Starland County

Part of the Red Deer River Basin
Parts of Tp 028 to 034, R 15 to 22, W4M
Regional Groundwater Assessment

Prepared for

STARLAND COUNTY

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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1 PROJECT OVERVIEW

"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 also 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 Starland County toward the management of the groundwater resource, which is a key component toward 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 Starland County, (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, maps showing 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.

Appendix E provides a list of water wells recommended for field verification.

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 and the accompanying maps represent Modules 2 and 3.

1.3 Purpose

This project is a regional groundwater assessment of Starland County. 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 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

Starland County is situated in south-central Alberta. This area is part of the Alberta Plains region. The County exists within the Red Deer River Basin. The western boundary is the Red Deer River. The other boundaries follow township or section lines. The area includes some or all of townships 028 to 034, ranges 15 to 22, west of the 4th Meridian.

Regionally, the topographic surface varies between 600 and 1,100 metres above mean sea level (AMSL), with the lowest elevation occurring in the Red Deer River Valley in the western part of the County as shown in Figure 1.

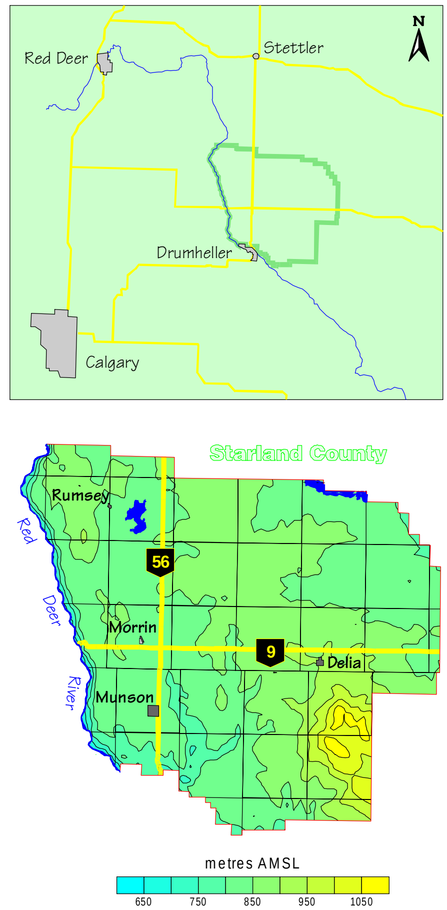

Figure 1. Index Map

2.2 Climate

Starland County lies within 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 Mixed Grass region, a transition between Aspen Parkland and Dry Mixed Grass Ecoregions.

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 four meteorological stations within the County measured 360 millimetres (mm), based on data from 1938 to 1993. The mean annual temperature averaged 3.6 °C, with the mean monthly temperature reaching a high of 18.2 °C in July, and dropping to a low of -12.9 °C in January. The calculated annual potential evapotranspiration is 546 millimetres.

2.3 Background Information

There are currently records for 1,616 water wells in the groundwater database for the County. Of the 1,616 water wells, 1,349 are for domestic/stock purposes. The remaining 267 water wells were completed for a variety of uses, including municipal, investigation, observation and industrial purposes. Based on a rural population of 2,075, there are 2.6 domestic/stock water wells per family of four. The domestic or stock water wells vary in depth from 2.4 metres to 426.7 metres below ground level. Lithologic details are available for 840 water wells.

Data for casing diameters are provided on 658 records, with 636 having a diameter of less than 350 mm and 22 having a diameter of more than 550 mm. The casing diameters of greater than 550 mm are mainly bored water wells and those with a surface casing of less than 350 mm are drilled water wells.

Steel, plastic and galvanized steel represent 99% of the materials that have been used for surface casing in drilled water wells over the last 40 years in water wells completed in the County. From before 1955 to the mid-1960s, the type of surface casing used was unknown in a significant number of the drilled water wells. Steel casing has been the dominant type of surface casing used over the last 40 years. The use of steel casing has declined since plastic casing was used for the first time in August 1978. Galvanized steel surface casing has been used in only 4% of the drilled water wells over the last 40 years and has not been used since November 1981.

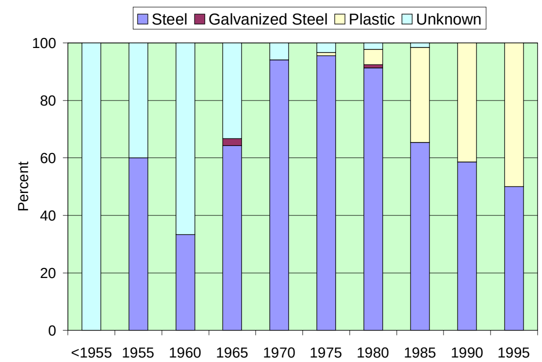

Figure 2. Surface Casing Types used in Drilled Water Wells

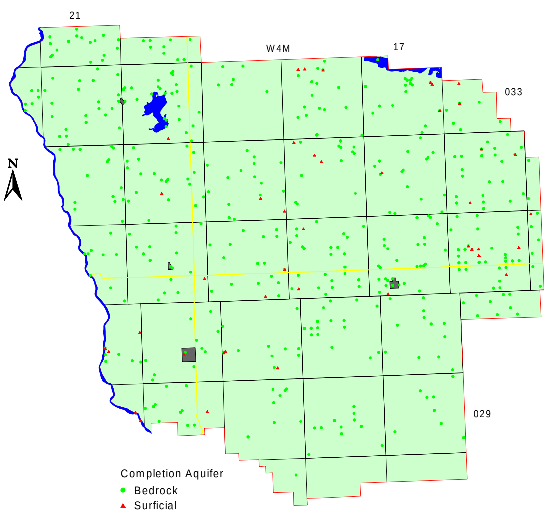

Figure 3. Location of Water Wells

There are 629 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 surface 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 51. The adjacent map shows that these water wells occur sporadically over most of the County. Approximately 85% of the water wells completed in the surficial aquifers have a completion depth of less than 30 metres.

The remaining 578 water wells have the top of their completion interval deeper than the depth to the bedrock surface. From Figure 3, it can be seen that the water wells completed in bedrock aquifers also occur over most of the County.

Water wells not used for domestic needs must be licensed. At the end of 1996, 61 groundwater diversions were licensed in the County. Of the 61 licensed groundwater users, 38 are for agricultural purposes, 22 are for municipal purposes and 1 is for industrial purposes. The total maximum authorized diversion from the water wells associated with these licences is 1,893.4 cubic metres per day (m^3/day); 50% of the authorized groundwater diversion is allotted for industrial use. The largest licensed industrial groundwater diversion within the County is for a saline water source well in 08-31-032-20 W4M licensed to Anderson Oil & Gas Inc. This saline water source well is completed at a depth of more than 1,750 metres below ground surface.

The largest licensed groundwater diversion within the County not used for industrial purposes is for the Village of Morrin, having a diversion of 67.6 m³/day from a water supply well completed in the Upper Horseshoe Canyon Aquifer.

The adjacent table shows a breakdown of the 61 licensed groundwater diversions by the aquifer in which the water well is completed. Even though one saline water source well is licensed, these supplies no longer need to be licensed. The next highest diversions are for licensed water wells completed in the Upper Horseshoe Canyon Aquifer, of which the majority of the groundwater is used for municipal purposes. There is a fairly even proportion of groundwater diversions that has been licensed for agricultural and municipal purposes.

	Licensed Groundwater Users (m³/day)			
Aquifer	Agricultural	Municipal	Industrial	Total
Upper Sand and Gravel	10.2	0.0	0.0	10.2
Upper Horseshoe Canyon	272.2	390.6	0.0	662.8
Middle Horseshoe Canyon	121.6	57.4	0.0	179.0
Lower Horseshoe Canyon	43.9	13.6	0.0	57.5
Saline Source Wells	0.0	0.0	953.4	953.4
Unknown	30.5	0.0	0.0	30.5
Total	478.4	461.6	953.4	1,893.4

Table 1. Licensed Groundwater Diversions

Based on the 1996 Agriculture Census, the water requirement for livestock for Starland County is in the order of five times the licensed groundwater diversion for agricultural purposes.

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

Groundwaters from the surficial deposits can be expected to be chemically hard with a high dissolved iron content. The total dissolved solids (TDS) concentrations in the groundwaters from the upper bedrock in the County are generally less than 2,000 milligrams per litre (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. Less than 5% of the chemical analyses indicate a fluoride concentration above 1.5 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 provided by the Alberta Energy and Utilities Board (EUB), 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.

Over approximately 80% of the County, the depth to the Base of Groundwater Protection is more than 250 metres. There are only a few areas where the depth to the Base of Groundwater Protection is less than 150 metres; these areas are mainly within a few kilometres of the Red Deer River as shown on the adjacent map.

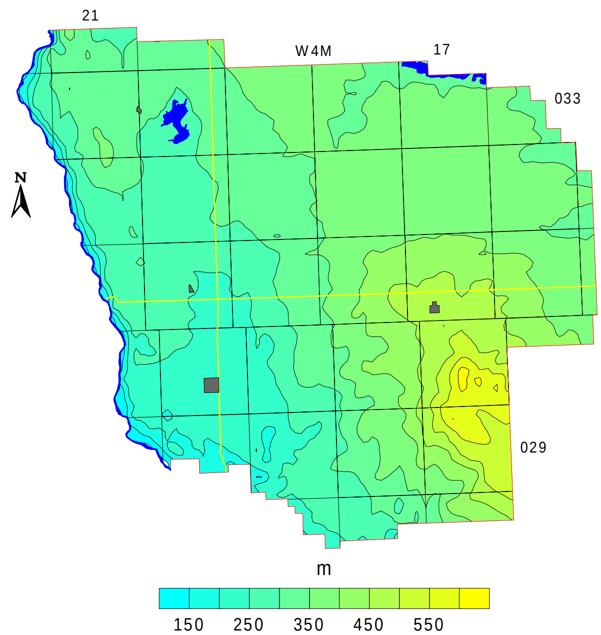

Figure 4. Depth to Base of Groundwater Protection (after EUB, 1995)

Proper management of the groundwater resource requires water-level data. These data are often collected from observation water wells. At the present time, there are no AEP-operated observation water wells within the County. However, there are three AEP-operated observation water wells within Special Area 2, two of which are located within five kilometres of the County in 04-28-029-16 W4M. Additional data can be obtained from some of the licensed groundwater diversions. In the past, these data for licensed diversions 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

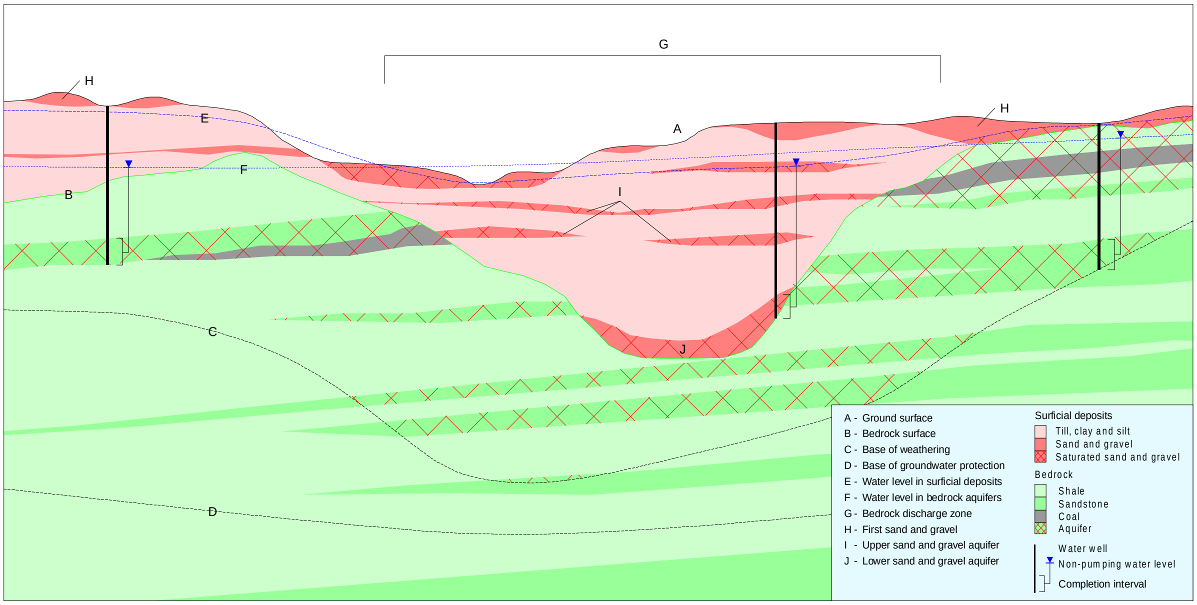

Figure 5. Generalized Cross-Section (for terminology only)

Lithology	Lithologic Description	Group and Formation: Thickness (m)	Group	Group and Formation: Designation	Member: Thickness (m)	Member: Designation	Zone: Thickness (m)	Zone: Designation
	sand, gravel, till, clay, silt	<60		Surficial Deposits	<60	Upper	<15	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)
					20-60	Lower	<1	Nevis Coal Seam
	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	~100	Upper		
					~100	Middle		
					<10	Drumheller Member		
					~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	10-220	Belly River Group	*continental* Foremost Formation			<20	Taber Coal Zone
							<20	McKay Coal Zone
	sandstone, shale	<200	Belly River Group	*marine* Foremost Formation (Basal Belly River Sandstone)	<30	Birch Lake Member		Milan Aquifer
					<30	Ribstone Creek Member		
					<30	Victoria Member		
					<30	Brosseau Member		
	shale, siltstone	100-200		Lea Park Formation	50-100	Upper		
					50-100	Lower		

Figure 6. Geologic Column

METHODOLOGY

3.1 Data Collection and Synthesis

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

1) water well drilling reports;
2) aquifer test results from some water wells;
3) location of some springs;
4) water well locations determined during water well surveys;
5) chemical analyses for some groundwaters;
6) location of flowing shot holes;
7) location of structure test holes; 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. Unlike other areas in the Province, duplicate water well IDs are not a problem in Starland County. 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 NW ¼ of section 15, township 031, range 20, W4M would have a horizontal coordinate with an Easting of 154,725 metres and a Northing of 5,723,055 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 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.

Values for apparent transmissivity and hydraulic conductivity have been calculated from the DST summaries for the Oldman Aquifer. Also, the types of fluids present in the Oldman Aquifer have been obtained 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.

3.2 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 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

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

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.

3.3 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 these parameters must be determined. The distribution of individual parameters involves the same process as the distribution of geological surfaces. This means establishing a representative data set and then preparing a grid.

3.3.1 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

3.4 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 NPWL and the elevation of the top of the aquifer are combined to determine the available drawdown[7]. The available drawdown data and the transmissivity values are used to calculate values for projected long-term yields for individual water wells, completed in a specific aquifer.

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

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 NPWLs. 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.

3.5 Software

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

- Microsoft Professional Office 97
- Surfer 6.04
- ArcView 3.1
- AutoCAD 14.01
- CorelDRAW! 8.0
- Acrobat 3.0

[7] See glossary

4 AQUIFERS

4.1 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.

4.1.1 Surficial Aquifers

Surficial deposits in the County are mainly less than 30 metres thick, except in areas of linear bedrock lows where the thickness of the surficial deposits can exceed 50 metres. There are two main linear bedrock lows in the County. One is present in the western part of the County and trends generally from north to south. The other linear bedrock low is present along the northeastern border of the County and trends generally from northwest to southeast. Cross-section A-A' passes across the Red Deer River Valley and both of the linear bedrock lows, and shows the thickness of the surficial deposits varying from less than 10 to more than 30 metres.

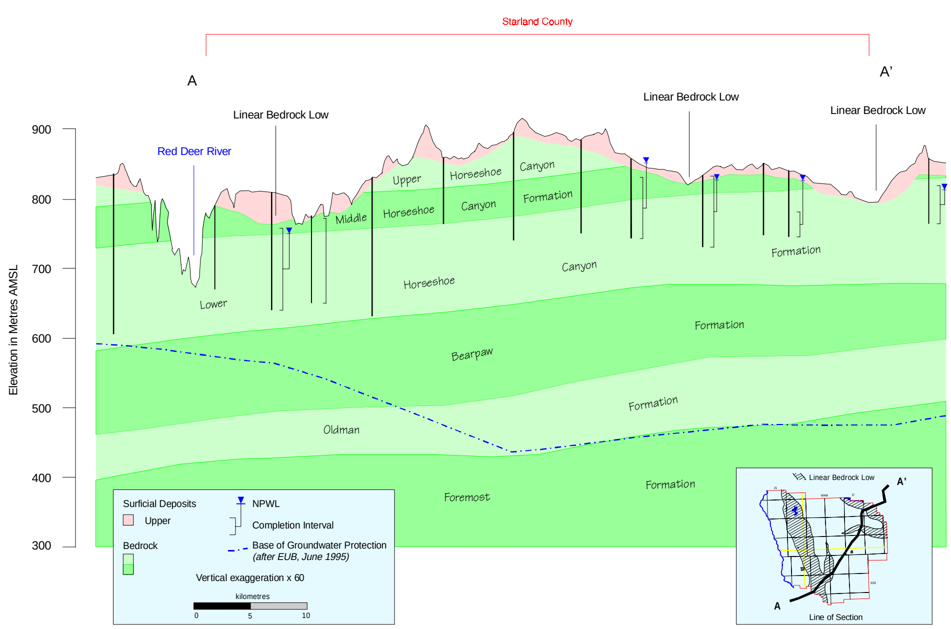

Figure 7. Cross-Section A - A'

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. Some 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 is usually treated before being used for domestic needs. Within the County, casing diameter information is available for 15 of the 51 water wells completed in the surficial deposits; only one of these water wells has a casing diameter of greater than 350 millimetres, and is assumed to be a dug or bored water well.

4.1.2 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 are permeable enough to transmit groundwater for a specific need. Water wells completed in bedrock aquifers usually do not require water well screens, though some of the sandstones are friable[8] and water well screens are a necessity. The groundwater from the bedrock aquifers is usually chemically soft.

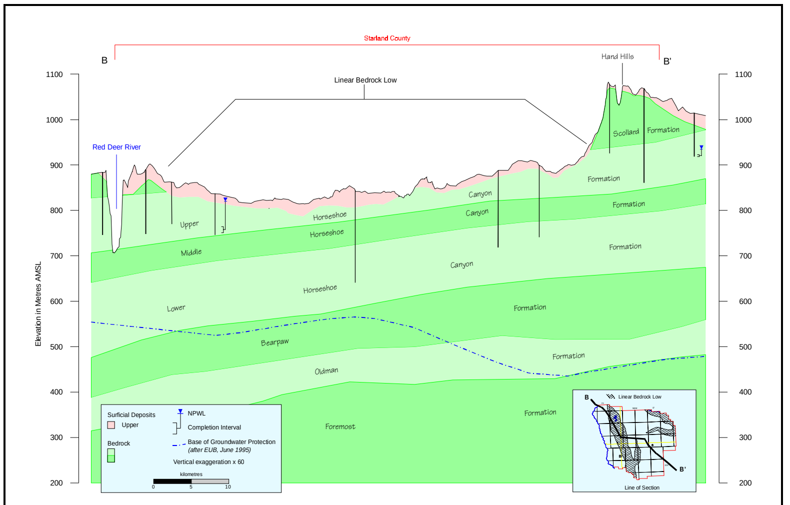

Figure 8. Cross-Section B - B'

The data for 578 water wells show 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 578 water wells, more than 99% have surface casing diameters of less than 350 mm and these bedrock water wells have been mainly completed with either a slotted liner or as open hole; there were only four bedrock water wells that were completed with a water well screen.

The upper bedrock includes parts of the Scollard and Horseshoe Canyon formations. The Bearpaw Formation is a regional aquitard[9] and underlies the Lower Horseshoe Canyon Formation. The Bearpaw Formation is not considered part of the upper bedrock in the Starland area, although in some areas it is less than 200 metres below the bedrock surface (Figure 8). Below the Bearpaw Formation is the Oldman Formation. While the top of the Oldman Formation is always below a depth of 250 metres in the County, the Oldman Aquifer is discussed later in the present report.

[8] See glossary
[9] See glossary

4.2 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 materials deposited directly or indirectly by glaciation. The lower surficial deposits include pre-glacial fluvial[10] and lacustrine[11] deposits. The lacustrine deposits include clay, silt and fine-grained sand. The upper surficial deposits include the more traditional glacial deposits of till[12] and meltwater deposits. In the County, no lower surficial deposits have been defined to date and the upper surficial deposits include mainly till.

4.2.1 Geological Characteristics of Surficial Deposits

While the surficial deposits are treated as one hydrogeological unit, they consist of two hydraulic parts. The first is the saturated sand and gravel deposits of the upper surficial deposits and the second 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 30 metres thick. The exceptions are mainly in association with the linear bedrock lows where the deposits can have a thickness of more than 30 metres. There are two main linear bedrock lows in the County as shown on the adjacent bedrock topography map.

Sand and gravel deposits can occur throughout the surficial deposits. The total thickness of sand and gravel deposits is generally less than 5 metres but can be more than 10 metres in the areas of the linear bedrock lows.

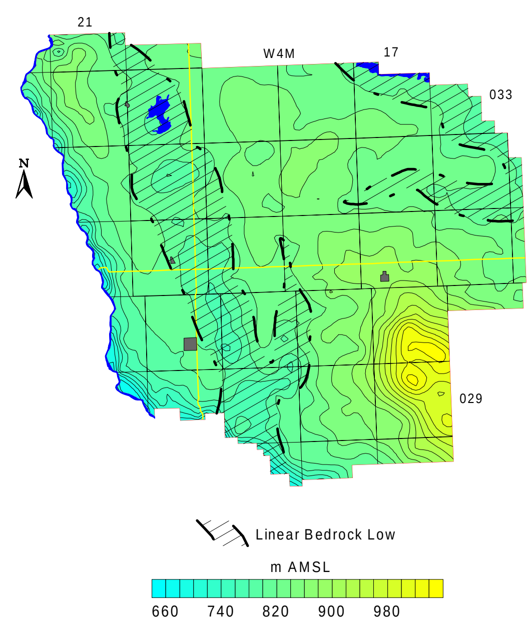

Figure 9. Bedrock Topography

10 See glossary
11 See glossary
12 See glossary

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 20% of the County where sand and gravel deposits are present, the sand and gravel deposits are more than 50% of the total thickness of the surficial deposits. Some areas where the sand and gravel percentages are higher are areas where linear bedrock lows are present. Other areas where sand and gravel deposits constitute more than 50% of the surficial deposits may be areas where linear bedrock lows exist but have not been identified due to a shortage of accurate bedrock control points. The higher percentage of sand and gravel in townships 031, 032 and 033, ranges 18 and 19 is extensive, with no evidence of a linear bedrock low.

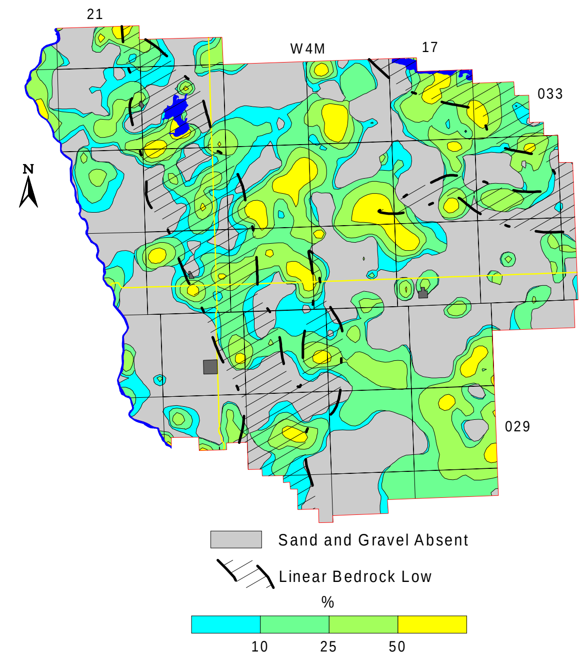

Figure 10. Amount of Sand and Gravel in Surficial Deposits

4.2.2 Sand and Gravel Aquifer(s)

One source of groundwater in the County includes aquifers in the surficial deposits. Since the sand and gravel aquifer(s) are not everywhere, the actual aquifer that is developed at a given location is usually dictated by the aquifer that is present. From the present hydrogeological analysis, 408 water wells are completed in aquifers in the upper surficial deposits. This number of 408 water wells completed in aquifers in the surficial deposits is eight times the number of water wells determined to be completed in aquifers in the surficial deposits based on lithologies given on the water well drilling reports.

The water wells completed in the upper surficial deposits are located throughout the County, as shown in Figure 11.

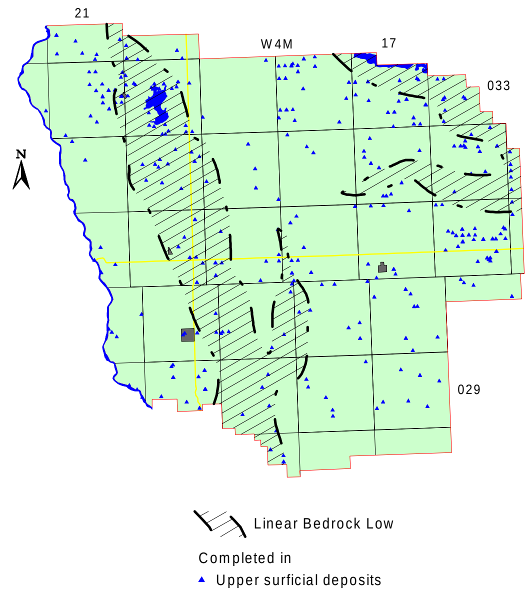

Figure 11. Water Wells Completed in Surficial Deposits

The adjacent map shows water well yields that are expected in the County, based on sand and gravel aquifer(s) that have been developed by existing water wells. These data show that 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. The most notable areas where yields of more than 100 m³/day are present are mainly in the north-central parts of the County. Over the majority of the County where the sand and gravel aquifer(s) are present, water wells completed in the sand and gravel aquifer(s) would have apparent yields of less than 100 m³/day. In 60% of the County there are no sand and gravel aquifer(s) present.

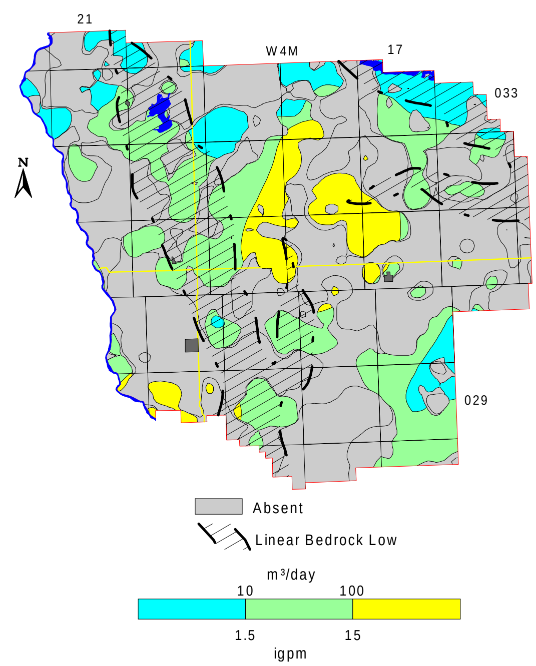

Figure 12. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)

4.2.2.1 Chemical Quality of Groundwater from Surficial Deposits

The Piper tri-linear diagram[13] shows that all chemical types of groundwater occur in the surficial deposits. However, the majority of the groundwaters have calcium or sodium as the main cation, and bicarbonate or sulfate as the main anion. The TDS concentrations in the groundwaters from the surficial deposits range from less than 500 to more than 2,000 mg/L. In more than 50% of the area, TDS values are less than 1,500 mg/L. The groundwaters with a TDS of more than 2,000 mg/L occur mainly in the northwestern part of the County.

The groundwaters with elevated levels of sulfate generally occur in areas where there are elevated levels of total dissolved solids. There are very few groundwaters from the surficial deposits with appreciable concentrations of the chloride ion and in most of the County, the chloride ion concentration is less than 100 mg/L.

Groundwaters from the surficial deposits are expected to have dissolved iron concentrations of greater than 1 mg/L.

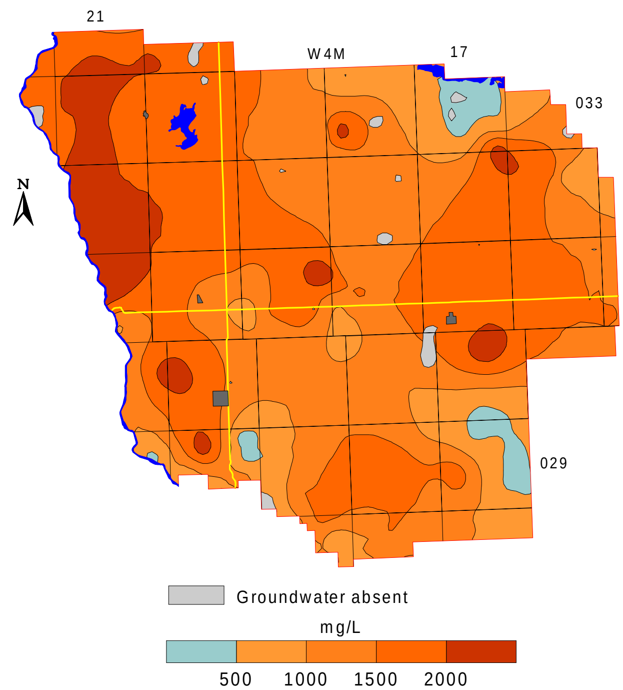

Figure 13. Total Dissolved Solids in Groundwater from Surficial Deposits

[13] See glossary

4.3 Bedrock

4.3.1 Geological Characteristics

The upper bedrock in the County is the Edmonton Group. The Edmonton Group 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.

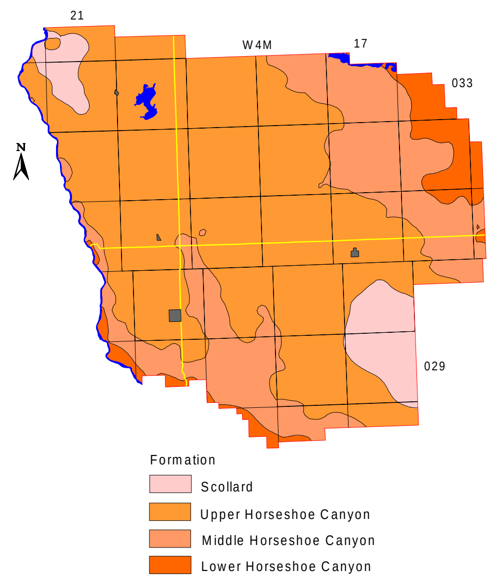

Figure 14. Bedrock Geology

The Scollard Formation is the upper bedrock and subcrops mainly in the northwestern and southeastern parts of the County. The Scollard Formation has a maximum thickness of 120 metres within the County and includes the Upper and Lower Scollard formations. The Upper Scollard consists mainly of sandstone, siltstone, shale and coal seams or zones. Two prominent coal zones within the Upper Scollard are the Ardley Coal (up to 20 metres thick) and the Nevis Coal (up to 3.5 metres thick). The bottom of the Nevis Coal Seam is the border between the Upper and Lower Scollard formations. The Lower Scollard Formation has a maximum thickness of 40 metres and is composed mainly of shale and sandstone.

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 northwestern and southeastern parts 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 ubiquitous nature of the bentonite in the Battle and Whitemud formations, there is very little significant permeability within these two formations; they are, therefore, included with the Upper Horseshoe Canyon Formation on Figure 14 and in the Groundwater Query.

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 350 metres and within the County includes the Upper, Middle and Lower Horseshoe Canyon formations. The Upper Horseshoe Canyon, which can be up to 100 metres thick, is the upper bedrock in the majority of the County immediately adjacent to the area where the Scollard Formation subcrops. The Middle Horseshoe Canyon, which is up to 80 metres thick, is the upper bedrock in the southwestern and northeastern parts of the County. The Lower Horseshoe Canyon, which is up to 180 metres thick, is the upper bedrock along the southwestern and northeastern edges of the County.

The Horseshoe Canyon Formation consists of deltaic[14] and fluvial 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 and the upper 30 to 50 metres of the Horseshoe Canyon Formation 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[15], shallow marine (shoreface[16]) and open marine facies[17] deposits. In the County, the Bearpaw Formation is composed mainly of shale and as such is a regional aquitard. 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. Because the Bearpaw Formation is an aquitard, there will be no direct review of the Bearpaw Aquitard in the text of this report. However, maps associated with the Bearpaw Aquitard are included on the CD-ROM.

The Belly River Group includes the Oldman and Foremost 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 up to 20,000 mg/L. However, parts of the Oldman Formation are also porous and permeable and attempts have been made to develop some groundwater supplies from the Oldman Formation. A limited discussion of the Oldman Formation is included in the present report.

4.3.2 Aquifers

Of the 1,616 water wells in the database, 578 were defined as being completed in bedrock aquifers based on the top of the completion interval being below the bedrock surface. However, less than half of the water well records in the database have values for the top of their completion intervals. The information that is available for the majority of water wells is their completion depth. In order to make use of additional information within the groundwater database, it was statistically determined that water wells typically have completion intervals equivalent to one quarter of their completed depth. This relationship was used to increase the number of water wells identified as completed in bedrock aquifers to 1,233 from 578. With the use of geological surfaces that were determined from the interpretation of geophysical logs, it has been possible to assign the water wells completed in bedrock aquifers to specific aquifers based on their completion intervals. Of the 1,233 bedrock water wells, 1,142 could be assigned a specific aquifer. The bedrock water wells are mainly completed in the Horseshoe Canyon aquifers as shown in the adjacent table.

Bedrock Aquifer	No. of Water Wells
Scollard	56
Upper Horseshoe Canyon	626
Middle Horseshoe Canyon	308
Lower Horseshoe Canyon	149
Oldman	3
Other	91
Total	1233

Table 3. Completion Aquifer

[14] See glossary
[15] See glossary
[16] See glossary
[17] See glossary

In general, water wells in the bedrock aquifers in the County can be expected to provide only limited quantities of groundwater.

There are 255 records for bedrock water wells that have apparent yield values, 20% of all bedrock water wells. In the County, water well yields in the upper bedrock aquifer(s) are mainly less than 100 m³/day. The areas of higher yields that are indicated on the adjacent figure are mainly in the northwestern and eastern parts of the County and the lower yields mainly trend from the southwest to the northeast through the centre of the County. The higher yields in the northwestern part of the County may be a result of increased permeability resulting from the weathering process in association with the linear bedrock lows.

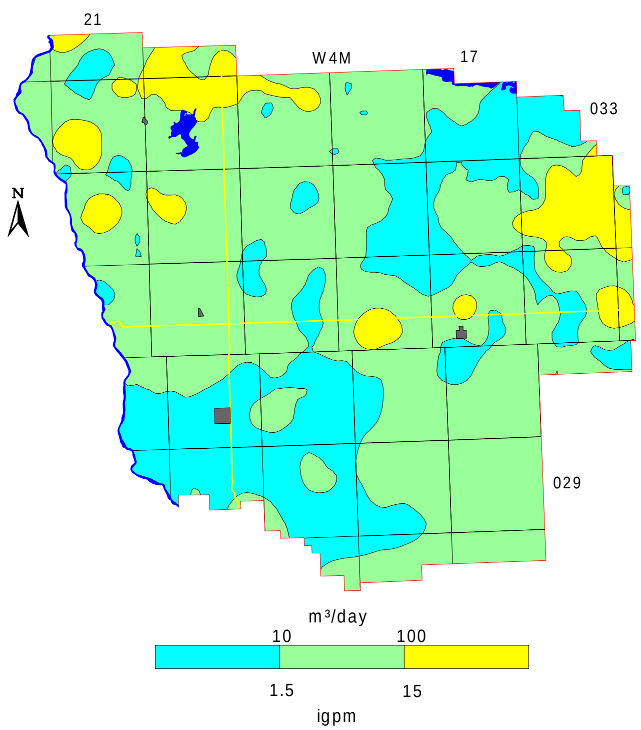

Figure 15. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

There are 251 apparent yield values that can be assigned to a specific bedrock aquifer. The majority of the water wells completed in the bedrock aquifers have apparent yields that range from 10 to 100 m³/day, as shown in the table below.

Aquifer	No. of Water Wells with Apparent Yields	Number of Water Wells with Apparent Yields <10 m³/day	10 to 100 m³/day	>100 m³/day
Scollard	13	6	6	1
Upper Horseshoe Canyon	149	39	85	25
Middle Horseshoe Canyon	54	26	22	6
Lower Horseshoe Canyon	35	5	16	14
Totals	251	76	129	46

Table 4. Apparent Yields of Bedrock Aquifers

4.3.3 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 60% of the area, TDS values are less than 1,500 mg/L, with only a few areas having TDS concentrations of less than 500 mg/L. The higher values are expected mainly in the western and eastern parts of the County.

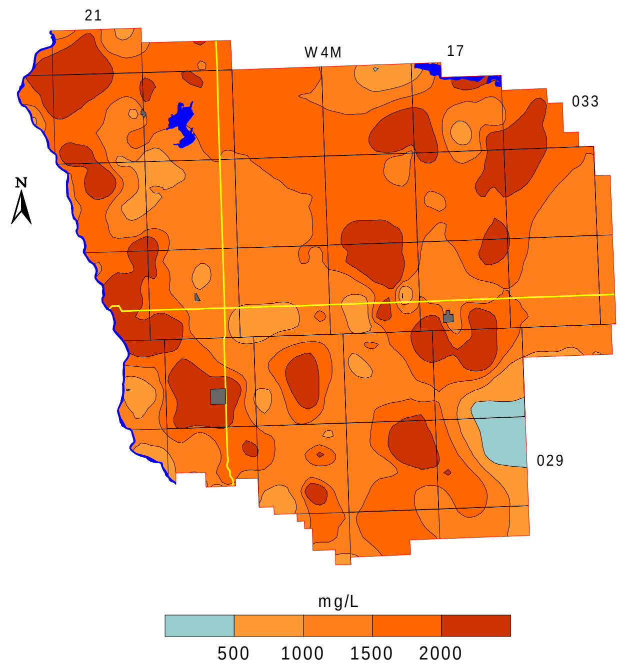

Figure 16. Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

The relationship between TDS and sulfate concentrations shows that when TDS values in the upper bedrock aquifer(s) exceed 1,200 mg/L, the sulfate concentrations exceed 400 mg/L. The chloride concentrations in the groundwaters from the upper bedrock aquifer(s) are less than 100 mg/L in more than 90% of the County.

In more than 95% of the County, the fluoride ion concentration in the groundwaters from the upper bedrock aquifer(s) is less than 1.5 mg/L.

The Piper tri-linear diagrams (see Appendix A) show that all chemical types of groundwater occur in the bedrock aquifers. However, the majority of the groundwaters are sodium-bicarbonate and sodium-sulfate types.

4.3.4 Scollard Aquifer

The Scollard Aquifer comprises the porous and permeable parts of the Scollard Formation that underlies the surficial deposits in approximately 170 square kilometres in the northwestern and southeastern parts of the County. The Scollard Formation is mainly less than 20 metres thick in the northwestern area but is mainly more than 50 metres thick in the southeastern area; in most of the County, the Scollard Formation has been eroded.

4.3.4.1 Depth to Top

The depth to the top of the Scollard Formation is mainly between 10 and 30 metres. The greatest depth is predominantly in the southeastern part of the County where the Formation is present.

4.3.4.2 Apparent Yield

The apparent yields for individual water wells completed through the Scollard Aquifer in the northwestern part of the County are mainly less than 10 m³/day and are predominantly between 10 and 100 m³/day in the southeastern part of the County. Adjacent to the Red Deer River Valley in township 034, range 22, W4M, the Scollard Formation is expected to be drained.

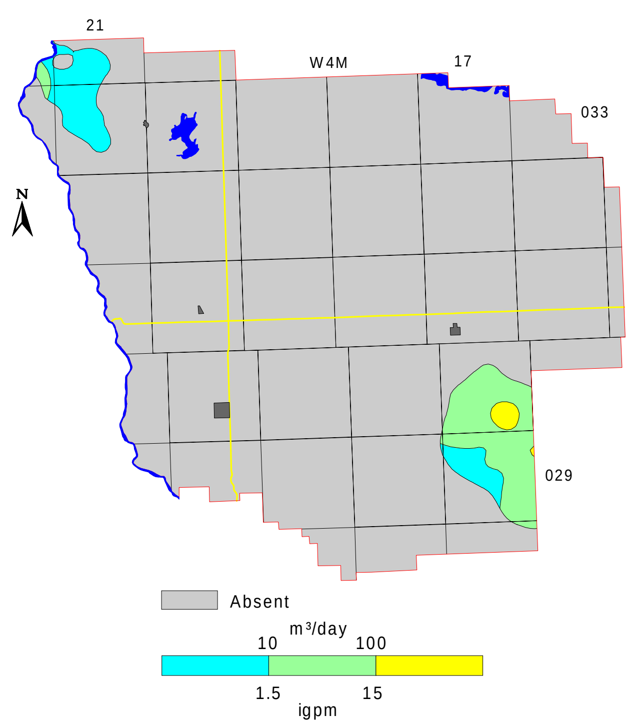

Figure 17. Apparent Yield for Water Wells Completed through Scollard Aquifer

4.3.4.3 Quality

The groundwaters from the Scollard Aquifer are mainly sodium-bicarbonate or sodium-sulfate types (see CD-ROM). The TDS concentrations range from less than 500 to more than 2,000 mg/L. The higher values are in the northwestern part of the County and the lower values are in the southeastern part of the County. The sulfate concentrations are more than 500 mg/L in the northwestern part of the County and mainly less than 100 mg/L in the southeastern part of the County. Chloride concentrations in the groundwaters from the Scollard Aquifer range from less than 5 to more than 10 mg/L, with the lower values in the southeastern part of the County.

4.3.5 Upper Horseshoe Canyon Aquifer

The Upper Horseshoe Canyon Aquifer comprises the porous and permeable parts of the Upper Horseshoe Canyon Formation. The Upper Horseshoe Canyon Formation subcrops under the surficial deposits in the majority of the County and underlies the Scollard Formation, where present. The Upper Horseshoe Canyon Formation varies from less than 20 metres thick at the eastern edge of the subcrop to more than 200 metres thick in Tp 050, R 14, W4M. Higher local permeability can be expected when the depth of burial is less than 100 metres and fracturing or weathering has occurred.

4.3.5.1 Depth to Top

The depth to the top of the Upper Horseshoe Canyon Formation is variable, ranging from less than 20 metres in areas of subcrop to more than 140 metres in townships 029 and 030, range 17, W4M where the Scollard Formation is present.

4.3.5.2 Apparent Yield

The apparent yields for individual water wells completed in the Upper Horseshoe Canyon Aquifer are mainly between 10 and 100 m³/day. The adjacent map indicates that apparent yields of more than 100 m³/day mainly are expected in the northwestern part of the County.

A water supply well for the Village of Morrin in NW 15-031-20 W4M (AEP, 1980) is reported to have a 20-year safe yield of more than 100 m³/day. The water supply well is completed in the Upper Horseshoe Canyon Aquifer in an area of the County where water wells yields are expected to be between 10 and 100 m³/day. This situation helps to illustrate that the maps are regional in nature and that the hydrogeological conditions at a given location must be determined by an appropriate groundwater investigation.

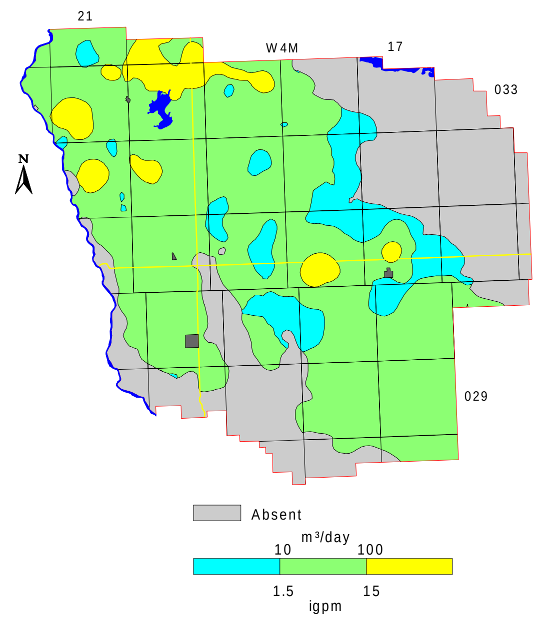

Figure 18. Apparent Yield for Water Wells Completed through Upper Horseshoe Canyon Aquifer

4.3.5.3 Quality

The groundwaters from the Upper Horseshoe Canyon Aquifer are mainly sodium-bicarbonate or sodium-sulfate types (see CD-ROM). The TDS concentrations are expected to be mainly less than 2,000 mg/L. The higher values are mostly in the western part of the County. The sulfate concentrations are usually less than 500 mg/L. Chloride concentrations in the groundwaters from the Upper Horseshoe Canyon are mainly less than 100 mg/L.

Groundwater from the Village of Morrin water supply well (AEP, 1980), that is completed in the Upper Horseshoe Canyon Formation, has a TDS concentration of 1,260 mg/L, a sulfate concentration of 20 mg/L and a chloride concentration of 64 mg/L.

4.3.6 Middle Horseshoe Canyon Aquifer

The Middle Horseshoe Canyon Aquifer comprises the porous and permeable parts of the Middle Horseshoe Canyon Formation that underlies the Upper Horseshoe Canyon Formation, and subcrops under the surficial deposits in a third of the southwestern and northeastern parts of the County. The thickness of the Middle Horseshoe Canyon Formation is mainly between 50 and 60 metres but varies from less than 10 metres at the northeastern and southwestern edges to more than 60 metres in the northwestern part of the County.

4.3.6.1 Depth to Top

The depth to the top of the Middle Horseshoe Canyon Formation is mainly less than 20 metres below ground level, but can be more than 220 metres in the southeastern part of the County in townships 029 and 030, range 17, W4M.

4.3.6.2 Apparent Yield

There are 54 control points used to prepare the map for apparent yield through the Middle Horseshoe Canyon Aquifer. Of 54 apparent yield values, 48% are less than 10 m³/day, 41% are between 10 and 100 m³/day and 11% are greater than 100 m³/day. The adjacent map shows that approximately 65% of the County is underlain by the Middle Horseshoe Canyon Formation where apparent yields are expected to be between 10 and 100 m²/day. This discrepancy occurs because of the distribution of the control points. The map shows the control points are concentrated in the eastern and southwestern parts of the County. There is a 15-kilometre-wide swath through the County, from the southeast to the northwest, where no data are available. The areas where water wells with higher yields are expected are in parts of township 033, ranges 18 and 19, W4M.

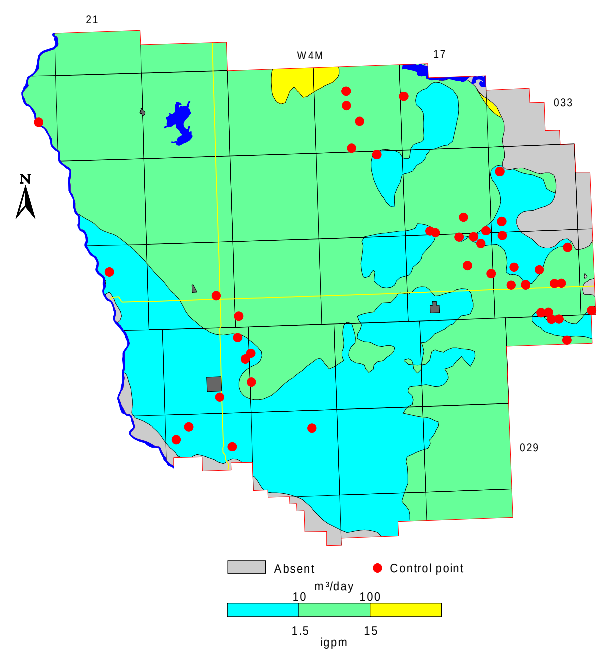

Figure 19. Apparent Yield for Water Wells Completed through Middle Horseshoe Canyon Aquifer

4.3.6.3 Quality

The groundwaters from the Middle Horseshoe Canyon Aquifer are mainly sodium-bicarbonate or sodium-sulfate types (see CD-ROM). The TDS concentrations are expected to be mostly less than 1,500 mg/L with higher values in the southwestern and northeastern parts of the County. The sulfate concentrations are mainly less than 500 mg/L. Chloride concentrations in the groundwaters from the Middle Horseshoe Canyon Aquifer are mainly less than 100 mg/L.

4.3.7 Lower Horseshoe Canyon Aquifer

The Lower Horseshoe Canyon Aquifer comprises the porous and permeable parts of the Lower Horseshoe Canyon Formation that underlies the Middle Horseshoe Canyon Formation, and either outcrops or subcrops along the southwestern edge of the County and subcrops in parts of townships 031 to 033, ranges 15 and 16, W4M. The thickness of the Lower Horseshoe Canyon Formation is mainly between 120 and 140 metres but varies from less than 60 metres at the southwestern edge to more than 160 metres along the northwestern edge of the County.

4.3.7.1 Depth to Top

The depth to the top of the Lower Horseshoe Canyon Formation varies from less than 20 metres to more than 280 metres below ground level. The greatest depth is in the southeastern part of the County in townships 029 and 030, range 17, W4M.

4.3.7.2 Apparent Yield

There are 35 control points used to prepare the map for apparent yield from the Lower Horseshoe Canyon Formation. Of 35 apparent yield values, 14% are less than 10 m³/day, 46% are between 10 and 100 m³/day and 40% are greater than 100 m³/day. The adjacent map shows that approximately 10% of the County is underlain by the Lower Horseshoe Canyon Formation where apparent yields are expected to be greater than 100 m³/day. This discrepancy between percent of actual values vs. area of distribution occurs because of the location of the control points. The map shows the control points are concentrated in the eastern and southwestern parts of the County. The areas where water wells with higher yields are expected are in parts of townships 031 and 032, ranges 15 and 16, W4M. This would be the area where the Lower Horseshoe Canyon Formation would be most subjected to weathering processes.

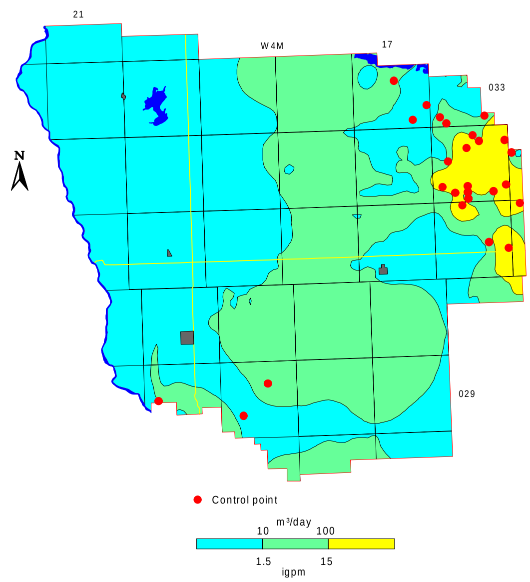

Figure 20. Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer

4.3.7.3 Quality

The groundwaters from the Lower Horseshoe Canyon Aquifer are mainly sodium-bicarbonate or sodium-sulfate types (see CD-ROM). The TDS concentrations are mostly less than 2,000 mg/L. The higher values are in the northern and northwestern parts of the County. The sulfate concentrations are usually less than 500 mg/L, with higher values in parts of townships 032 and 033, ranges 16 and 17, W4M. Chloride concentrations in the groundwaters from the Lower Horseshoe Canyon Aquifer range from less than 10 to more than 250 mg/L. The higher values are in most of the northwestern half of the County.

Oldman Aquifer

The Oldman Aquifer comprises the porous and permeable parts of the Oldman Formation that underlies the Bearpaw Formation. The depth to the top of the Oldman Formation is mainly greater than 200 metres throughout the County. The shallower locations are in the northeastern and southwestern parts of the County. There are 247 records in the database for holes that have been drilled to depths of greater than 200 metres. However, most of the holes were structure test holes or core holes. While these records provide lithologic information, they do not provide details for the aquifer parameters or the chemical quality of the groundwater. There are three records in the database for water wells used for stock and/or domestic purposes that are more than 200 metres deep. A projected long-term yield has been calculated from the data included with one record and a second record includes the results of a chemical analysis. The projected long-term yield is 0.2 cubic metres per day. The chemical analysis results indicate the TDS is 3,721 mg/L and the chloride ion concentration is 2,182 mg/L. The chemical analysis results are similar to the results of a groundwater sample obtained from a water test hole completed in the Foremost Formation east of the County (Hydrogeological Consultants Ltd., 1997). In the eastern half of the County, the Oldman Formation is above the Base of Groundwater Protection and in the western half of the County the Formation is below the Base of Groundwater Protection.

The projected long-term yield for the water test hole east of the County is 70 m³/day, significantly more than the yield of the water well completed in the County. The difference in yield is undoubtedly related to the presence of natural gas in the Oldman Aquifer.

In addition to the data available from the groundwater database, the summary results of drill stem tests are available from the EUB database. The DST summaries often provide a description of fluid obtained during the DST. Therefore, the DST summaries can be used to determine an apparent yield and the quality of fluid available from the Aquifer.

There are 162 DSTs that have a completion interval that includes at least a part of the Oldman Aquifer. The fluids from the 162 DSTs have been grouped as water, gas and water, and oil.

Of the 162 DSTs, 75 have sufficient information to allow for the calculation of an apparent long-term yield. The projected long-term yield values vary from less than 1 m³/day to a maximum of 383 m³/day, with the mean being 26 m³/day and the median 12 m³/day.

The data from the DSTs have been used to prepare the adjacent map. The contours outline the different fluids expected at various locations and the posting shows the expected long-term yield at individual locations.

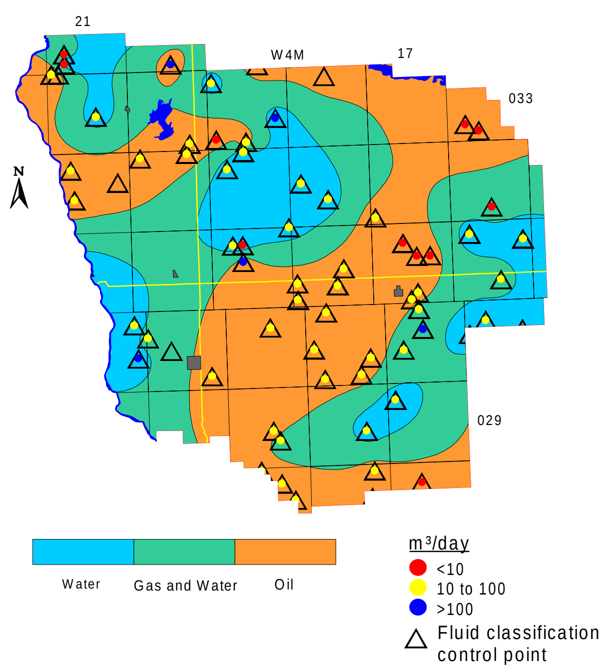

Figure 21. Type of Fluid Encountered in Oldman Aquifer

5 GROUNDWATER BUDGET

5.1 Groundwater Flow

A direct measurement of groundwater recharge or discharge is not possible from the data that are available for the County. One indirect method of measuring recharge is to determine the quantity of groundwater flowing laterally 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 through an aquifer 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 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 lateral 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)
Upper Horseshoe Canyon	7.6	0.0025	18	West	340	662.8
Middle Horseshoe Canyon					780	179.0
	4.6	0.00278	50	West	640	
	4.6	0.00125	24	East	140	
Lower Horseshoe Canyon					1,750	57.5
	7.5	0.00347	50	West	1,300	
	7.5	0.00208	29	East	450	

The above table indicates there is more groundwater flowing through two of the aquifers than has been authorized to be diverted by AEP. However, the unlicensed groundwater diversion for livestock is five times greater than the licensed diversion; therefore, it is possible that the groundwater use is greater than the quantity flowing through the aquifers. From the third aquifer, the Upper Horseshoe Canyon Aquifer, the authorized diversion is more than the quantity of groundwater flowing through the Aquifer. 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. Also, it should be noted that the quantity of groundwater being used could be less than the amount of groundwater authorized.

In the case of the Upper Sand and Gravel Aquifer, no value has been calculated for the flow through the Aquifer because of the difficulty in obtaining a reasonable value for hydraulic gradient in the Upper Sand and Gravel Aquifer.

5.2 Quantity of Groundwater

An estimate of the volume of groundwater stored in the sand and gravel aquifers in the surficial deposits is 2 to 11 cubic kilometres. This volume is based on an areal extent of 3,000 square kilometres and a saturated sand and gravel thickness of four 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% (Sonderegger et al., 1989), which gives the low value of the total volume. The high estimate is based on a porosity of 30% (Ozoray, Dubord and Cowen, 1990).

The adjacent water-level map has been prepared by considering water wells completed in surficial deposits. These water levels were used for the calculation of saturated surficial deposits and for the calculation of recharge/discharge areas.

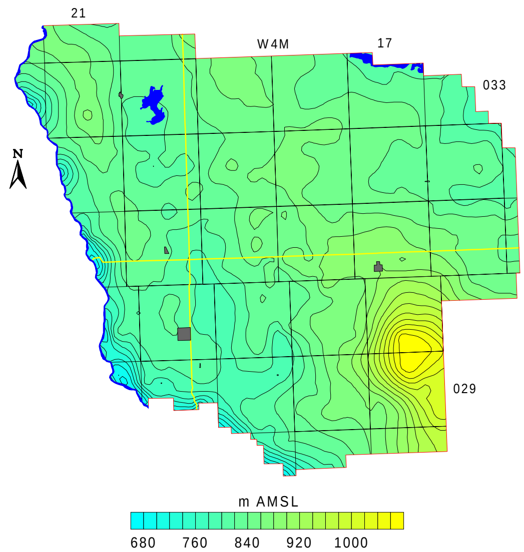

Figure 22. Non-Pumping Water-Level Surface in Surficial Deposits

5.3 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 from the bedrock aquifers, and a recharge area to the surficial deposits.

5.3.1.1 Surficial Deposits/Upper Bedrock Aquifer(s)

The hydraulic gradient between the surficial deposits and the upper bedrock aquifer(s) has been determined by subtracting the non-pumping water-level surface associated with all water wells completed in the upper bedrock aquifer(s) from the non-pumping water-level surface determined for all water wells in the surficial deposits. The recharge classification on the map in Figure 23 includes those areas where the elevation of the water level in the surficial deposits is more than five metres above the elevation of the water level in the upper bedrock aquifer(s). The discharge areas are where the elevation of the water level in the surficial deposits is more than five metres lower than the elevation of the water level in the bedrock. When the elevation of the water level in the surficial deposits is between five metres above and five metres below the elevation of the water level in the bedrock, the area is classified as a transition.

The adjacent map shows that, in more than 70% of the County, there is a downward hydraulic gradient from the surficial deposits toward the upper bedrock aquifer(s). Areas where there is an upward hydraulic gradient from the bedrock to the surficial deposits are mainly in the vicinity of the Red Deer River Valley. The remaining parts of the County are areas where there is a transition condition.

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

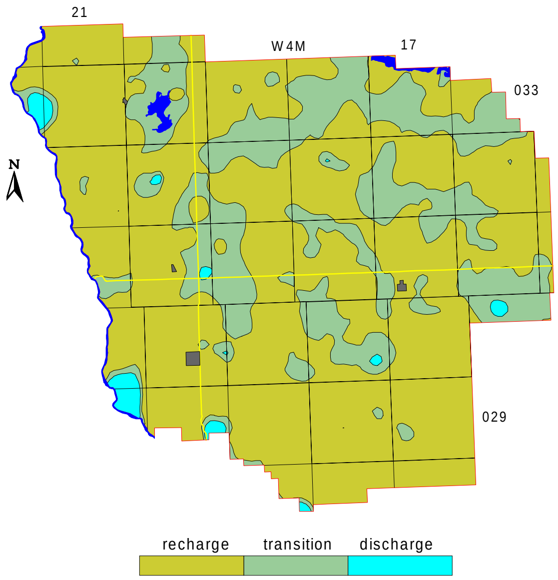

Figure 23. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)

5.3.1.2 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, i.e. recharge to the bedrock aquifers. 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 Upper Horseshoe Canyon Aquifer indicates that in more than 70% of the County where the Upper Horseshoe Canyon Aquifer is present, there is a downward hydraulic gradient. Discharge areas for the Upper Horseshoe Canyon Aquifer are associated with the edge of the Aquifer. The hydraulic relationship between the surficial deposits and the remainder of the bedrock aquifers present in the County indicates there is mainly a downward hydraulic gradient.

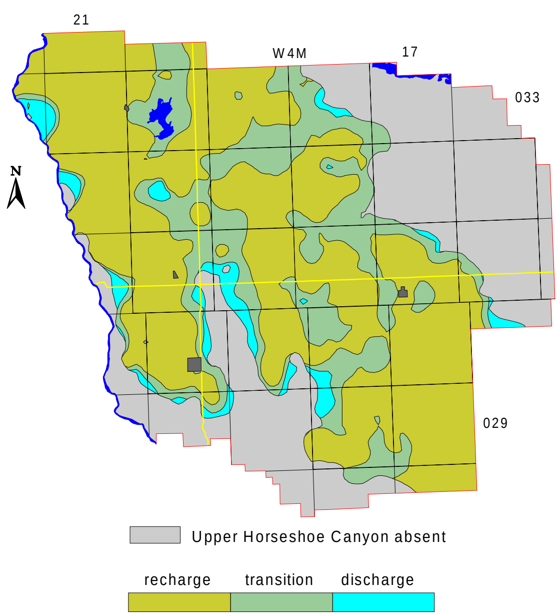

Figure 24. Recharge/Discharge Areas between Surficial Deposits and Upper Horseshoe Canyon Aquifer

6 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 the spreading of fertilizers, pesticides, herbicides and manure. The spreading of highway salt can also degrade groundwater quality.

When activities occur that can or do 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. In 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 1,018 records in the area of the County with lithological descriptions, 77 have sand and gravel within one metre of ground level. In the remaining 941 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.

6.1.1 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 5. Risk of Groundwater Contamination Criteria

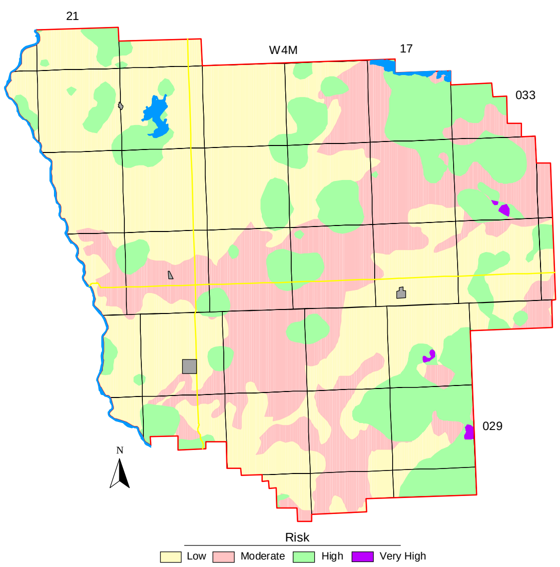

Figure 25. Risk of Groundwater Contamination

The Risk of Groundwater Contamination map shows that there is a high or very high risk of the groundwater being contaminated, in less than 25% of the County. 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.

7 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 first step would be to field-verify the 27 existing water wells listed in Appendix E. These water well records indicate that a complete water well drilling report is available along with at least a partial chemical analysis. 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 linear bedrock low present in the western part of the County. The present analysis has shown that the groundwater flow in the Upper Horseshoe Canyon Aquifer may not be sufficient to sustain the authorized diversion by AEP. However, because this analysis is based on a regional study, the results should be considered no more than an indication and further work should be completed to quantify the flow through the aquifers.

In the bedrock there are indications that a useable aquifer may be present in parts of the Oldman Aquifer. The top of the Oldman Aquifer varies between 250 and 550 metres below ground level. This Aquifer would represent the maximum depth that can be considered for the development of groundwater supplies for traditional purposes. Because of the depth of the Aquifer, it would not normally be developed because of the cost and the risk of not encountering a suitable groundwater supply. Therefore, a test-drilling program could be considered to evaluate the Oldman Aquifer in areas where only limited groundwater supplies are available from shallower aquifers. One such area could be in the southwestern part of the County where less than 10 m^3/day of groundwater is available from the Middle Horseshoe Canyon Aquifer. The purpose of the program would be to determine the parameters of the Oldman Aquifer and the chemical quality of the groundwater from the Oldman Aquifer to assist local residents in determining if an attempt should be made to develop a groundwater supply from the Oldman Aquifer.

One of the main shortages of data for the determination of a groundwater budget is water levels as a function of time. There are no 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, for example, 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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9 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.
Friable	poorly cemented.
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.
Piper tri-linear diagram	a method that permits the major cation and anion compositions of single or multiple samples to be represented on a single graph. This presentation allows groupings or trends in the data to be identified.
Shoreface	the narrow zone seaward from the low-tide shoreline, permanently covered by water, over which beach sand and gravels actively oscillate with changing wave conditions.
Surficial Deposits	includes all sediments above the bedrock.
Till	a sediment deposited directly by a glacier that is unsorted and consisting of any grain size ranging from clay to boulders.
Transgression	the speading of sea over land areas.

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.

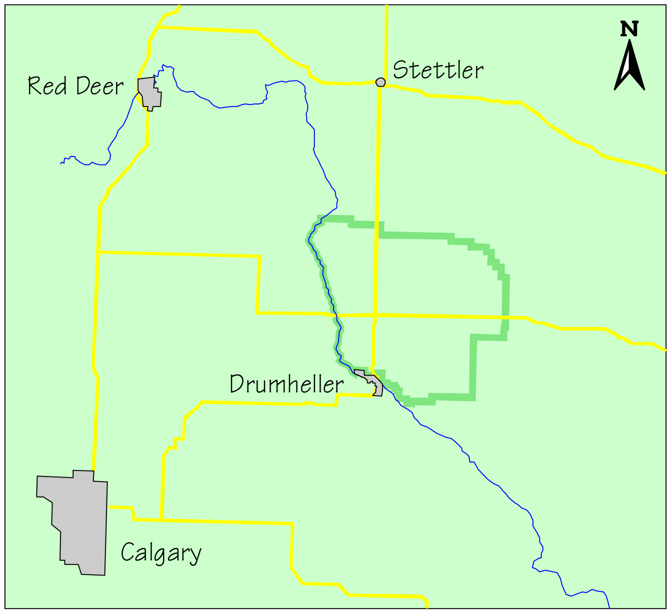
Apparent Yield: based mainly on apparent transmissivity.

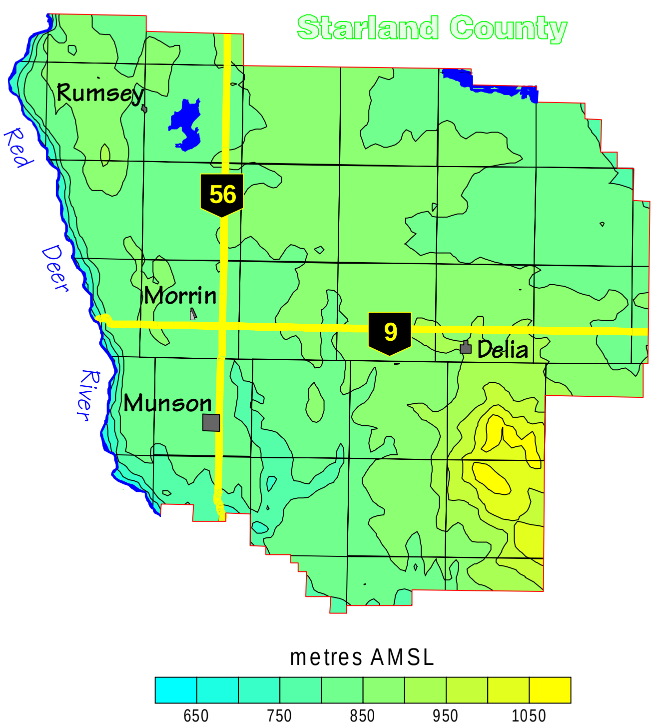
Long-Term Yield: based on effective transmissivity.

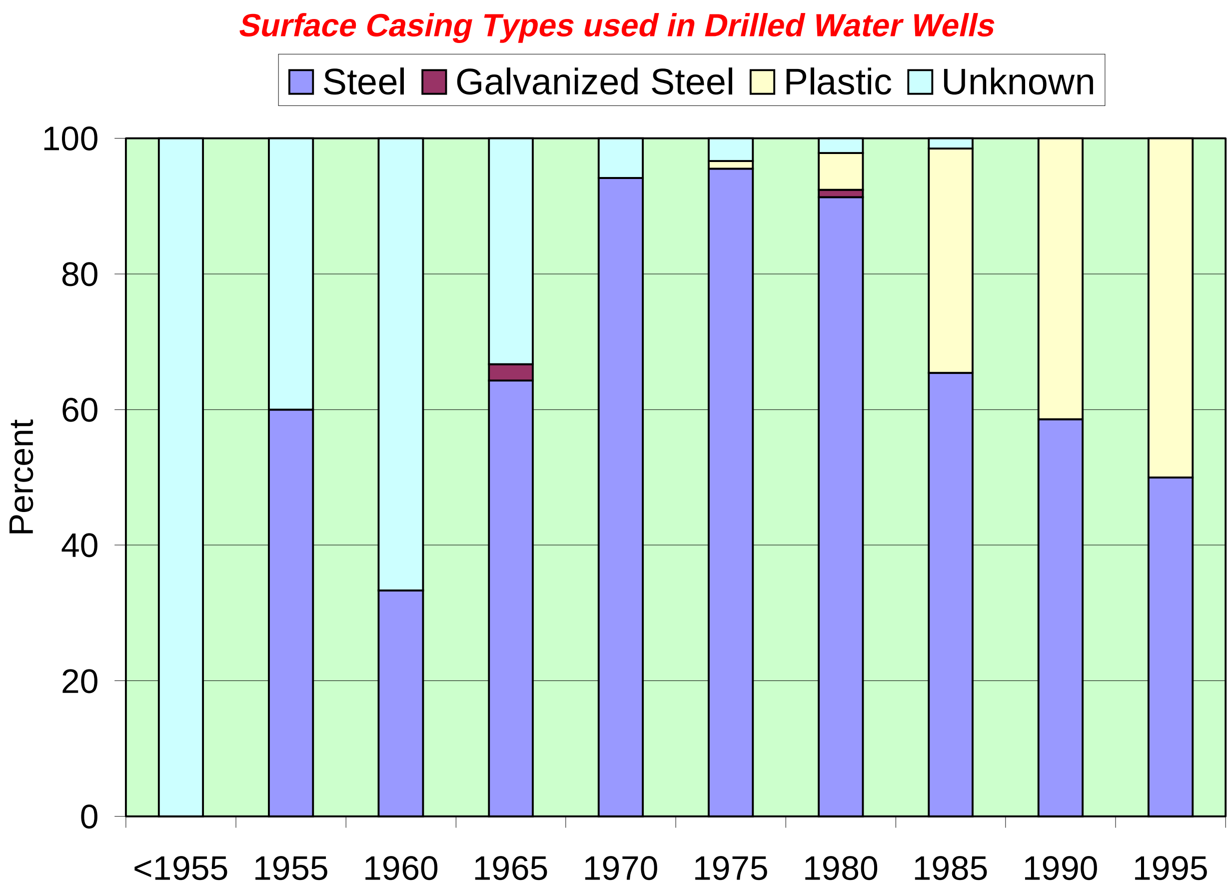
STARLAND COUNTY
Appendix A

HYDROGEOLOGICAL MAPS AND FIGURES

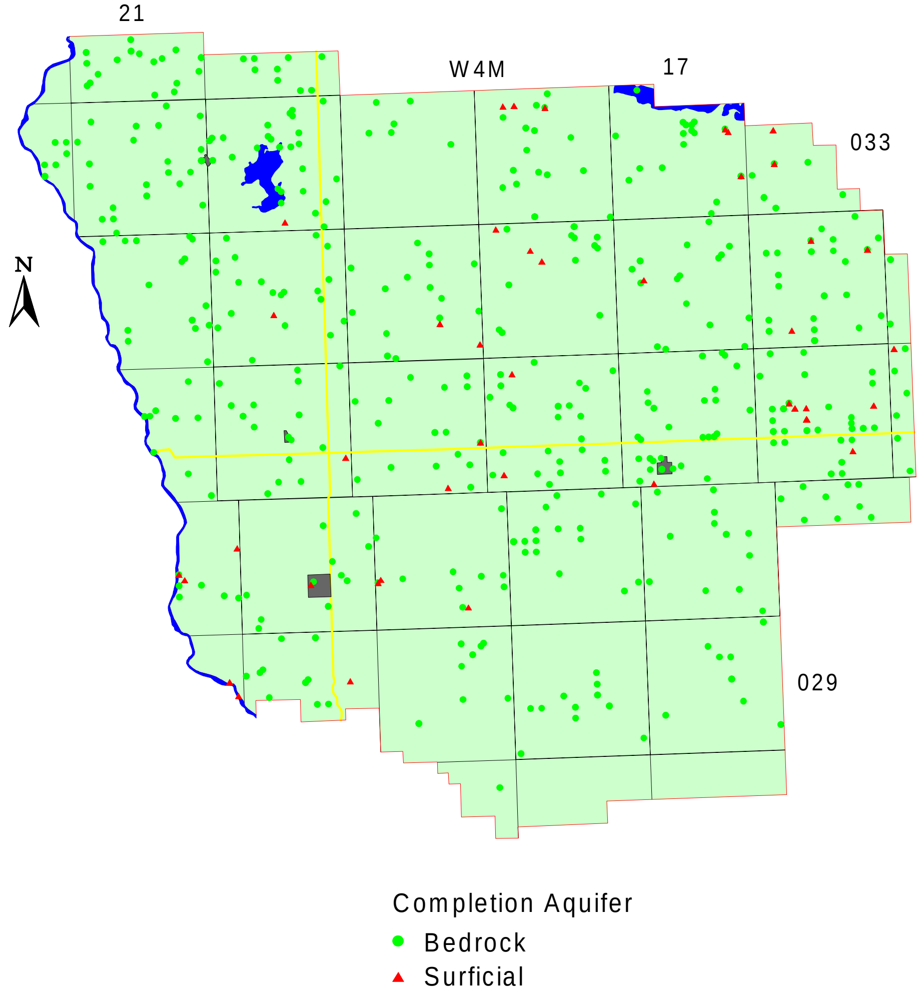
Index Map


N
Red Deer
Stettler
Drumheller
Calgary

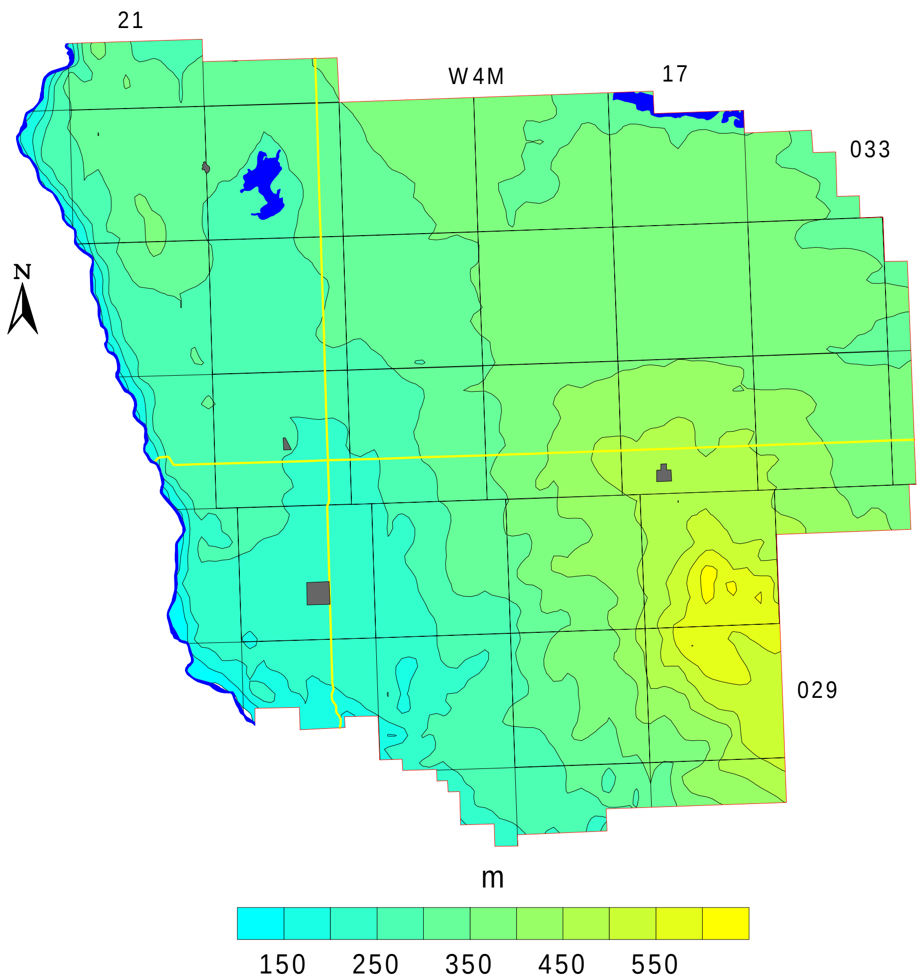

Starland County
Rumsey
56
Red
Deer
River
Morrin
9
Delia
Munson
metres AMSL
650
750
850
950
1050

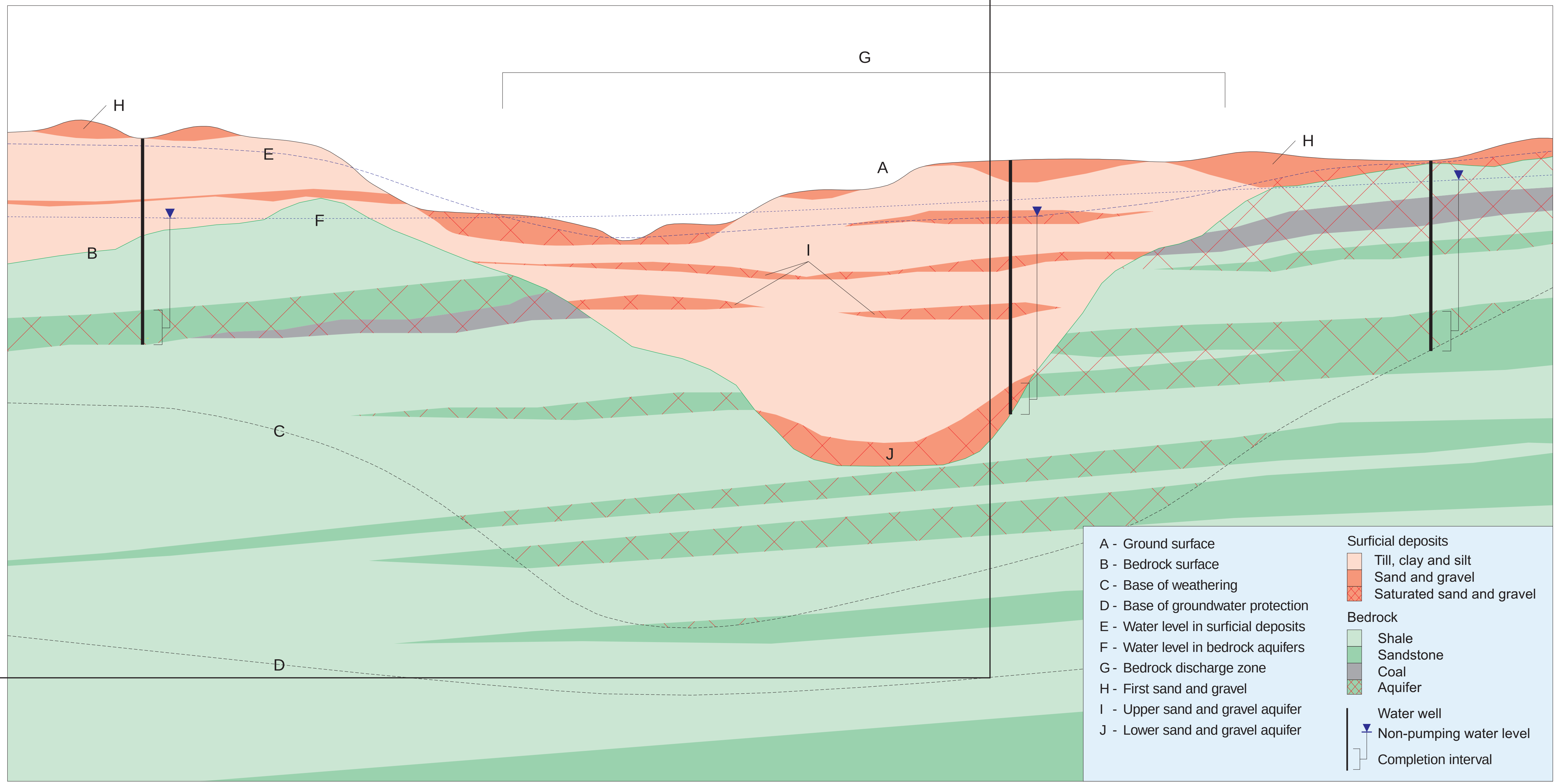

Surface Casing Types used in Drilled Water Wells
Steel
Galvanized Steel
Plastic
Unknown
Percent
100
80
60
40
20
0
<1955
1955
1960
1965
1970
1975
1980
1985
1990
1995

Location of Water Wells



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





Generalized Cross-Section
(for terminology only)

Lithologic Description	Group and Formation: Thickness (m)	Group	Group and Formation: Designation	Member: Thickness (m)	Member: Designation	Zone: Thickness (m)	Zone: Designation
sand, gravel, till, clay, silt	<60		Surficial Deposits	<60	Upper	<15	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	~100	Upper		
				~100	Middle		
				<10	Drumheller Member		
				~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	10-220	Belly River Group	*continental* Foremost Formation			<20	Taber Coal Zone
						<20	McKay Coal Zone
sandstone, shale	<200	Belly River Group	*marine* Foremost Formation (Basal Belly River Sandstone)	<30	Birch Lake Member		Milan Aquifer
				<30	Ribstone Creek Member		
				<30	Victoria Member		
				<30	Brosseau Member		
shale, siltstone	100-200		Lea Park Formation	50-100	Upper		
				50-100	Lower		

Geologic Column

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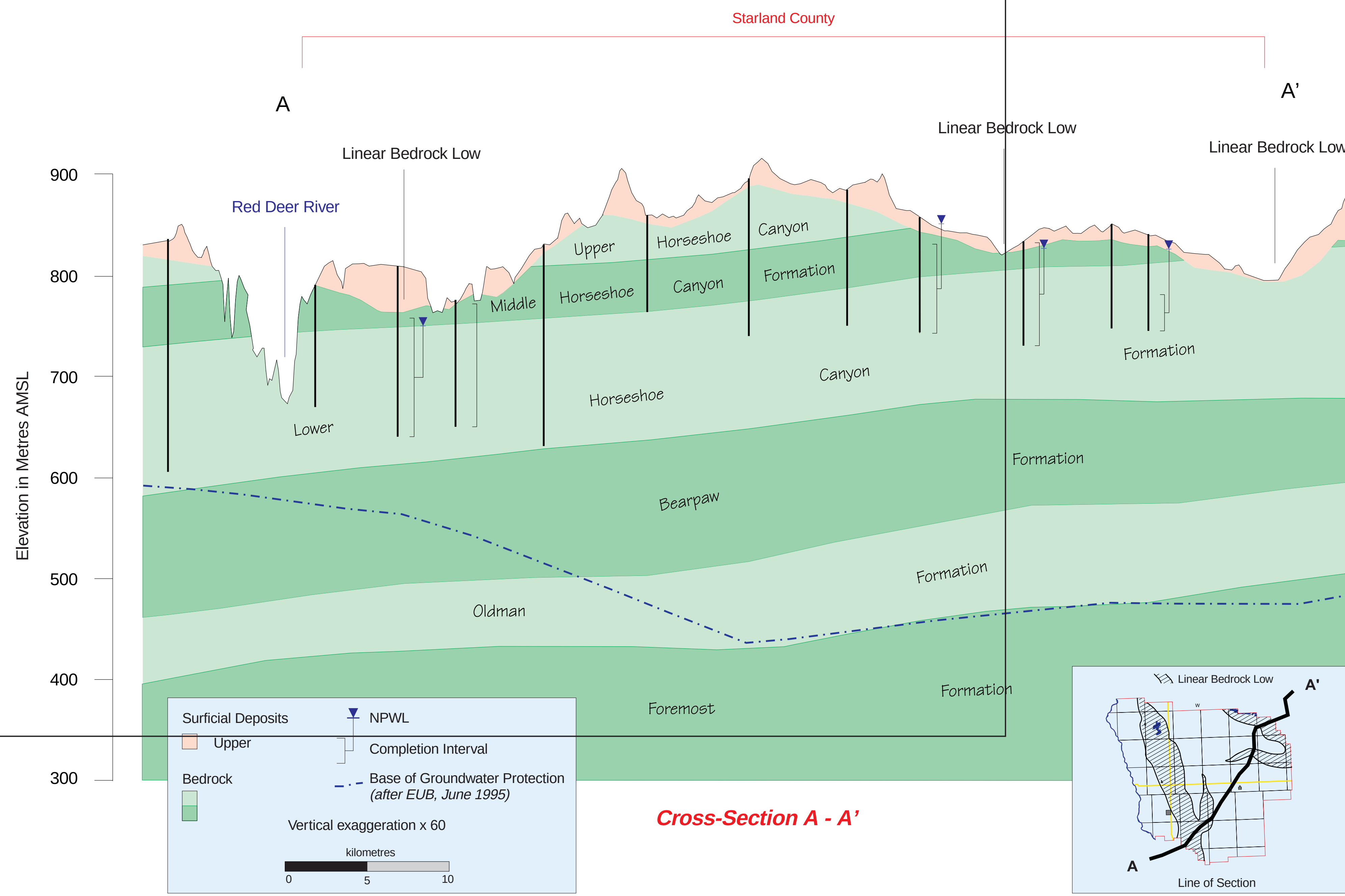
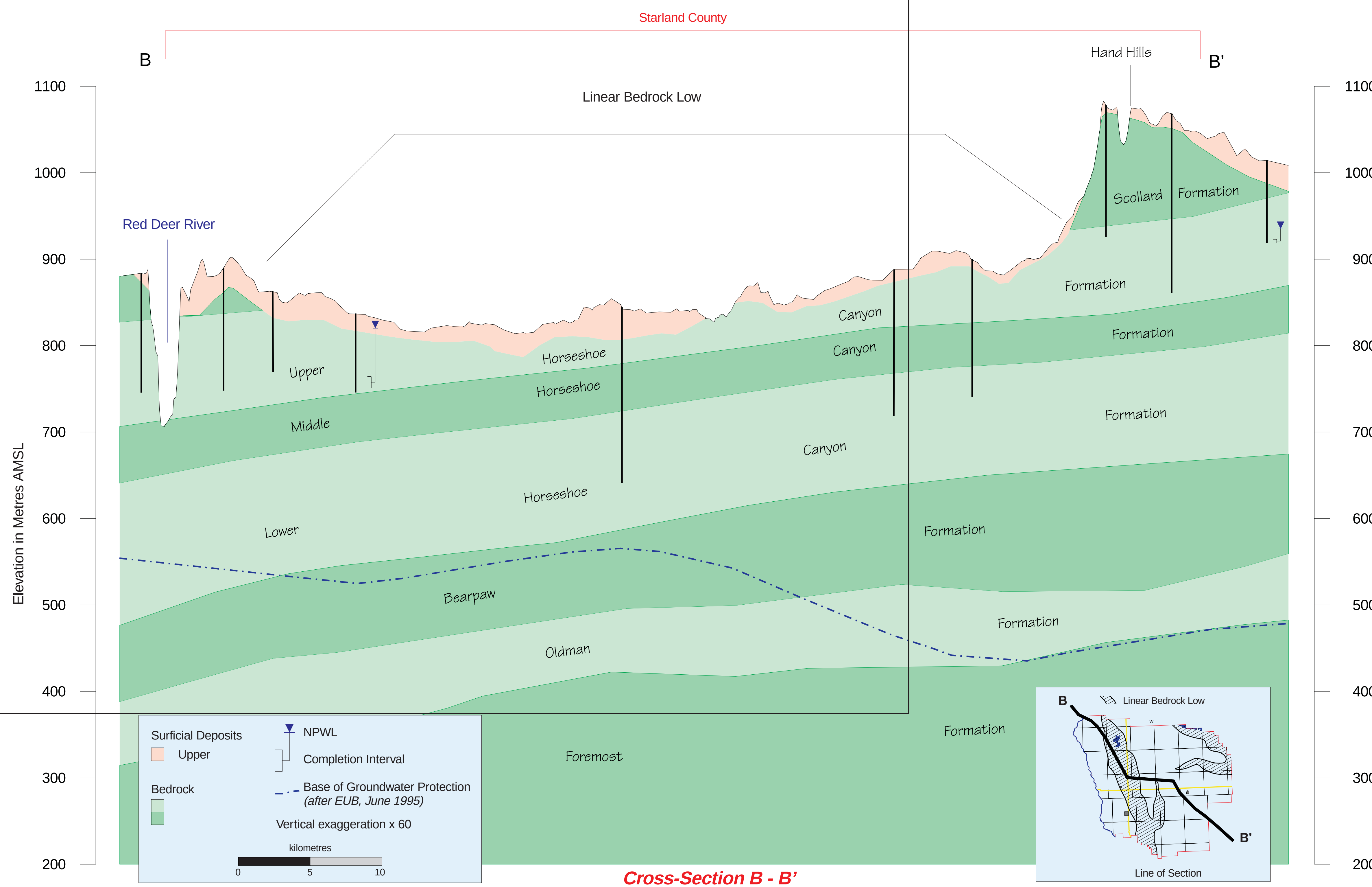


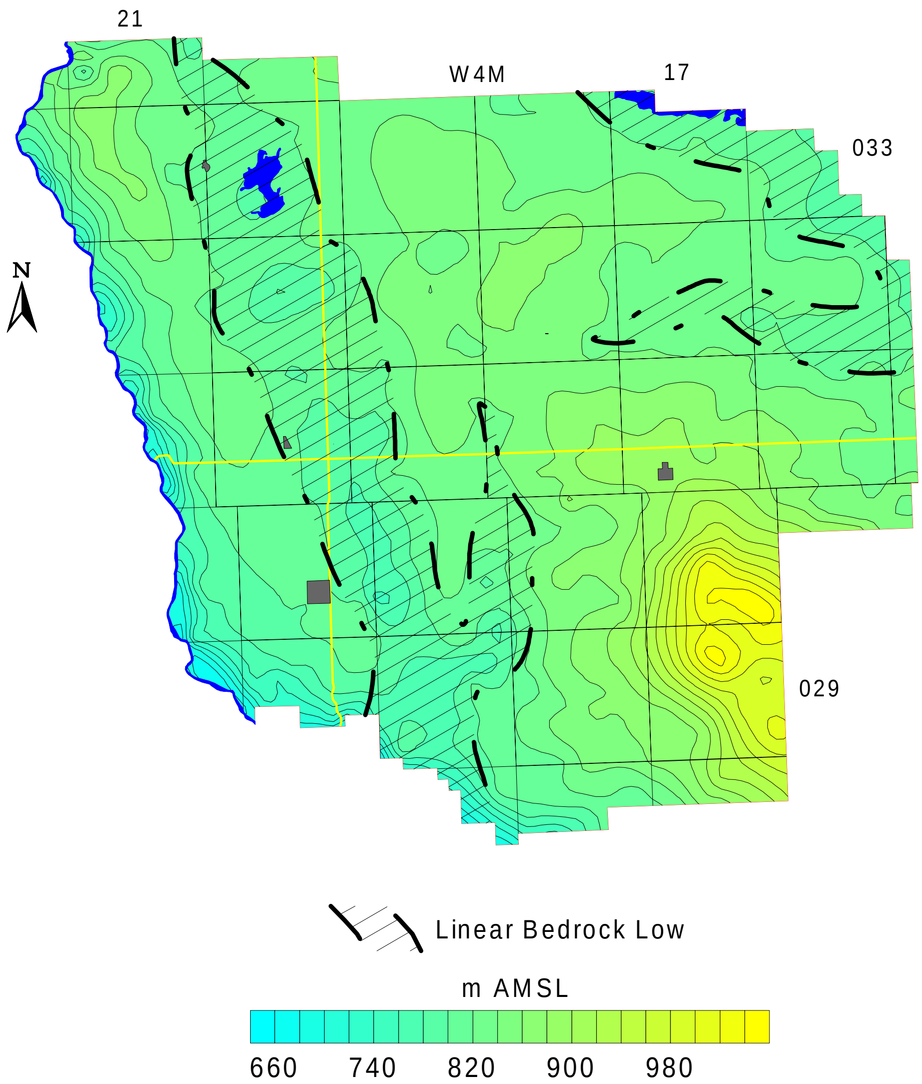
Cross-Section A - A'



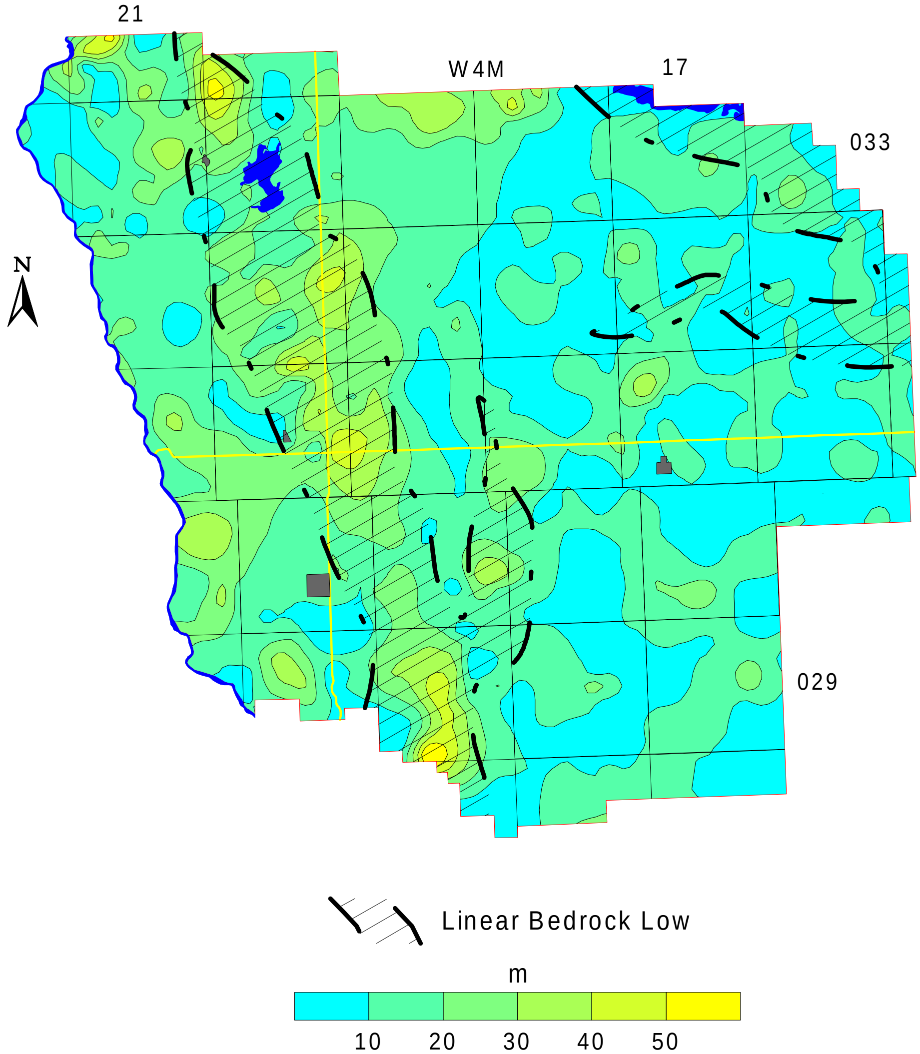
Cross-Section B - B'

hydrogeological consultants ltd.

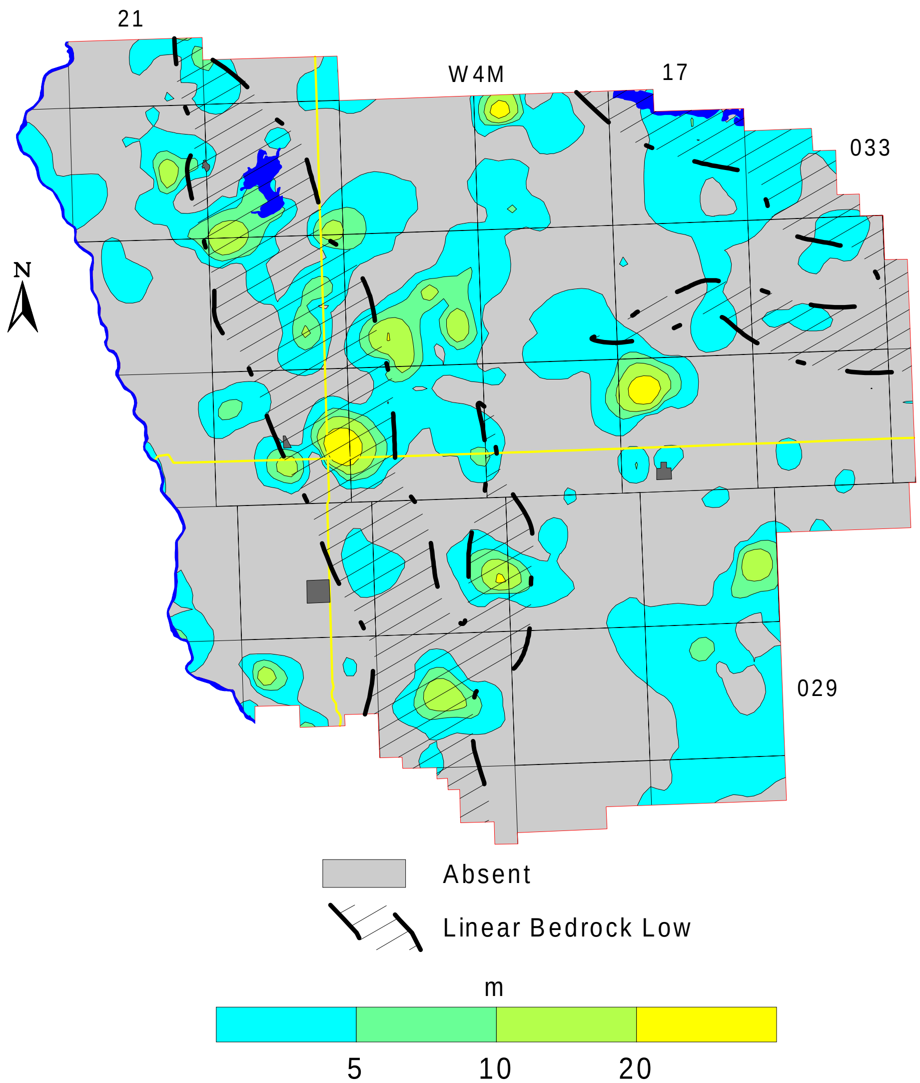
Bedrock Topography



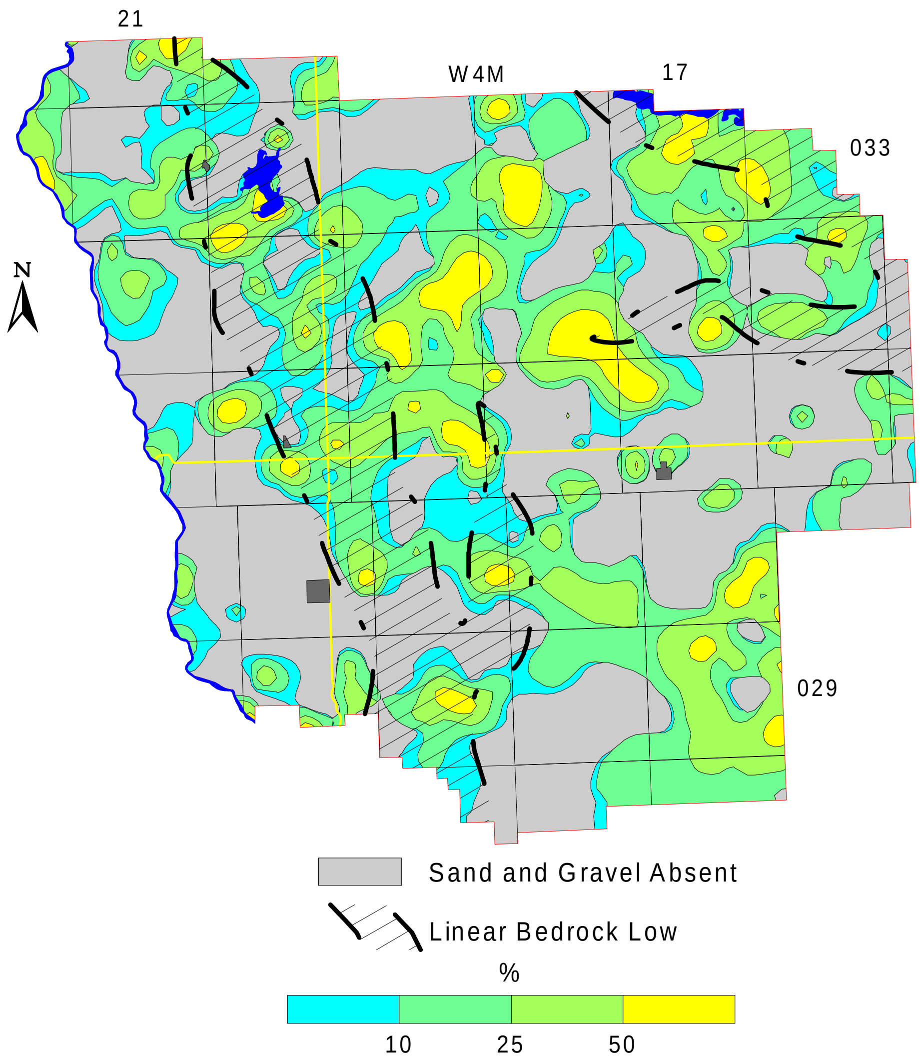
Thickness of Surficial Deposits



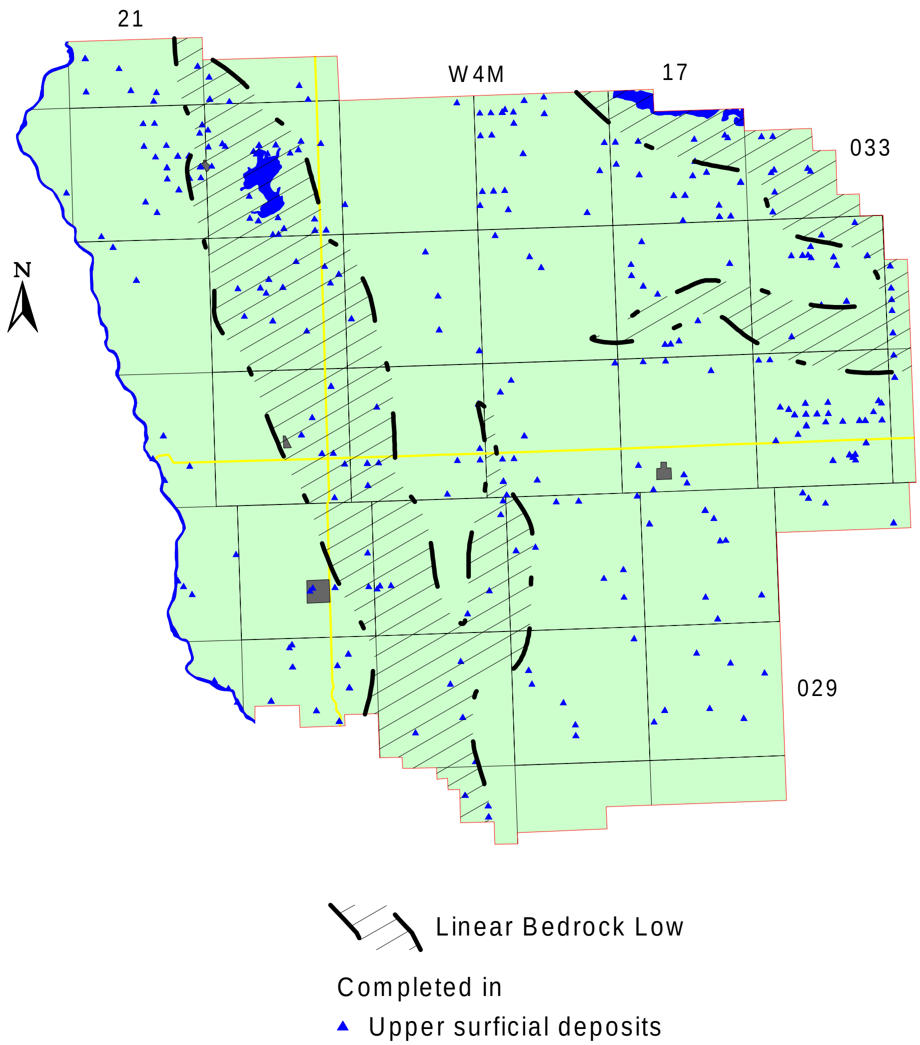
Thickness of Sand and Gravel Aquifer(s)



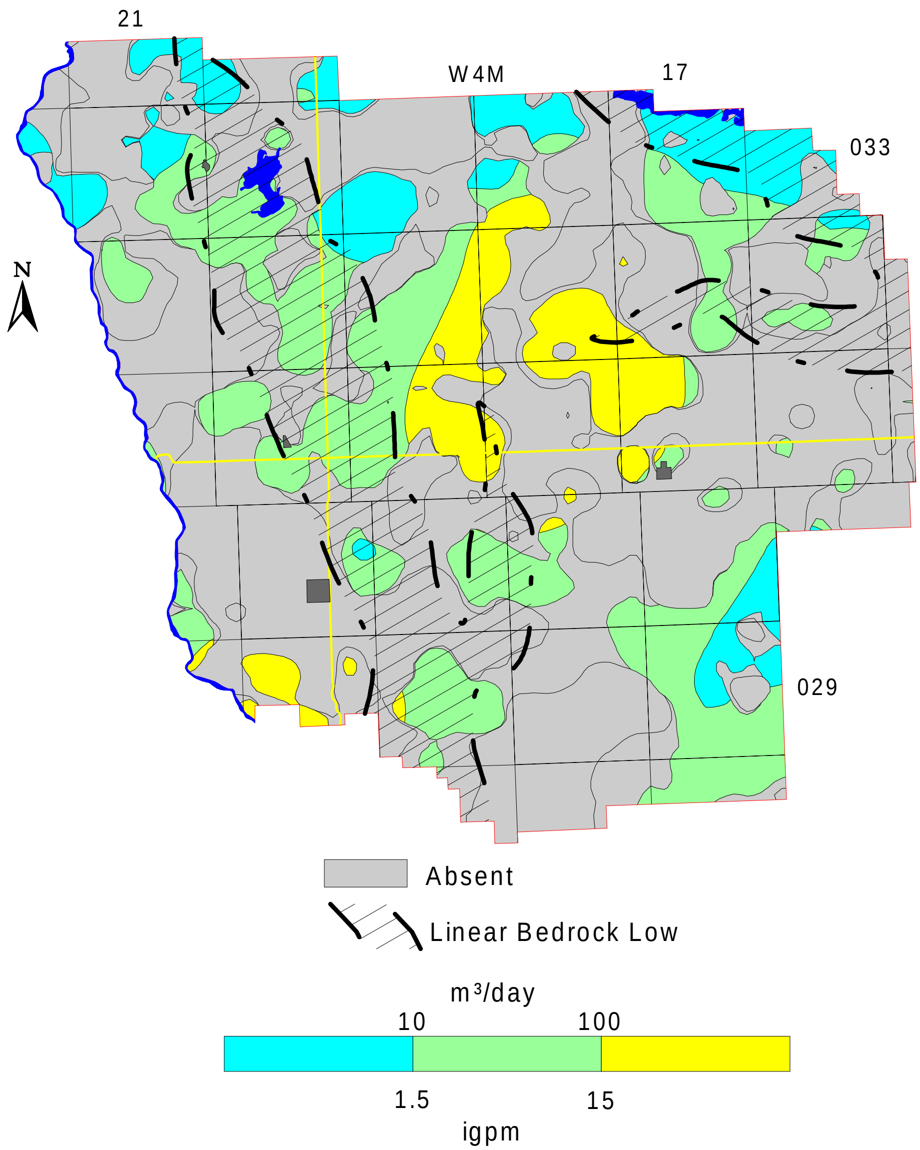
Amount of Sand and Gravel in Surficial Deposits



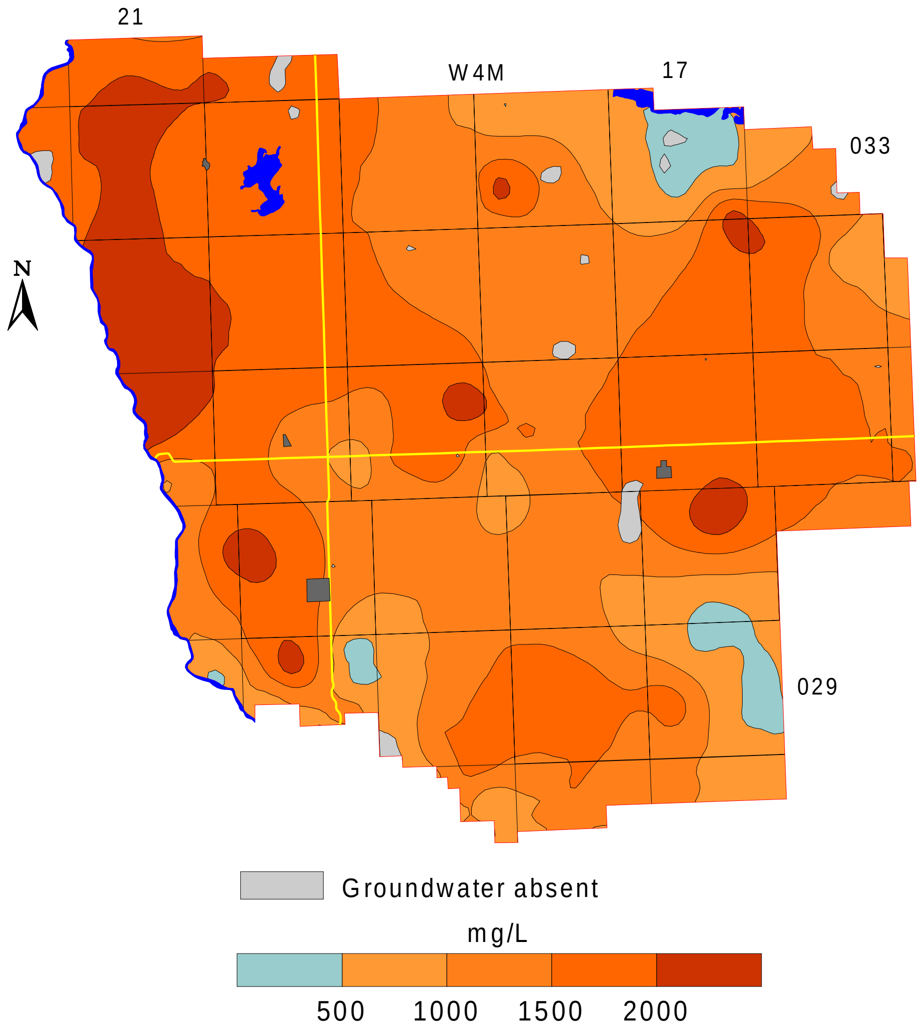
Water Wells Completed in Surficial Deposits



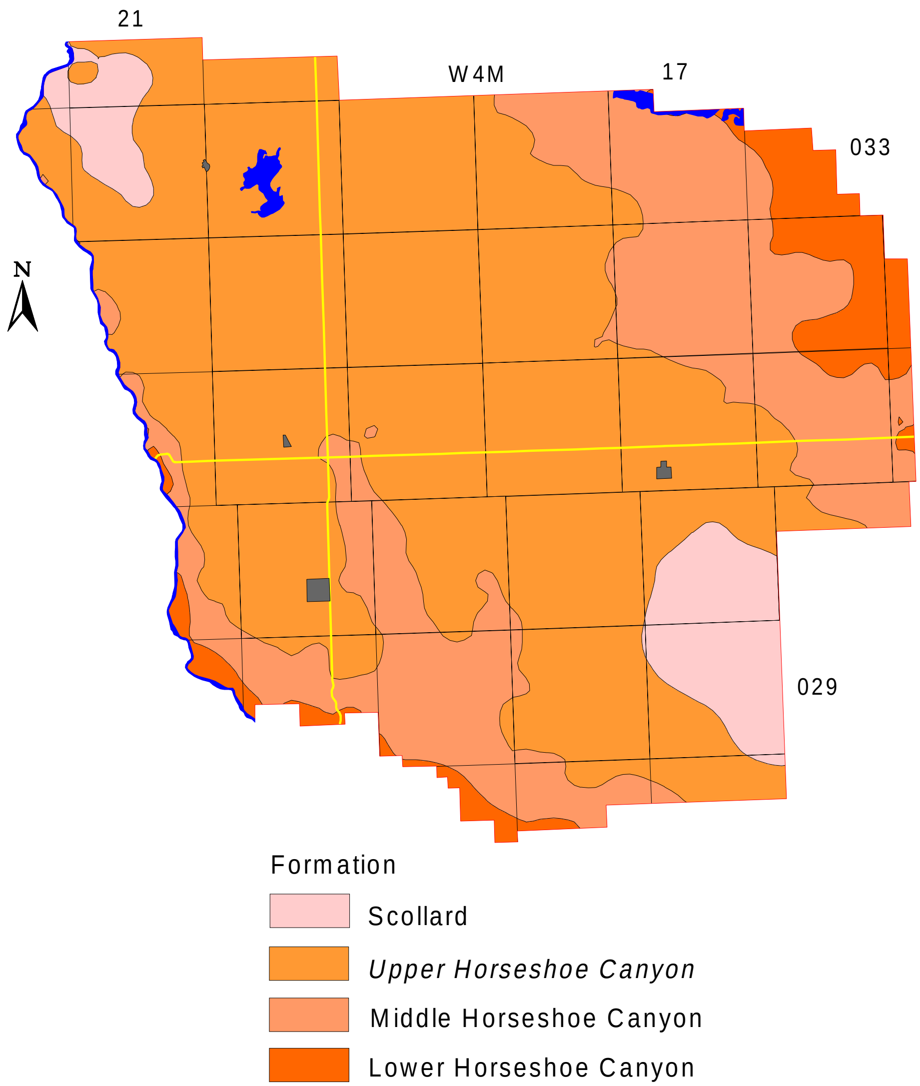
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)



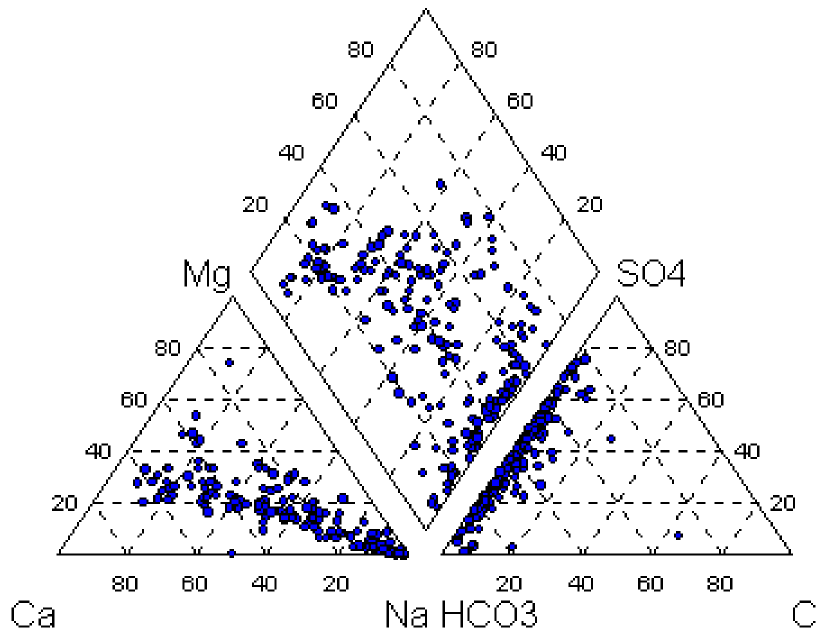
Total Dissolved Solids in Groundwater from Surficial Deposits



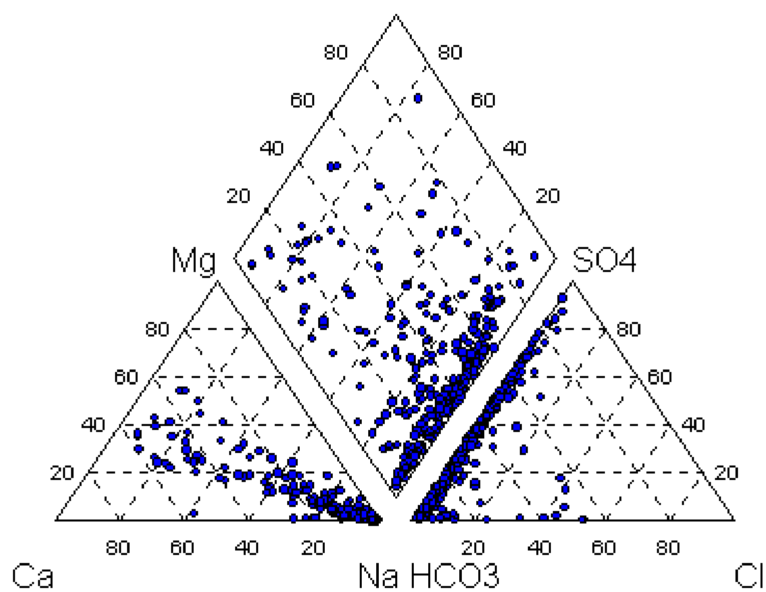
Bedrock Geology



Piper Diagrams

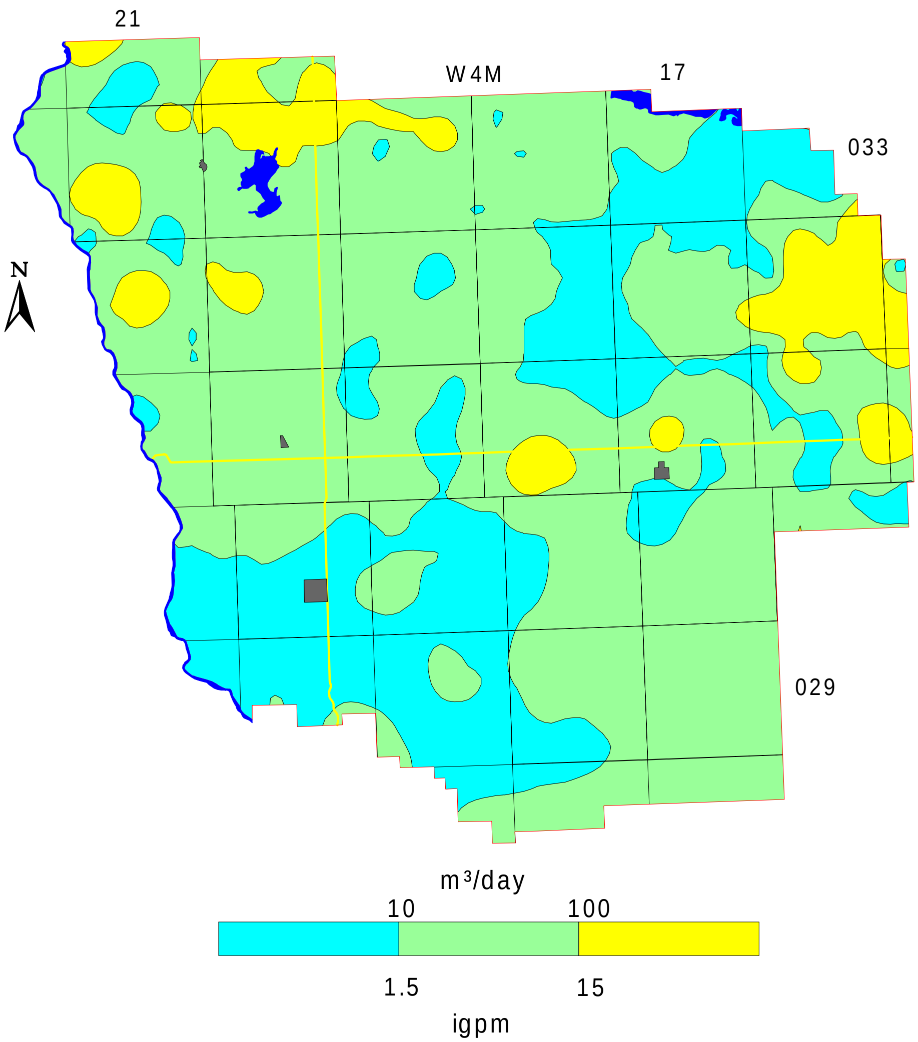


Surficial Deposits

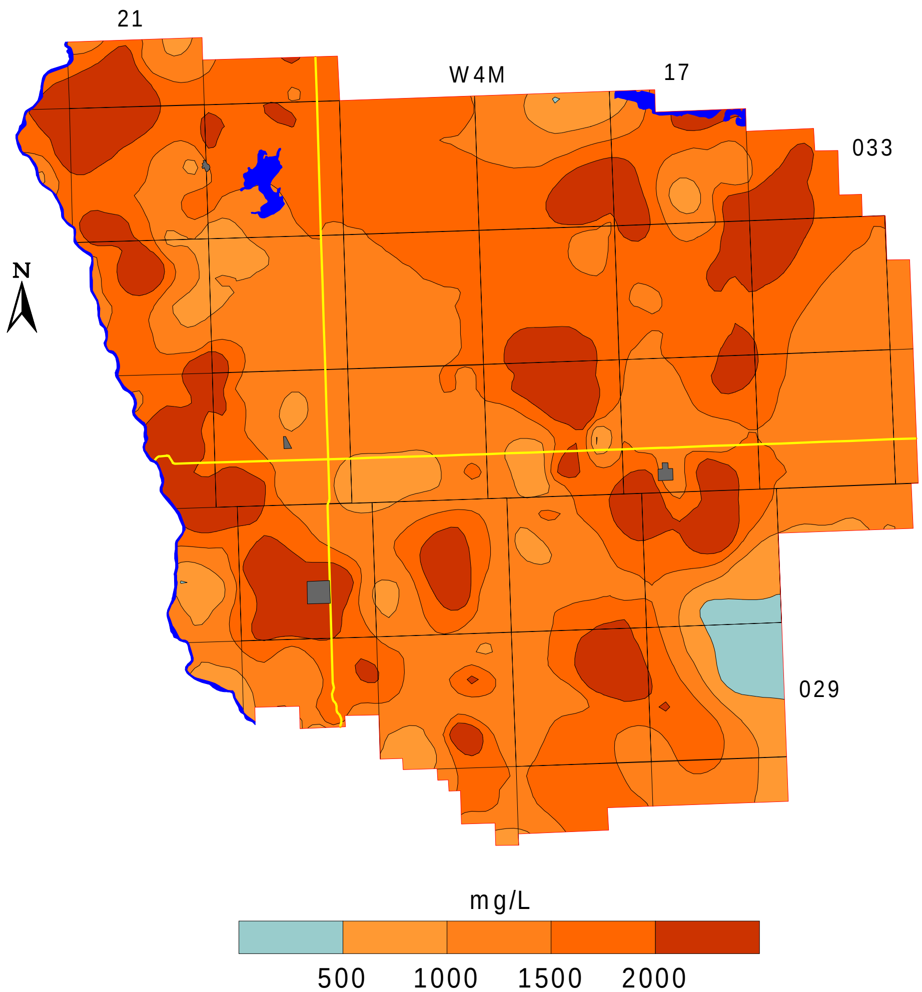


Bedrock Aquifers

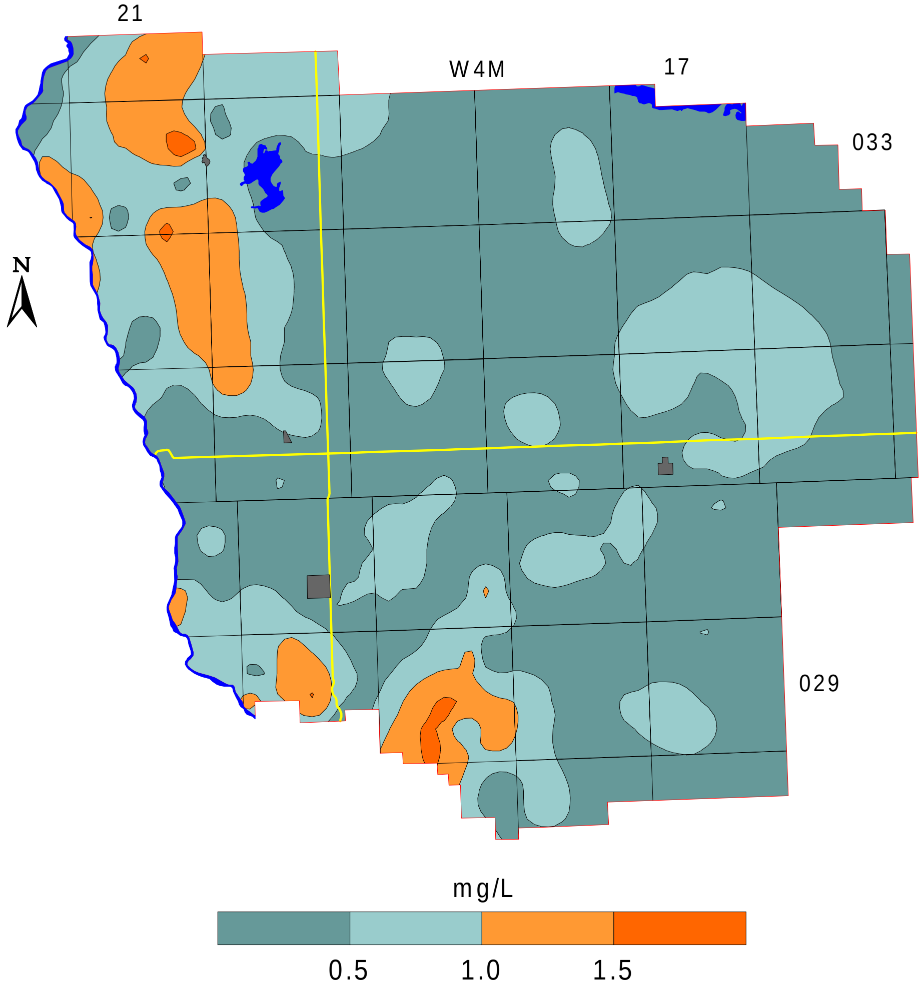
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



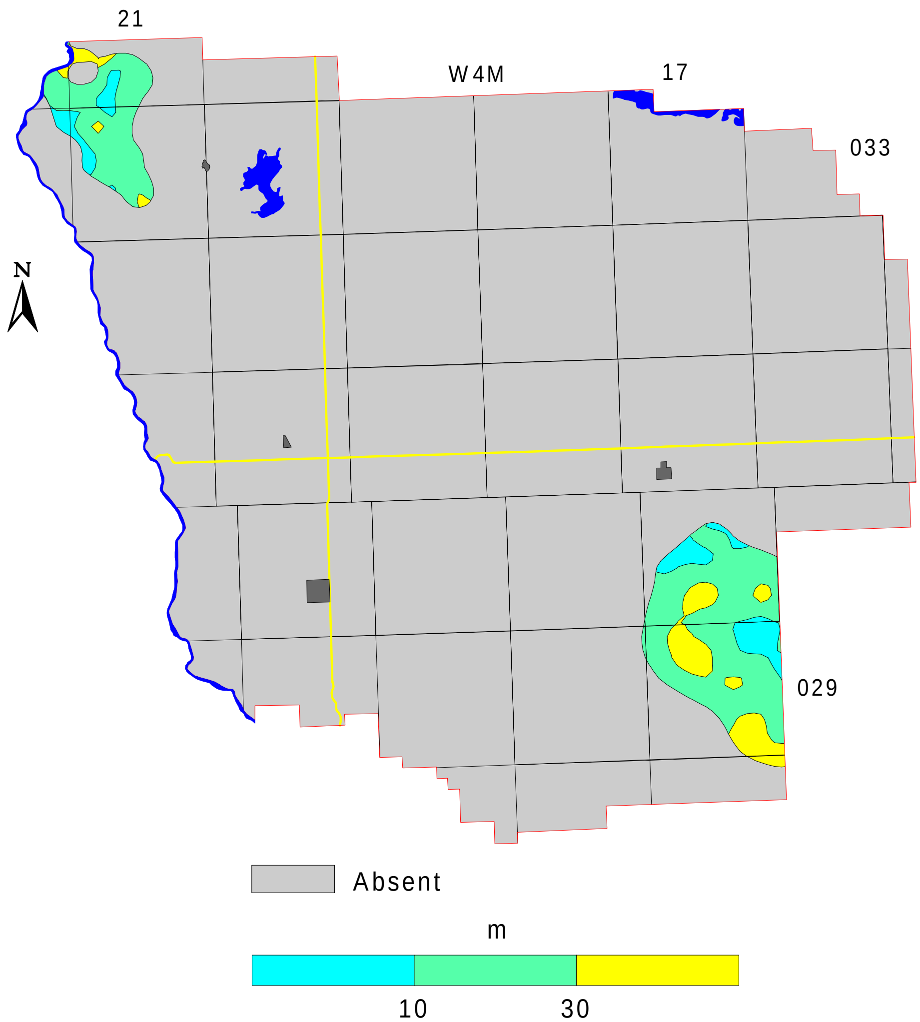
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



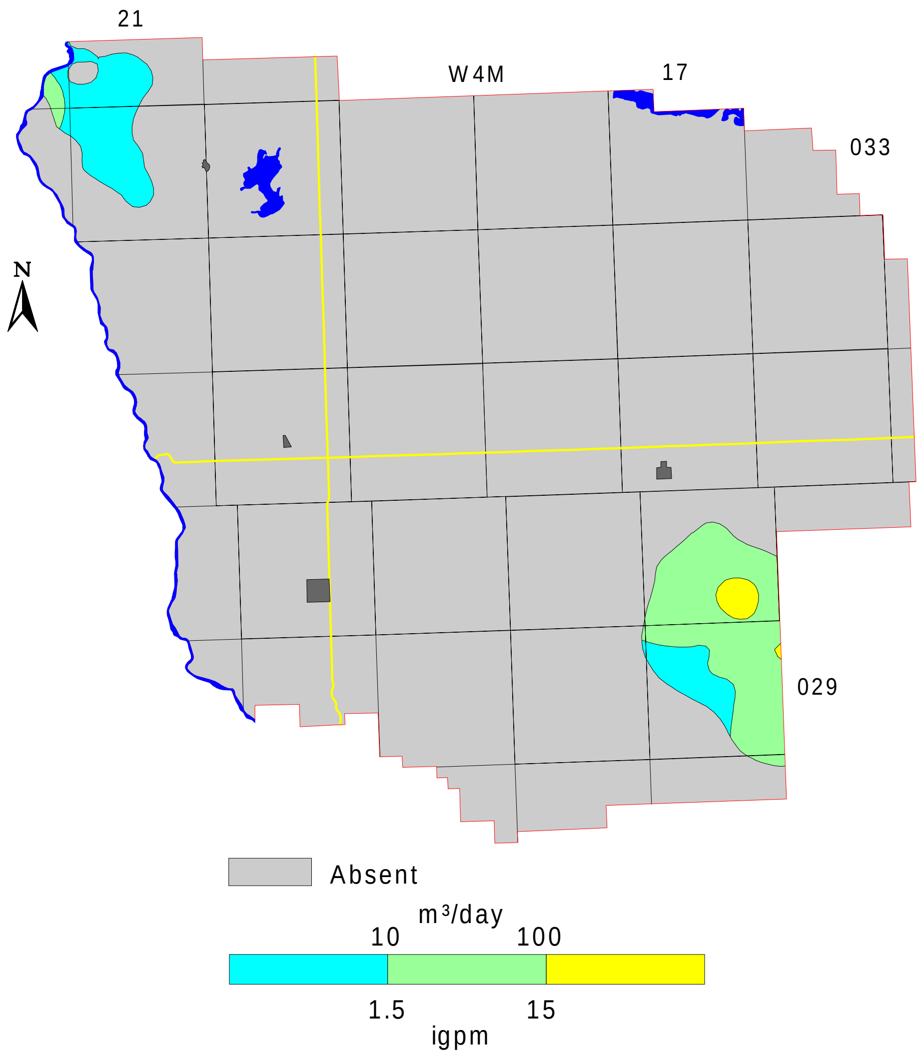
Fluoride in Groundwater from Upper Bedrock Aquifer(s)



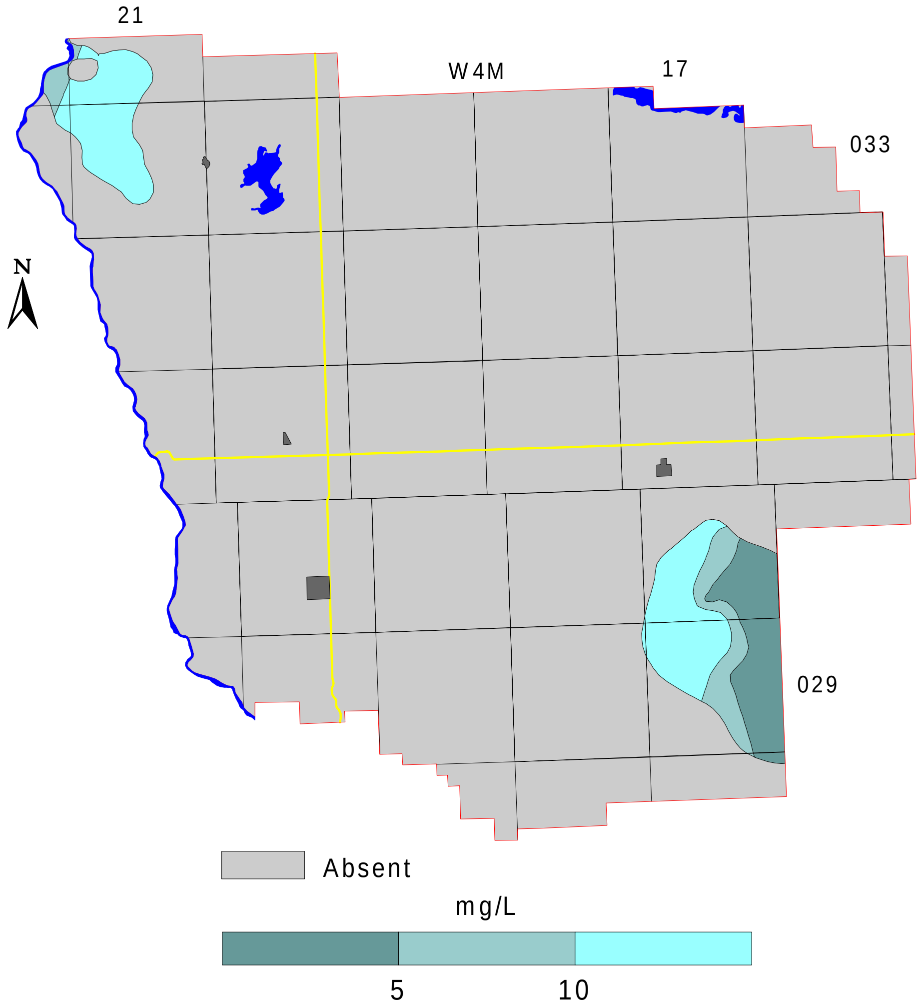
Depth to Top of Scollard Formation



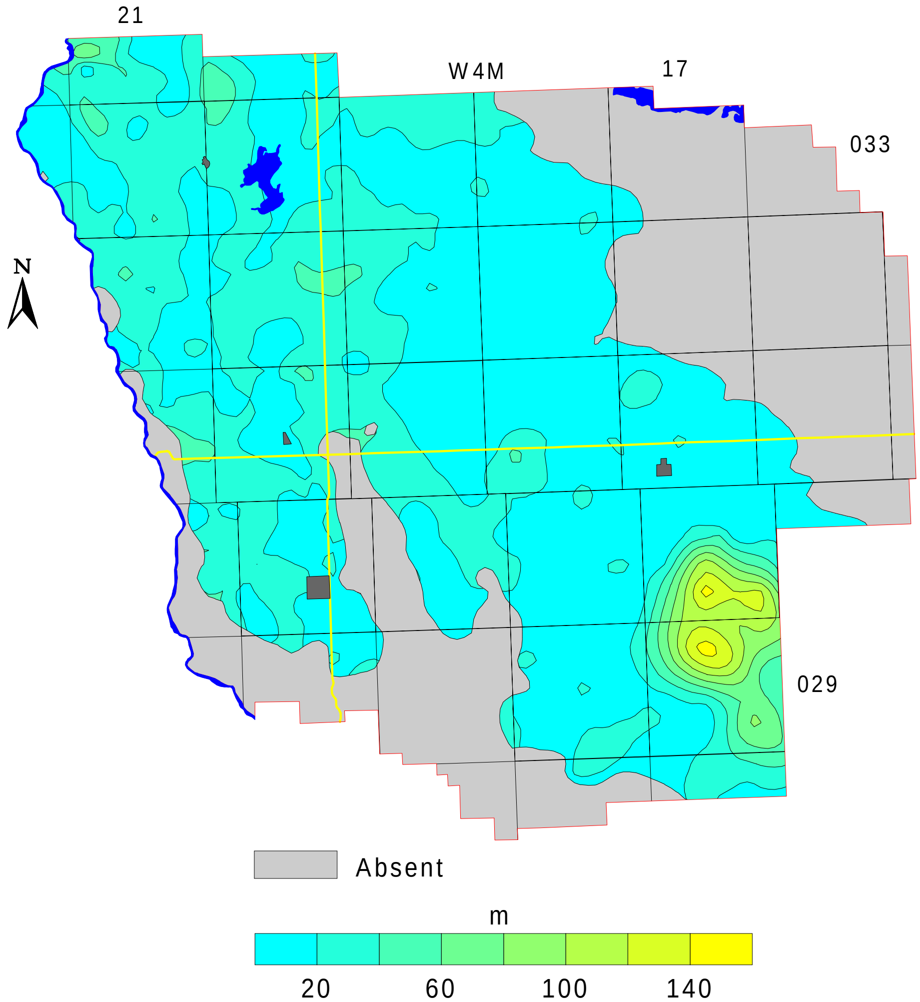
Apparent Yield for Water Wells Completed through Scollard Aquifer



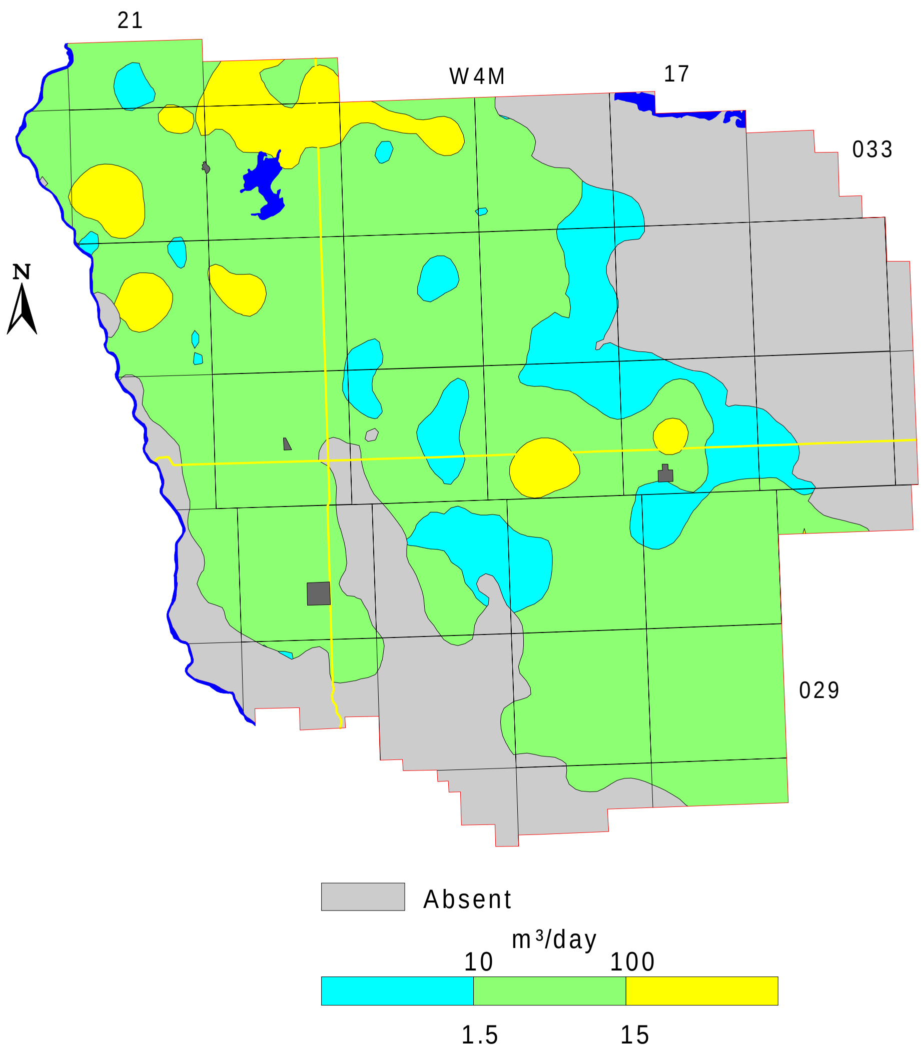
Chloride in Groundwater from Scollard Aquifer



Depth to Top of Upper Horseshoe Canyon Formation



Apparent Yield for Water Wells Completed through Upper Horseshoe Canyon Aquifer



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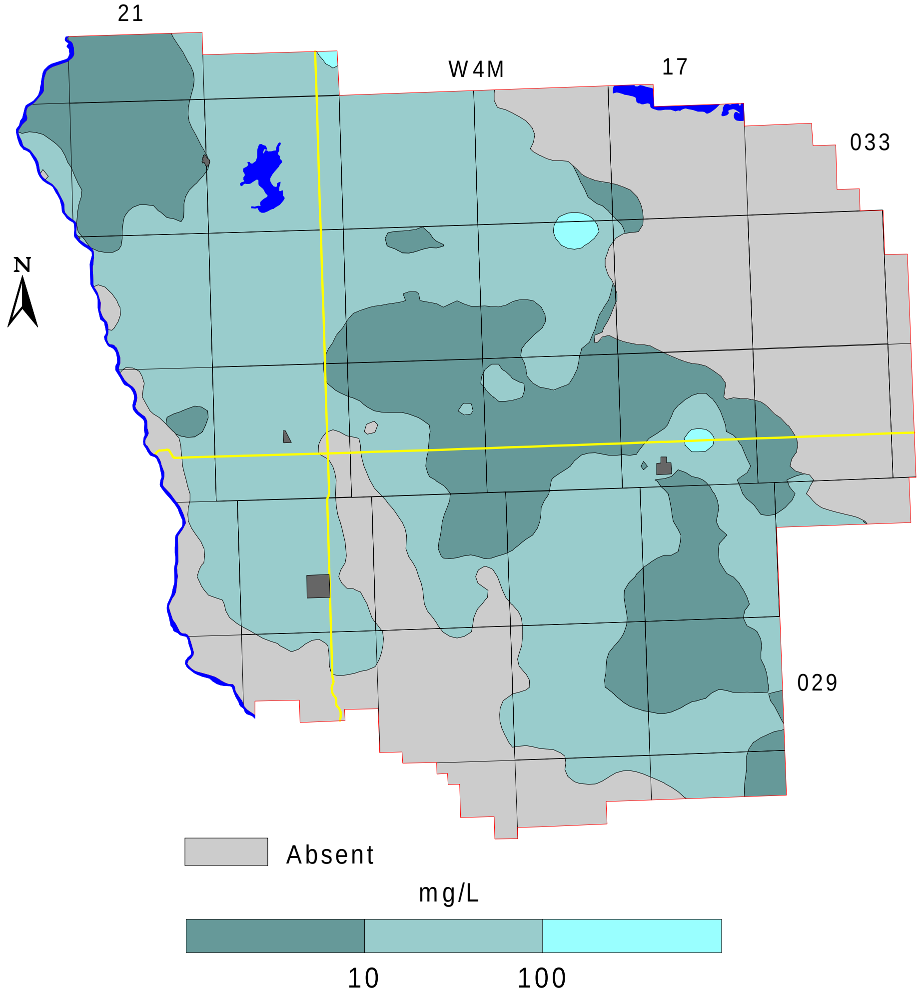
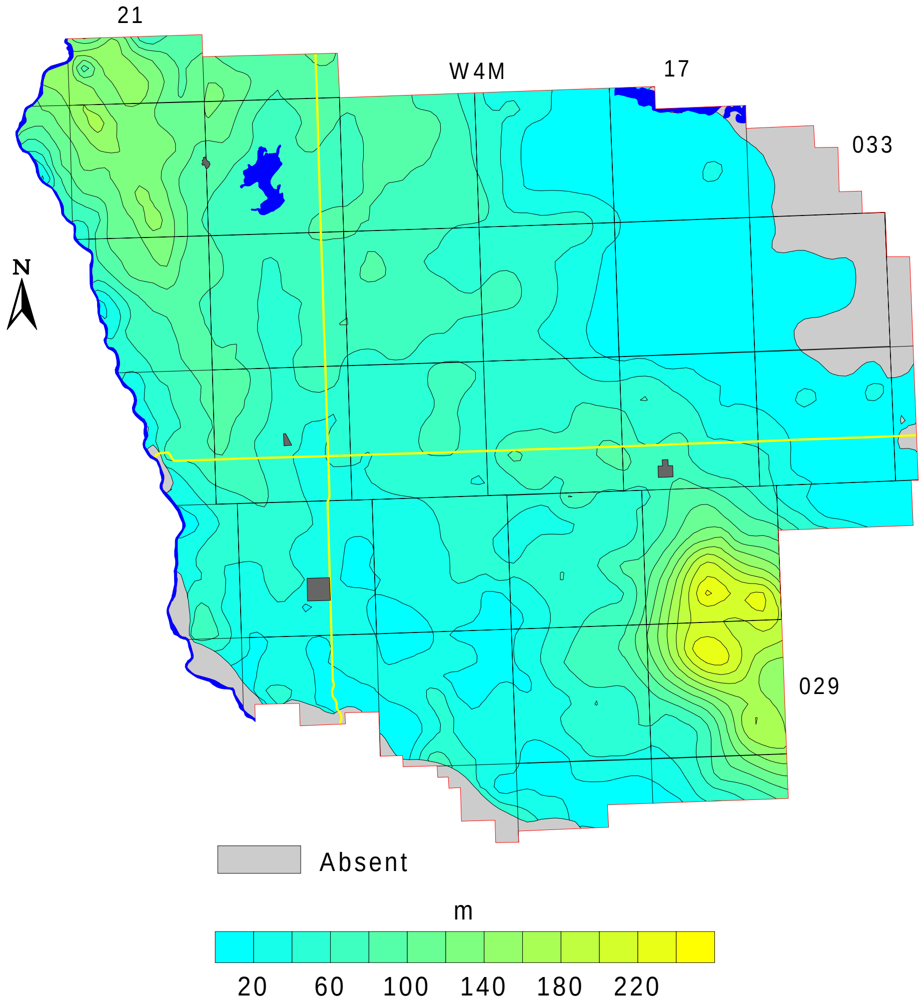
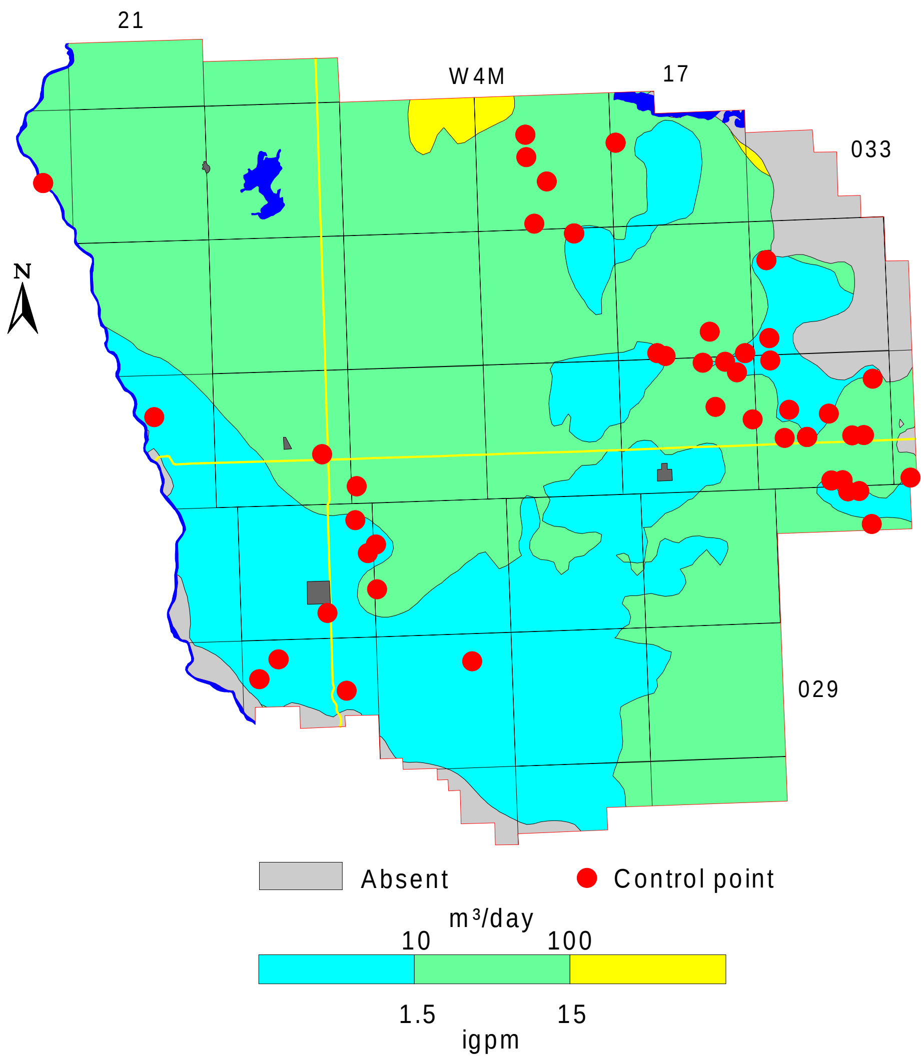
Chloride in Groundwater from Upper Horseshoe Canyon Aquifer



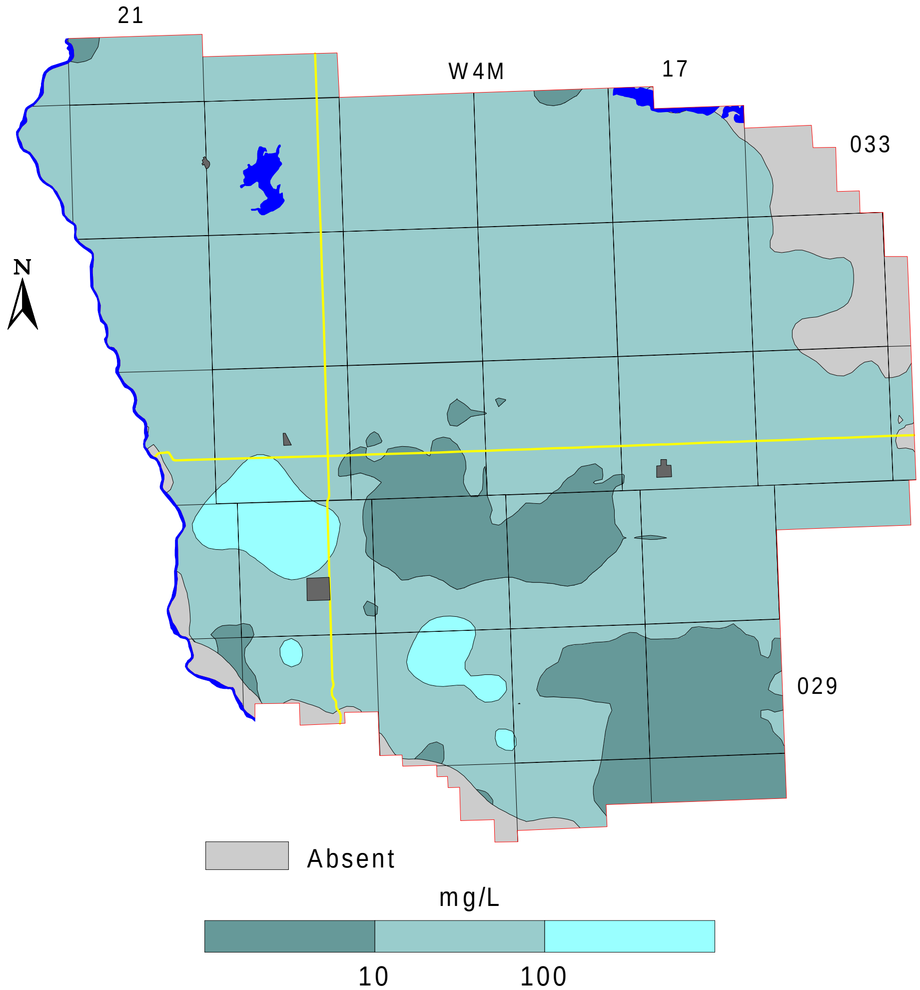
Depth to Top of Middle Horseshoe Canyon Formation



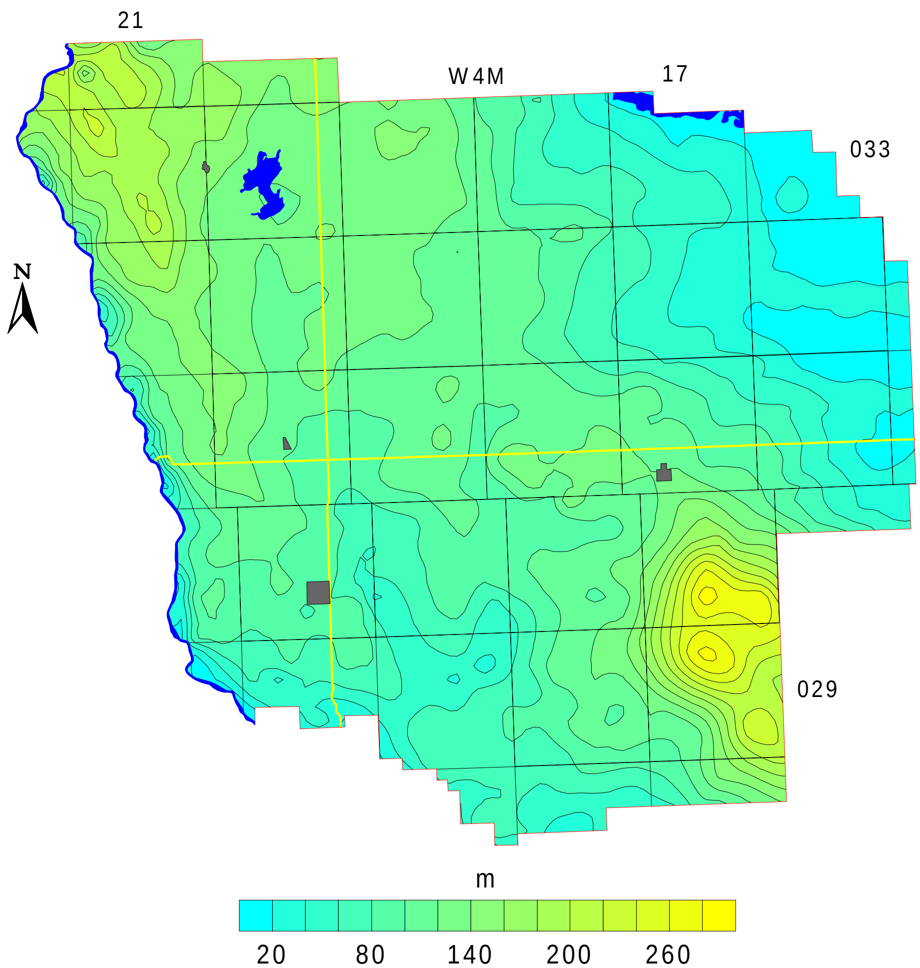
Apparent Yield for Water Wells Completed through Middle Horseshoe Canyon Aquifer



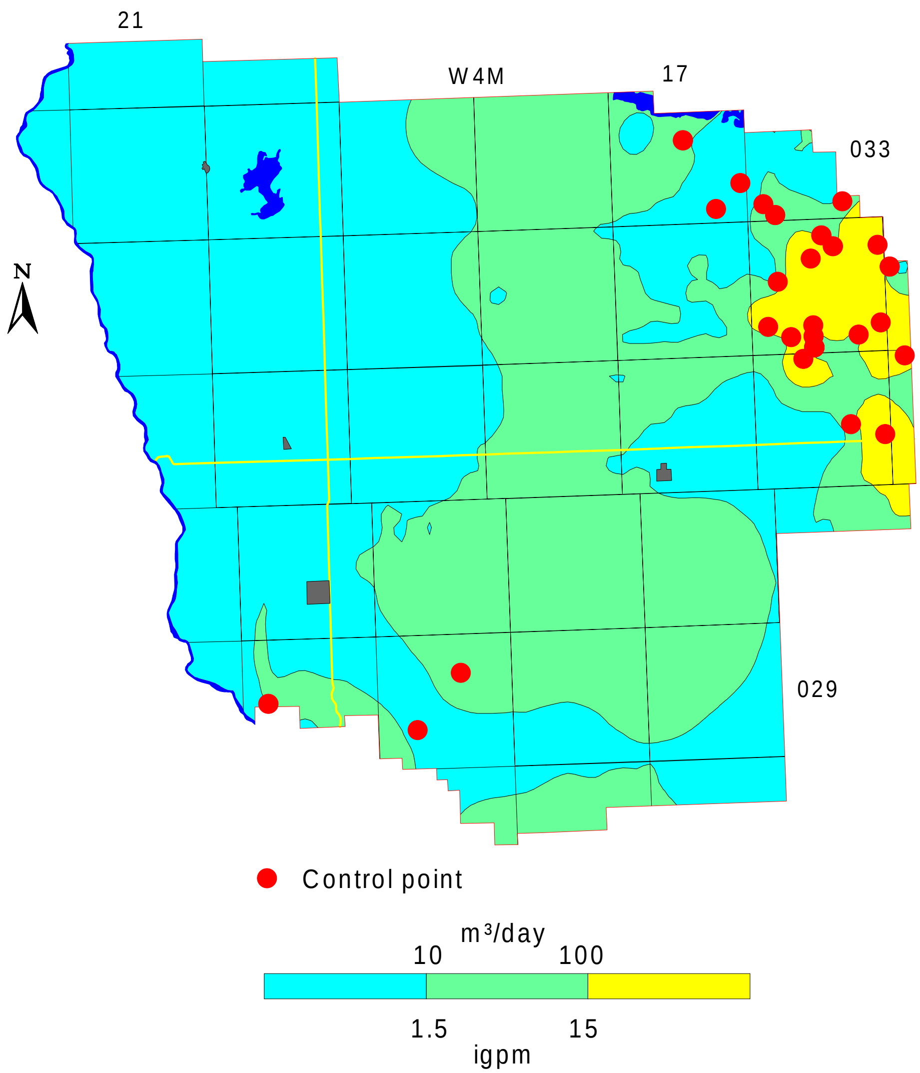
Chloride in Groundwater from Middle Horseshoe Canyon Aquifer



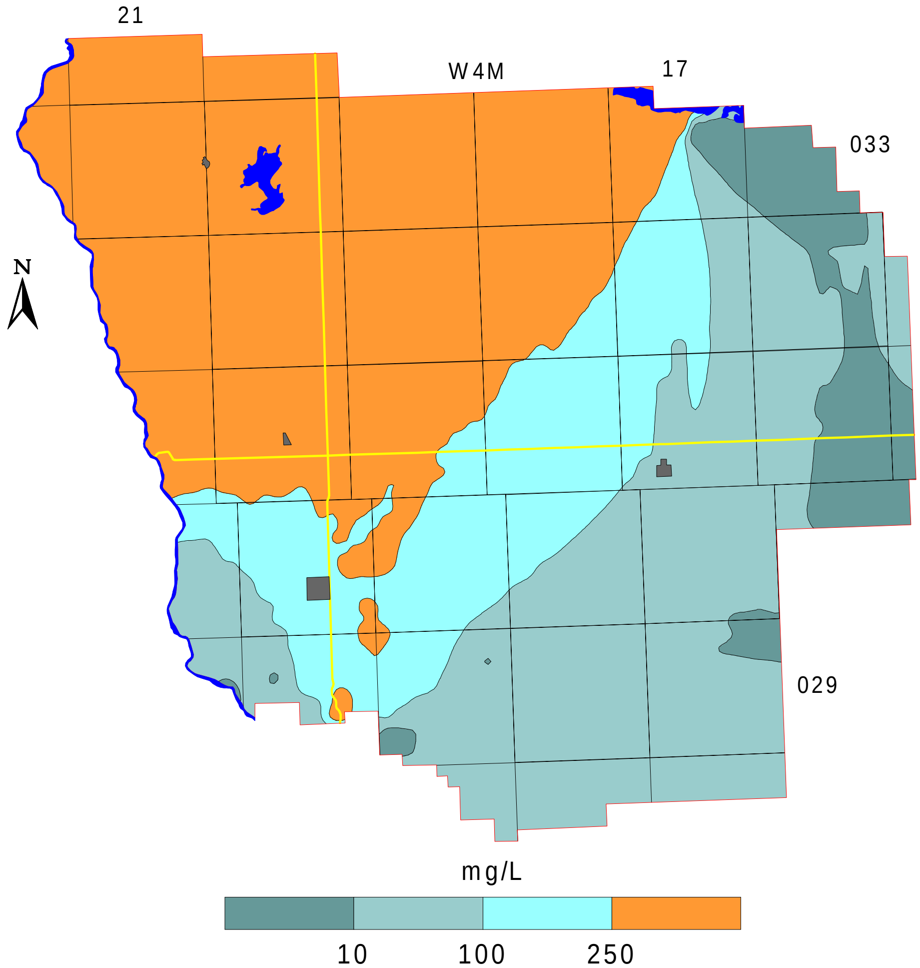
Depth to Top of Lower Horseshoe Canyon Formation



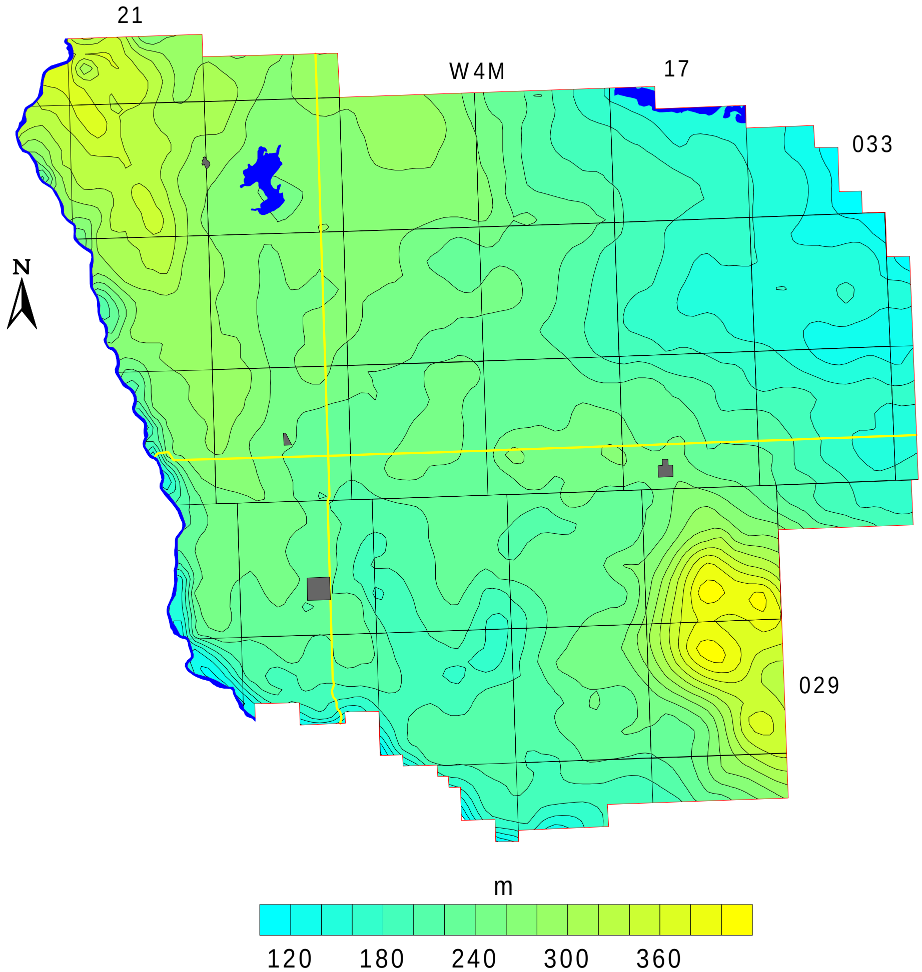
Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer



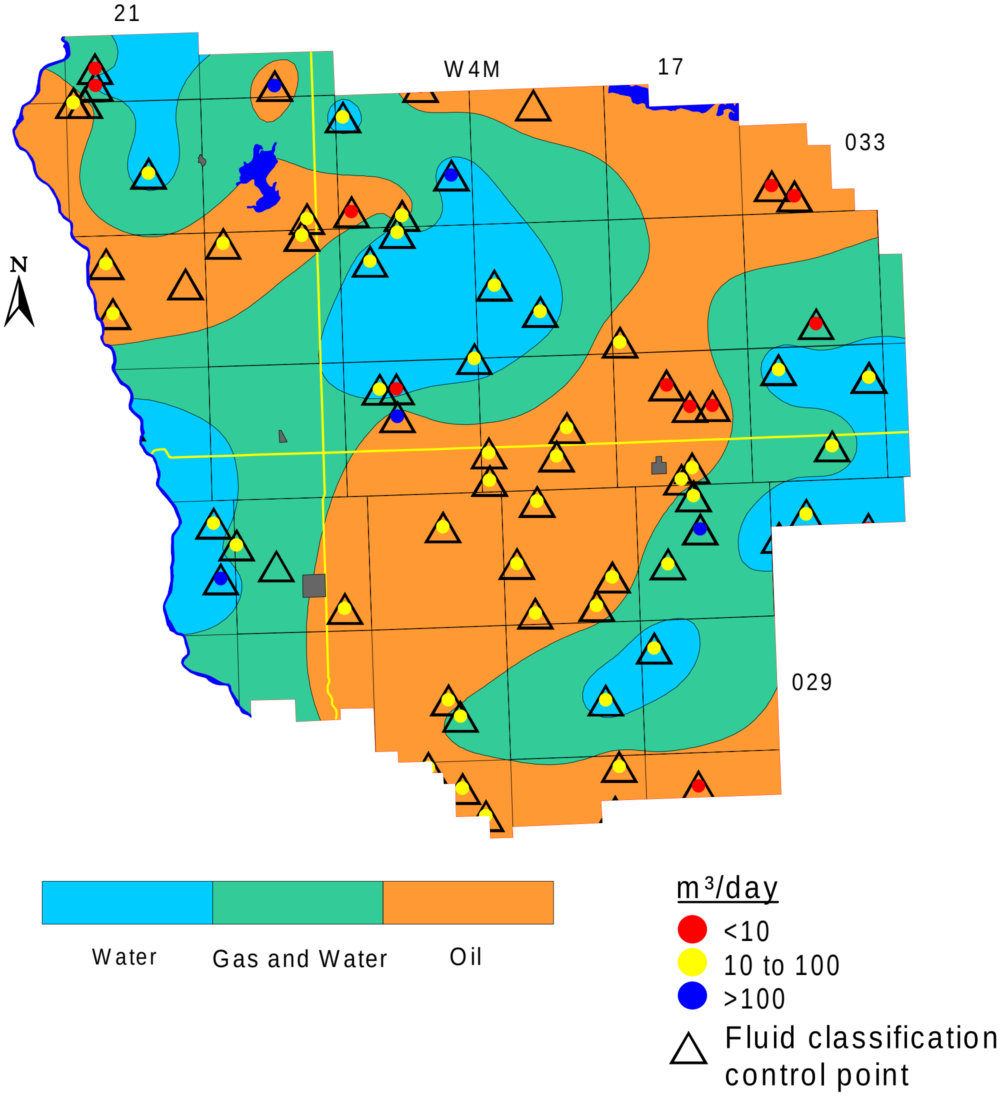
Chloride in Groundwater from Lower Horseshoe Canyon Aquifer



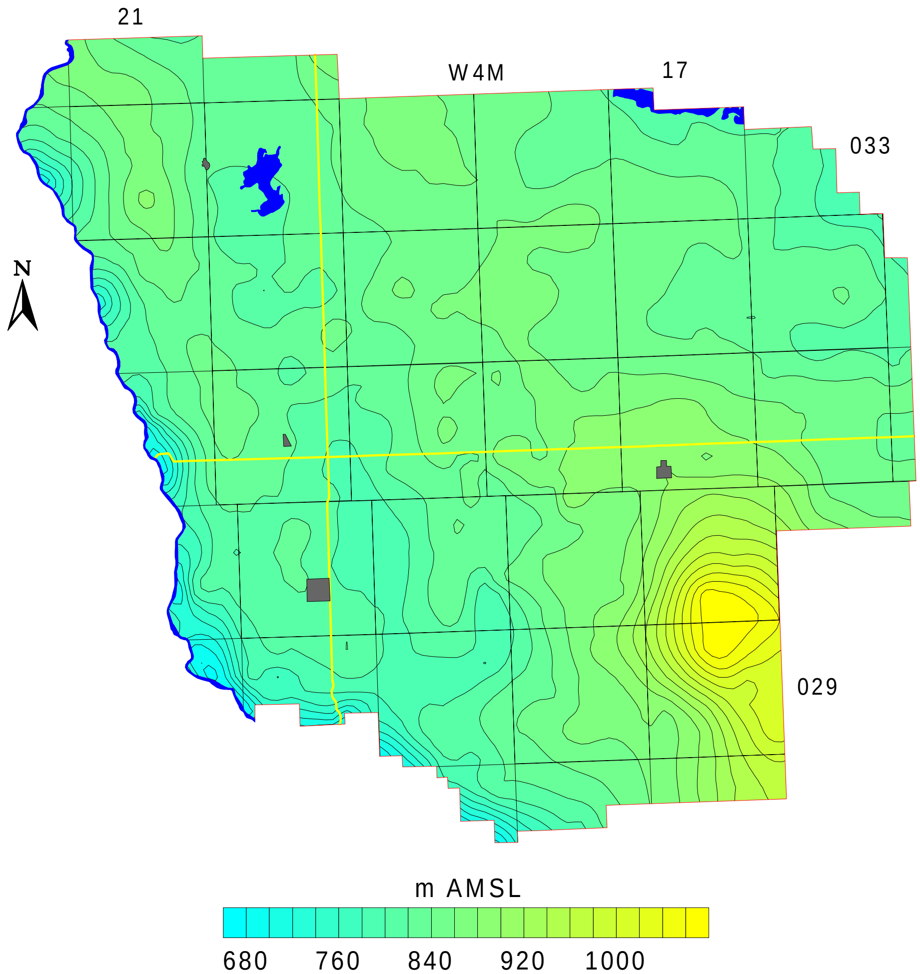
Depth to Top of Bearpaw Aquitard



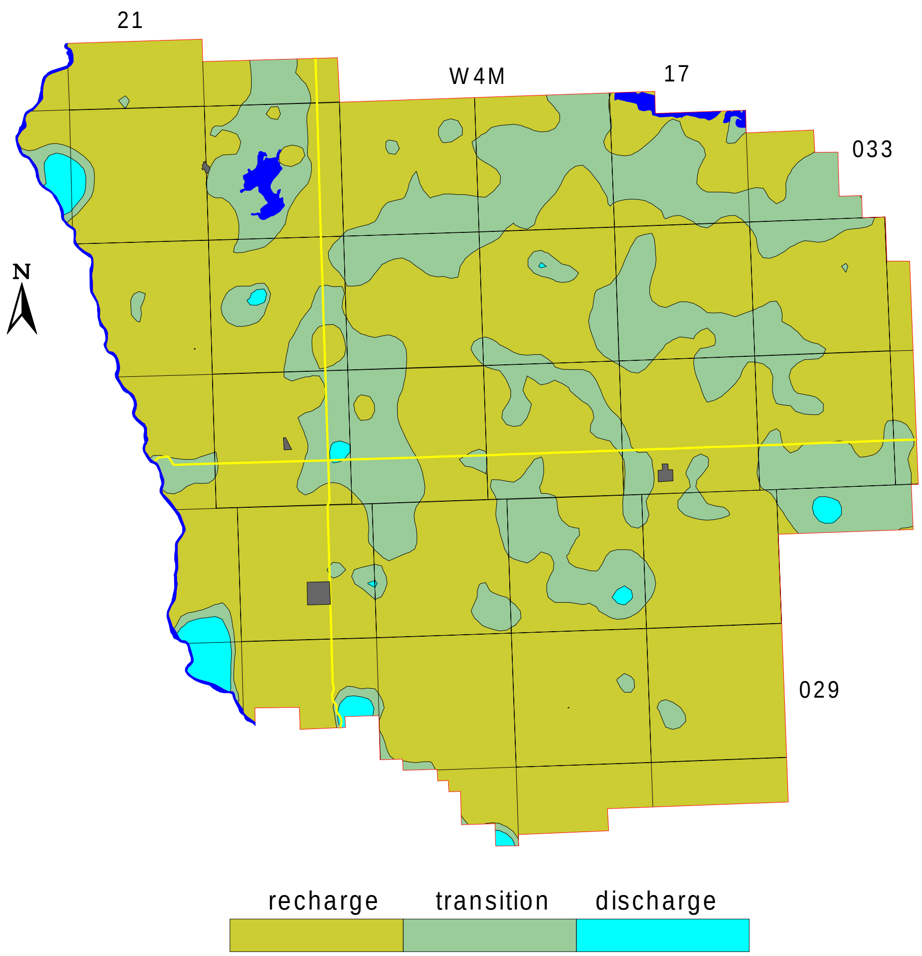
Type of Fluid Encountered in Oldman Aquifer



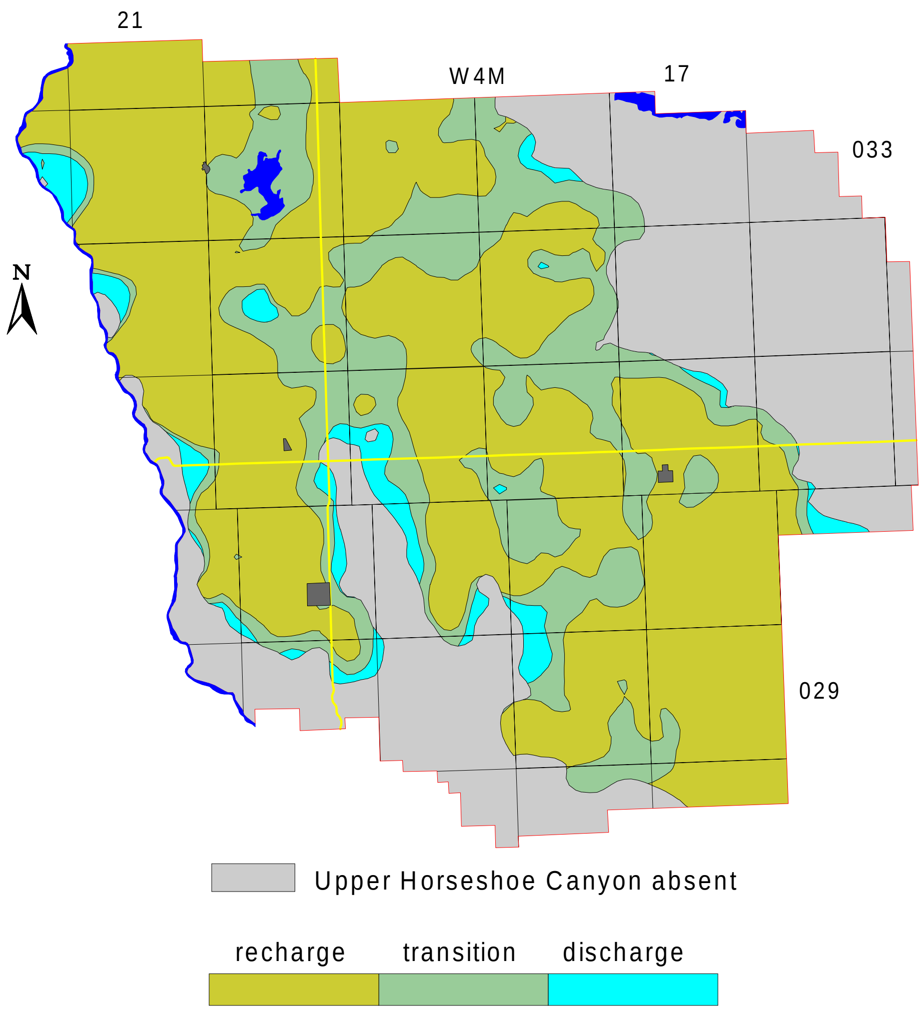
Non-Pumping Water-Level Surface in Surficial Deposits



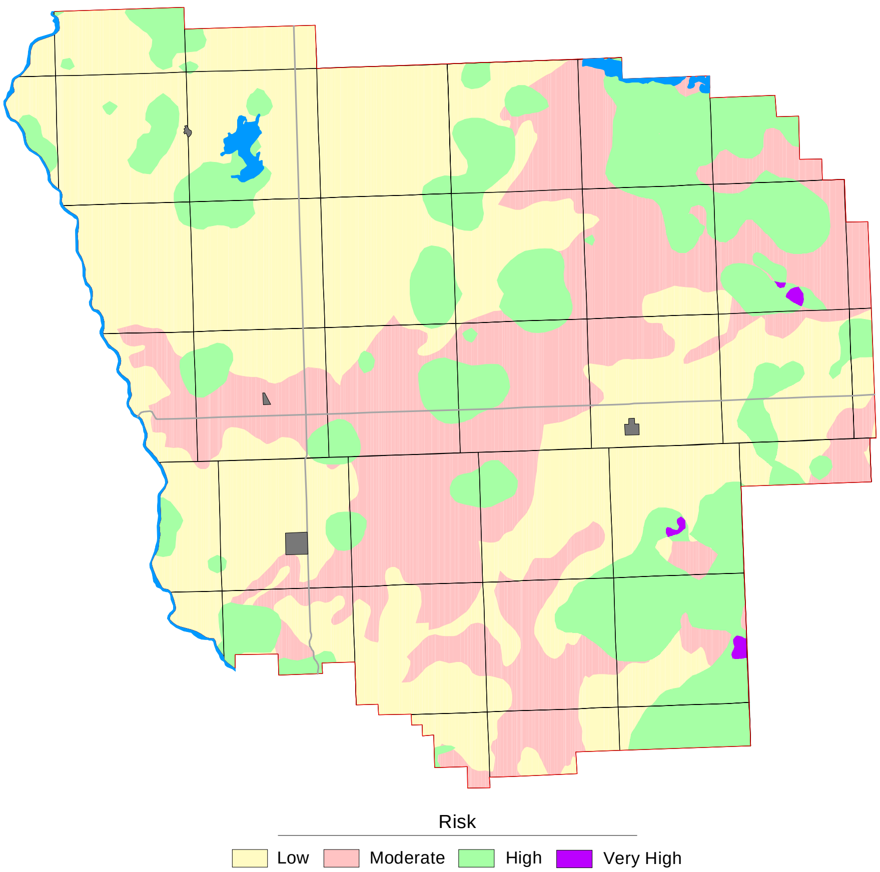
Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)



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



Risk of Groundwater Contamination



STARLAND COUNTY
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
- Surface Casing Types used in Drilled Water Wells
- Location of Water Wells
- Depth of Existing Water Wells
- Depth to Base of Groundwater Protection
- Bedrock Topography
- Bedrock Geology
- Cross-Section A - A'
- Cross-Section B - B'
- Geologic Column
- Generalized Cross-Section (for terminology only)
- Risk of Groundwater Contamination
- Relative Permeability
- Type of Fluid Encountered in the Oldman Aquifer

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- Chloride in Groundwater from Surficial Deposits
- Fluoride in Groundwater from Surficial Deposits
- Total Hardness of Groundwater from Surficial Deposits
- Piper Diagram - Surficial Deposits
- Amount of Sand and Gravel in Surficial Deposits
- Thickness of Sand and Gravel Aquifer(s)
- Water Wells Completed in Surficial Deposits
- Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)

b) First Sand and Gravel

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

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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)
- Total Hardness of 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(s)

b) Scollard Aquifer

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

c) Upper Horseshoe Canyon Aquifer

Depth to Top of Upper Horseshoe Canyon Formation
Structure-Contour Map - Top of Upper Horseshoe Canyon Formation
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Apparent Yield for Water Wells Completed through Upper Horseshoe Canyon Aquifer
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Piper Diagram - Upper Horseshoe Canyon Aquifer
Recharge/Discharge Areas between Surficial Deposits and Upper Horseshoe Canyon Aquifer

d) Middle Horseshoe Canyon Aquifer

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Structure-Contour Map - Top of Middle Horseshoe Canyon Formation
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Recharge/Discharge Areas between Surficial Deposits and Middle Horseshoe Canyon Aquifer

e) Lower Horseshoe Canyon Aquifer

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

f) Bearpaw Aquitard

Depth to Top of Bearpaw Aquitard
Structure-Contour Map - Top of Bearpaw Aquitard

g) Oldman Aquifer

Depth to Top of Oldman Aquifer
Structure-Contour Map - Top of Oldman Aquifer
Type of Fluid Encountered in Oldman Aquifer

STARLAND COUNTY

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 four-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

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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)-(n) of the Environmental Protection and Enhancement Act.

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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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Colin Samis (Lac La Biche: 403-623-5235)

GEOPHYSICAL INSPECTION SERVICE

Edmonton: 403-427-3932

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PRAIRIE FARM REHABILITATION ADMINISTRATION

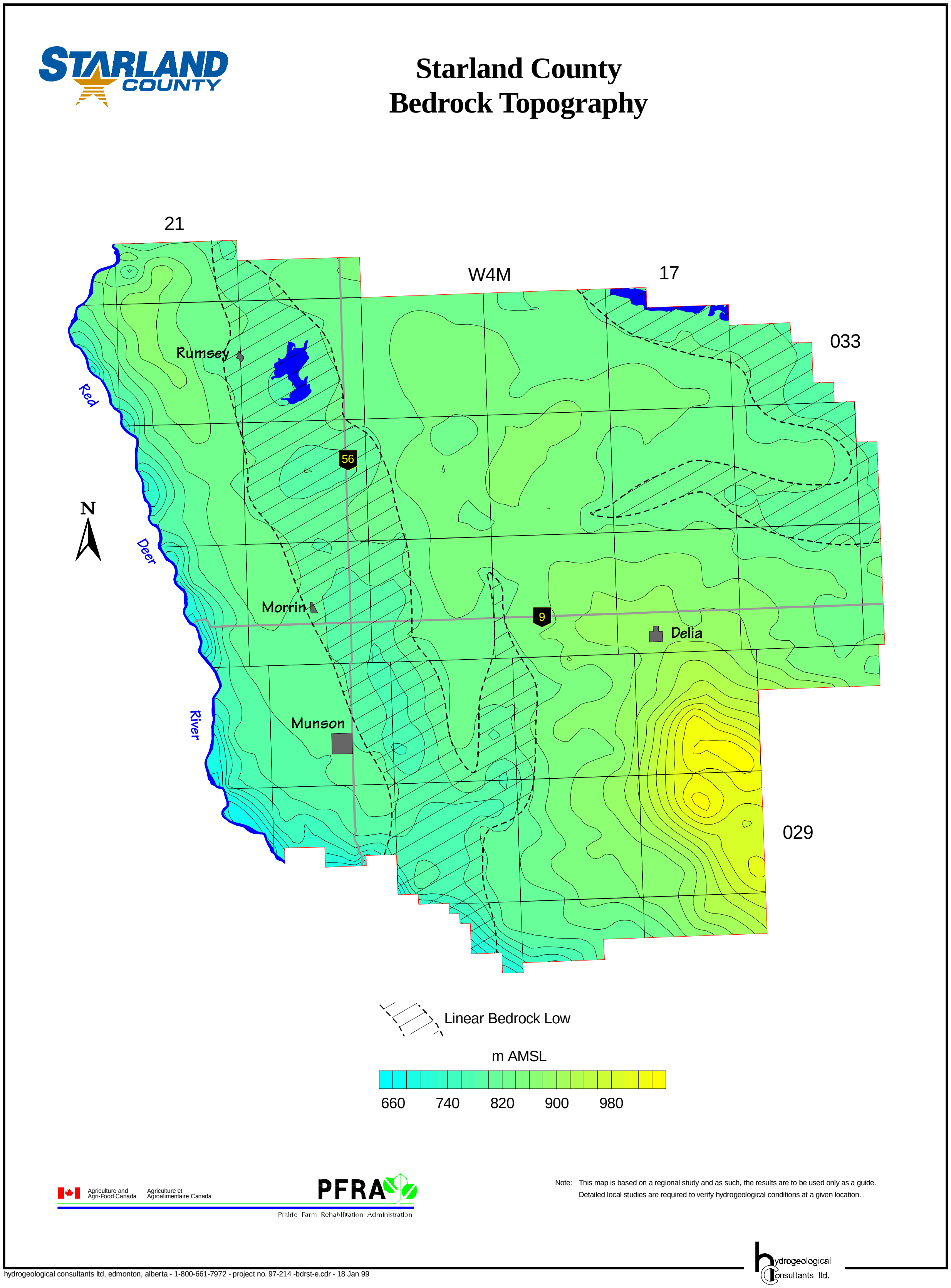
Dave Seitz (Hanna: 403 854-4448)

LOCAL HEALTH DEPARTMENTS

STARLAND COUNTY

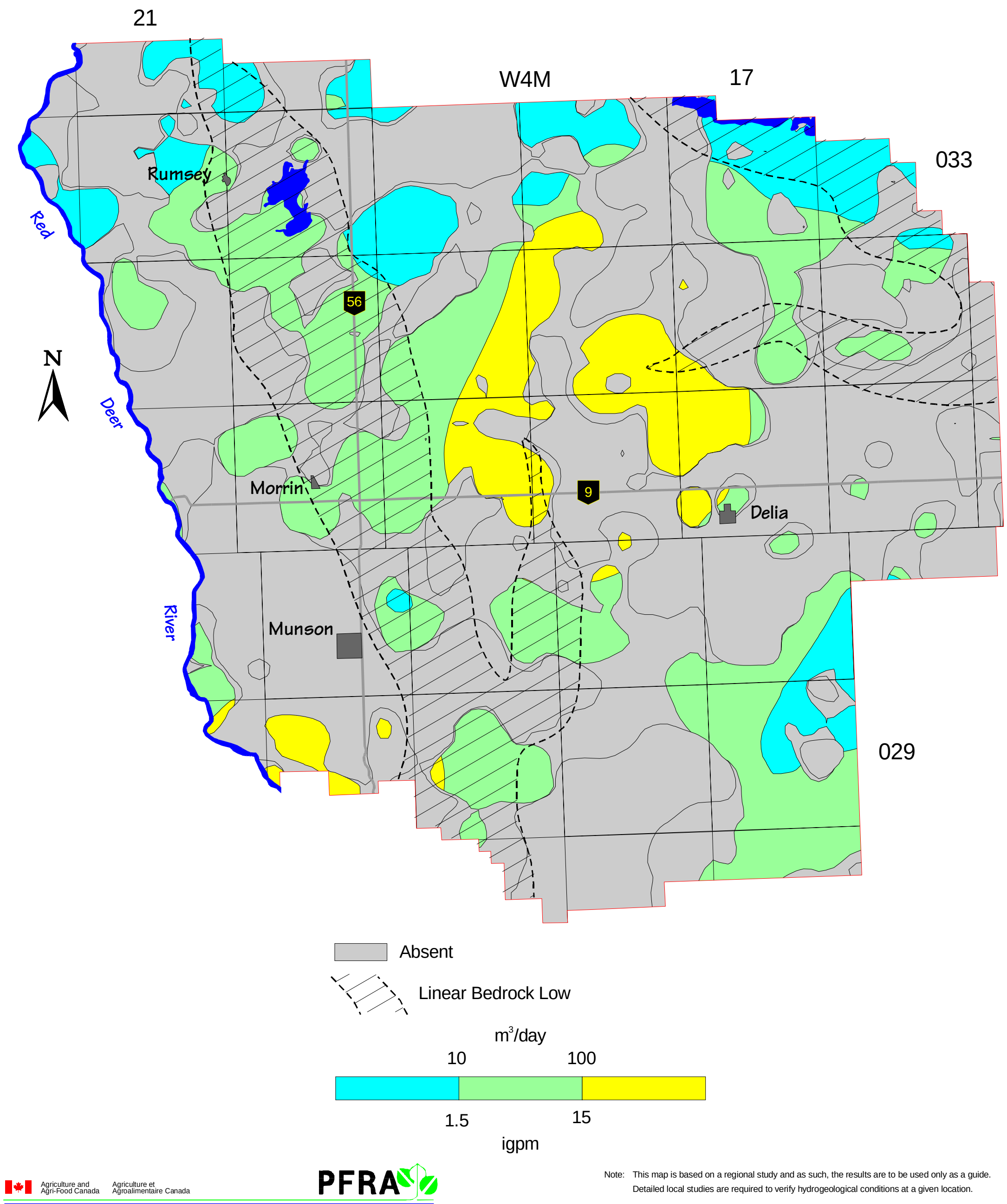
Appendix D

MAPS AND FIGURES INCLUDED AS LARGE PLOTS


STARLAND COUNTY
Starland County
Bedrock Topography
21
W4M
17
033
029
Rumsey
56
Morrin
9
Delia
Munson
Red
Deer
River
N
Linear Bedrock Low
m AMSL
660
740
820
900
980
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.
hydrogeological consultants ltd.
hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 97-214 -bdrst-e.cdr - 18 Jan 99

STARLAND COUNTY

Starland County
Apparent Yield for Water Wells
Completed in Sand and Gravel Aquifer(s)



Agriculture and Agri-Food Canada Agriculture et Agroalimentaire Canada

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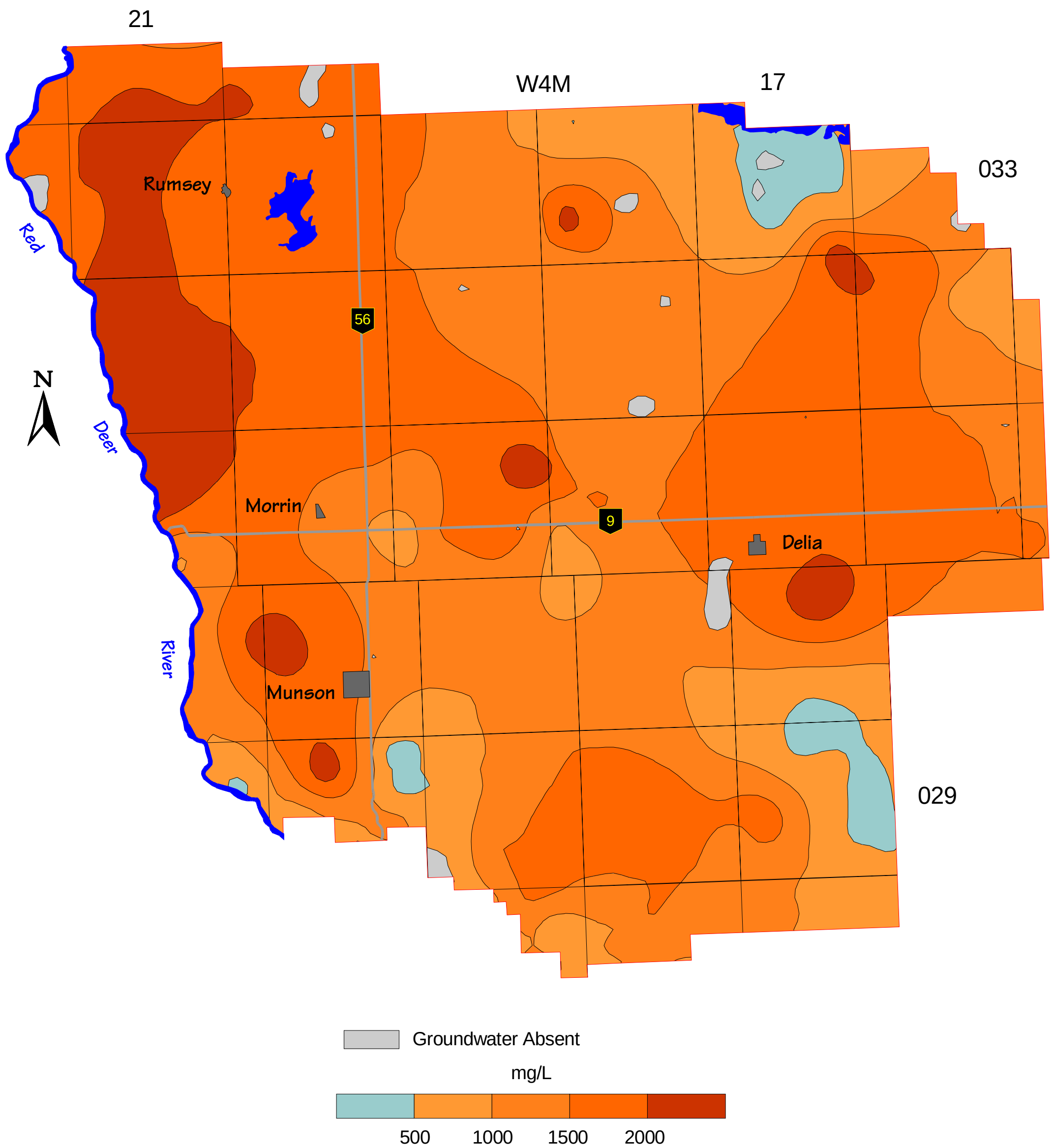
Starland County
Total Dissolved Solids in Groundwater from Surficial Deposits



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

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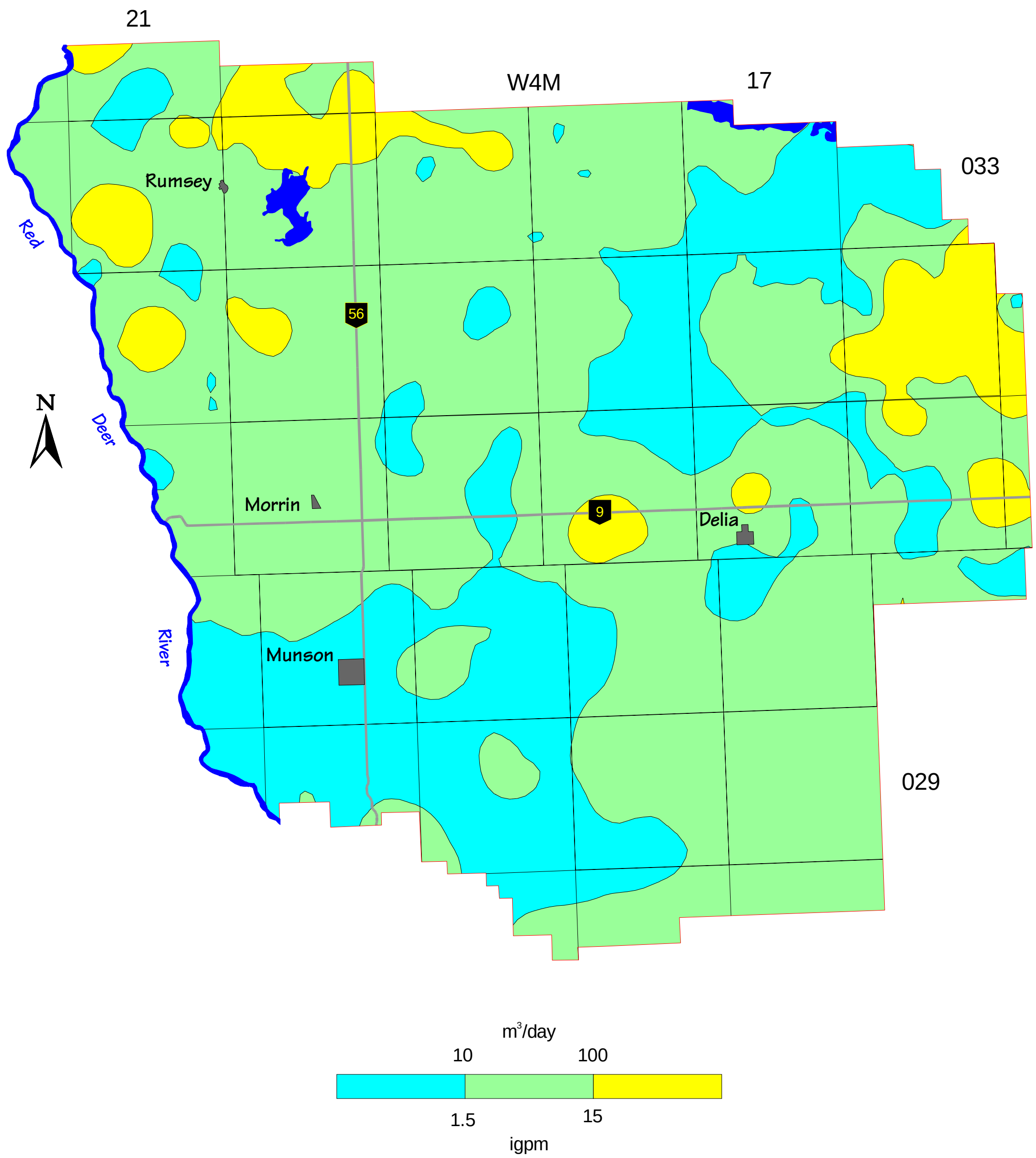
hydrogeological consultants ltd.

STARLAND COUNTY

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



Agriculture and Agri-Food Canada Agriculture et Agroalimentaire Canada

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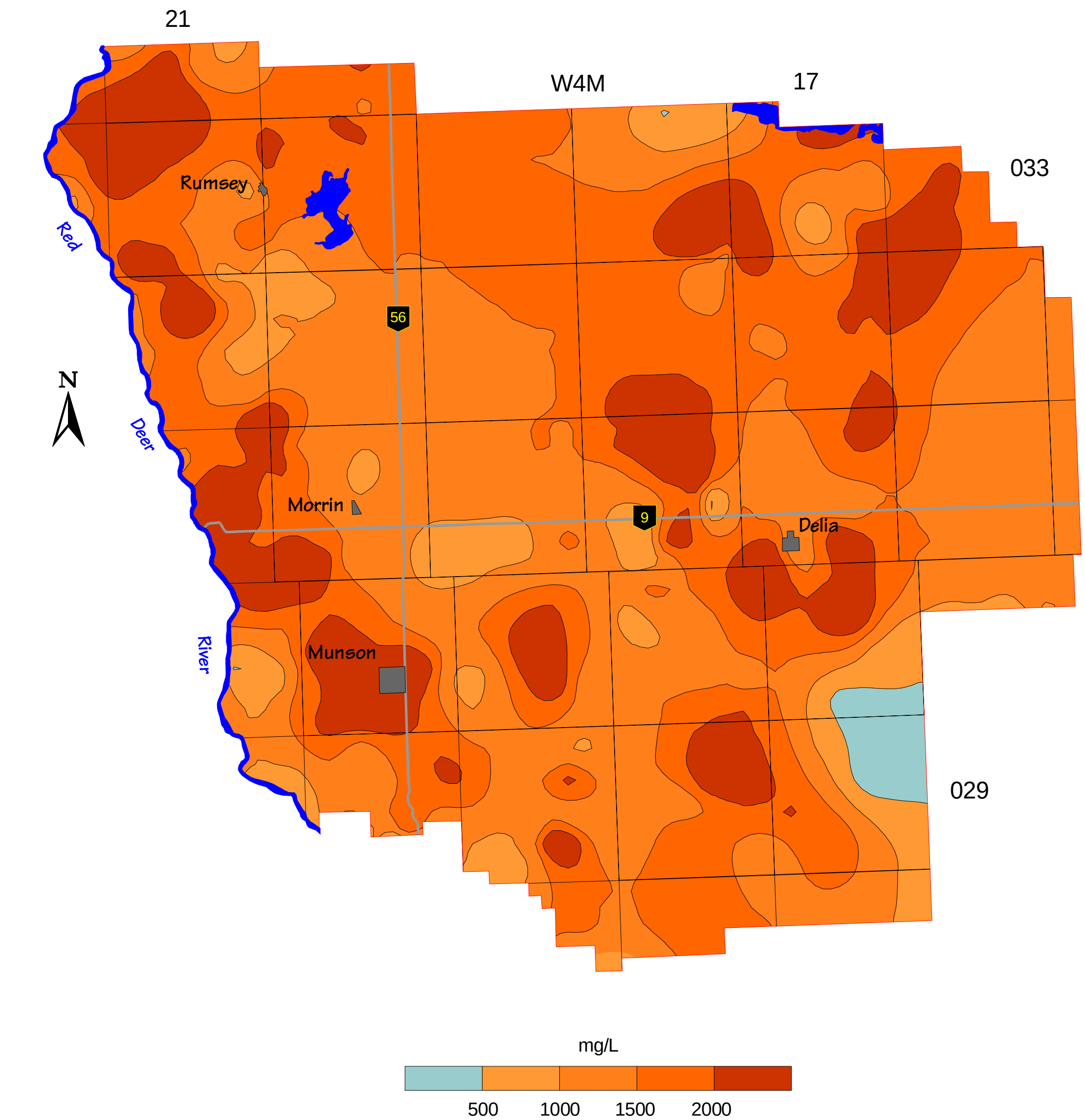
Starland County
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



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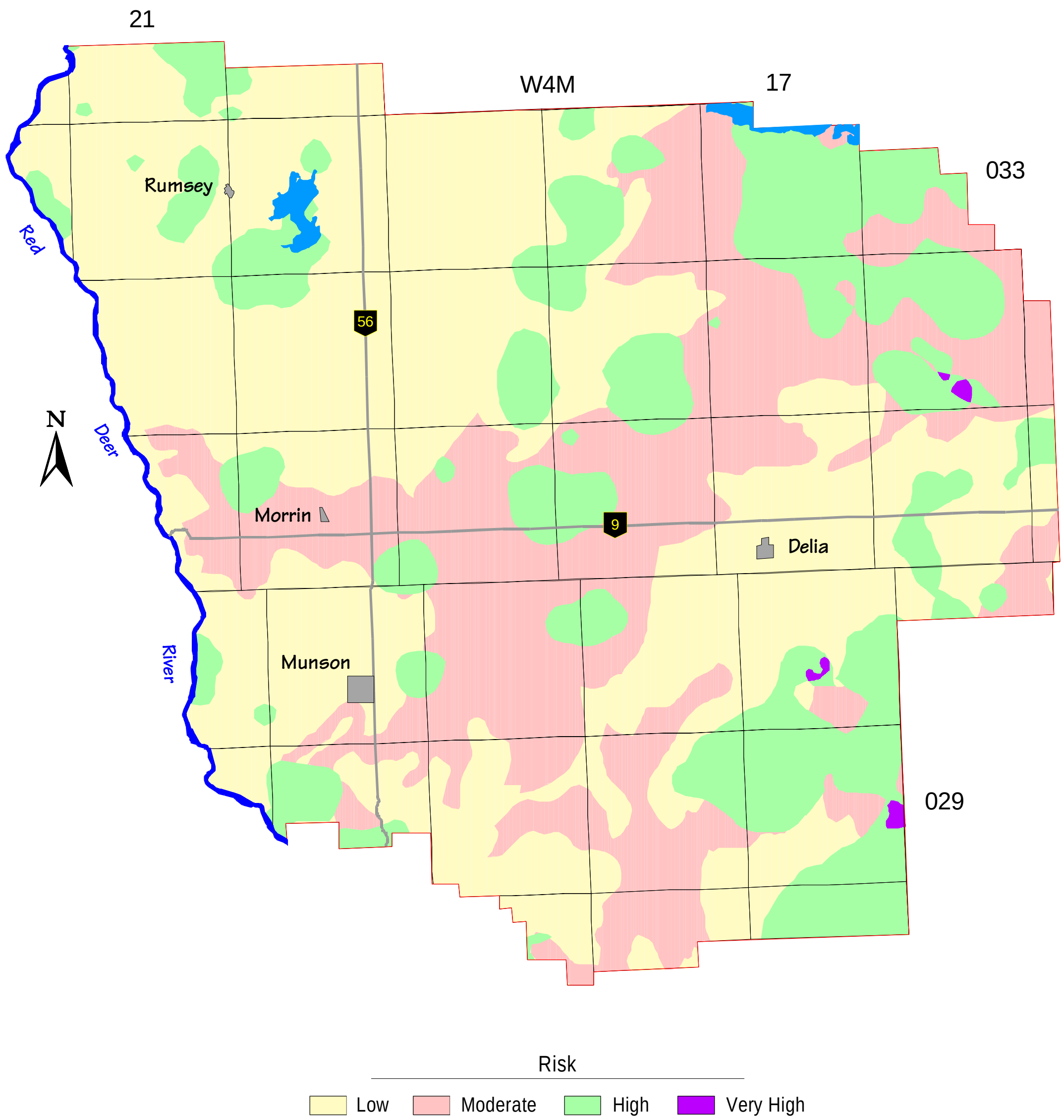
Starland County
Risk of Groundwater Contamination



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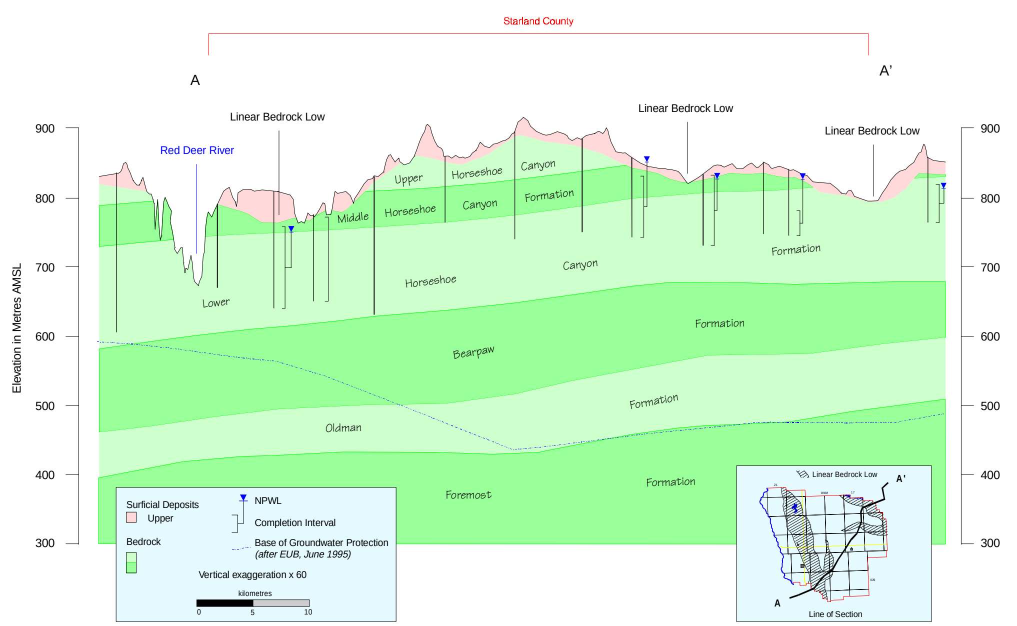
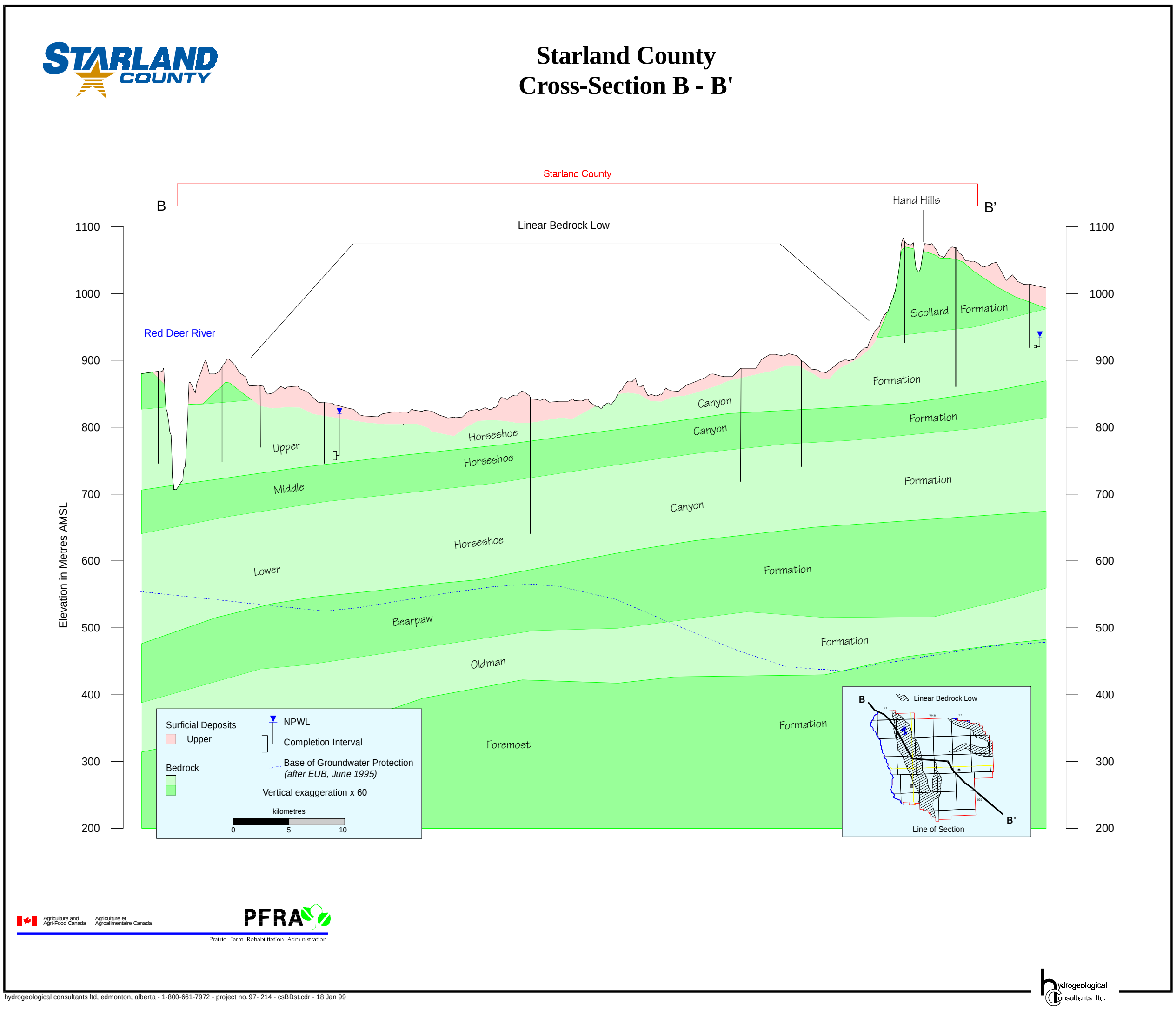
Starland County
Cross-Section A - A'




Starland County
Cross-Section B - B'
Starland County
B
B'
Hand Hills
Linear Bedrock Low
Red Deer River
Elevation in Metres AMSL
1100
1000
900
800
700
600
500
400
300
200
Scollard Formation
Upper Horseshoe Canyon Formation
Middle Horseshoe Canyon Formation
Lower Horseshoe Canyon Formation
Bearpaw Formation
Oldman Formation
Foremost Formation
Surficial Deposits
Upper
Bedrock
NPWL
Completion Interval
Base of Groundwater Protection
(after EUB, June 1995)
Vertical exaggeration x 60
kilometres
0
5
10
Linear Bedrock Low
Line of Section
PFRA
hydrogeological consultants ltd.
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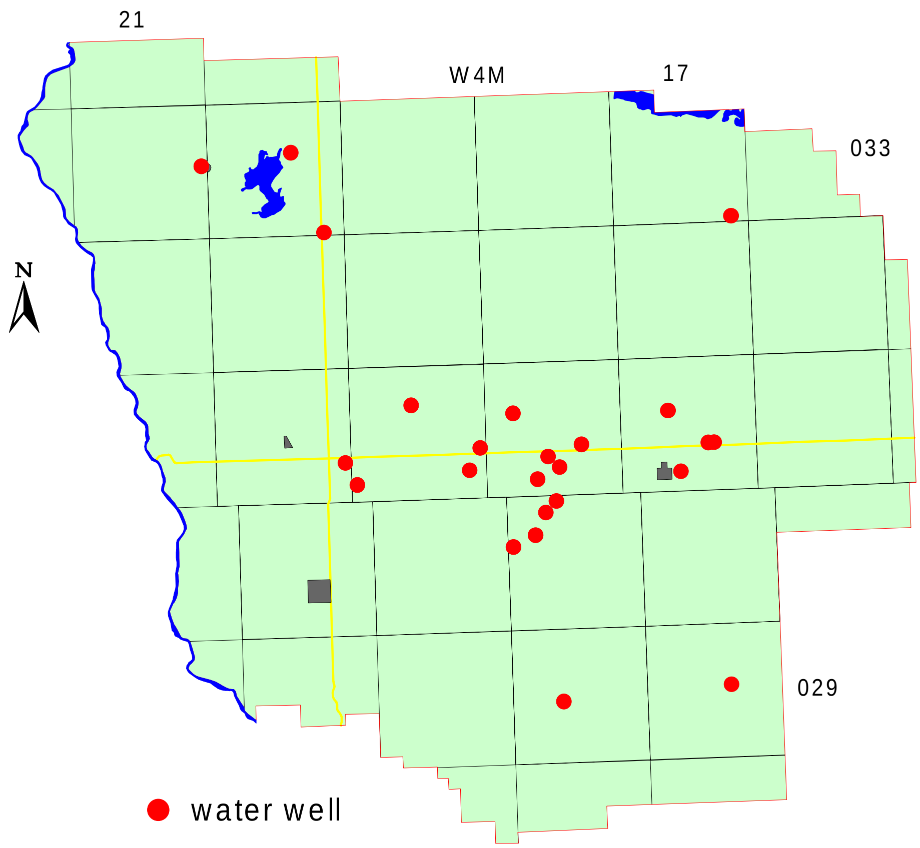
STARLAND COUNTY

Appendix E

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Water Wells Recommended for Field Verification

(details on following page)



Water Wells Recommended for Field Verification

Owner	Location	Water Well Contractor	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet
Ben Olsen	NW 06-031-19 4	Hirate Drilling 1985 Ltd.	Jul-78	46.9	154.0	26.4	86.6
Alois Rauch	SE 22-029-17 4	Hoover Drilling	Nov-80	46.0	151.0	32.0	105.0
Harvey Rowe	SW 29-030-18 4	Harvey Drlg Co	Jul-76	32.0	105.0	6.7	22.0
Gerald Faesier	01-033-20 4	Ross Drilling	May-73	64.0	210.0	45.7	150.0
Edward Dietrich	NE 22-033-20 4	Ross Drilling	Nov-80	27.4	90.0	10.7	35.0
Nick Kashuba	SE 24-033-21 4	Lousana Water Wells Ltd.	Apr-73	29.0	95.0	16.7	54.9
E.C. Hendricks	SE 24-033-21 4	Ross Drilling	Jul-77	38.1	125.0	8.5	28.0
Ronald Stevenson	NW 04-031-18 4	Harvey Drlg Co	Sep-76	36.6	120.0	28.0	92.0
R. Knotter	NW 19-030-18 4	Hoover Drilling	Aug-78	22.9	75.0	14.3	47.0
Bill Wilson	04-031-17 4	Hoover Drilling	Mar-86	42.7	140.0	13.9	45.5
Gordon Adams	SE 28-031-19 4	Lin Murray Drilling	Oct-71	27.4	90.0	15.2	50.0
H. Rowe	SW 29-030-18 4	North Side Garage	Jul-66	15.2	50.0	3.7	12.0
Edwards Gch Ltd	14-031-17 4	Kern Water Well Ltd.	Nov-81	41.2	135.0	13.7	45.0
Don Wright	SE 32-030-18 4	Harvey Drlg Co	Jul-76	10.1	33.0	4.3	14.0
William Doktokchik	NW 33-030-18 4	North Side Garage	Jul-66	18.6	61.0	9.1	30.0
Dave Kitridge	15-031-17 4	Kern Water Well Ltd.	Feb-83	48.8	160.0	9.8	32.0
Albert Mason	21-031-17 4	Lin Murray Drilling	Aug-73	32.0	105.0	12.2	40.0
Herb Raugust	NE 09-031-18 4	Harvey Drlg Co	Dec-70	36.6	120.0	26.2	86.0
Barry Raugust	SW 10-031-18 4	Harvey Drlg Co	Oct-80	37.8	124.0	25.9	85.0
Herb Raugust	SW 14-031-18 4	Harvey Drlg Co	May-73	32.0	105.0	20.7	68.0
R.C. # Well 2 Fraser	NW 20-031-18 4	North Side Garage	Jun-61	17.4	57.0	9.1	30.0
Harold Kingcott	SW 12-031-19 4	North Side Garage	Nov-61	27.7	91.0	12.2	40.0
Grant E. Telford	NW 19-030-18 4	Lin Murray Drilling	Apr-82	29.0	95.0	15.2	50.0
Jim Mcguire	SW 01-033-17 4	Ama Drilling Co. Ltd.	Jun-80	15.2	50.0	2.4	8.0
Douglas Grenville	NE 12-031-20 4	Lin Murray Drilling	Jun-73	41.2	135.0	19.8	65.0
Verdant Valley Colony	NW 16-029-18 4	Doering Drilling Ltd.	Oct-74	18.3	60.0	10.7	35.0
Harold Nelson	SE 13-031-19 4	Lin Murray Drilling	Dec-72	13.7	45.0	2.7	9.0