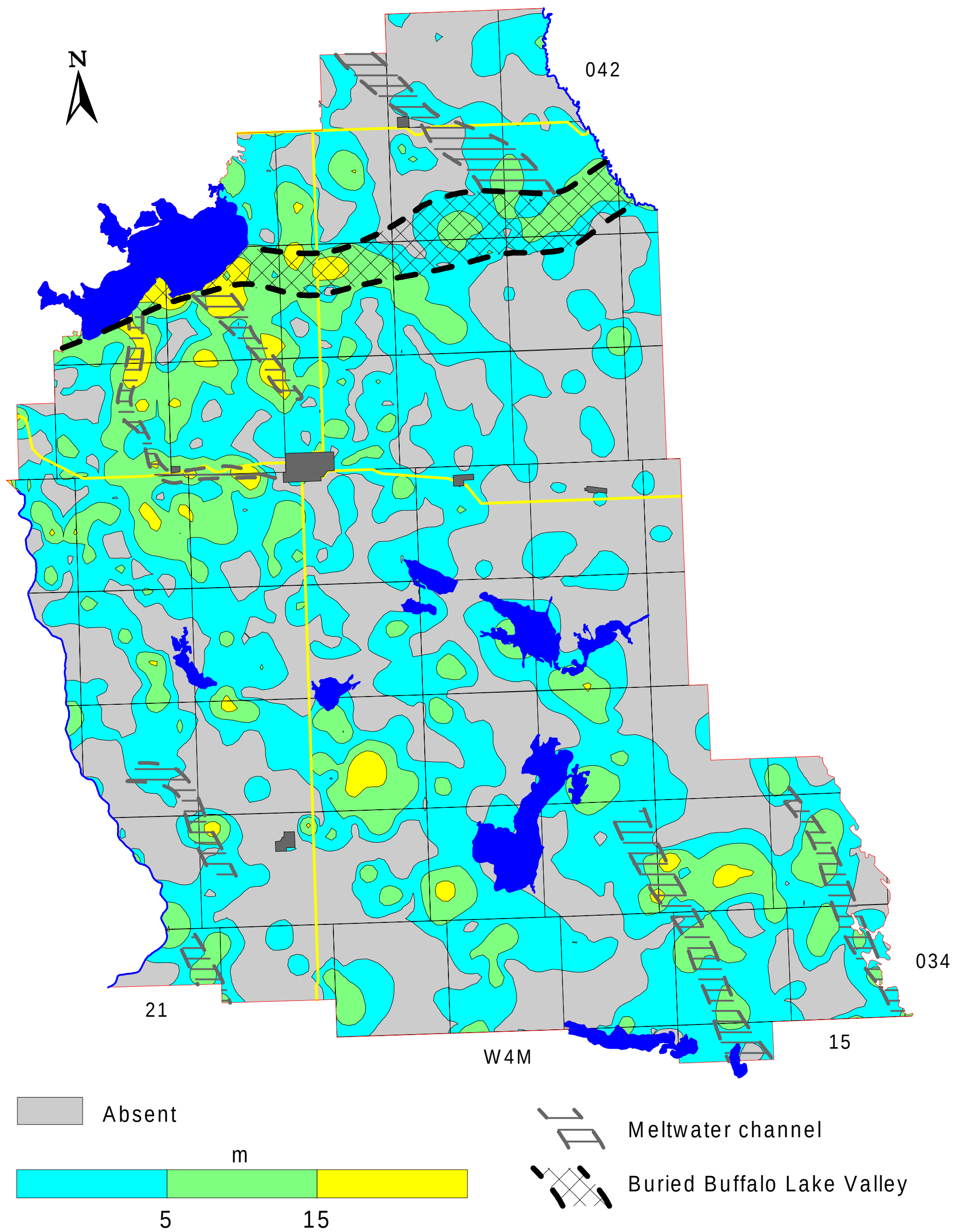
Bedrock Topography



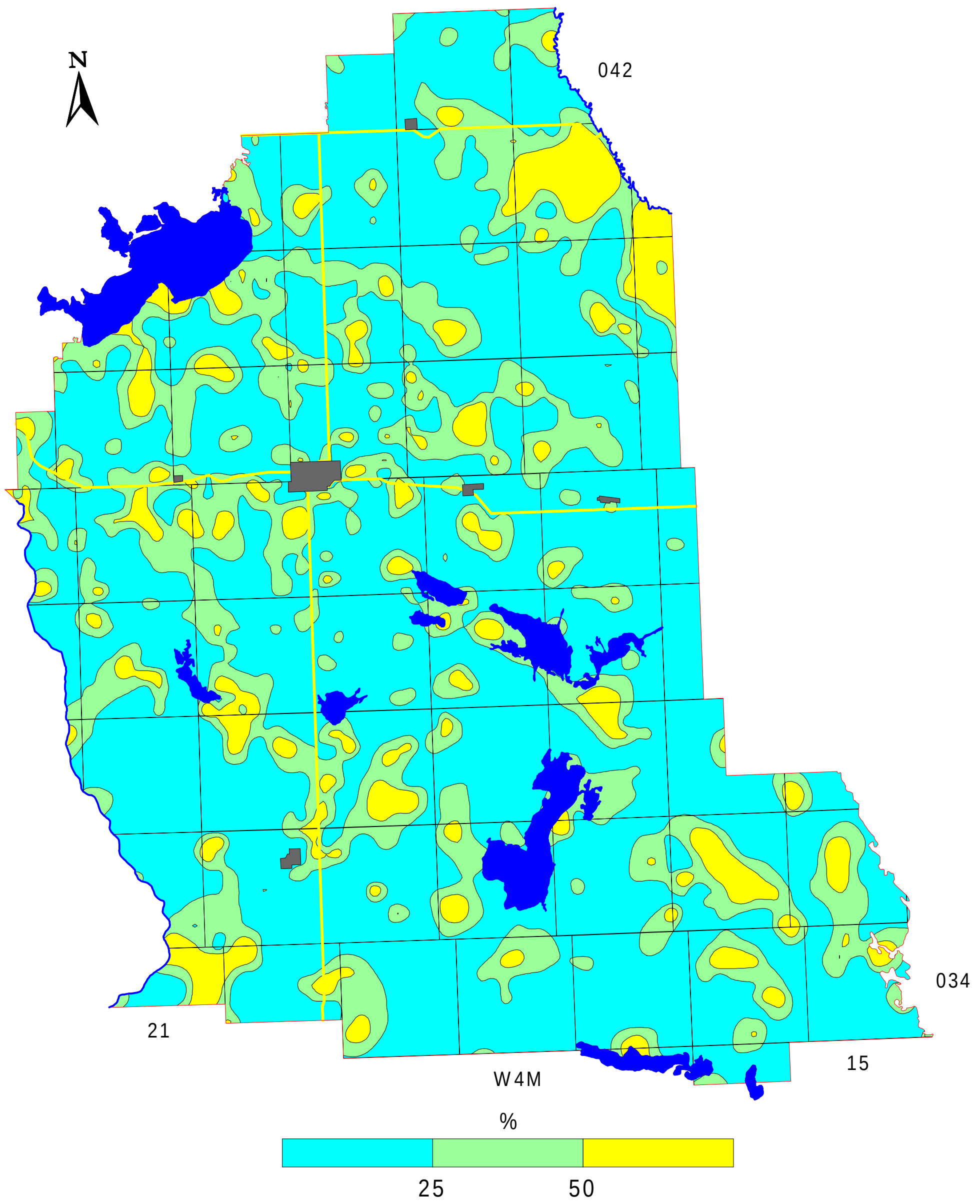
Thickness of Surficial Deposits



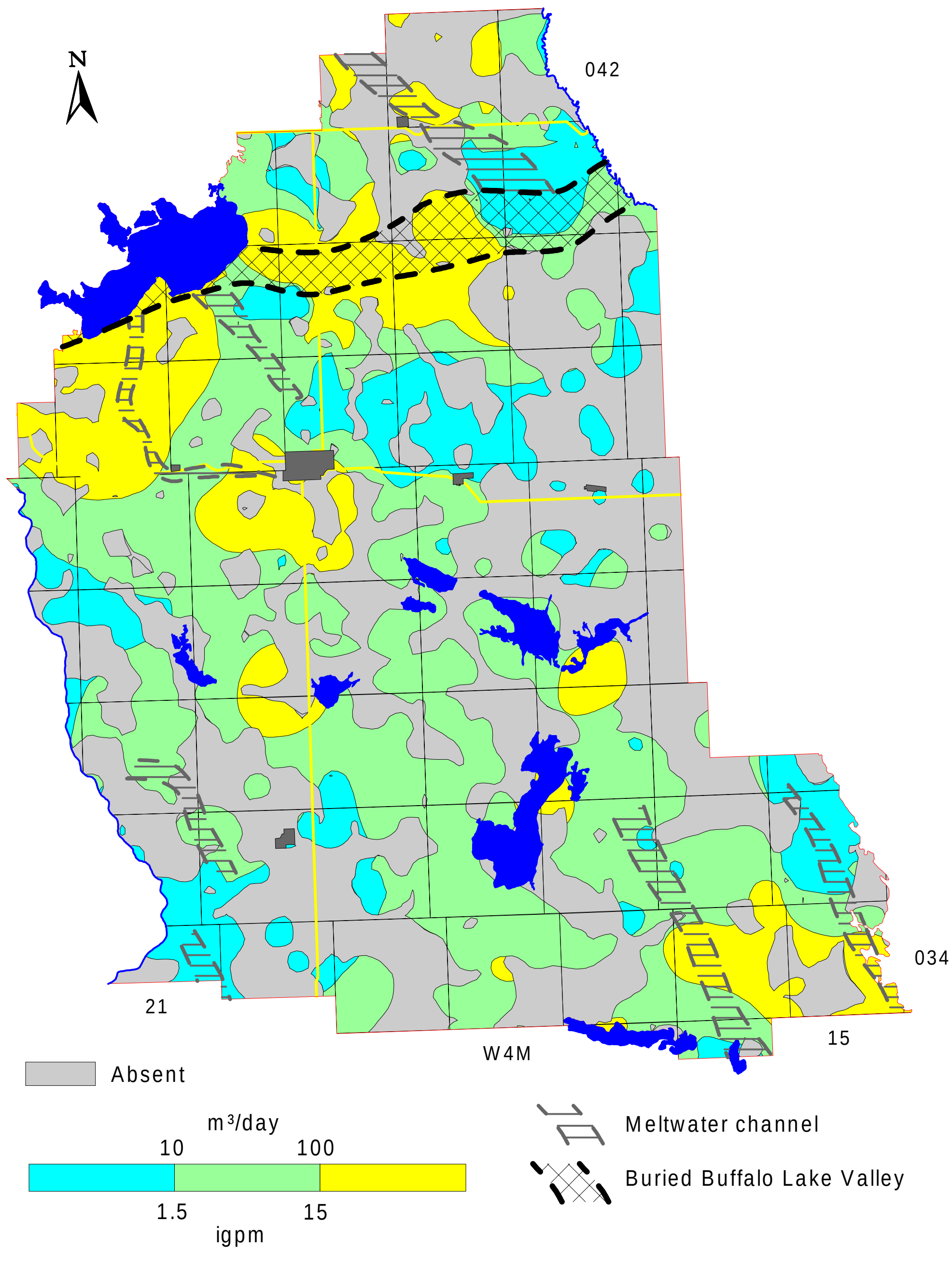
Thickness of Sand and Gravel Aquifer(s)



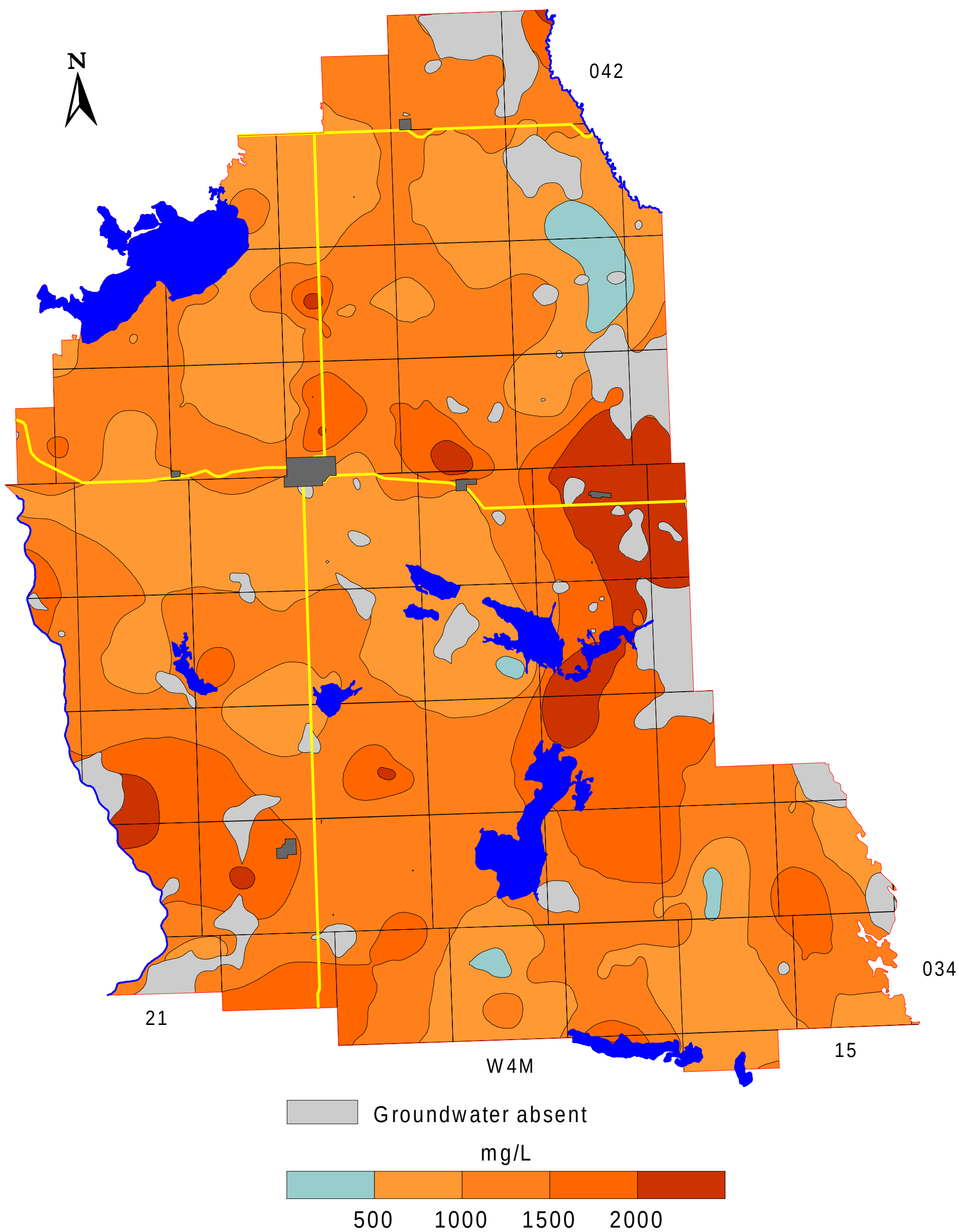
Amount of Sand and Gravel in Surficial Deposits



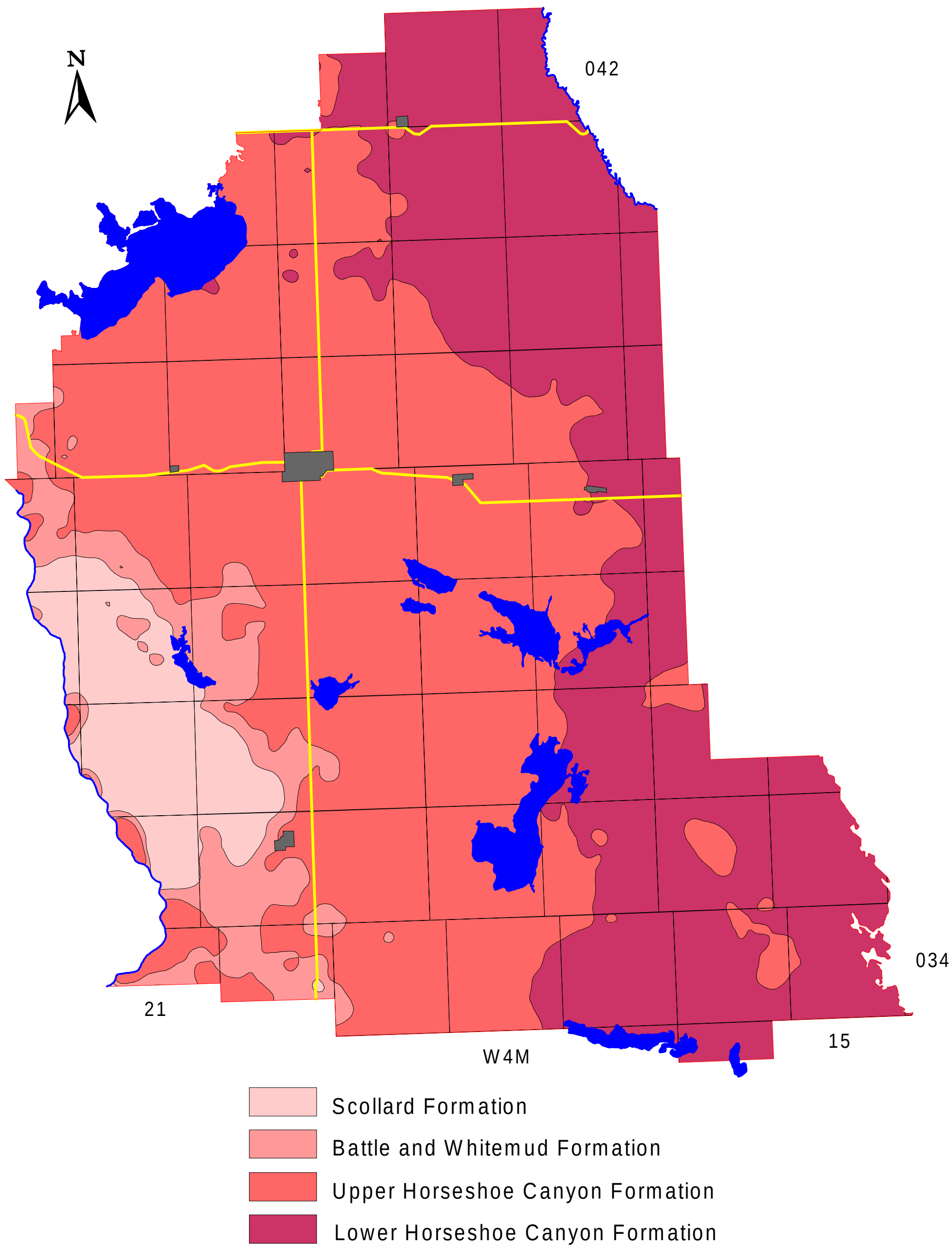
Apparent Yield for Water Wells Completed through Sand and Gravel Aquifer(s)



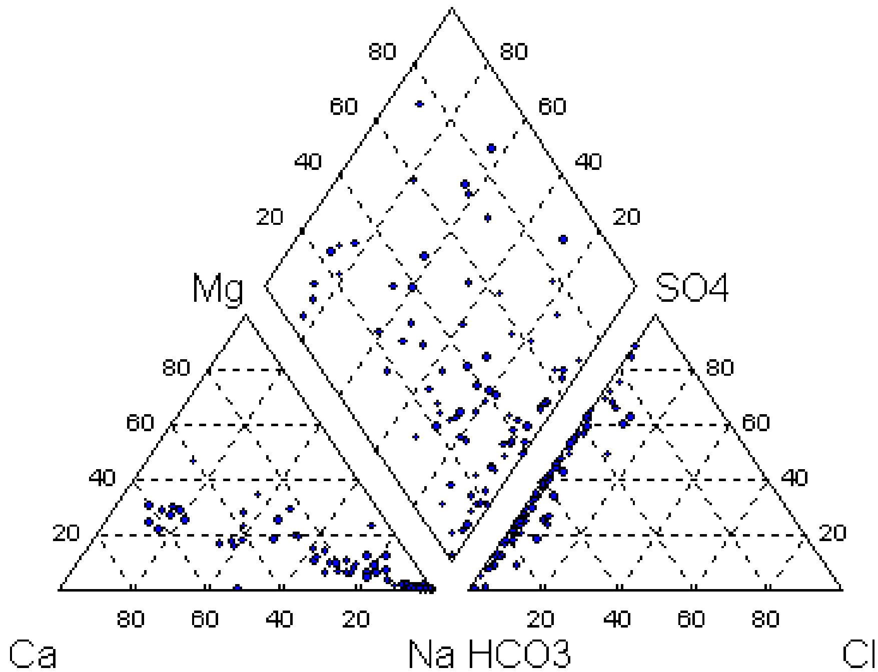
Total Dissolved Solids in Groundwater from Surficial Deposits



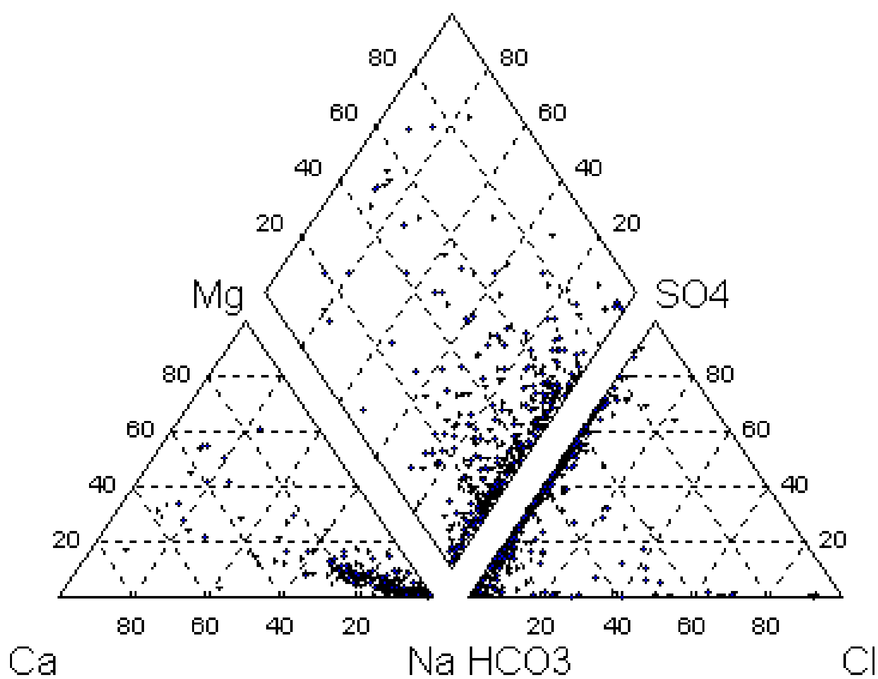
Bedrock Geology



Piper Diagrams

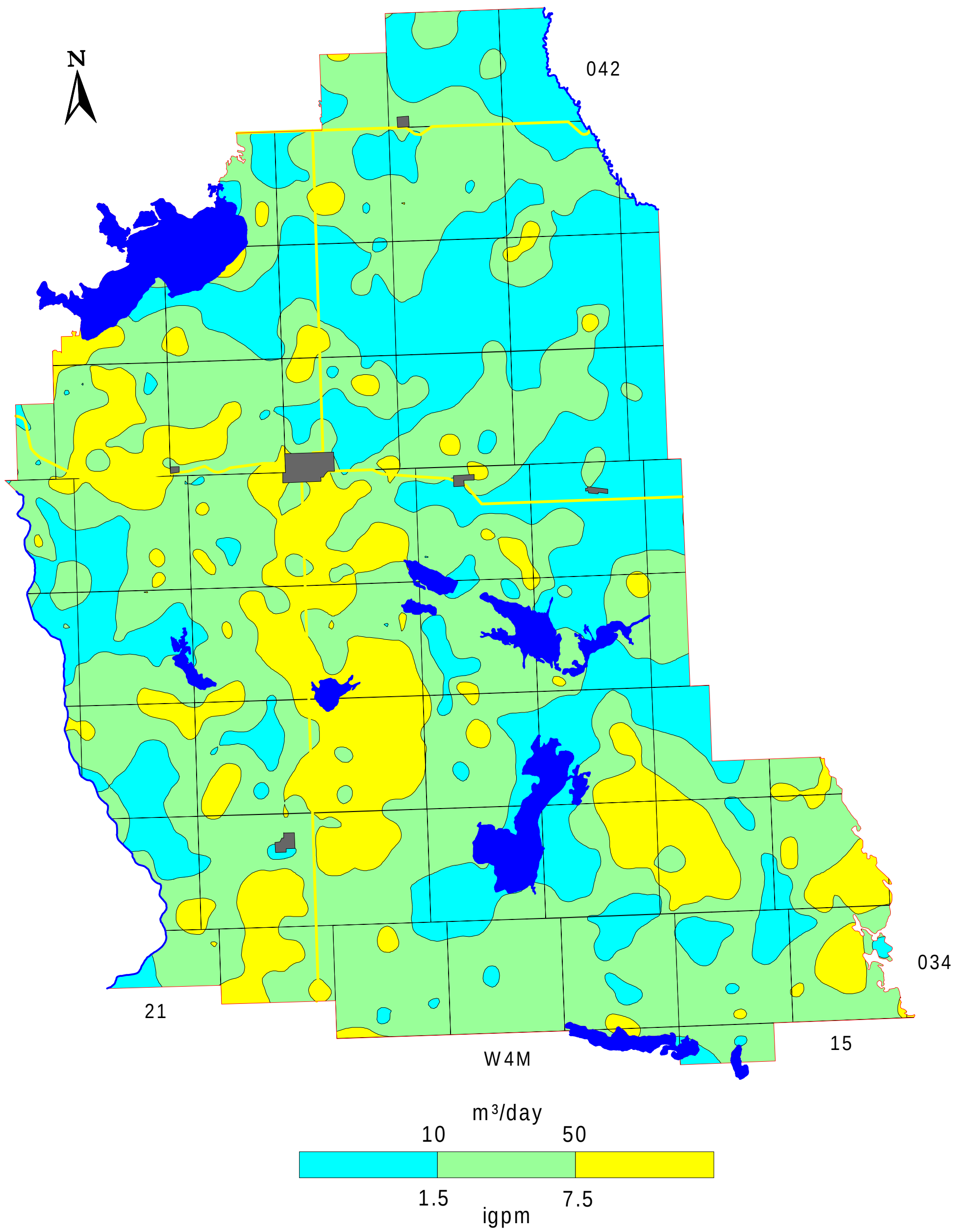


Surficial Deposits

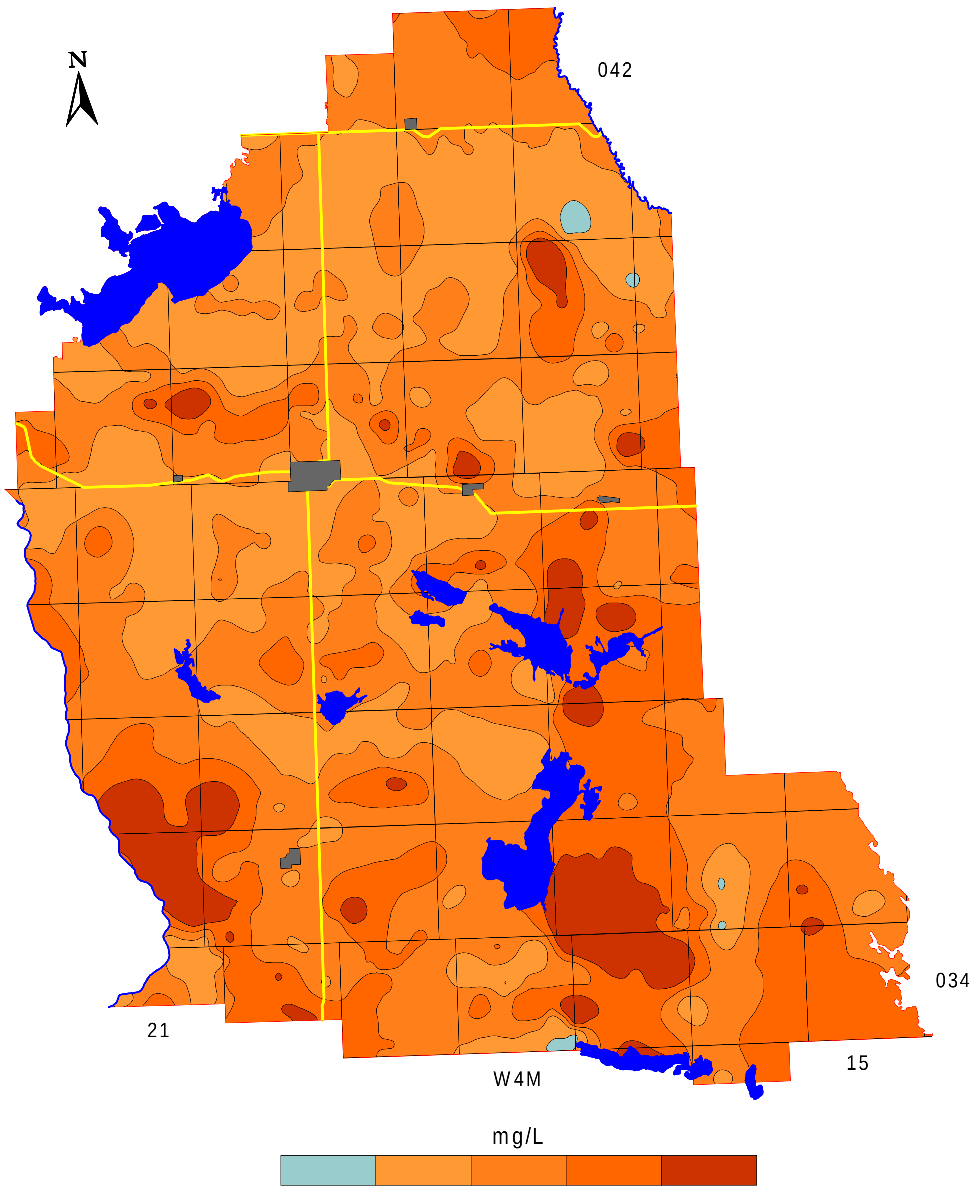


Bedrock Aquifers

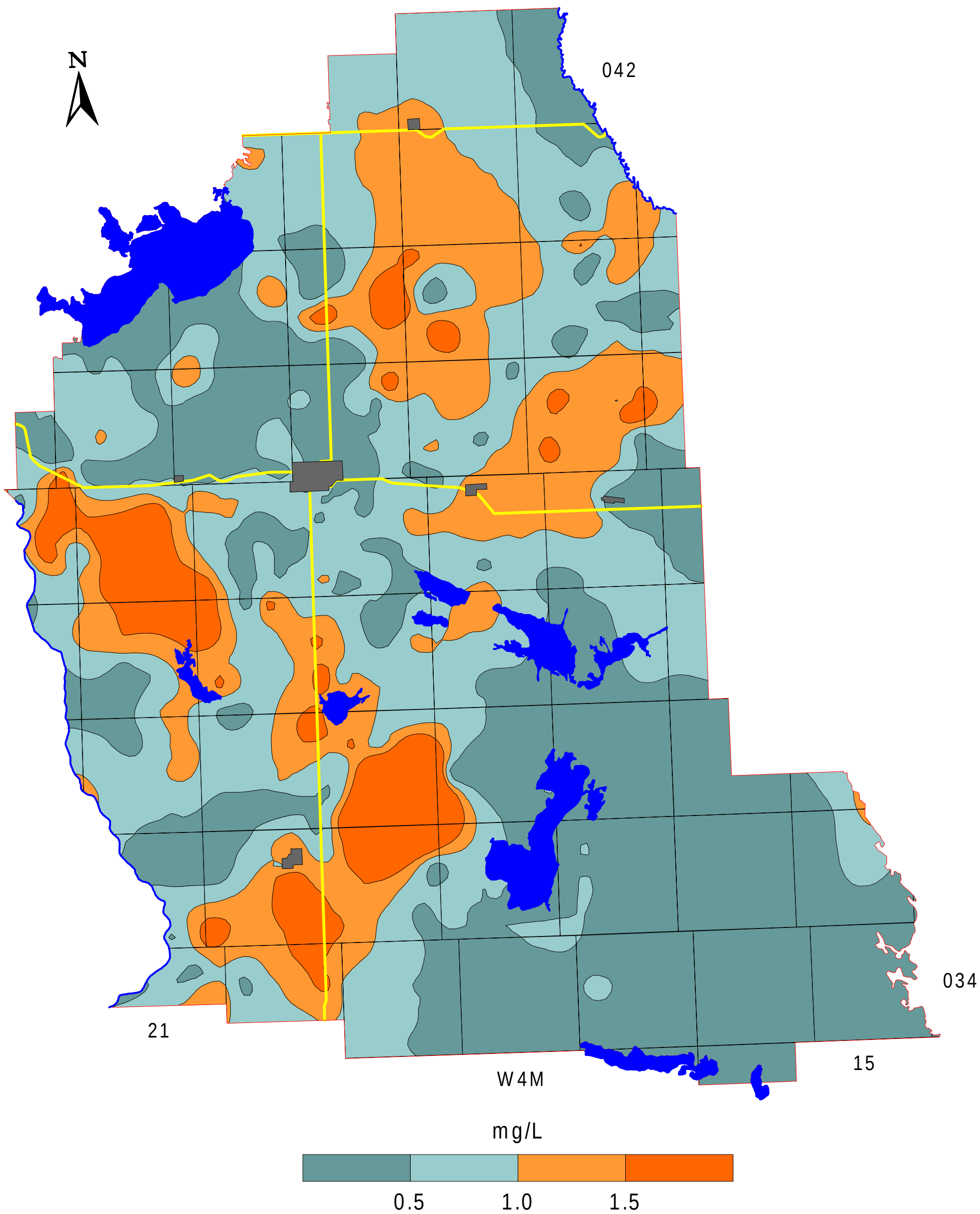
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



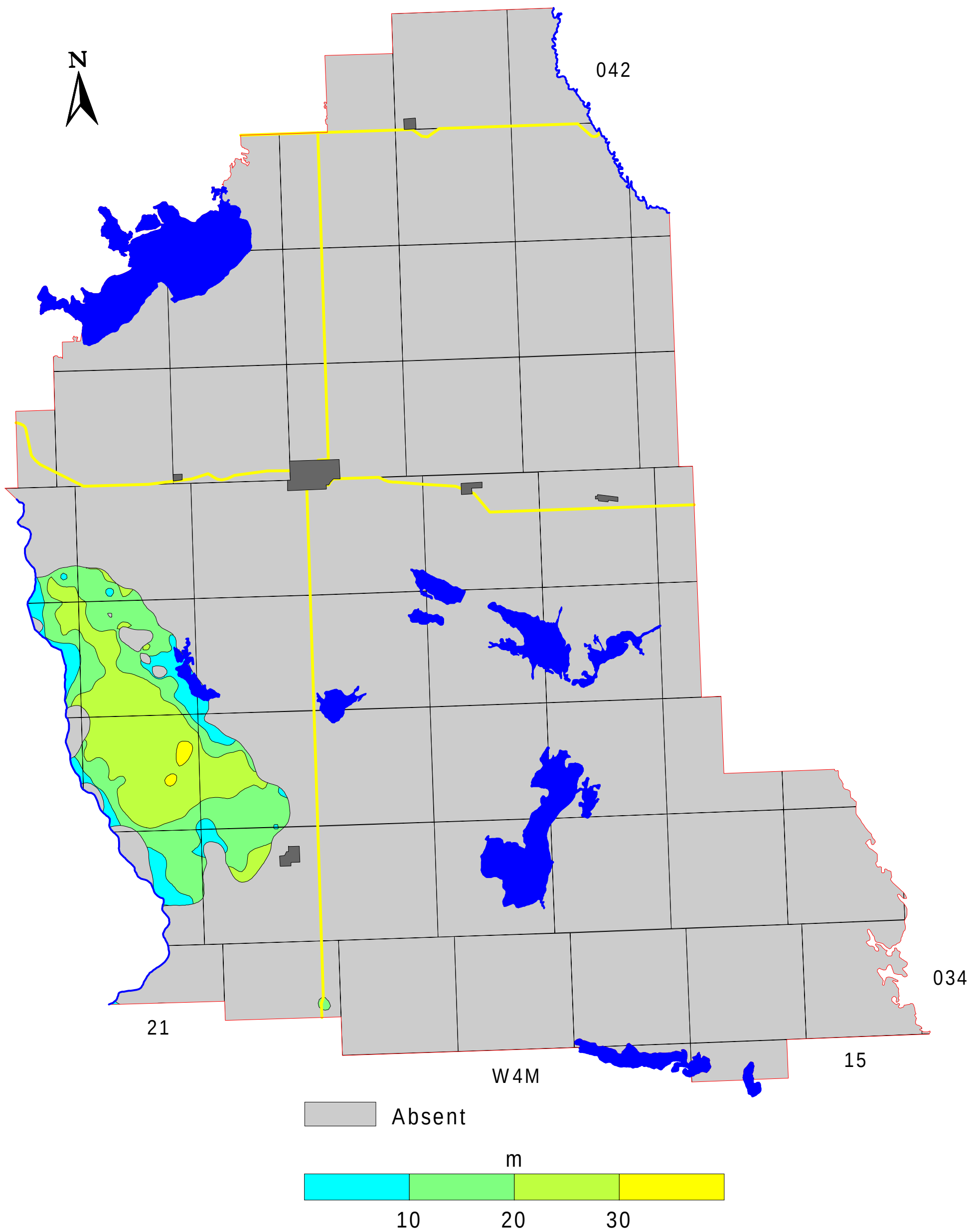
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



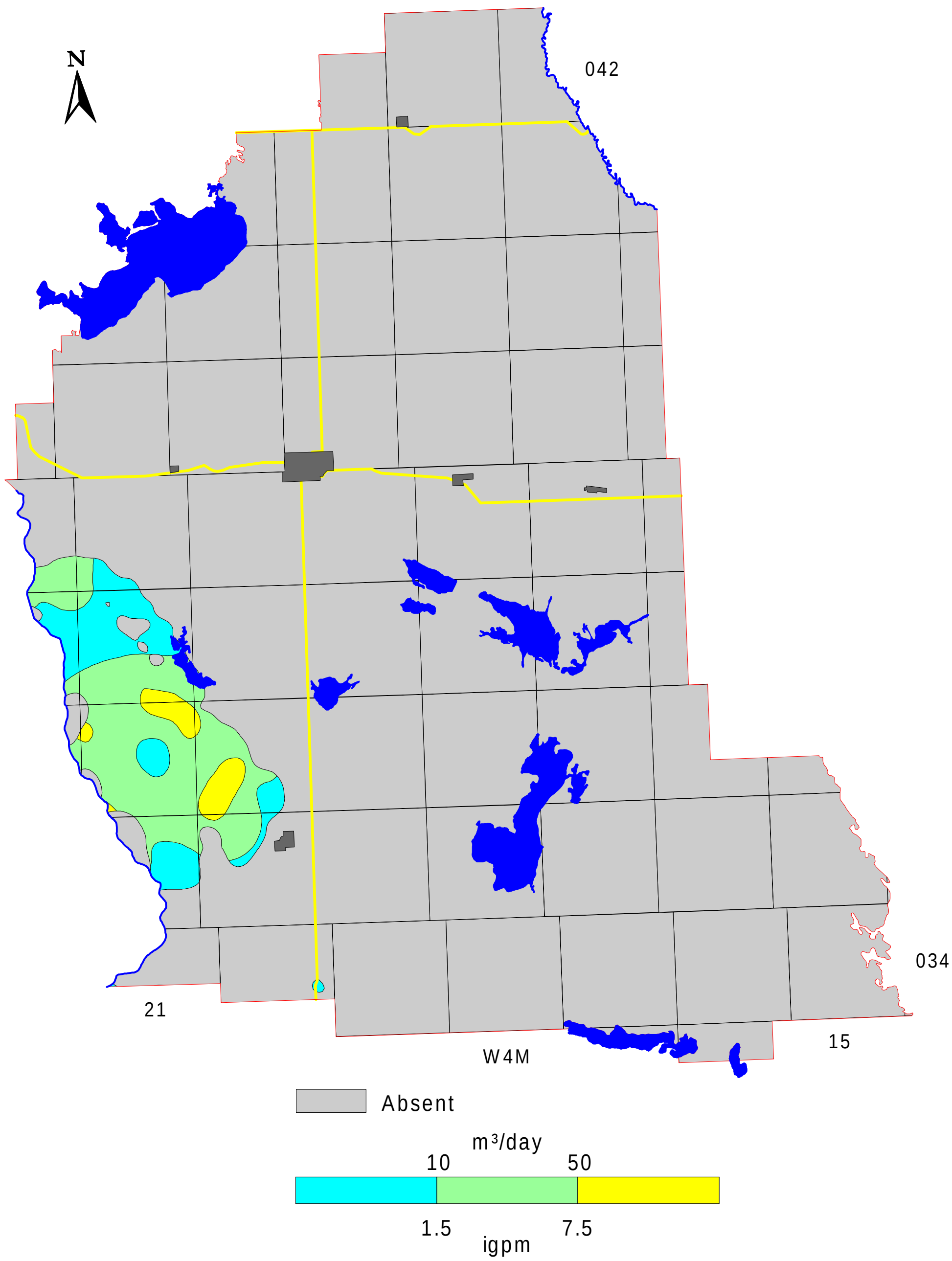
Fluoride in Groundwater from Upper Bedrock Aquifer(s)



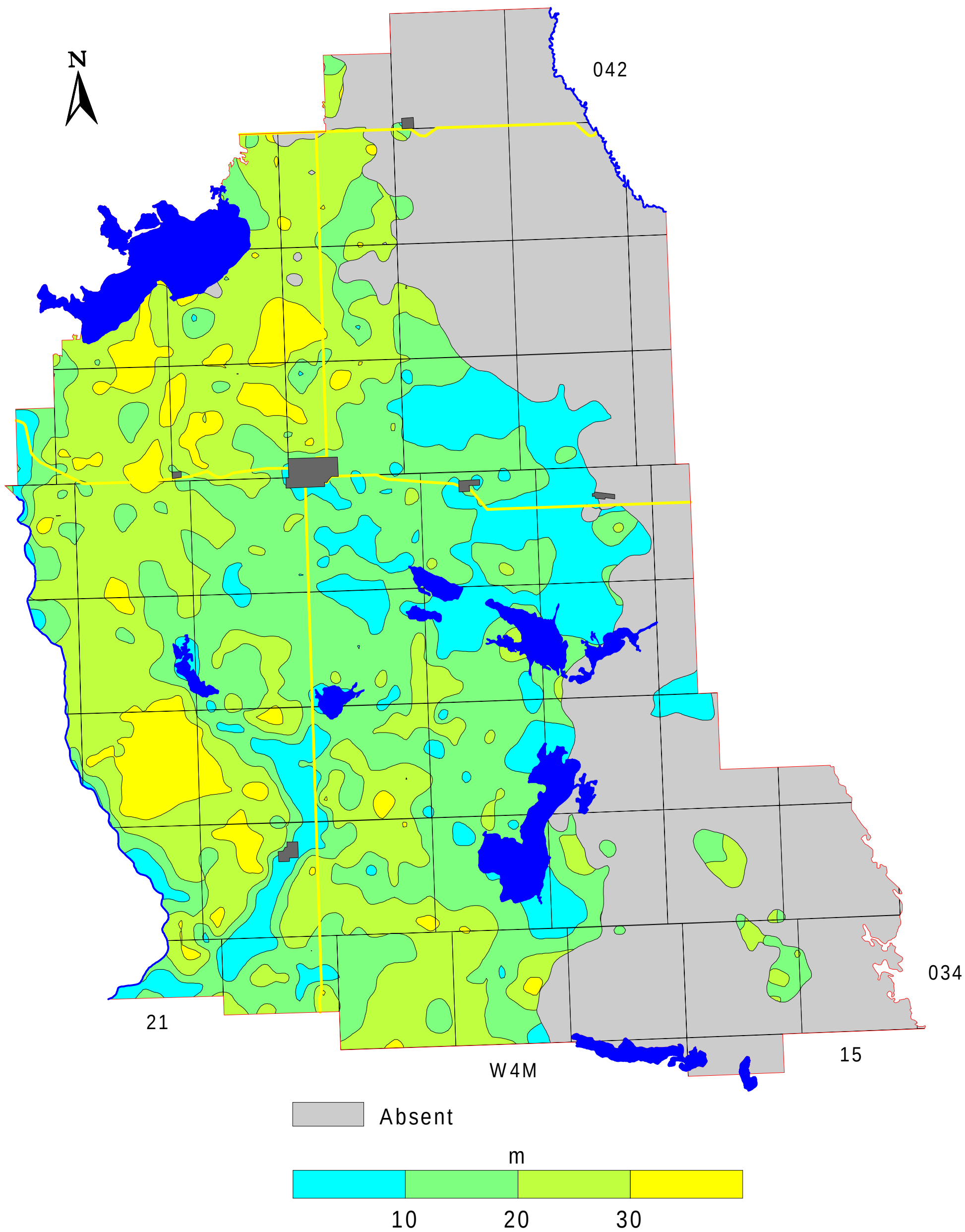
Depth to Top of Scollard Formation



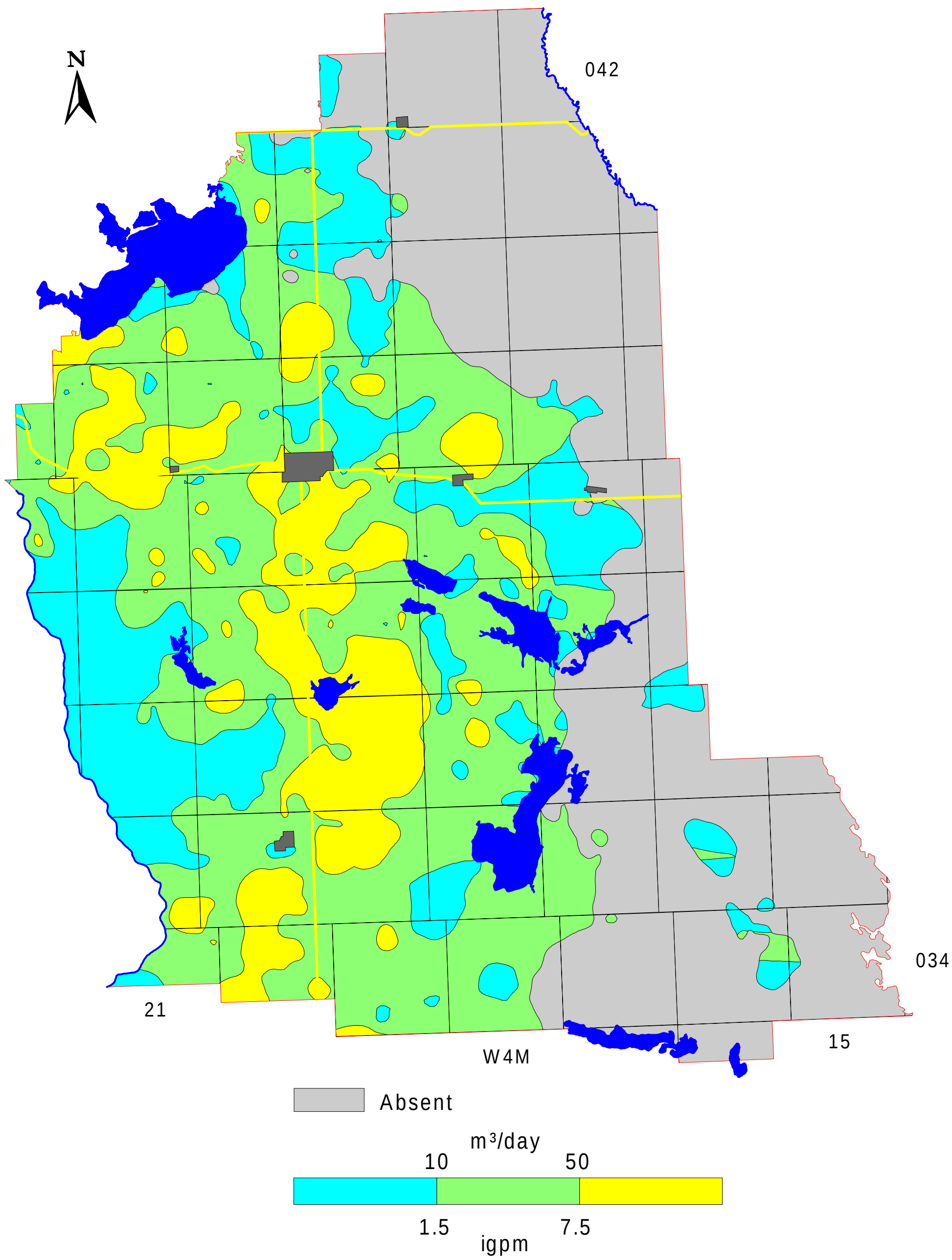
Apparent Yield for Water Wells Completed through Scollard Aquifer



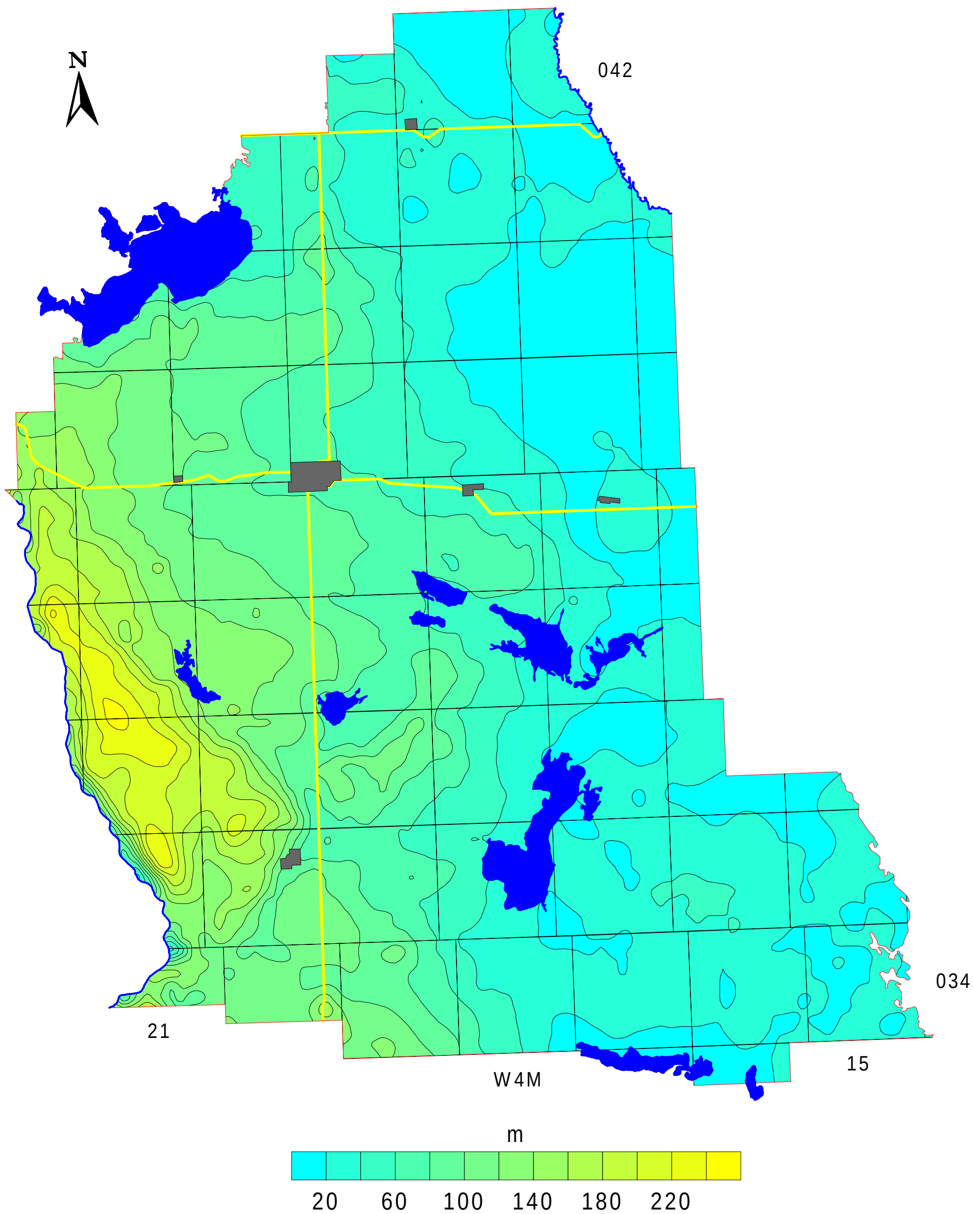
Depth to Top of Upper Horseshoe Canyon Formation



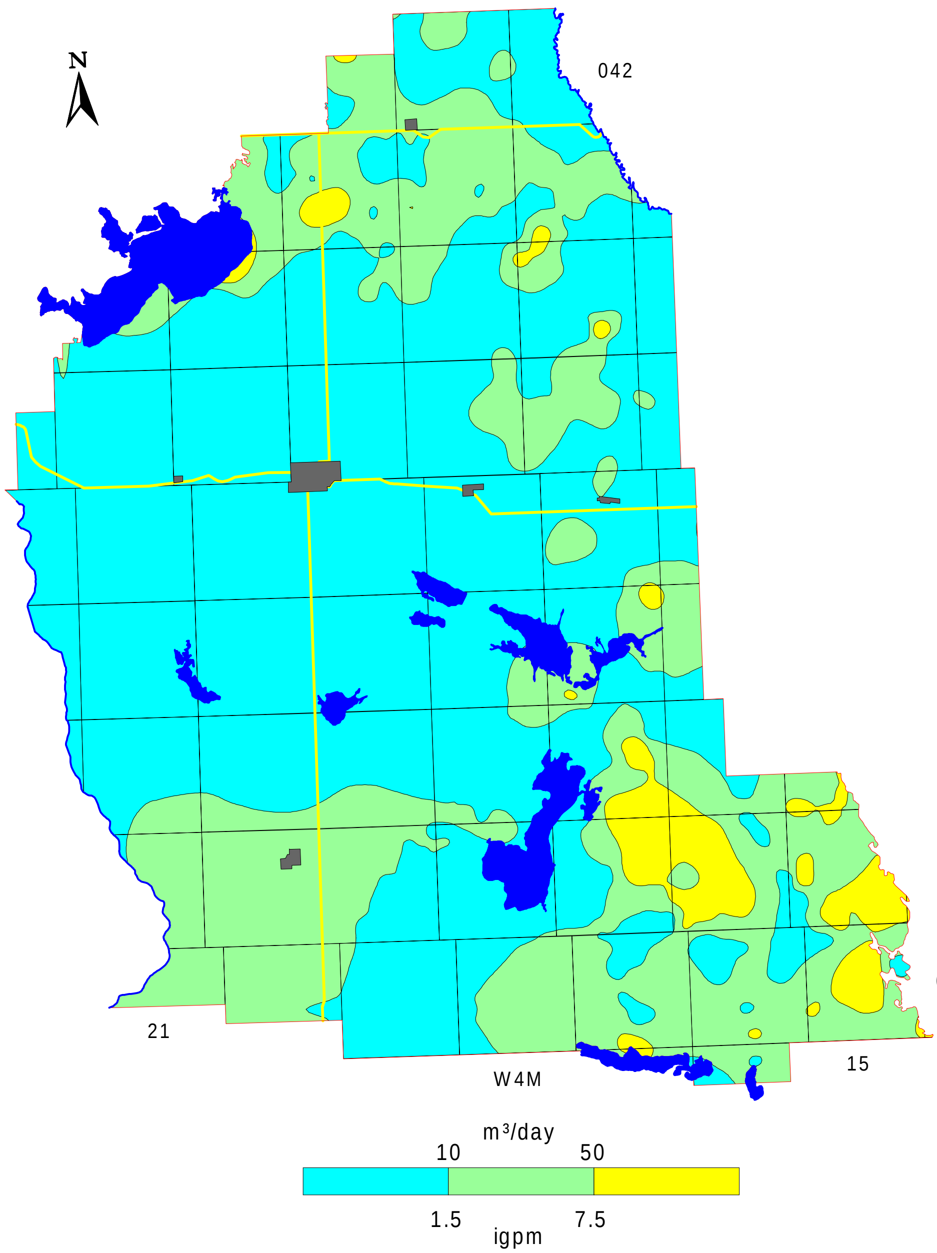
Apparent Yield for Water Wells Completed through Upper Horseshoe Canyon Aquifer



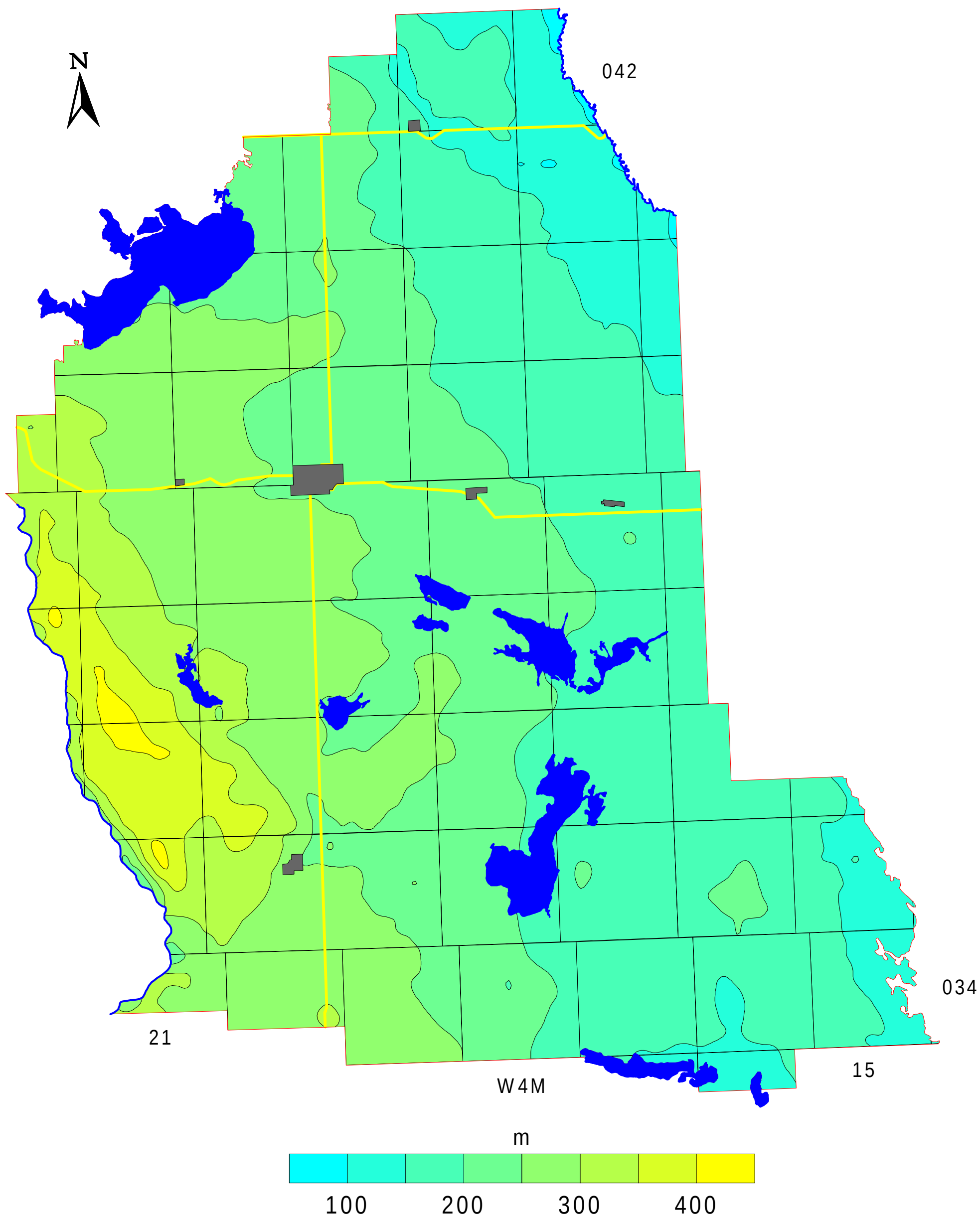
Depth to Top of Lower Horseshoe Canyon Formation



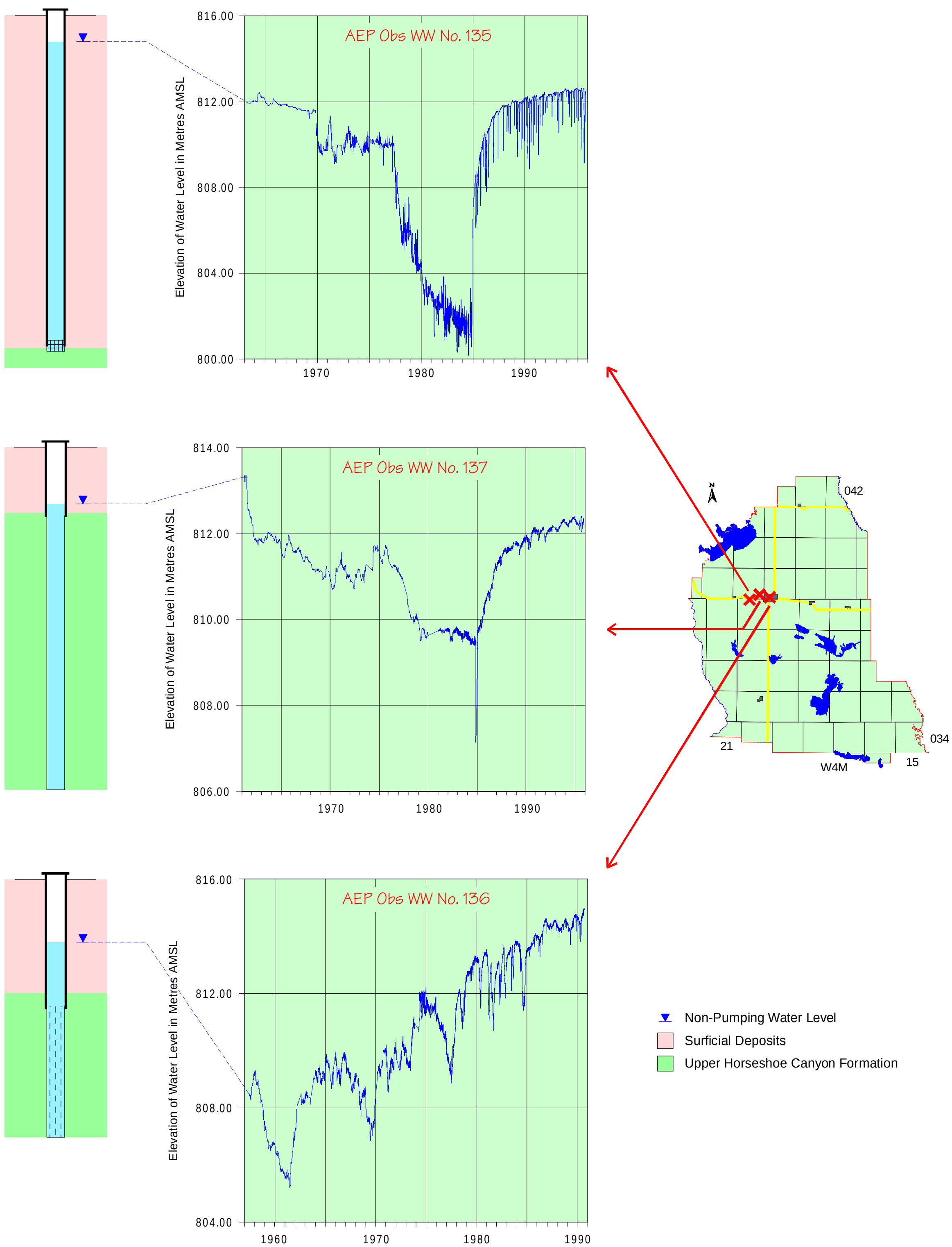
Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer



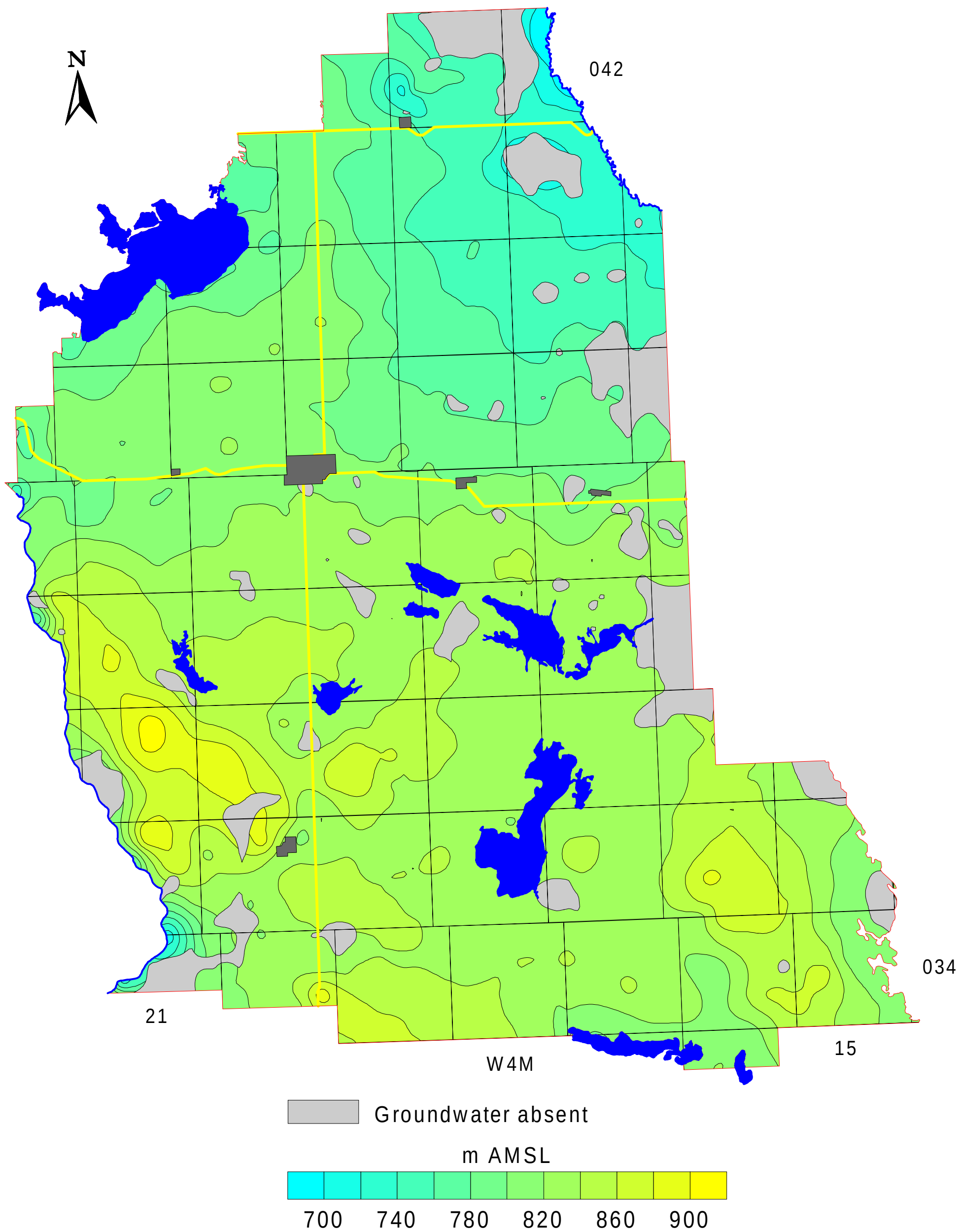
Depth to Top of Bearpaw Formation



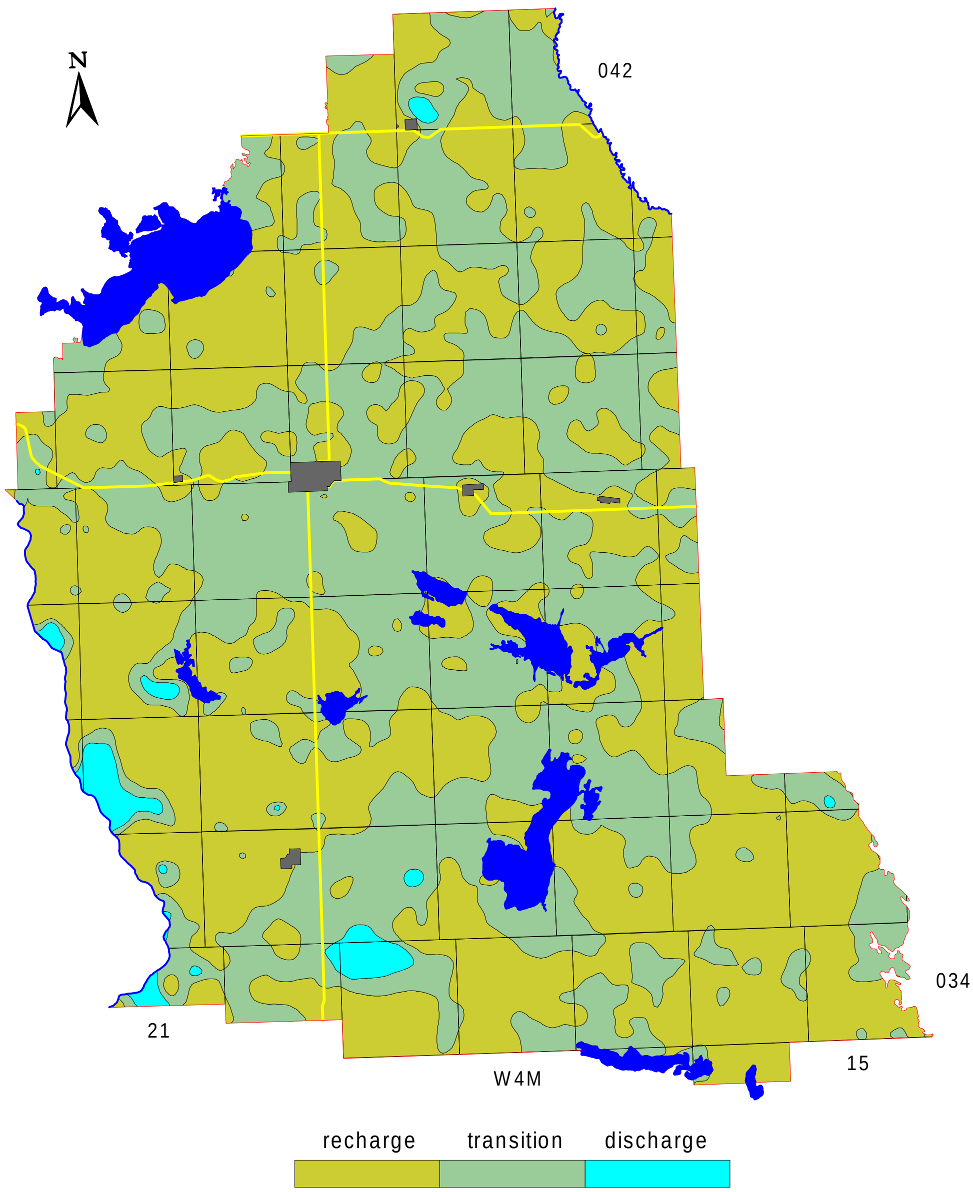
Hydrographs - AEP Observation Water Wells



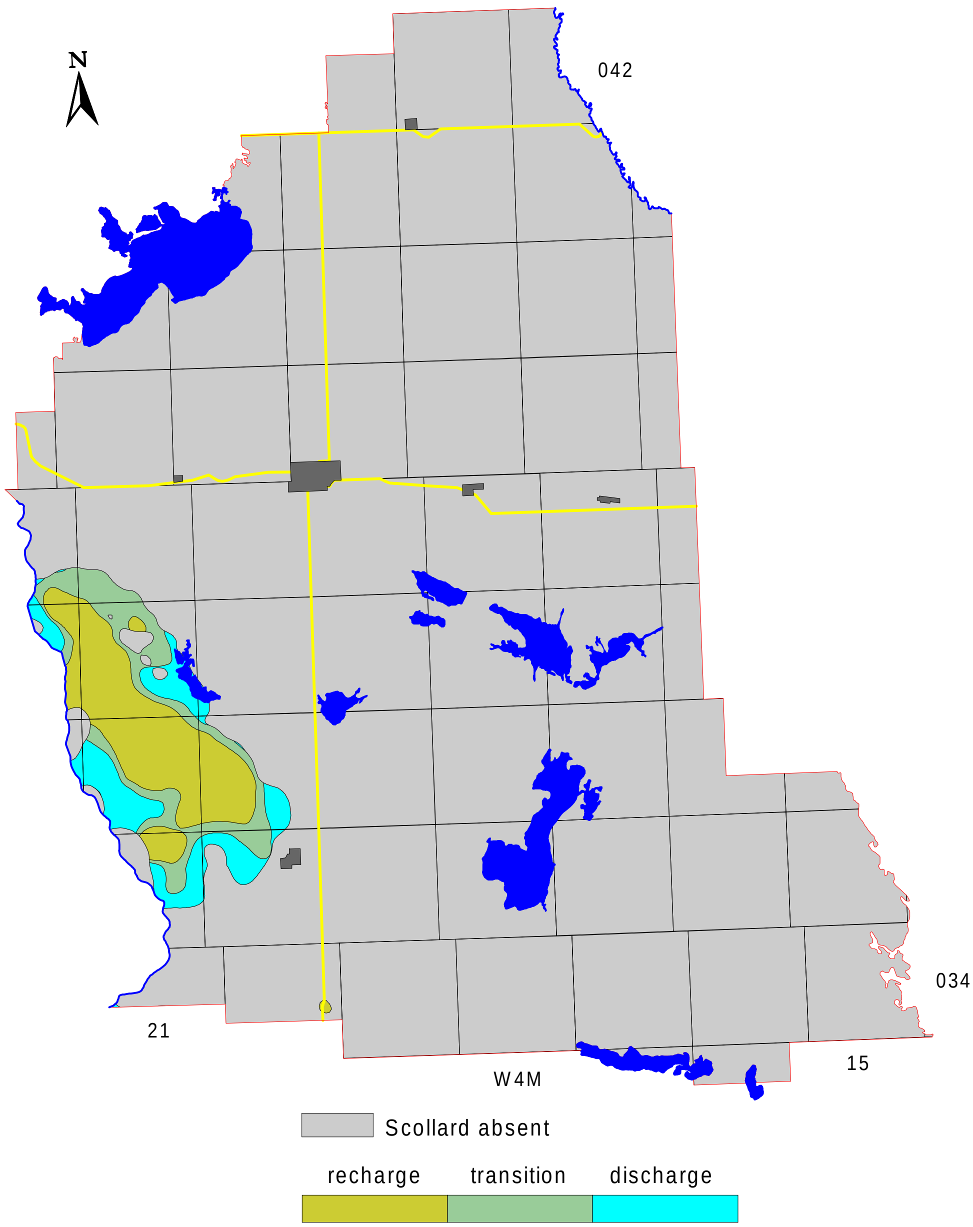
Non-Pumping Water-Level Surface in Water Wells Shallower than 15 metres



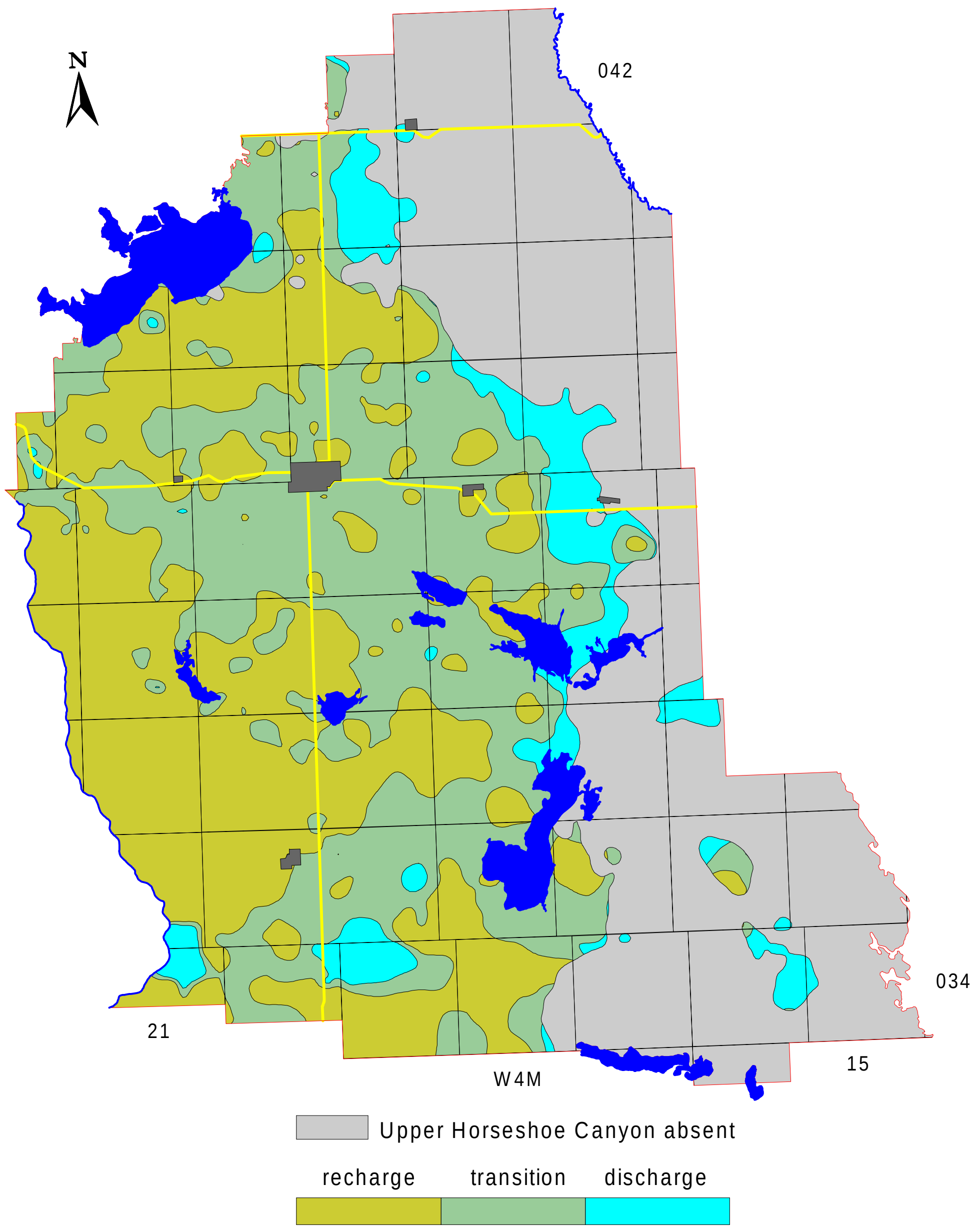
Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)



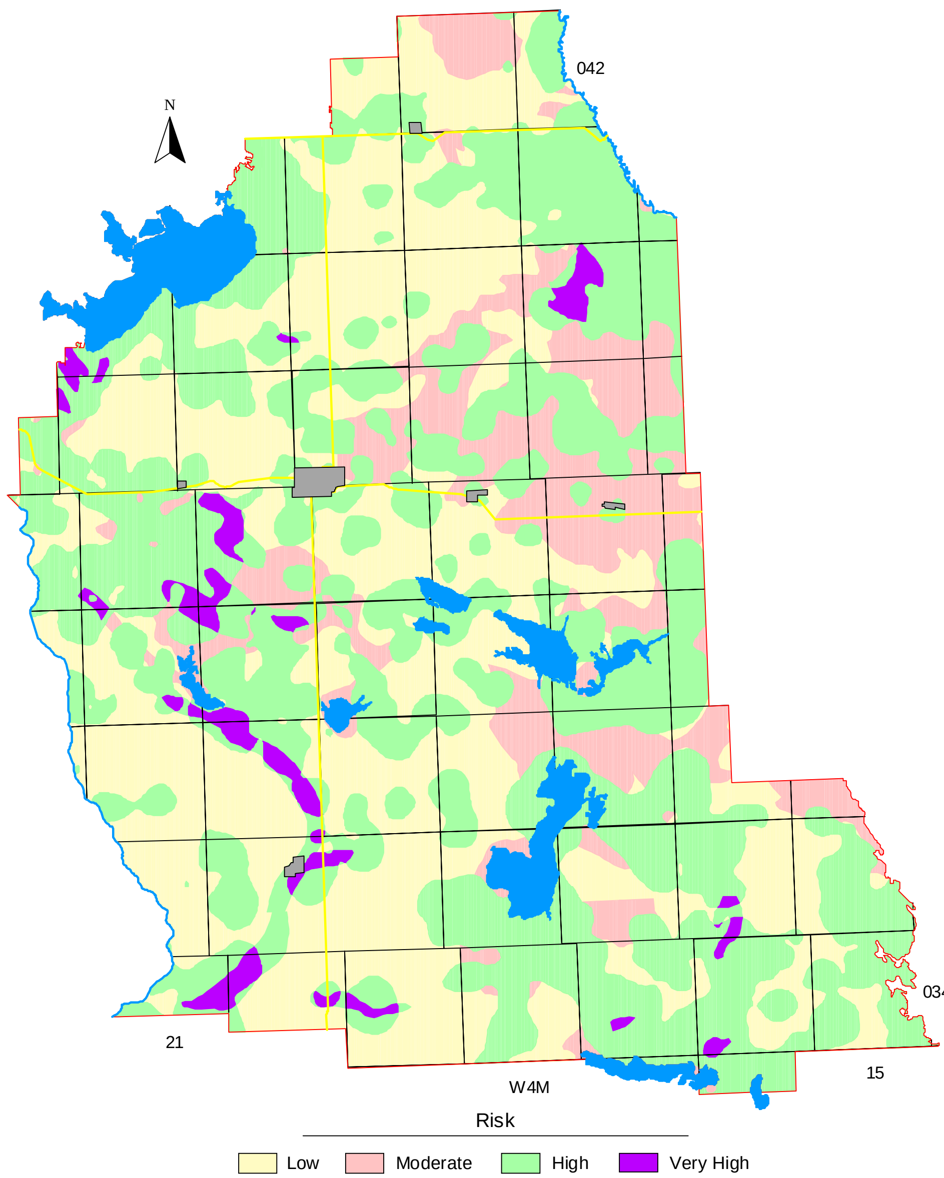
Recharge/Discharge Areas between Surficial Deposits and Scollard Aquifer



Recharge/Discharge Areas between Surficial Deposits and Upper Horseshoe Canyon Aquifer



Risk of Groundwater Contamination



COUNTY OF STETTLER NO. 6

Appendix B

MAPS AND FIGURES ON CD-ROM

CD-ROM

A) Database
B) ArcView Files
C) Query
D) Maps and Figures

1) General

Index Map
Water Wells Deeper than 120 metres
Location of Water Wells
Depth of Existing Water Wells
Bedrock Topography
Bedrock Geology
Cross-Section A - A'
Cross-Section B - B'
Geologic Column
Generalized Cross-Section
Risk of Groundwater Contamination
Relative Permeability
Hydrographs - AEP Observation Water Wells

2) Surficial Aquifers

a) Surficial Deposits

Thickness of Surficial Deposits
Non-Pumping Water-Level Surface in Water Wells Shallower than 15 metres
Total Dissolved Solids in Groundwater from Surficial Deposits
Sulfate in Groundwater from Surficial Deposits
Chloride in Groundwater from Surficial Deposits
Fluoride in Groundwater from Surficial Deposits
Piper Diagram - Surficial Deposits
Amount of Sand and Gravel in Surficial Deposits
Thickness of Sand and Gravel Aquifer(s)
Apparent Yield for Water Wells Completed through Sand and Gravel Aquifer(s)

b) First Sand and Gravel

Thickness of First Sand and Gravel
First Sand and Gravel - Saturation

3) Bedrock Aquifers

a) General

Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)
Sulfate in Groundwater from Upper Bedrock Aquifer(s)
Chloride in Groundwater from Upper Bedrock Aquifer(s)
Fluoride in Groundwater from Upper Bedrock Aquifer(s)
Piper Diagram - Bedrock Aquifers
Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)
Non-Pumping Water-Level Surface in Upper Bedrock Aquifer

c) ScollardAquifer

Depth to Top of Scollard Formation
Structure-Contour Map - Top of Scollard Formation
Non-Pumping Water-Level Surface - Scollard Aquifer
Apparent Yield for Water Wells Completed through Scollard Aquifer
Total Dissolved Solids in Groundwater from Scollard Aquifer
Sulfate in Groundwater from Scollard Aquifer
Chloride in Groundwater from Scollard Aquifer
Piper Diagram - Scollard Aquifer
Recharge/Discharge Areas between Surficial Deposits and Scollard Aquifer

d) Upper Horseshoe Canyon Aquifer

Depth to Top of Upper Horseshoe Canyon Formation
Structure-Contour Map - Top of Upper Horseshoe Canyon Formation
Non-Pumping Water-Level Surface - Upper Horseshoe Canyon Aquifer
Apparent Yield for Water Wells Completed through Upper Horseshoe Canyon Aquifer
Total Dissolved Solids in Groundwater from Upper Horseshoe Canyon Aquifer
Sulfate in Groundwater from Upper Horseshoe Canyon Aquifer
Chloride in Groundwater from Upper Horseshoe Canyon Aquifer
Piper Diagram - Upper Horseshoe Canyon Formation
Recharge/Discharge Areas between Surficial Deposits and Upper Horseshoe Canyon Aquifer

e) Lower Horseshoe Canyon Aquifer

Depth to Top of Lower Horseshoe Canyon Formation
Structure-Contour Map - Top of Lower Horseshoe Canyon Formation
Non-Pumping Water-Level Surface - Lower Horseshoe Canyon Aquifer
Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer
Total Dissolved Solids in Groundwater from Lower Horseshoe Canyon Aquifer
Sulfate in Groundwater from Lower Horseshoe Canyon Aquifer
Chloride in Groundwater from Lower Horseshoe Canyon Aquifer
Piper Diagram - Lower Horseshoe Canyon Formation
Recharge/Discharge Areas between Surficial Deposits and Lower Horseshoe Canyon Aquifer

e) Bearpaw Aquifer

Depth to Top of Bearpaw Aquifer
Structure-Contour Map - Top of Bearpaw Formation

COUNTY OF STETTLER NO. 6
Appendix C

GENERAL WATER WELL INFORMATION

Domestic Water Well Testing

Purpose and Requirements

The purpose of the testing of domestic water wells is to obtain background data related to:

1) the non-pumping water level for the aquifer - Has there been any lowering of the level since the last measurement?
2) the specific capacity of the water well, which indicates the type of contact the water well has with the aquifer;
3) the transmissivity of the aquifer and hence an estimate of the projected long-term yield for the water well;
4) the chemical, bacteriological and physical quality of the groundwater from the water well.

The testing procedure involves conducting an aquifer test and collecting of groundwater samples for analysis by an accredited laboratory. The date and time of the testing are to be recorded on all data collection sheets. A sketch showing the location of the water well relative to surrounding features is required. The sketch should answer the question, "If this water well is tested in the future, how will the person doing the testing know this is the water well I tested?"

The water well should be taken out of service as long as possible before the start of the aquifer test, preferably not less than 30 minutes before the start of pumping. The non-pumping water level is to be measured 30, 10, and 5 minutes before the start of pumping and immediately before the start of pumping which is to be designated as time 0 for the test. All water levels must be from the same designated reference, usually the top of the casing. Water levels are to be measured during the pumping interval and during the recovery interval after the pump has been turned off; all water measurements are to be with an accuracy of ± 0.01 metres.

During the pumping and recovery intervals, the water level is to be measured at the appropriate times. An example of the time schedule for a 4-hour test is as follows, measured in minutes after the pump is turned on and again after the pump is turned off:

1,2,3,4,6,8,10,13,16,20,25,32,40,50,64,80,100,120.

For a four-hour test, the reading after 120 minutes of pumping will be the same as the 0 minutes of recovery. Under no circumstance will the recovery interval be less than the pumping interval.

Flow rate during the aquifer test should be measured and recorded with the maximum accuracy possible. Ideally, a water meter with an accuracy of better than ±1% displaying instantaneous and total flow should be used. If a water meter is not available, then the time required to completely fill a container of known volume should be recorded, noting the time to the nearest 0.5 seconds or better. Flow rate should be determined and recorded often to ensure a constant pumping rate.

Groundwater samples should be collected as soon as possible after the start of pumping and within 10 minutes of the end of pumping. Initially only the groundwater samples collected near the end of the pumping interval need to be submitted to the accredited laboratory for analysis. All samples must be properly stored for transportation to the laboratory and, in the case of the bacteriological analysis, there is a maximum time allowed between the time the sample is collected and the time the sample is delivered to the laboratory. The first samples collected are only analyzed if there is a problem or a concern with the first samples submitted to the laboratory.

Procedure

Site Diagrams

These diagrams are a map showing the distance to nearby significant features. This would include things like a corner of a building (house, barn, garage etc.) or the distance to the half-mile or mile fence. The description should allow anyone not familiar with the site to be able to unequivocally identify the water well that was tested.

In lieu of a map, UTM coordinates accurate to within five metres would be acceptable. If a hand-held GPS is used, the post-processing correction details must be provided.

Surface Details

The type of surface completion must be noted. This will include such things as a pitless adapter, well pit, pump house, in basement, etc. Also, the reference point used for measuring water levels needs to be noted. This would include top of casing (TOC) XX metres above ground level; well pit lid, XX metres above TOC; TOC in well pit XX metres below ground level.

Groundwater Discharge Point

Where was the flow of groundwater discharge regulated? For example was the discharge through a hydrant downstream from the pressure tank; discharged directly to ground either by connecting directly above the well seal or by pulling the pump up out of the pitless adapter; from a tap on the house downstream from the pressure tank? Also note must be made if any action was taken to ensure the pump would operate continuously during the pumping interval and whether the groundwater was passing through any water-treatment equipment before the discharge point.

Water-Level Measurements

How were the water-level measurements obtained? If obtained using a contact gauge, what type of cable was on the tape, graduated tape or a tape with tags? If a tape with tags, when was the; last time the tags were calibrated? If a graduated tape, what is the serial number of the tape and is the tape shorter than its original length (i.e. is any tape missing)?

If water levels are obtained using a transducer and data logger, the serial numbers of both transducer and data logger are needed and a copy of the calibration sheet. The additional information required is the depth the transducer was set and the length of time between when the transducer was installed and when the calibration water level was measured, plus the length of time between the installation of the transducer and the start of the aquifer test.

All water levels must be measured at least to the nearest 0.01 metres.

Discharge Measurements

Type of water meter used. This could include such things as a turbine or positive displacement meter. How were the readings obtained from the meter? Were the readings visually noted and recorded or were they recorded using a data logger?

Water Samples

A water sample must be collected between the 4- and 6-minute water-level measurements, whenever there is an observed physical change in the groundwater being pumped, and 10 minutes before the end of the planned pumping interval. Additional water samples must be collected if it is expected that pumping will be terminated before the planned pumping interval.

Environmental Protection and Enhancement Act

Water Well Regulation

PROVINCE OF ALBERTA

ENVIRONMENTAL PROTECTION AND ENHANCEMENT ACT

WATER WELL REGULATION

Alberta Regulation 123/93

EXTRACT FROM THE ALBERTA GAZETTE

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Environmental Protection and Enhancement Act

WATER WELL REGULATION

Filed: April 22, 1993

Made by the Minister of Environmental Protection pursuant to sections 81(1)(a) and (f), 138(a)-(e), (g), (h), (j)-(u) of the Environmental Protection and Enhancement Act.

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Additional Information

VIDEOS

Will the Well Go Dry Tomorrow? (Mow-Tech Ltd.: 1-800 GEO WELL)
Water Wells that Last (PFRA – Edmonton Office: 403-495-3307)
Ground Water and the Rural Community (Ontario Ground Water Association)

BOOKLET

Water Wells that Last (PFRA – Edmonton Office: 403-495-3307)

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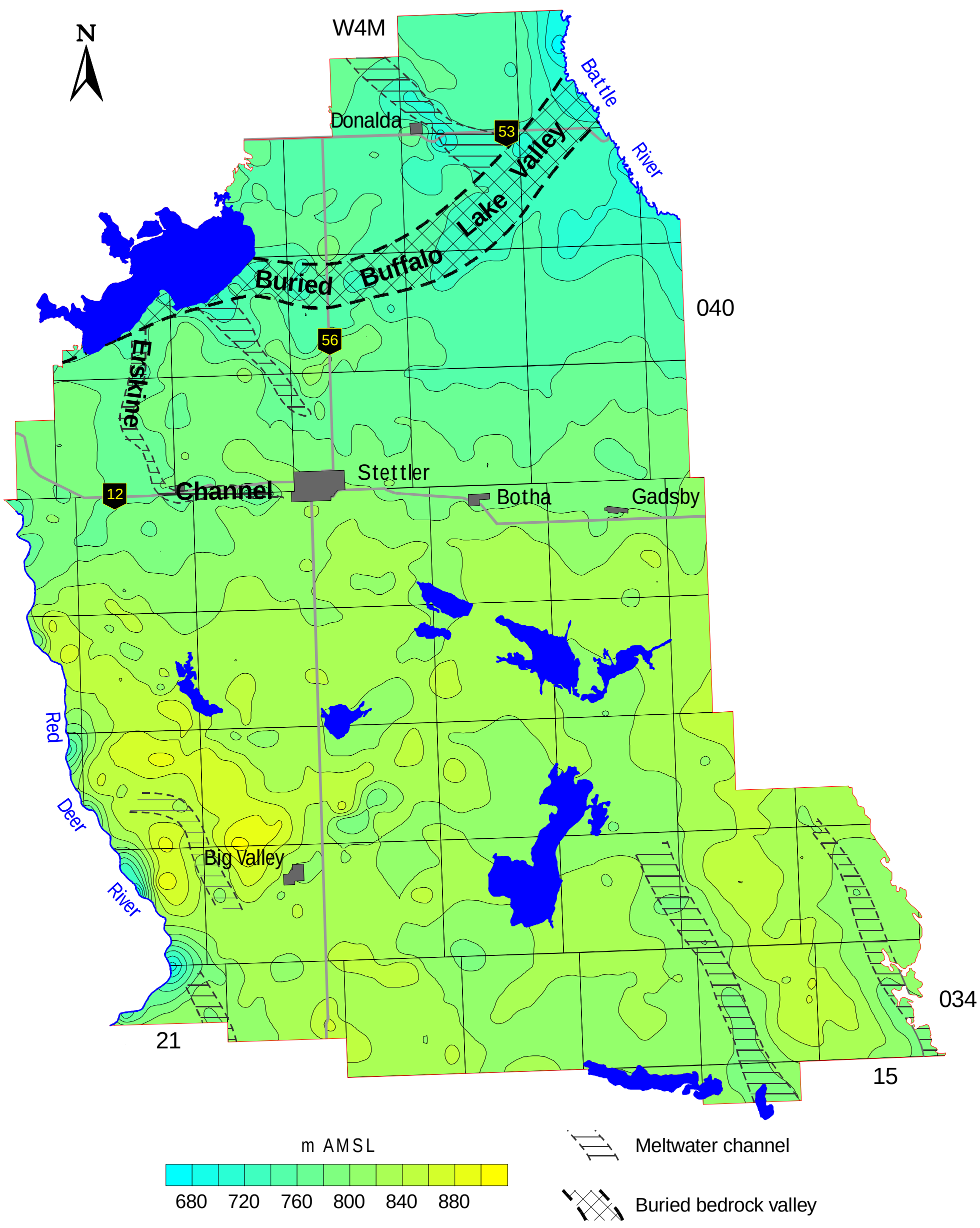
LOCAL HEALTH DEPARTMENTS

COUNTY OF STETTLER NO. 6

Appendix D

MAPS AND FIGURES INCLUDED AS LARGE PLOTS

County of Stettler No. 6
Bedrock Topography



Agriculture and Agri-Food Canada Agriculture et Agroalimentaire Canada
PFRA
Prairie Farm Rehabilitation Administration

Note: This map is based on a regional study and as such, the results are to be used only as a guide. Detailed local studies are required to verify hydrogeological conditions at a given location.

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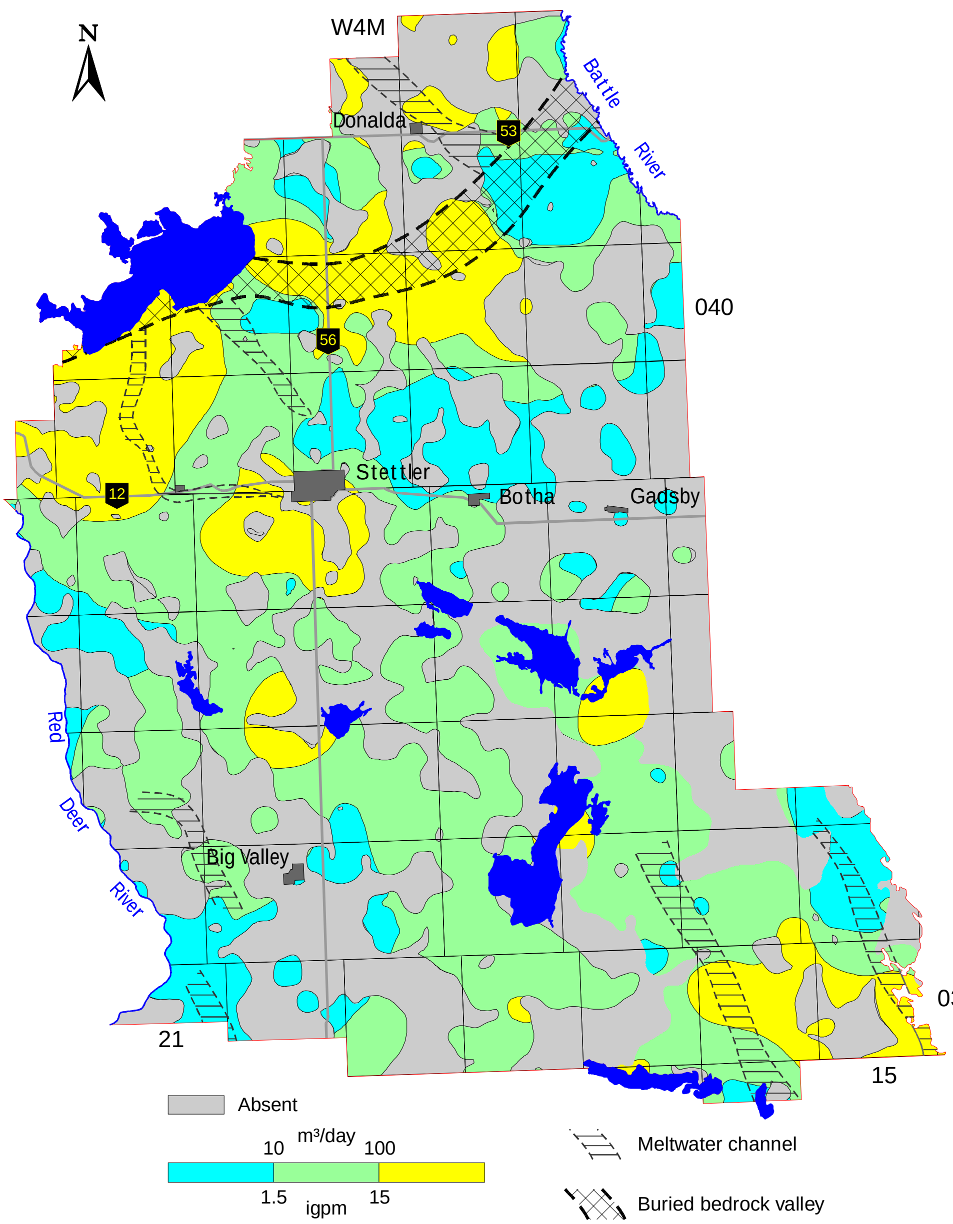
County of Stettler No. 6
Apparent Yield for Water Wells Completed through Sand and Gravel Aquifer(s)



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PFRA Prairie Farm Rehabilitation Administration

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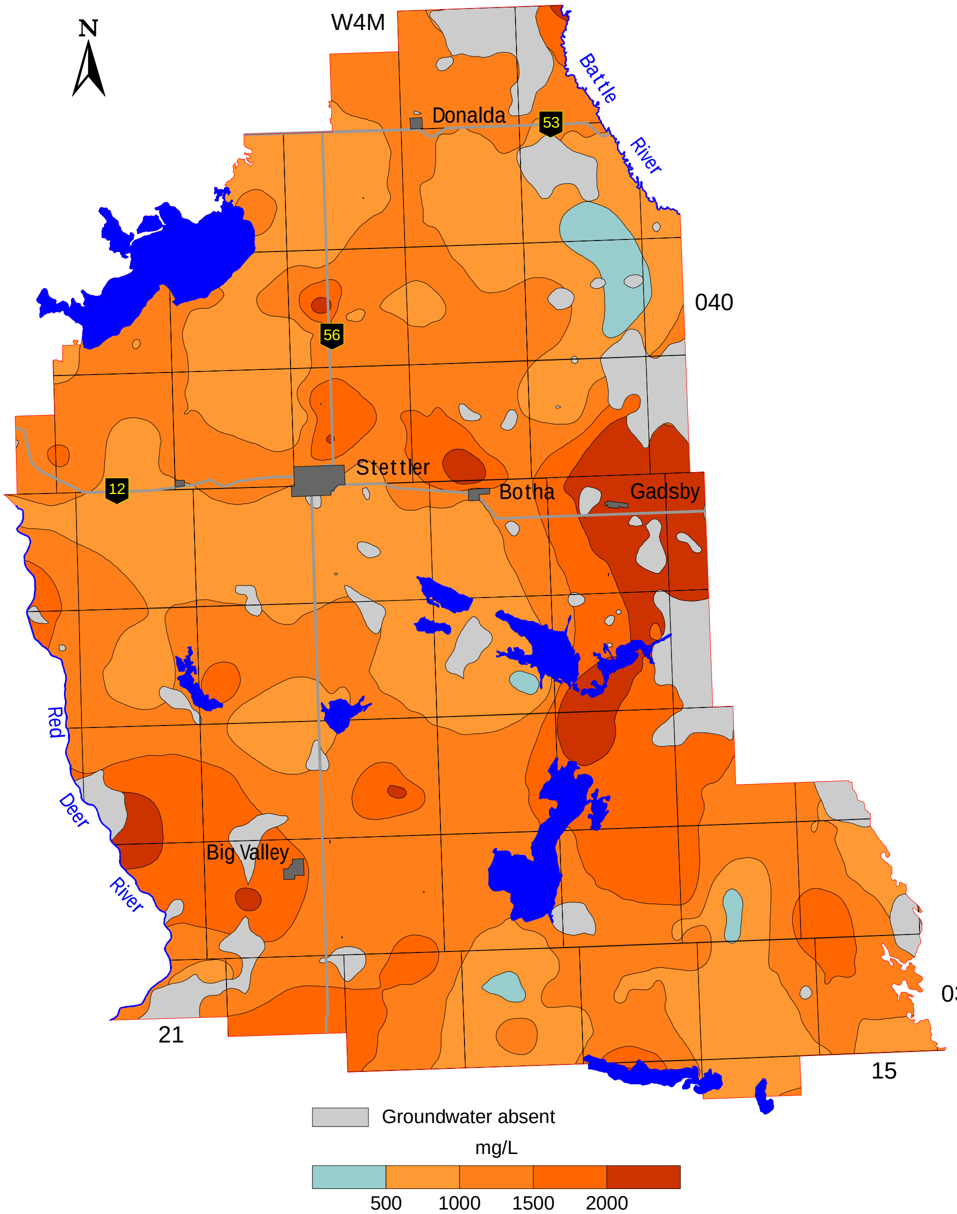
County of Stettler No. 6
Total Dissolved Solids in Groundwater from Surficial Deposits



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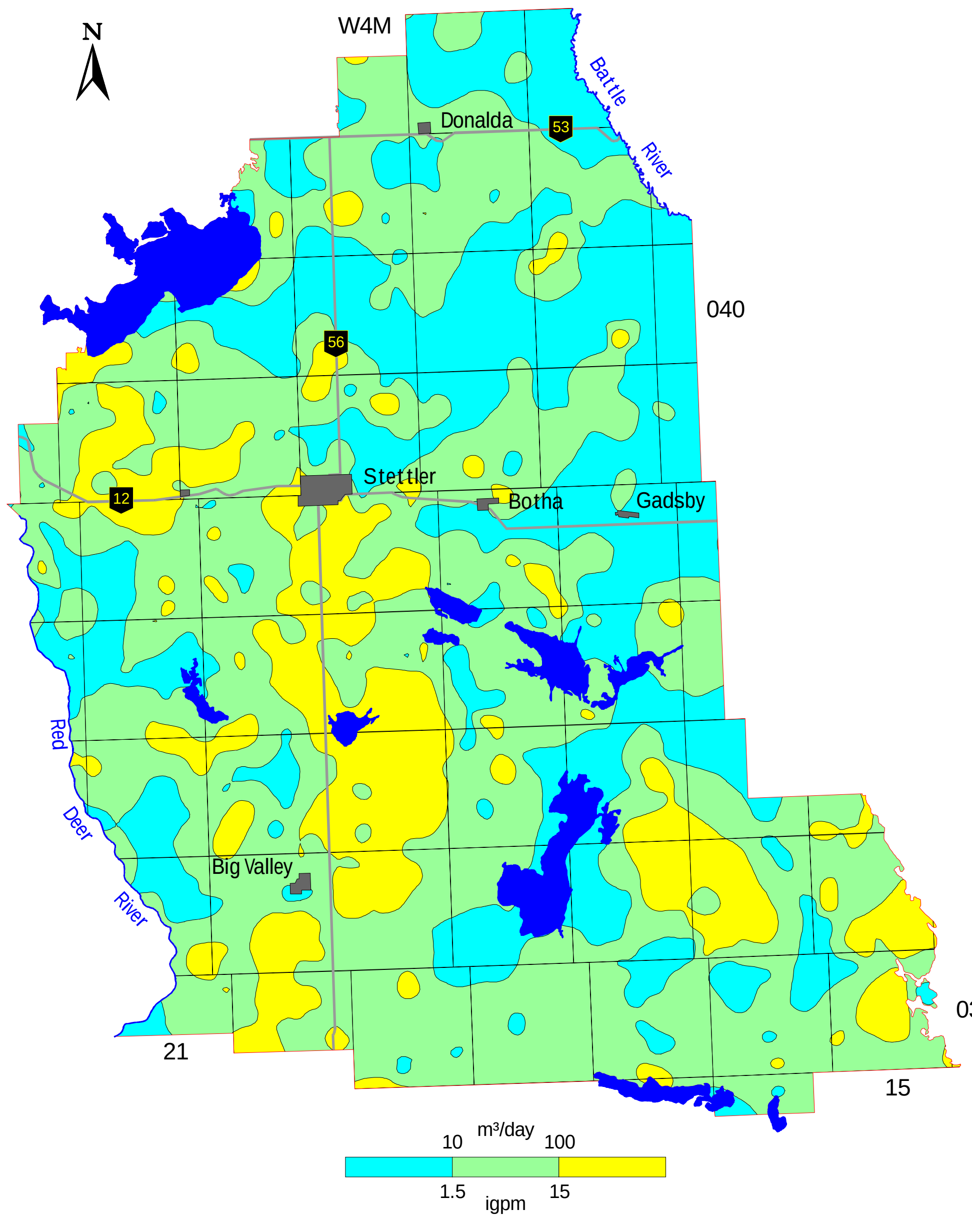
PFRA Prairie Farm Rehabilitation Administration

Note: This map is based on a regional study and as such, the results are to be used only as a guide. Detailed local studies are required to verify hydrogeological conditions at a given location.

County of Stettler No. 6
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



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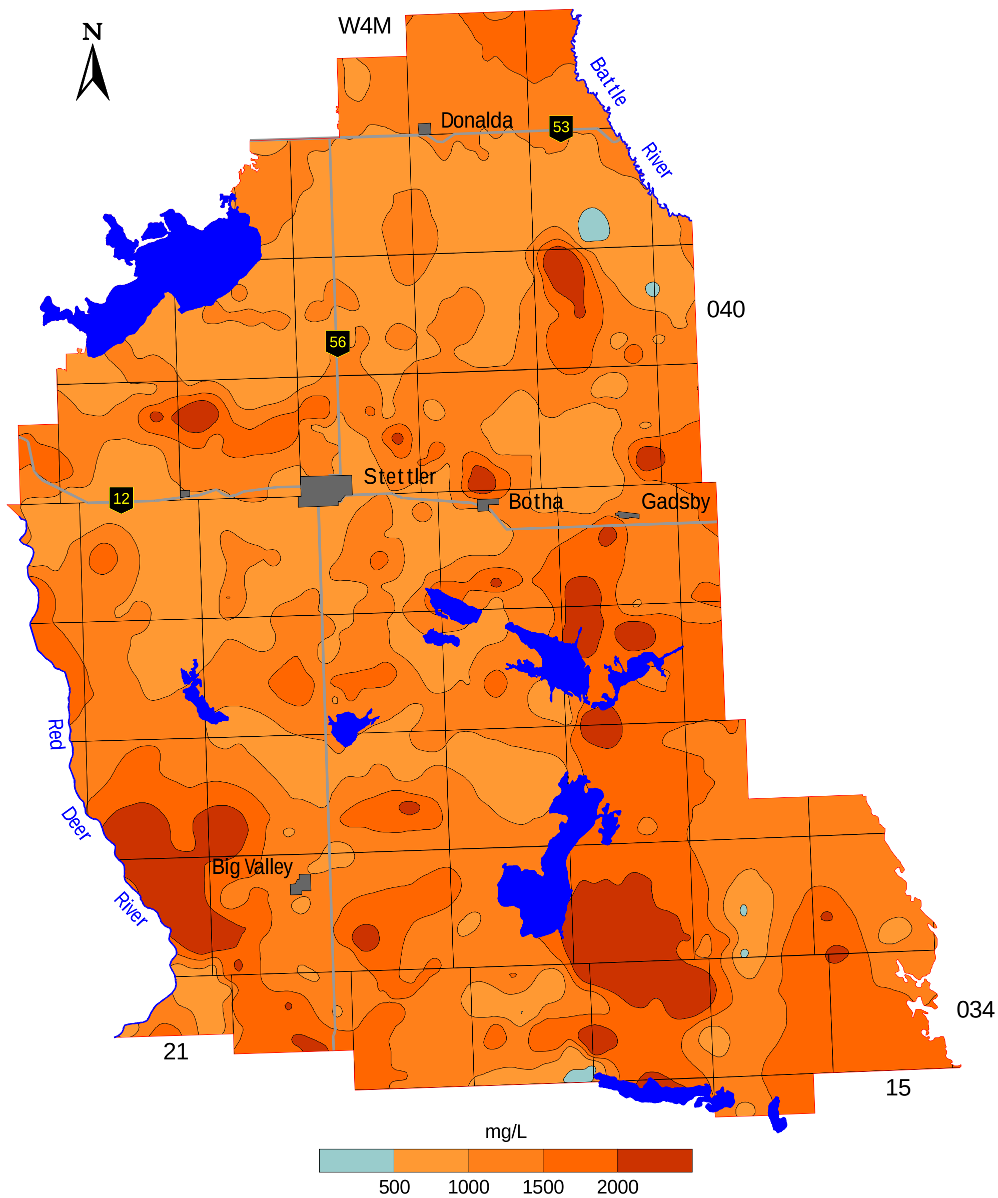
Note: This map is based on a regional study and as such, the results are to be used only as a guide. Detailed local studies are required to verify hydrogeological conditions at a given location.

County of Stettler No. 6
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



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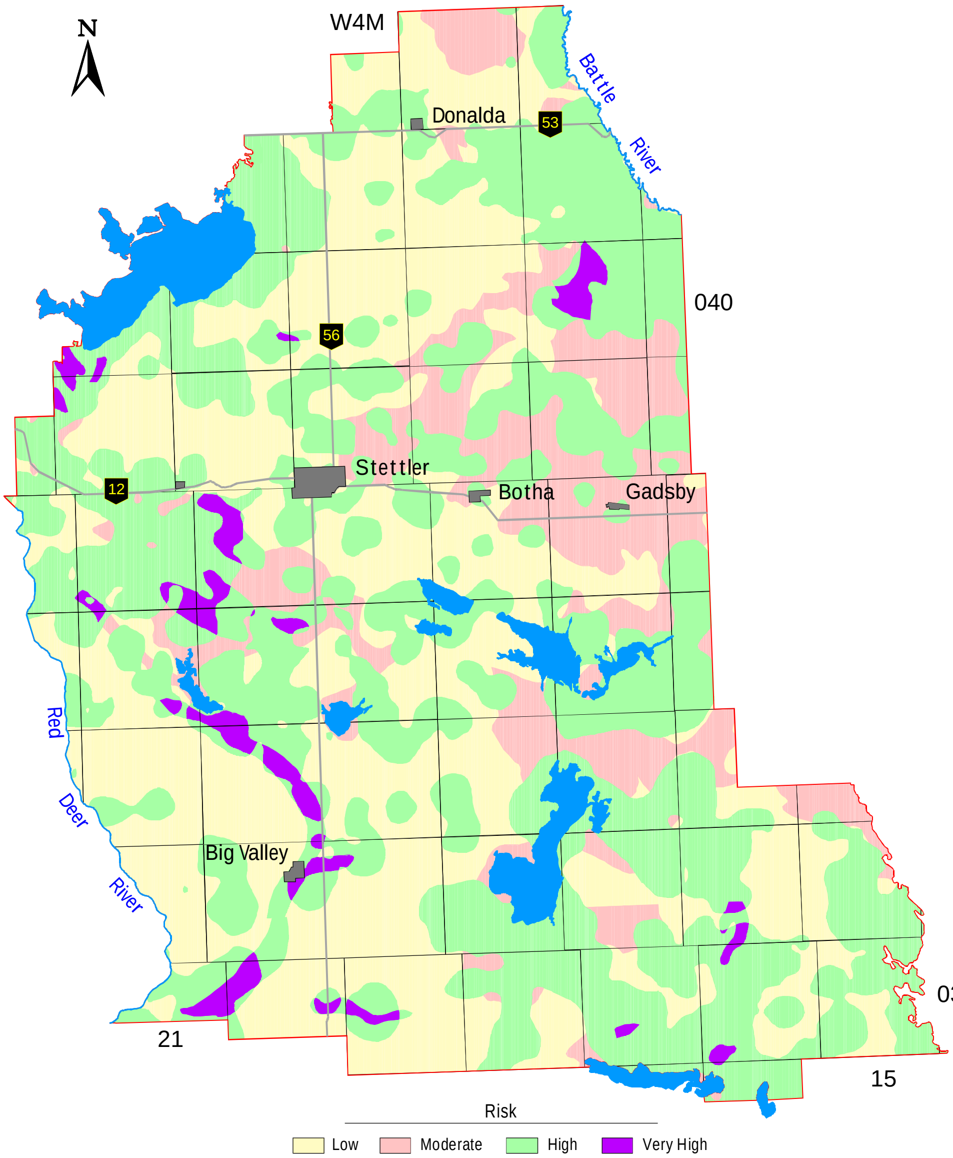
County of Stettler No. 6
Risk of Groundwater Contamination



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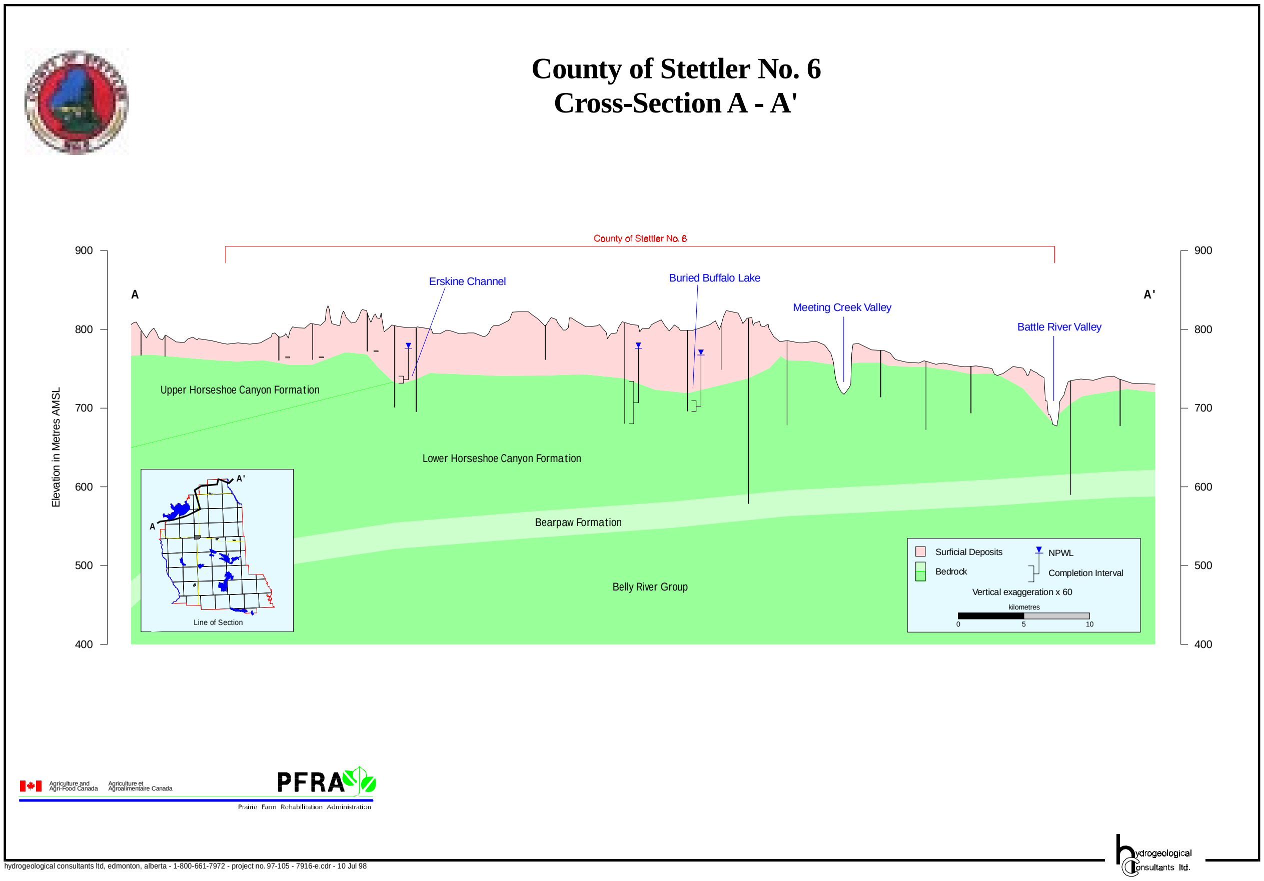
County of Stettler No. 6
Cross-Section A - A'
County of Stettler No. 6
Erskine Channel
Buried Buffalo Lake
Meeting Creek Valley
Battle River Valley
A
A'
Elevation in Metres AMSL
900
800
700
600
500
400
Upper Horseshoe Canyon Formation
Lower Horseshoe Canyon Formation
Bearpaw Formation
Belly River Group
Line of Section
Surficial Deposits
Bedrock
NPWL
Completion Interval
Vertical exaggeration x 60
kilometres
0
5
10
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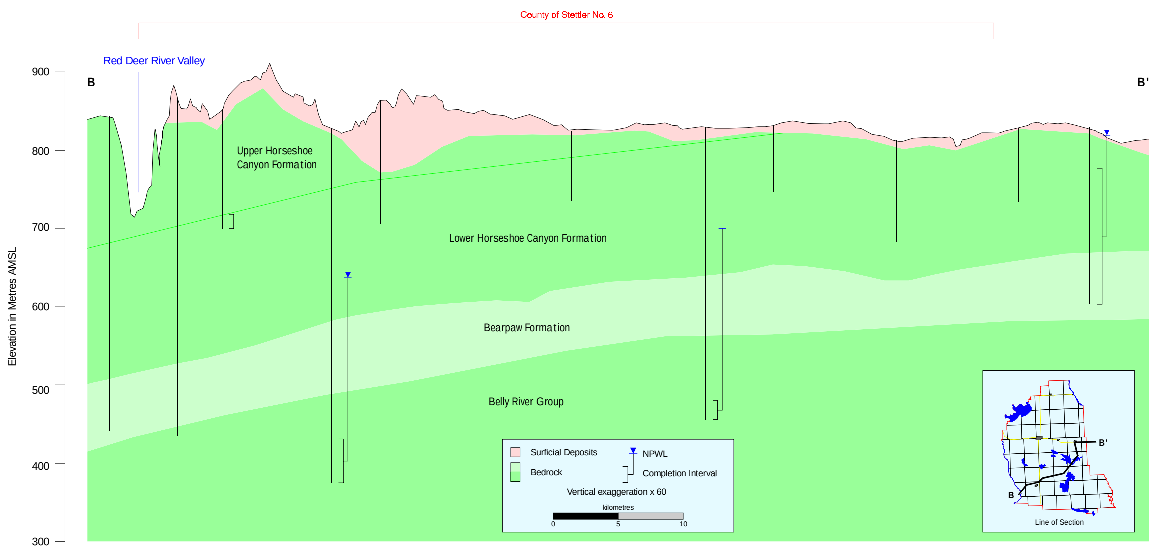
County of Stettler No. 6
Cross-Section B - B'



Cross-Section B - B'

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