County of Minburn No. 27

Part of the North Saskatchewan River Basin
Parts of Tp 047 to 054, R 08 to 16, W4M
Regional Groundwater Assessment

Prepared for

In conjunction with

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Prairie Farm Rehabilitation Administration | Administration du rétablisseme agricole des Prairies

Canada

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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 the County of Minburn No. 27 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 the County of Minburn No. 27, (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.

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 the County of Minburn No. 27. 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.

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[1] See glossary
[2] See glossary

2 INTRODUCTION

2.1 Setting

The County of Minburn No. 27 is situated in east-central Alberta. This area is part of the Alberta Plains region. The County exists within the North Saskatchewan River Basin. The Vermilion River flows through the western and eastern parts of the County. The County boundaries follow township or section lines. The area includes some or all of townships 047 to 054, ranges 08 to 16, west of the 4th Meridian.

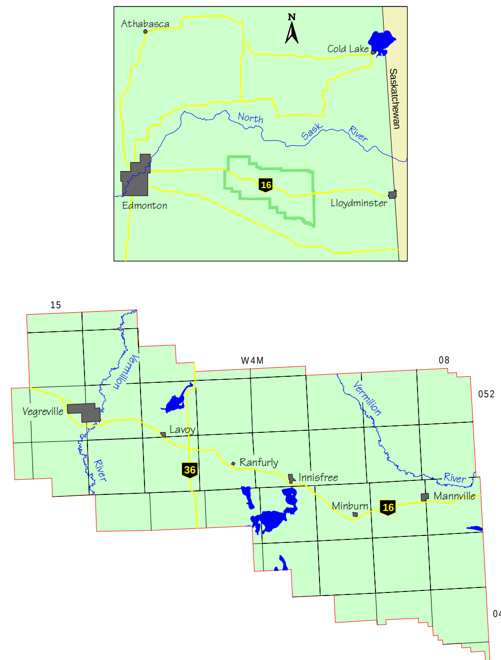

Figure 1. Index Map

Regionally, the topographic surface varies between 580 and 740 metres above mean sea level (AMSL), with the lowest elevation occurring in the Vermilion River Valley in the northeastern part of the County.

2.2 Climate

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

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

The mean annual precipitation averaged from four meteorological stations within the County measured 407 millimetres (mm), based on data from 1961 to 1993. The annual temperature averaged 1.7 °C, with the mean monthly temperature reaching a high of 16.4 °C in July, and dropping to a low of -15.4 °C in January. The calculated annual potential evapotranspiration is 510 millimetres.

2.3 Background Information

There are currently records for 3,329 water wells in the groundwater database for the County. Of the 3,329 water wells, 2,668 are for domestic/stock purposes. The remaining 661 water wells were completed for a variety of uses, including municipal, investigation, observation and industrial purposes. Based on a rural population of 3,405, there are 3.1 domestic/stock water wells per family of four. The domestic or stock water wells vary in depth from 2.1 metres to 183.0 metres below ground level. Lithologic details are available for 1,665 water wells.

Data for casing diameters are provided on 1,326 records, with 1,050 having a diameter of less than 220 mm and 276 having a diameter of more than 400 mm. The casing diameters of greater than 400 mm are mainly bored water wells and those with a surface casing of less than 220 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 was in use in the 1950s and is still used in 12% of the new water wells being drilled in the County. Galvanized steel surface casing was used in 6% of the new water wells in the mid-1950s. By the early 1960s, galvanized steel casing was being used in 22% of the new water wells, more than at any other time. The last reported use of galvanized steel was in January 1990. Plastic casing was used for the first time in May 1982. The percentage of water wells with plastic casing has increased and in the mid-1990s, plastic casing was used in 88% of the water wells drilled in the County.

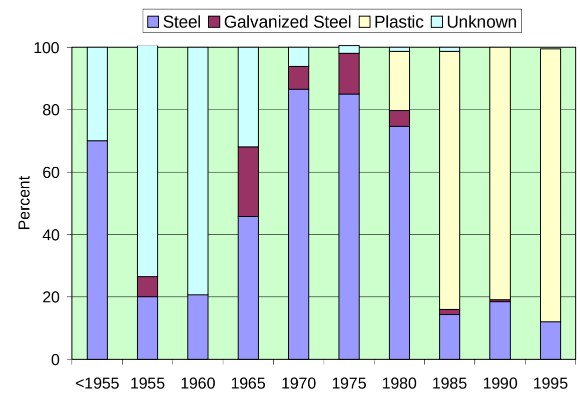

Figure 2. Surface Casing Types used in Drilled Water Wells

There are 1,347 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 438. The adjacent map shows that these water wells occur over most of the County. Approximately 70% of the water wells completed in the surficial aquifers have a completion depth of less than 25 metres and 30% have a completion depth of more than 25 metres. The water wells completed in the surficial aquifers having a completion depth of less than 25 metres are mainly located outside linear bedrock lows.

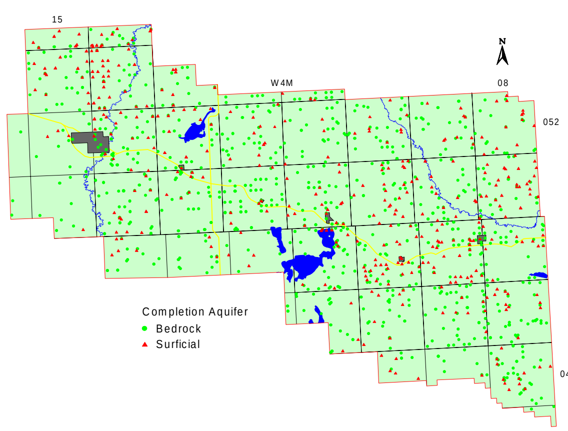

Figure 3. Location of Water Wells

The remaining 909 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, 83 groundwater diversions were licensed in the County. The total maximum authorized diversion from these 83 water wells is 4,859.7 cubic metres per day (m³/day); nearly 80% of the authorized groundwater diversion is allotted for industrial use. The largest licensed industrial groundwater diversion within the County is for three PanCanadian Petroleum Limited saline water source wells in Tp 048, R 09, W4M. Each of these water source wells has been licensed for 760.7 m³/day. These saline water source wells are completed at a depth of more than 700 metres below ground surface.

The largest licensed groundwater diversion within the County not used for industrial purposes is for the Village of Mannville, having a diversion of 172.5 m³/day from a water supply well completed in the Victoria Aquifer.

The adjacent table shows a breakdown of the 83 licensed groundwater diversions by the aquifer in which the water well is completed. Even though five saline water source wells are licensed, these supplies no longer need to be licensed. The next highest diversions are for licensed water wells completed in the Brosseau Aquifer, of which all of the groundwater is used for industrial purposes. The highest use of groundwater in the County, other than for industrial purposes, is for municipal purposes with most of the groundwater being diverted from the Victoria Aquifer for the Village of Mannville.

	Licensed Groundwater Users (m³/day)				
Aquifer	Agricultural	Industrial	Irrigation	Municipal	Total
Upper Sand and Gravel	6.8	0.0	0.0	30.4	37.2
Lower Sand and Gravel	0.0	0.0	3.4	0.0	3.4
Oldman	203.1	0.0	0.0	16.9	220.0
continental Foremost	134.5	0.0	0.0	152.2	286.7
Birch Lake	16.9	0.0	0.0	20.3	37.2
Ribstone Creek	113.3	0.0	0.0	16.9	130.2
Victoria	10.1	64.2	0.0	307.7	382.0
Brosseau	0.0	1,234.1	0.0	0.0	1,234.1
Saline Source Wells	0.0	2,528.9	0.0	0.0	2,528.9
Total	484.7	3,827.2	3.4	544.4	4,859.7

Table 1. Licensed Groundwater Diversions

At many locations within the County, more than one water well is completed at one legal location. Digitally processing this information is difficult. To obtain a better understanding of the completed depths of water wells, a 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 1,500 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 1.0 mg/L.

Alberta Environmental Protection (AEP) defines the Base of Groundwater Protection as the elevation below which the groundwater is expected to have more than 4,000 mg/L of total dissolved solids. By using the ground elevation, the bedrock surface and the Base of Groundwater Protection, a depth to the Base of Groundwater Protection can be determined. This depth, for the most part, would be the maximum drilling depth for a water supply well. Over approximately 60% of the County, the depth to the Base of Groundwater Protection is more than 150 metres. There are only a few areas where the depth to the Base of Groundwater Protection is less than 100 metres, which mainly are areas within a few kilometres of the Vermilion River as shown on the adjacent map.

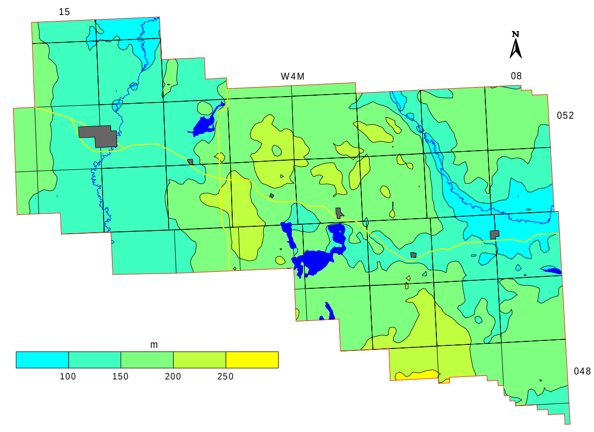

Figure 4. Depth to Base of Groundwater Protection

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

However, even with the available sources of data, the number of water-level data points relative to the size of the County is too few to provide a reliable groundwater budget. The most cost-efficient method to collect additional groundwater monitoring data would be to have the water well owners measuring the water level in their own water well on a regular basis.

3 TERMS

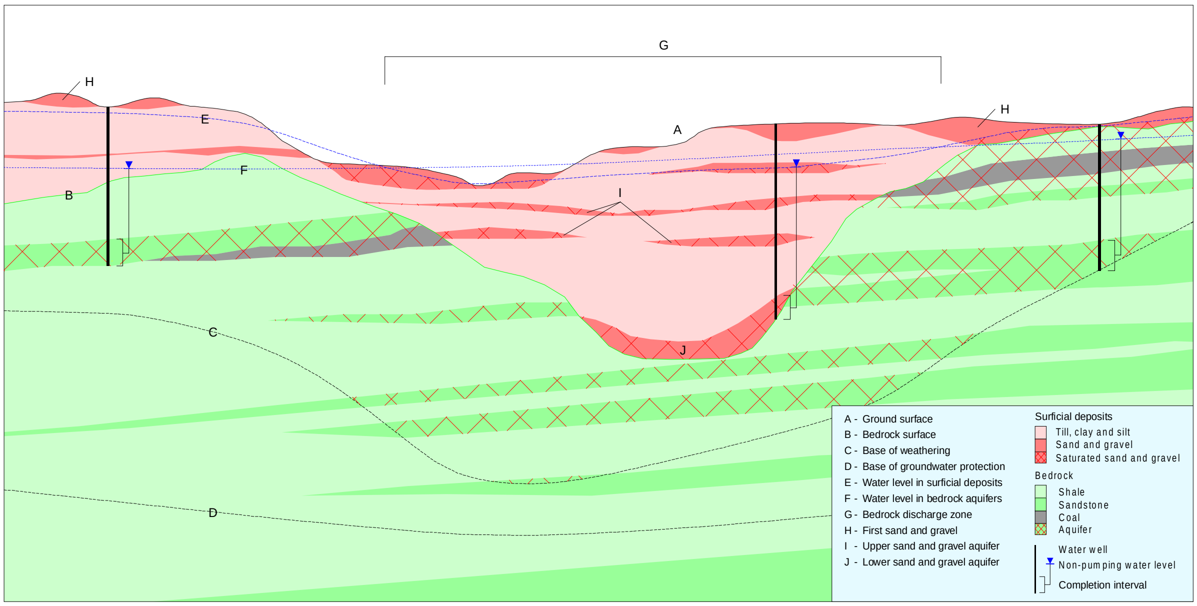

Figure 5. Generalized Cross-Section (for terminology only)

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	<80		Surficial Deposits	<80	Upper	<30	First Sand and Gravel
					<80	Lower		
	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		*continental* Foremost Formation			<20	Taber Coal Zone
							<20	McKay Coal Zone
	sandstone, shale	<200		*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

4 METHODOLOGY

4.1 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. 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 SE ¼ of section 23, township 052, range 15, W4M would have a horizontal coordinate with an Easting of 192,518 metres and a Northing of 5,929,378 metres, the centre of the quarter section. Once the horizontal coordinates are determined, a ground elevation is obtained from the 1:20,000 Digital Elevation Model (DEM) from the Resource Data Division of AEP.

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

Where possible, determinations are made from individual records for the following:

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

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

The Alberta Energy and Utilities Board (EUB) well database includes records for all of the wells drilled by the oil and gas industry. The information from this source includes:

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

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

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

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

4.2 Spatial Distribution of Aquifers

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

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

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

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

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

necessitates creating a representative sample set obtained from the entire data set. If the data set is large enough, it can be treated as a normal population and the removal of extreme values can be done statistically. When data sets are small, the process of data reduction involves a more direct assessment of the quality of individual points. Because of the uneven distribution of the data, all data sets are gridded using the Kriging[6] method.

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

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

4.3 Hydrogeological Parameters

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

After the water wells are assigned to a specific aquifer, the parameters from the water well records are assigned to the individual aquifers. The parameters include non-pumping (static) water level (NPWL), transmissivity and projected water well yield. The total dissolved solids, chloride and sulfate concentrations from the chemical analysis of the groundwater are also assigned to applicable aquifers.

Once the values for the various parameters of the individual aquifers are established, the spatial distribution of 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.

4.3.1 Risk Criteria

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

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

Table 2. Risk of Groundwater Contamination Criteria

6 See glossary

4.4 Maps and Cross-Sections

Once grids for geological surfaces have been prepared, various grids need to be combined to establish the extent and thickness of individual geological units. For example, the relationship between an upper bedrock unit and the bedrock surface must be determined. This process provides both the aquifer outline and the aquifer thickness. The aquifer thickness is used to determine the aquifer transmissivity by multiplying the hydraulic conductivity by the thickness.

Grids must also be combined to allow the calculation of projected long-term yields for individual water wells. The grids related to the elevation of the 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.

4.5 Software

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

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

[7] See glossary

5 AQUIFERS

5.1 Background

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

5.1.1 Surficial Aquifers

Surficial deposits in the County are mainly less than 40 metres thick, except in areas of linear bedrock lows where the thickness of the surficial deposits can exceed 80 metres. The Buried Vegreville and Vermilion valleys are two of the main linear bedrock lows. The Buried Vegreville Valley is present in the western part of the County and trends generally from south to north. The Buried Vermilion Valley is present in the eastern half of the County and trends generally from southwest to northeast. Cross-section A-A' passes across both the Buried Vegreville and Vermilion valleys, and shows the thickness of the surficial deposits varies from less than 10 to more than 60 metres.

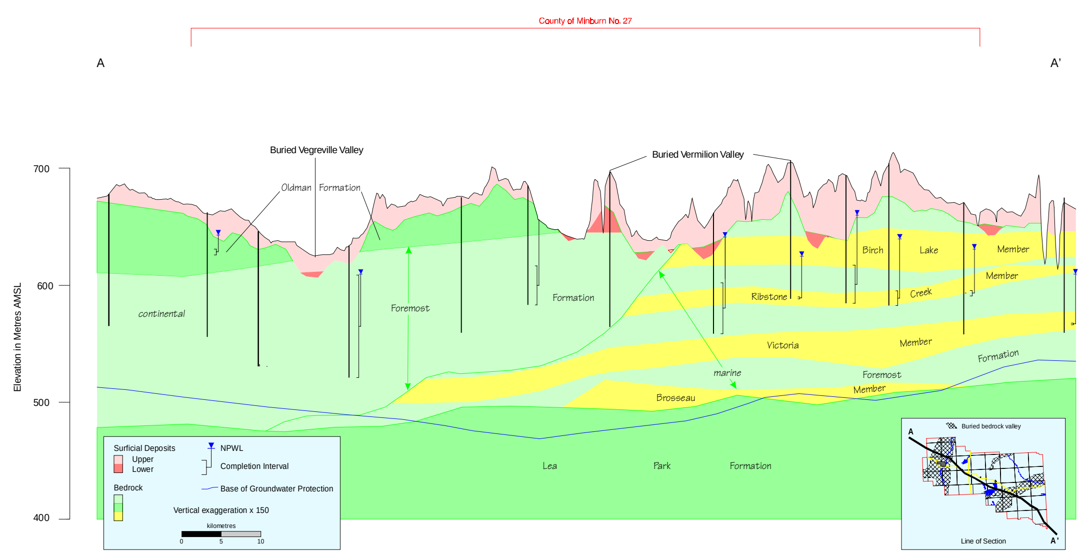

Figure 7. Cross-Section A - A'

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, 59% of the water wells completed in the surficial deposits have a casing diameter of greater than 400 millimetres or no reported diameter for the surface casing, and are assumed to be dug or bored water wells.

5.1.2 Bedrock Aquifers

The upper bedrock includes rocks that are less than 200 metres below the bedrock surface. Some of this bedrock contains porous, permeable and saturated rocks that 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. The data for 909 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 909 water wells, more than 97% have surface casing diameters of less than 220 mm and 40% of these bedrock water wells have been completed with water well screens. Of the drilled water wells completed in bedrock aquifers without water well screens, 70% have completion intervals of 20 metres or less; the largest completion interval for a drilled water well completed in a bedrock aquifer within the County is 100 metres.

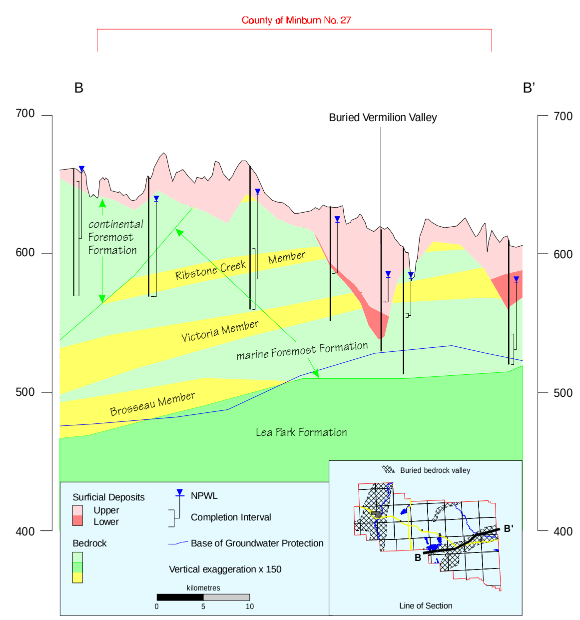

Figure 8. Cross-Section B - B'

The upper bedrock includes parts of the Belly River Group. The Belly River Group, which has a maximum thickness of 250 metres in the County, is underlain by the Lea Park Formation (Figure 8). The Belly River Group includes the Oldman Formation and both the *continental* and *marine* facies[9] of the Foremost Formation. The *marine* Foremost Formation is divided into shale and sandstone members. The sandstone units include the Birch Lake, Ribstone Creek, Victoria and Brosseau members. The lower 10 metres of the *continental* Foremost Formation and the upper part of the *marine* Foremost Formation is included in the Milan Aquifer. In the County, the Lea Park Formation is a regional aquitard[10].

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8 See glossary
9 See glossary
10 See glossary

5.2 Aquifers in Surficial Deposits

The surficial deposits are the sediments above the bedrock surface. This includes pre-glacial materials, which were deposited before glaciation, and materials deposited directly or indirectly by glaciation. The lower surficial deposits include pre-glacial fluvial[11] and lacustrine[12] deposits. The lacustrine deposits include clay, silt and fine-grained sand. The upper surficial deposits include the more traditional glacial deposits of till and meltwater deposits. In the County, pre-glacial materials are expected to be present in association with the Buried Vegreville and Vermilion valleys.

5.2.1 Geological Characteristics of Surficial Deposits

While the surficial deposits are treated as one hydrogeological unit, they consist of three hydraulic parts. The first is the sand and gravel deposits of the lower surficial deposits, the second is the saturated sand and gravel deposits of the upper surficial deposits and the third is the sand and gravel close to ground level, which is usually unsaturated. The sand and gravel deposits in the upper part of the surficial deposits can extend above the upper limit of the saturation zone and because they are not saturated, they are not an aquifer. However, these sand and gravel deposits are significant since they provide a pathway for liquid contaminants to move downward into the groundwater. Because of the significance of the shallow sand and gravel deposits, they have been mapped where they are present within one metre of the ground surface and are referred to as the “first sand and gravel”.

Over the majority of the County, the surficial deposits are less than 40 metres thick. The exceptions are mainly in association with the linear bedrock lows where the deposits can have a thickness of more than 80 metres. The two most significant linear bedrock lows in the County have been designated as the Buried Vegreville and Vermilion valleys. The Buried Vegreville Valley is in the western part of the County as shown on the adjacent map. The Buried Vegreville Valley trends mainly from south to north, is approximately 5 to 15 kilometres wide within the County, with local bedrock relief being less than 60 metres. Sand and gravel deposits can be present in association with this bedrock low, but the thickness of the sand and gravel deposits is expected to be mainly less than 20 metres.

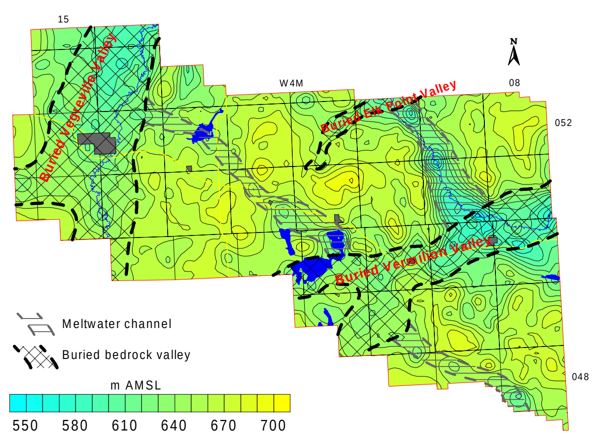

Figure 9. Bedrock Topography

The second linear bedrock low, the Buried Vermilion Valley, trends from southwest to northeast in the eastern half of the County. The Buried Vermilion Valley is approximately 5 to 10 kilometres wide, with local bedrock relief being less than 60 metres. Sand and gravel deposits can be expected to be present in association with this bedrock low, with the thickness of the deposits expected to be mainly less than 20 metres.

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[11] See glossary
[12] See glossary

In addition to the Buried Vegreville and Vermilion valleys, there is a linear bedrock low in the northeastern part of the County that has been designated as the Buried Elk Point Valley. The Buried Elk Point Valley, trending from southwest to northeast, is approximately three kilometres wide, with local bedrock relief being less than 60 metres.

There are other linear bedrock lows shown on the bedrock topography map. The majority of these lows trend northwest to southeast in the County and are indicated as being of meltwater origin. However, because sediments associated with the lower surficial deposits are indicated as being present in these linear bedrock lows, it is possible that the bedrock lows were originally tributaries to the Buried Vegreville and Vermilion Valley drainage systems.

The lower surficial deposits are composed mainly of fluvial and lacustrine deposits. Lower surficial deposits occur over approximately 15% of the County, in association with linear bedrock lows. The total thickness of the lower surficial deposits is mainly less than 10 metres, but can be up to 20 metres in the areas of linear bedrock lows. The lowest part of the lower surficial deposits includes pre-glacial sand and gravel deposits. These deposits would generally be expected to directly overlie the bedrock surface in the Buried Vegreville and Vermilion valleys. The lowest sand and gravel deposits are of fluvial origin, are usually less than 4 metres thick and may be discontinuous.

The upper surficial deposits are either directly or indirectly a result of glacial activity. The deposits include till plus sand and gravel deposits of meltwater origin. The thickness of the upper surficial deposits is mainly less than 20 metres. The greatest thickness of upper surficial deposits occurs mainly in association with the Buried Vermilion Valley.

Sand and gravel deposits can occur throughout the entire unconsolidated section. The total thickness of sand and gravel deposits is generally less than 30 metres but can be more than 50 metres in the areas of the buried bedrock lows and meltwater channels.

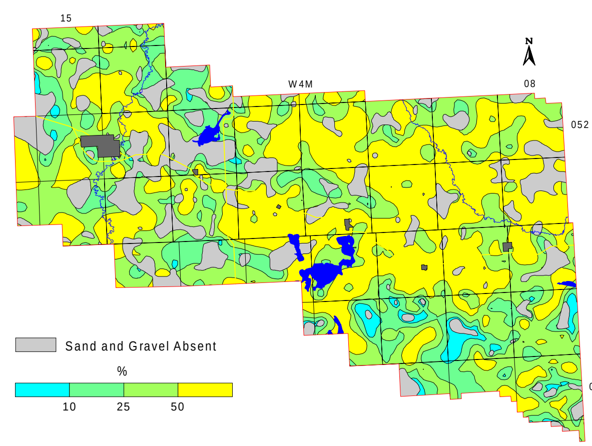

Figure 10. Amount of Sand and Gravel in Surficial Deposits

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 70% 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. The main areas where the sand and gravel percentages are higher are areas where linear bedrock lows are present. The other areas where sand and gravel deposits constitute more than 50% of the surficial deposits can be areas of meltwater channels or areas where linear bedrock lows exist but have not been identified due to a shortage of accurate bedrock control points.

5.2.2 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, 54 water wells are completed in aquifers in the lower surficial deposits and 1,079 are completed in aquifers in the upper surficial deposits. This number of 1,133 water wells completed in aquifers in the surficial deposits is more than twice 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. The majority of the water wells completed in the lower surficial deposits are located along the Buried Vegreville and Vermilion valleys.

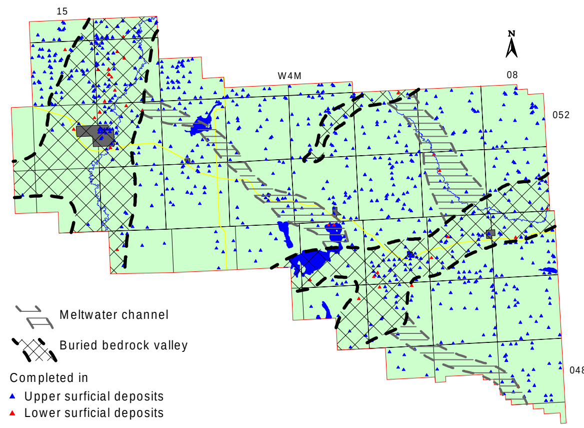

Figure 11. Water Wells Completed in Surficial Deposits

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 300 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 300 m³/day are expected are mainly in or adjacent to the areas of linear bedrock lows. Over the majority of the County, water wells completed in the sand and gravel aquifer(s) would have apparent yields of less than 100 m³/day.

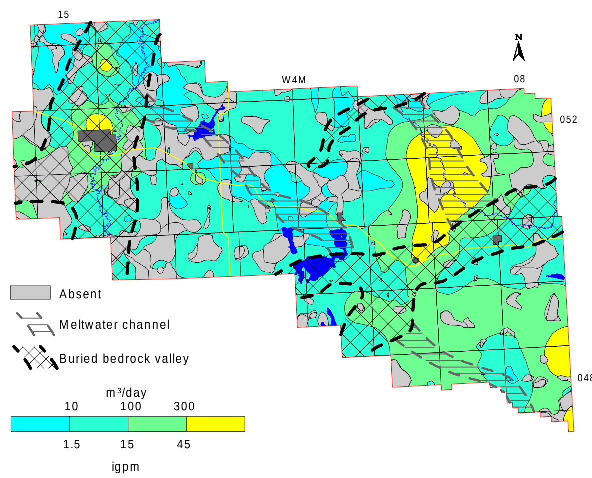

Figure 12. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)

5.2.2.1 Chemical Quality of Groundwater from Surficial Deposits

The chemical analysis results of groundwaters from the surficial deposits have not been differentiated based on aquifers in the upper or lower surficial deposits. The main reason for not separating the chemical analysis results into the different aquifers is the lack of control. Because of the limited areal extent of the lower surficial deposits, almost all of the analysis results are from the upper surficial deposits.

The other justification for not separating the analyses was that there appeared to be no major chemical difference between groundwaters from the upper and lower sand and gravel aquifers. The groundwaters from these aquifers are generally chemically hard and high in dissolved iron.

The groundwaters from the surficial deposits are mainly calcium-magnesium-bicarbonate or sodium-sulfate-type waters, with 75% of the groundwaters having a TDS of less than 1,000 mg/L. The groundwaters with a TDS of less than 1,000 mg/L occur mainly east of range 12, W4M. Groundwaters from the surficial deposits are expected to have dissolved iron concentrations of greater than 1 mg/L. Groundwater from a water supply well drilled for the AEP Laboratory near the Town of Vegreville completed in the Lower Sand and Gravel Aquifer has a TDS of 1,120 mg/L, a hardness of 408 mg/L, a chloride concentration of 16 mg/L and an iron concentration of 4.62 mg/L (EBA Engineering Consultants Ltd., 1975).

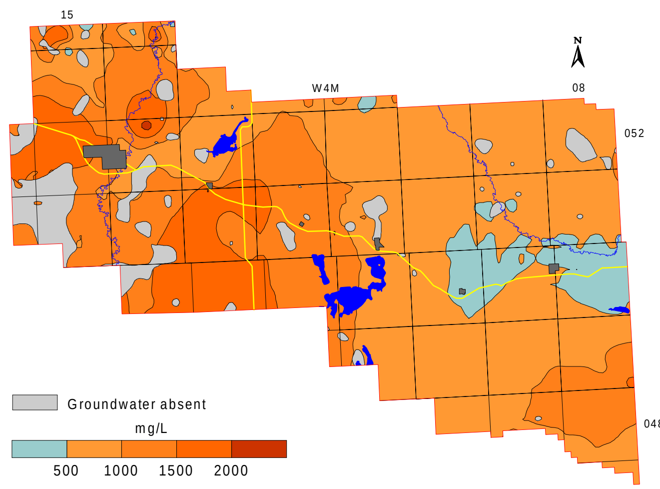

Figure 13. Total Dissolved Solids in Groundwater from Surficial Deposits

Although the majority of the groundwaters are calcium-magnesium-bicarbonate-type waters, there are groundwaters from the surficial deposits with sodium as the main cation; there are also groundwaters with significant concentrations of the sulfate ion. The groundwaters with elevated levels of sulfate generally occur in areas where there are elevated levels of total dissolved solids. One exception is in the northeastern part of the County, which may be a result of lack of control. 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.

5.2.3 Upper Sand and Gravel Aquifer

The Upper Sand and Gravel Aquifer includes saturated sand and gravel deposits in the upper surficial deposits. Typically, these aquifers directly overlie or are close to the bedrock surface. Saturated sand and gravel deposits are not continuous but are expected over approximately 80% of the County.

5.2.3.1 Aquifer Thickness

The thickness of the Upper Sand and Gravel Aquifer is a function of two parameters: (1) the elevation of the non-pumping water-level surface associated with the upper surficial deposits; and (2) the depth to the bedrock surface. Since the non-pumping water-level surface in the surficial deposits tends to be a subdued replica of the bedrock surface, the thickness of the Upper Sand and Gravel Aquifer tends to be directly proportional to the thickness of the surficial deposits.

While the sand and gravel deposits in the upper surficial deposits are not continuous, the Upper Sand and Gravel Aquifer includes all of the aquifers present in the upper surficial deposits. The Upper Sand and Gravel Aquifer is more than 20 metres thick in a few areas, but over the majority of the County, is less than ten metres thick; over 20% of the County, the Aquifer is absent. Most of the greater thickness in the Upper Sand and Gravel Aquifer occurs in the areas of linear bedrock lows.

5.2.3.2 Apparent Yield

The permeability of the Upper Sand and Gravel Aquifer can be high. The high permeability combined with significant thickness leads to an extrapolation of water wells with high yields; however, because the sand and gravel deposits occur mainly as hydraulically discontinuous pockets, the apparent yields of the water wells are limited. The apparent yields for water wells completed in this Aquifer are expected to be mainly less than 30 m³/day. Where the Upper Sand and Gravel Aquifer is absent and where the yields are low, the development of water wells for the domestic needs of single families may not be possible.

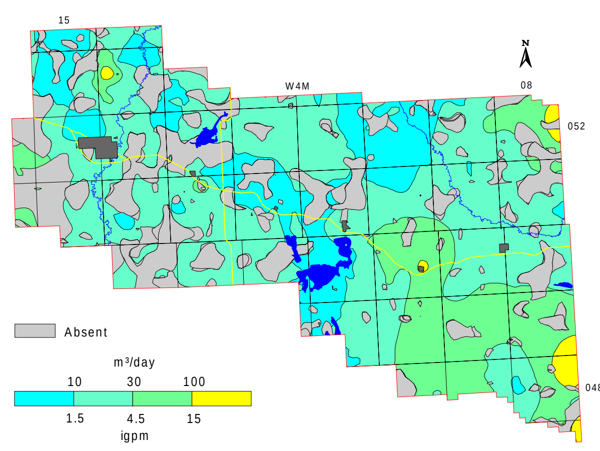

Figure 14. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

5.2.4 Lower Sand and Gravel Aquifer

The Lower Sand and Gravel Aquifer is a saturated sand and gravel deposit that occurs at or near the base of the surficial deposits in the deepest part of the pre-glacial linear bedrock lows. The thickness of the sand and gravel deposits is mainly less than 10 metres. The Lower Sand and Gravel Aquifer is mostly restricted to the Buried Vegreville and Vermilion valleys and meltwater channels in the County.

5.2.4.1 Apparent Yield

Water wells completed in the Lower Sand and Gravel Aquifer range from less than 10 m³/day to more than 100 m³/day. The highest yields are expected in the Buried Vermilion Valley, in the meltwater channel north of the Buried Vermilion Valley, and in the Buried Vegreville Valley near the Town of Vegreville in township 052, ranges 14 and 15, W4M.

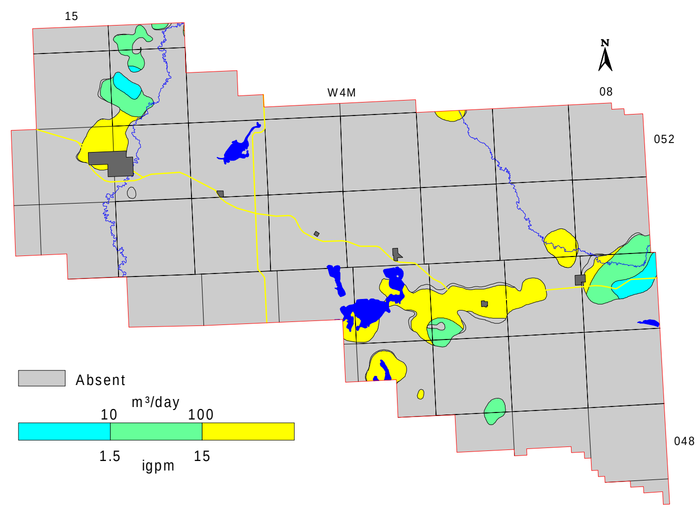

Figure 15. Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer

AEP has completed at least some of its water test holes in the Lower Sand and Gravel Aquifer associated with the Buried Vegreville Valley in 10-23-052-15 W4M. One water test hole was completed as a water supply well and two were completed as observation water wells for the AEP Laboratory. The projected long-term yield from the water supply well is in excess of 1,250 m³/day based on a transmissivity of 151 m²/day and a corresponding storativity of 1.38 x 10^{-4} (EBA Engineering Consultants Ltd., 1975). Based on the groundwater requirements for the lab, the water supply well was licensed for 3.4 m³/day for irrigation purposes.

5.3 Bedrock

5.3.1 Geological Characteristics

The upper bedrock in the County includes the Belly River Group and the Lea Park Formation. The Lea Park Formation underlies the Belly River Group.

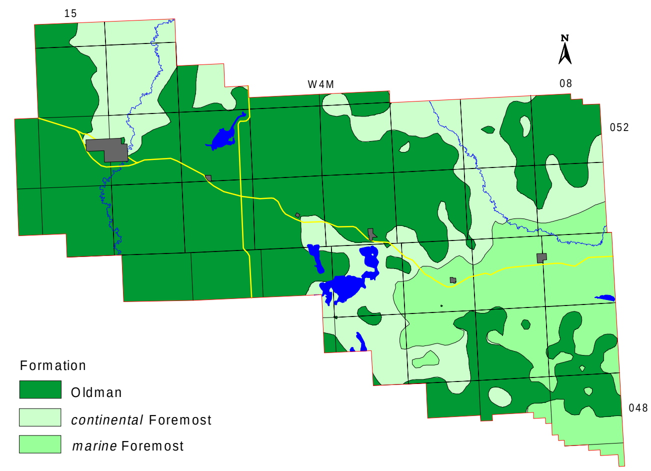

Figure 16. Bedrock Geology

The Belly River Group in the County has a maximum thickness of 250 metres, and includes the Oldman Formation and both the *continental* and *marine* facies of the Foremost Formation.

The upper part of the Belly River Group is the Oldman Formation. Within the County the Oldman Formation is present and forms the uppermost bedrock in predominantly the western part of the County and in 30% of the eastern half of the County. The Oldman Formation has a maximum thickness of 70 metres within the County and is composed of sandstone, siltstone, shale, and coal deposits of the Comrey and Upper Siltstone members.

The *continental* Foremost Formation underlies the Oldman Formation and subcrops under the surficial deposits in the northwestern part of the County and in 35% of the eastern half of the County. The *continental* Foremost Formation has a thickness of less than 200 metres within the County. The *continental* Foremost Formation, a backshore deposit, consists mainly of shale deposits with minor amounts of sandstone present. Coal zones occur within the *continental* Foremost Formation, with the main ones referred to as the McKay and the Taber Coal zones. There are also minor amounts of ironstone, a chemical deposit, in the *continental* Foremost Formation. Where the *continental* Foremost Formation is close to the bedrock surface, it can be fractured or weathered and can have significant local permeability.

The *marine* Foremost Formation has a maximum thickness of 200 metres within the County and underlies the *continental* Foremost Formation in the western and northern parts of the County. In the southeastern part of the County, the *marine* Foremost Formation subcrops.

In parts of eastern Alberta, the *marine* Foremost Formation can be separated into individual sandstone and shale members. However, close to the upper part of the *marine* Foremost Formation, and particularly toward the western extent, the sandstones making up the *marine* Foremost Formation cannot always be separated into individual members. This situation occurs because the sandstone members of the *marine* Foremost Formation thicken and the intervening shale layers thin toward the top and the western extent of the marine facies. Even though the individual members cannot be distinguished, the sandstone occurrence can be a significant aquifer and has been designated the “Milan Aquifer”. The top of the Milan Aquifer extends up to ten metres into the overlying *continental* Foremost Formation and can occupy the upper 40 metres of the *marine* Foremost Formation. The western extent of the Milan Aquifer coincides with the position where the Basal Belly River Sand can be distinguished. The Milan Aquifer is present in the western half of the County under the *continental* Foremost Formation.

The *marine* Foremost Formation facies can include most of the Milan Aquifer and up to four sandstone and intervening shale members. Because the significant individual aquifers can be distinguished in most of the area and because the upper bedrock discussion includes aquifers mainly associated with the *marine* Foremost Formation, there will be no direct review of the Milan Aquifer or the *marine* Foremost Formation in this report or on the CD-ROM.

The Lea Park Formation is mostly composed of shale, with only minor amounts of bentonitic sandstone present in some areas. Regionally, the Lea Park Formation is an aquitard. Because the Lea Park Formation is an aquitard, there will be no direct review of the Lea Park Aquifer in the text of this report. However, maps associated with the Lea Park Aquitard are included on the CD-ROM.

5.3.2 Aquifers

Of the 3,329 water wells in the database, 909 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 2,204 from 909. 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 2,204 bedrock water wells, 1,937 could be assigned a specific aquifer. The bedrock water wells are mainly completed in the Oldman and *continental* Foremost aquifers as shown in the adjacent table. There are 33 records that are not included in the six main aquifers ("Other" in adjacent table).

Bedrock Aquifer	No. of Water Wells
Oldman	433
continental Foremost	1008
Birch Lake Member	246
Ribstone Creek Member	140
Victoria Member	106
Brosseau Member	4
Other	33
Total	1970

Table 3. Completion Aquifer

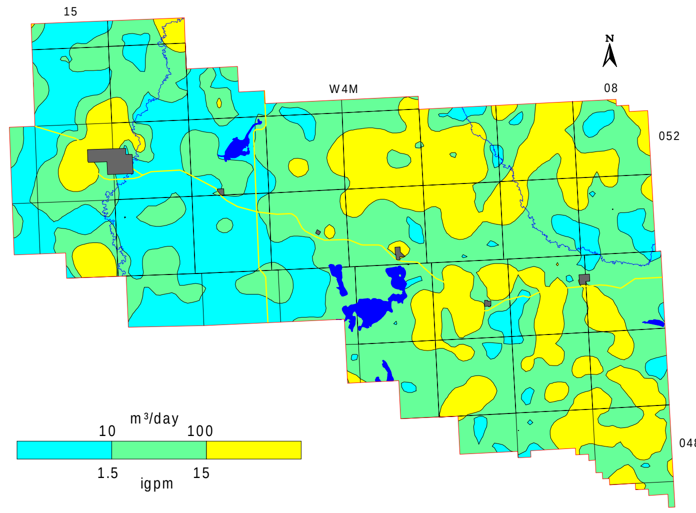

Figure 17. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

There are 698 records for bedrock water wells that have apparent yield values. 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 eastern half and the lower yields are mainly in the western half of the County. The higher yields in the western part of the County may be a result of increased permeability resulting from the weathering process in association with the Buried Vegreville Valley.

There are 618 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
Oldman	71	32	35	4
continental Foremost	303	88	123	92
Birch Lake Member	118	7	68	43
Ribstone Creek Member	73	9	40	24
Victoria Member	52	10	35	7
Brosseau Member	1	0	0	1
Totals	618	146	301	171

Table 4. Apparent Yields of Bedrock Aquifers

5.3.3 Chemical Quality of Groundwater

The TDS concentrations in the groundwaters from the upper bedrock aquifer(s) range from less than 500 to more than 2,000 mg/L. In more than 80% 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 southwestern parts of the County.

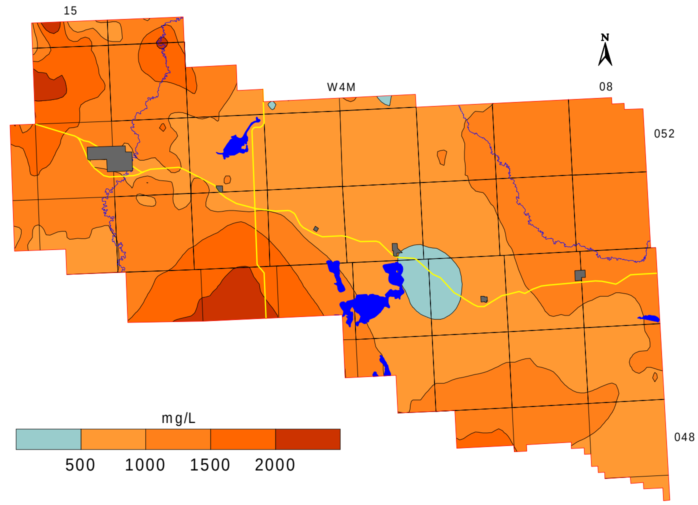

Figure 18. Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

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 80% of the County.

In more than 95% of the County, the fluoride ion concentrations in the groundwaters from the upper bedrock aquifer(s) are 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 types.

5.3.4 Oldman Aquifer

The Oldman Aquifer comprises the porous and permeable parts of the Oldman Formation that underlies the surficial deposits predominantly in the western part of the County and in 30% of the eastern half of the County. The thickness of the Oldman Formation varies from less than 20 metres at the edge of the subcrop to more than 60 metres at the western edge of the County. The thickness of the Oldman Formation decreases in the vicinity of the Vermilion River Valley as a result of erosional processes.

5.3.4.1 Depth to Top

The depth to the top of the Oldman Formation is mainly less than 20 metres in the northern two-thirds of the County, where it subcrops. In the southeastern part of the County, the depth to the top of the Oldman Formation can be more than 40 metres.

5.3.4.2 Apparent Yield

The apparent yields for individual water wells completed in the Oldman Aquifer in the western part of the County are mainly less than 10 m³/day and predominantly between 10 and 100 m³/day east of range 13, W4M.

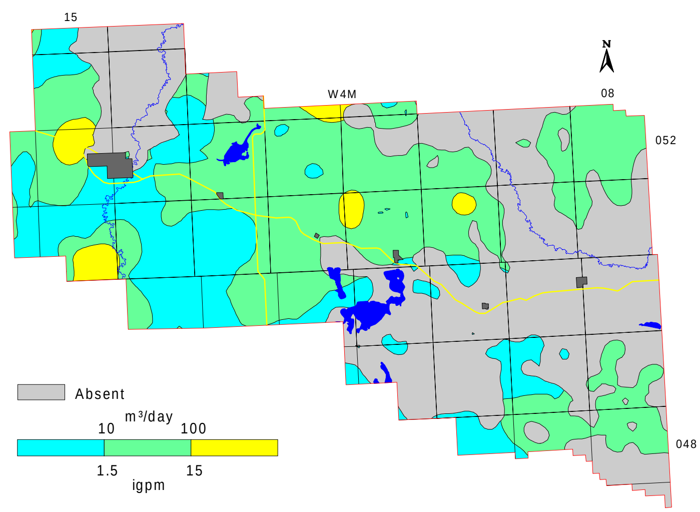

Figure 19. Apparent Yield for Water Wells Completed through Oldman Aquifer

5.3.4.3 Quality

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

5.3.5 *continental* Foremost Aquifer

The *continental* Foremost Aquifer comprises the porous and permeable parts of the *continental* Foremost Formation that underlies the Oldman Formation, and subcrops under the surficial deposits in the northwestern part of the County and in 35% of the eastern half of the County. The thickness of the *continental* Foremost Formation varies from less than 20 metres at the eastern edge of the subcrop to more than 200 metres in Tp 050, R 14, W4M. The *continental* Foremost Aquifer does not include the lower 10 metres of the Formation, which is the Milan Aquifer.

5.3.5.1 Depth to Top

The depth to the top of the Formation is variable, ranging from less than 20 metres to more than 80 metres at the western edge of the County.

5.3.5.2 Apparent Yield

The apparent yields for individual water wells completed in the *continental* Foremost Aquifer are mainly less than 10 m³/day west of range 12, W4M and between 10 and 100 m³/day east of range 13, W4M. The adjacent map indicates that apparent yields of more than 100 m³/day can be expected in townships 051 and 052, ranges range 08 to 12, W4M.

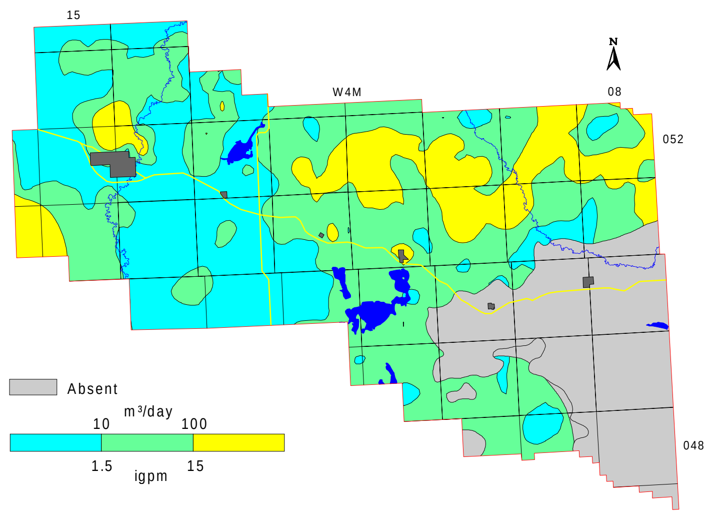

Figure 20. Apparent Yield for Water Wells Completed through continental Foremost Aquifer

5.3.5.3 Quality

The groundwaters from the *continental* Foremost Aquifer are mainly sodium-bicarbonate, sodium-sulfate or sodium-chloride types (see CD-ROM). The TDS concentrations are expected to be mainly less than 1,500 mg/L. The higher values are in the northwestern and southwestern parts of the County. The sulfate concentrations are mainly less than 500 mg/L. Chloride concentrations in the groundwaters from the Oldman Aquifer are mainly less than 250 mg/L. The indications are that in the western part of the County, the chloride concentrations are expected to be more than 250 mg/L.

5.3.6 *marine* Foremost Aquifer

There is no detailed discussion for the *marine* Foremost Aquifer in this report; however, discussions for three of the four sandstone members that comprise the *marine* Foremost Aquifer are provided in the following sections. Due to the lack of available data for the Brosseau Member, there is no discussion for this Member in this report.

5.3.7 Birch Lake Aquifer

The Birch Lake Aquifer comprises the porous and permeable parts of the Birch Lake Member. Structure contours have been prepared for the top and bottom of the Member, which underlies the southeastern part of the County. The structure contours show the Member being mostly less than 30 metres thick. The thickness of the Birch Lake Member is generally less than 10 metres at its northern edge.

5.3.7.1 Depth to Top

The depth to the top of the Birch Lake Member is mainly less than 60 metres below ground level, but can be more than 100 metres in the southern part of the County in township 048, range 10, W4M.

5.3.7.2 Apparent Yield

The apparent yields for individual water wells completed through the Birch Lake Aquifer are mainly in the range of 10 to 100 m³/day. The areas where water wells with higher yields are expected are mainly in a northwest-southeast-trending direction where the Aquifer is present in the County.

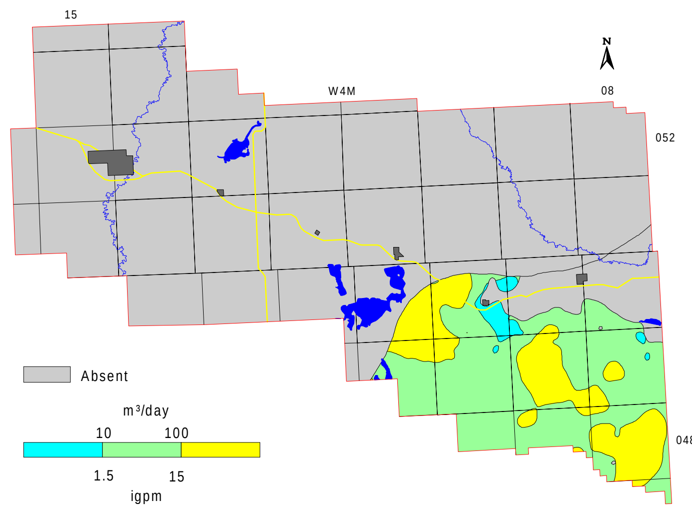

Figure 21. Apparent Yield for Water Wells Completed through Birch Lake Aquifer

5.3.7.3 Quality

There are nine water well records in the database with sufficient information to determine the chemical type of groundwaters from the Birch Lake Aquifer. The groundwaters from the Birch Lake Aquifer are mainly a sodium-bicarbonate type (see CD-ROM).

The TDS concentrations in the groundwaters from the Birch Lake Aquifer are expected to be less than 1,000 mg/L. The sulfate concentrations are mainly less than 300 mg/L. Chloride concentrations in the groundwaters from the Birch Lake Aquifer are mainly less than 10 mg/L.

5.3.8 Ribstone Creek Aquifer

The Ribstone Creek Aquifer comprises the porous and permeable parts of the Ribstone Creek Member. Structure contours have been prepared for the top and bottom of the Member, which underlies the southeastern part of the County, predominantly south of township 051 and east of range 12, W4M. The structure contours show the Member being mostly less than 20 metres thick.

5.3.8.1 Depth to Top

The depth to the top of the Ribstone Creek Member is mainly less than 100 metres below ground level but can be more than 120 metres in townships 048 and 049, ranges 09 and 10, W4M.

5.3.8.2 Apparent Yield

The apparent yields for individual water wells completed through the Ribstone Creek Aquifer are mainly in the range of 10 to 100 m³/day. The areas where water wells with higher yields are expected are mainly in parts of townships 049 and 050, W4M.

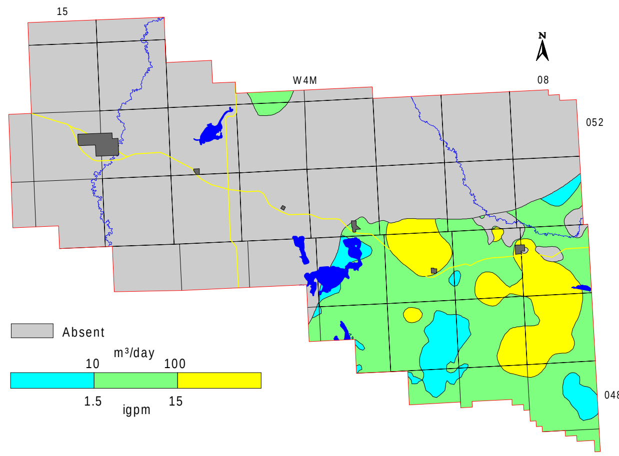

Figure 22. Apparent Yield for Water Wells Completed through Ribstone Creek Aquifer

5.3.8.3 Quality

There are not enough available data to determine the chemical type of the groundwaters from the Ribstone Creek Aquifer in the County. However, data available from the Aquifer in the M.D. of Wainwright suggest that, typically, the groundwaters from the Ribstone Creek Aquifer are a sodium-bicarbonate type.

The TDS concentrations in the groundwaters from the Ribstone Creek Aquifer are mainly less than 1,000 mg/L. The sulfate concentrations are mainly less than 200 mg/L. The higher sulfate concentrations are mainly along the southern edge of the County, where the Aquifer is present. Chloride concentrations in the groundwaters from the Ribstone Creek Aquifer are mainly less than 50 mg/L. The higher chloride values occur primarily in townships 049 and 050, range 08, W4M.

5.3.9 Victoria Aquifer

The Victoria Aquifer comprises the porous and permeable parts of the Victoria Member. Structure contours have been prepared for the top and bottom of the Member, which underlies 60% of the County. The structure contours show the Member being mostly less than 30 metres thick.

5.3.9.1 Depth to Top

The depth to the top of the Victoria Creek Member is mainly less than 140 metres below ground level but can be more than 180 metres in the southwestern part of the County where the Member is present.

5.3.9.2 Apparent Yield

The apparent yields for individual water wells completed through the Victoria Aquifer are mainly less than 100 m³/day. The areas where water wells with yields of less than 10 m³/day are expected are where the thickness of the Aquifer is generally less than 20 metres near the western and northern edges and in the central part of the Aquifer.

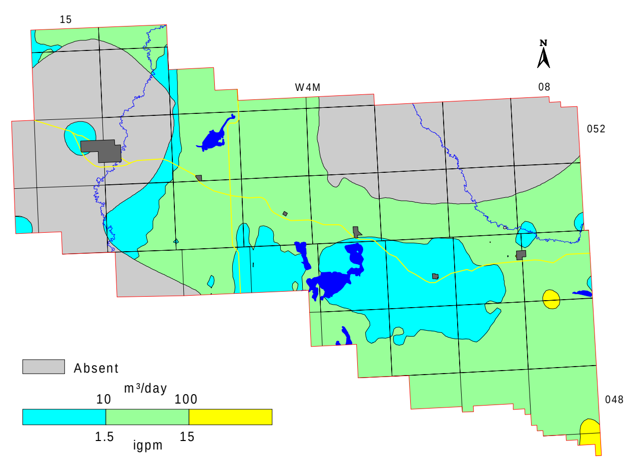

Figure 23. Apparent Yield for Water Wells Completed through Victoria Aquifer

5.3.9.3 Quality

There are not enough available data to determine the chemical type of the groundwaters from the Victoria Aquifer in the County. However, data available for the Victoria Aquifer in the M.D. of Wainwright suggests that, typically, the groundwaters from the Aquifer range from sodium-bicarbonate to calcium-magnesium-chloride types. There are two control points within the County of Minburn with TDS, sulfate and chloride concentrations. One control point is in NW 25-050-09 W4M and the other is in 10-26-049-08 W4M. By extrapolating these data with the data from the surrounding counties, TDS concentrations of less than 1,200 mg/L can be mainly expected west of range 11, W4M and more than 1,200 mg/L east of range 12, W4M. The sulfate concentrations are mainly less than 250 mg/L. Chloride concentrations in the groundwaters from the Victoria Aquifer are mainly less than 100 mg/L.

5.3.10 Lea Park Aquitard

The Lea Park Formation is composed mainly of shale and has a very low permeability. In most of the area, the top of the Lea Park coincides with the Base of Groundwater Protection. In some areas, the Base of Groundwater Protection extends above the Brosseau Member. A map showing the depth to the Base of Groundwater Protection is given on page 6 of this report, in Appendix A, and on the CD-ROM.

6 GROUNDWATER BUDGET

6.1 Hydrographs

There are five locations in the County where water levels are being measured and recorded with time. These sites are observation water wells (Obs WWs) that are part of the AEP regional groundwater-monitoring network. Three Obs WWs are in 05-23-052-15 W4M in the vicinity of the Town of Vegreville and two Obs WWs are in SW 30-050-10 W4M in the vicinity of the Village of Innisfree. Hydrographs for four of the five Obs WWs are shown on the adjacent figure; water-level measurements for one of the Obs WWs in 05-23-052-15 W4M are available for 1996 only and are of limited use.

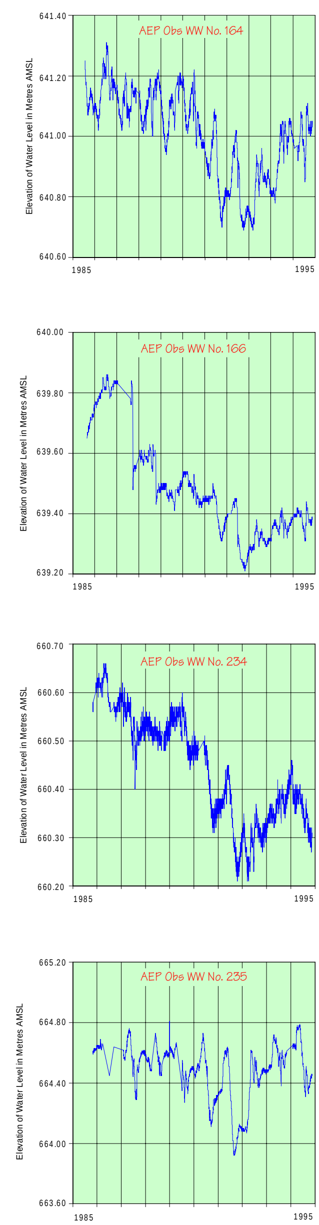

Figure 24. Hydrographs - AEP Observation Water Wells

AEP Obs WW No. 164 in 05-23-052-15 W4M is completed at a depth of 37.2 metres below ground level in the Lower Sand and Gravel Aquifer. This hydrograph shows annual cycles of recharge in spring and fall and declines in winter and summer. Overall annual fluctuations are approximately 20 to 40 centimetres. From 1985 to 1989, there is no apparent water-level decline. From 1990 to 1992, the water level declined approximately 30 centimetres. From 1993 to 1995, the water level rose in the order of 30 centimetres. There is only one licensed water well in the area that has been completed in the Lower Sand and Gravel Aquifer; this is the water well that has been authorized to use 3.4 m^3/day for irrigation purposes by the AEP Laboratory at Vegreville. There has been no authorized increase in groundwater for the AEP water well since 1977, when it was put into use.

The second AEP Obs WW in 05-23-052-15 W4M, Obs WW No. 166, is completed at a depth of 82.3 metres below ground level in the *continental* Foremost Aquifer. The water-level data from 1985 to 1988 are suspect, probably as a result of equipment calibration problems. This hydrograph also reflects a water-level decline from 1990 to 1992, followed by a rise beginning in 1993. Overall annual fluctuations are less than 20 centimetres.

AEP Obs WW No. 234 in SW 30-050-10 W4M is completed at a depth of 52.7 metres below ground level in the *continental* Foremost Aquifer. This hydrograph shows annual cycles of recharge in spring and fall and declines in winter and summer. Overall annual fluctuations are approximately 5 to 20 centimetres. This hydrograph also reflects a water-level decline from 1990 to 1992 of approximately 40 centimetres and a general water-level decline since 1986.

The fourth AEP Obs WW in SW 30-050-10 W4M, Obs WW No. 235, is completed at a depth of 16.8 metres below ground level in the *continental* Foremost Aquifer. This hydrograph also shows annual cycles of recharge and decline. Overall annual fluctuations are approximately 30 to 80 centimetres. This hydrograph also reflects a water-level decline from 1990 to 1992 of in the order of 40 centimetres. The Village of Innisfree is licensed to divert 74.4 m^3/day from the *continental* Foremost Aquifer. It is possible that this diversion is having an impact on the Aquifer; however, based on similar water-level declines in AEP Obs WW Nos. 164 and 166 and in AEP Obs WW No. 234, this water-level decline appears to be regional and not as a result of local influences.

6.2 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 (m²/day)	Gradient (m/m)	Width (km)	Main Direction of Flow	Quantity (m³/day)	Authorized Diversion (m³/day)
Surficial Deposits						**40.6**
Upper Sand and Gravel					**#N/A**	**37.2**
Upper Sand and Gravel West	8	#N/A	#N/A	#N/A	#N/A	
Upper Sand and Gravel East	10	#N/A	#N/A	#N/A	#N/A	
Lower Sand and Gravel					**600**	3.4
Lower Sand and Gravel West	20	0.002	12	North	500	
Lower Sand and Gravel East	10	0.002	7	East	100	
Oldman	3	0.002	100	Northwest	**600**	**220**
***continental* Foremost**					**720**	**286.7**
Western part of County	1	0.002	60	North	120	
Eastern part of County	5	0.002	60	East	600	
Birch Lake	10	0.003	20	North	**600**	**37.2**
Ribstone Creek	8	0.002	30	North	**500**	**130.2**
Victoria	2	0.002	50	Northeast	**200**	**382**

The above table indicates that there is more groundwater flowing through the aquifers than has been authorized to be diverted from the individual aquifers, with the exception of the Victoria Aquifer. 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. However, because of the very approximate nature of the calculation of the quantity of groundwater flowing through the individual aquifers, more detailed work is required to establish the flow through the aquifers.

6.3 Quantity of Groundwater

An estimate of the volume of groundwater stored in the sand and gravel aquifers in the surficial deposits is 0.6 to 3.6 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%, 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, except in the vicinity of the Buried Vegreville and Vermilion valleys. In these two valleys, only the water levels from water wells completed in the deeper sand and gravel deposits have been included. These water levels were used for the calculation of saturated surficial deposits and for the calculation of recharge/discharge areas.

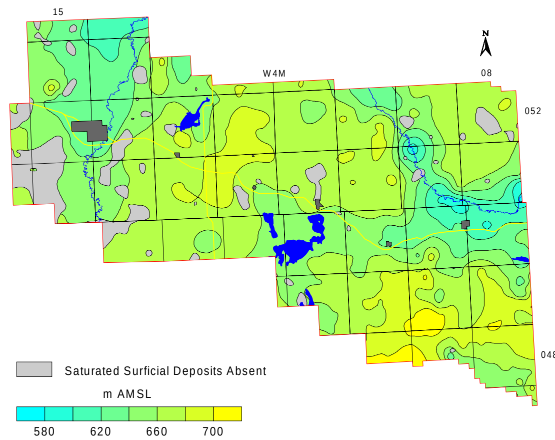

Figure 25. Non-Pumping Water-Level Surface in Surficial Deposits

6.4 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.

6.4.1.1 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 below includes those areas where the water level in the surficial deposits is more than five metres above the water level in the upper bedrock aquifer(s). The discharge areas are where the water level in the surficial deposits is more than five metres lower than the water level in the bedrock. When the water level in the surficial deposits is between five metres above and five metres below the water level in the bedrock, the area is classified as a transition.

The adjacent map shows that, in more than 80% 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 lows in the bedrock surface. 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.

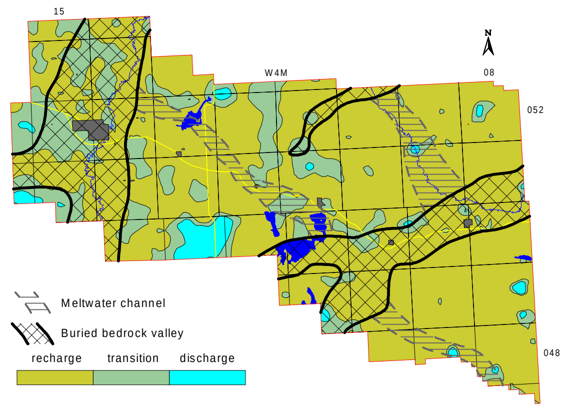

Figure 26. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)

6.4.1.2 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 Oldman Aquifer indicates that in more than 40% of the County where the Oldman Aquifer is present, there is a downward hydraulic gradient. Discharge areas for the Oldman Aquifer are either in or adjacent to the bedrock lows. 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.

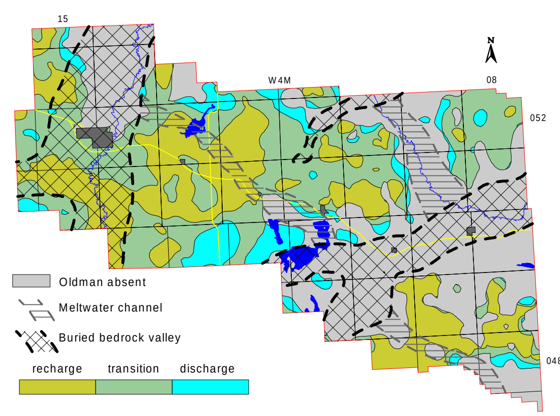

Figure 27. Recharge/Discharge Areas between Surficial Deposits and Oldman Aquifer

7 POTENTIAL FOR GROUNDWATER CONTAMINATION

The most common sources of contaminants that can impact groundwater originate on or near the ground surface. The contaminant sources can include leachate from landfills, effluent from leaking lagoons or from septic fields, and petroleum products from storage tanks or pipeline breaks. The agricultural activities that generate contaminants include 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 1,759 records in the area of the County with lithological descriptions, 239 have sand and gravel within one metre of ground level. In the remaining 1,520 records, the first sand and gravel is deeper or not present. This information was gridded to prepare a distribution of where the first sand and gravel deposit could be expected within one metre of ground level.

7.1.1 Risk of Contamination Map

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

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

Table 5. Risk of Groundwater Contamination Criteria

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

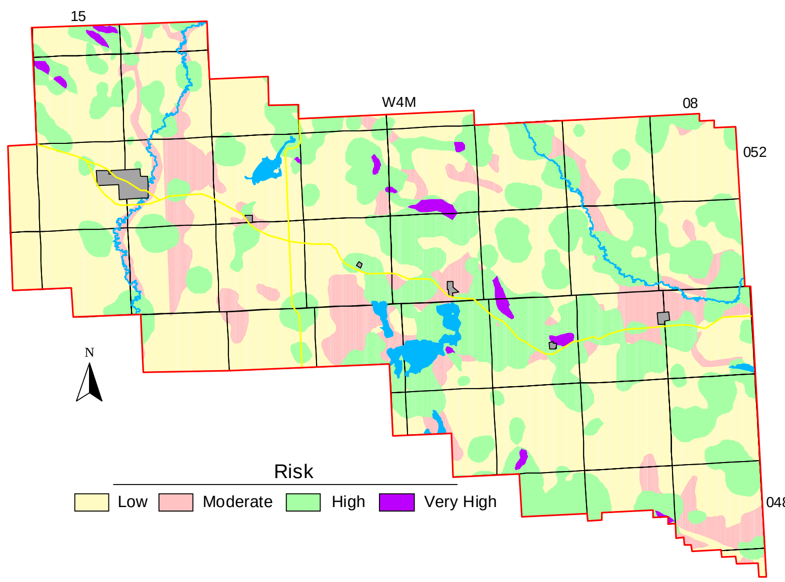

Figure 28. Risk of Groundwater Contamination

8 RECOMMENDATIONS

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

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

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

There is a shortage of hydrogeological information for the Lower Sand and Gravel Aquifer and the Aquifer needs to be better defined. The Lower Sand and Gravel Aquifer may be a source of large volumes of groundwater for the Village of Mannville. The development of water wells to ease drought conditions or disaster relief programs could be very significant. There is a water well used for domestic purposes in 01-29-050-09 W4M that is completed in the Lower Sand and Gravel Aquifer. An apparent yield of more than 300 m³/day was calculated from the available aquifer testing data recorded on the drilling log. It is recommended that a water test hole be drilled within 150 metres of this water well and completed within the Lower Sand and Gravel Aquifer. The water test hole should be used to conduct an extended aquifer test to better evaluate the Aquifer in the eastern part of the County.

There are very significant meltwater channels present in the northern part of the County. There is a domestic water well in NW 32-052-09 W4M that has a projected yield of in the order of 1,000 m³/day. There are indications that other significant meltwater channels are present and investigation of the aquifers associated with these features could be used to establish locations for high-yield water wells.

The present analysis has shown that the groundwater flow in the Victoria 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. It is recommended that a detailed study be completed to assess the volume of groundwater flowing through the Victoria Aquifer. The study would need to obtain all of the data for individual water wells authorized to divert groundwater from the Victoria Aquifer, document the quantity of groundwater being diverted, establish the water-level trends, and evaluate the hydraulic parameters for the Aquifer. The best method to analyze the data would be through the use of a computer model study.

One of the main shortages of data for the determination of a groundwater budget is water levels as a function of time. There are only five 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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10 GLOSSARY

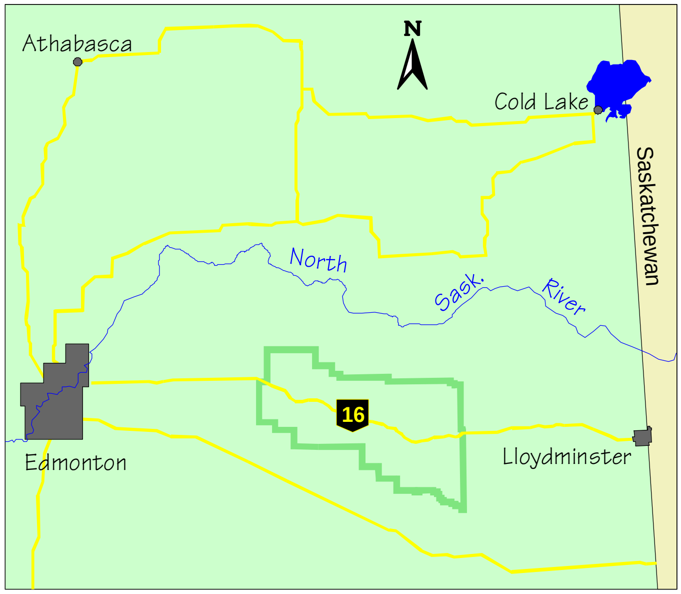
Aquifer	a formation, group of formations, or part of a formation that contains saturated permeable rocks capable of transmitting groundwater to water wells or springs in economical quantities.
Aquitard	a confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer.
Available Drawdown	in a confined aquifer, the distance between the non-pumping water level and the top of the aquifer. in an unconfined aquifer (water table aquifer), two thirds of the saturated thickness of the aquifer.
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.
Surficial Deposits	includes all sediments above the bedrock.
Transmissivity	the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient: a measure of the ease with which groundwater can move through the aquifer. Apparent Transmissivity: the value determined from a summary of aquifer test data, usually involving only two water-level readings. Effective Transmissivity: the value determined from late pumping and/or late recovery water-level data from an aquifer test. Aquifer Transmissivity: the value determined by multiplying the hydraulic conductivity of an aquifer by the thickness of the aquifer.
Yield	a regional analysis term referring to the rate a properly completed water well could be pumped, if fully penetrating the aquifer. Apparent Yield: based mainly on apparent transmissivity. Long-Term Yield: based on effective transmissivity.

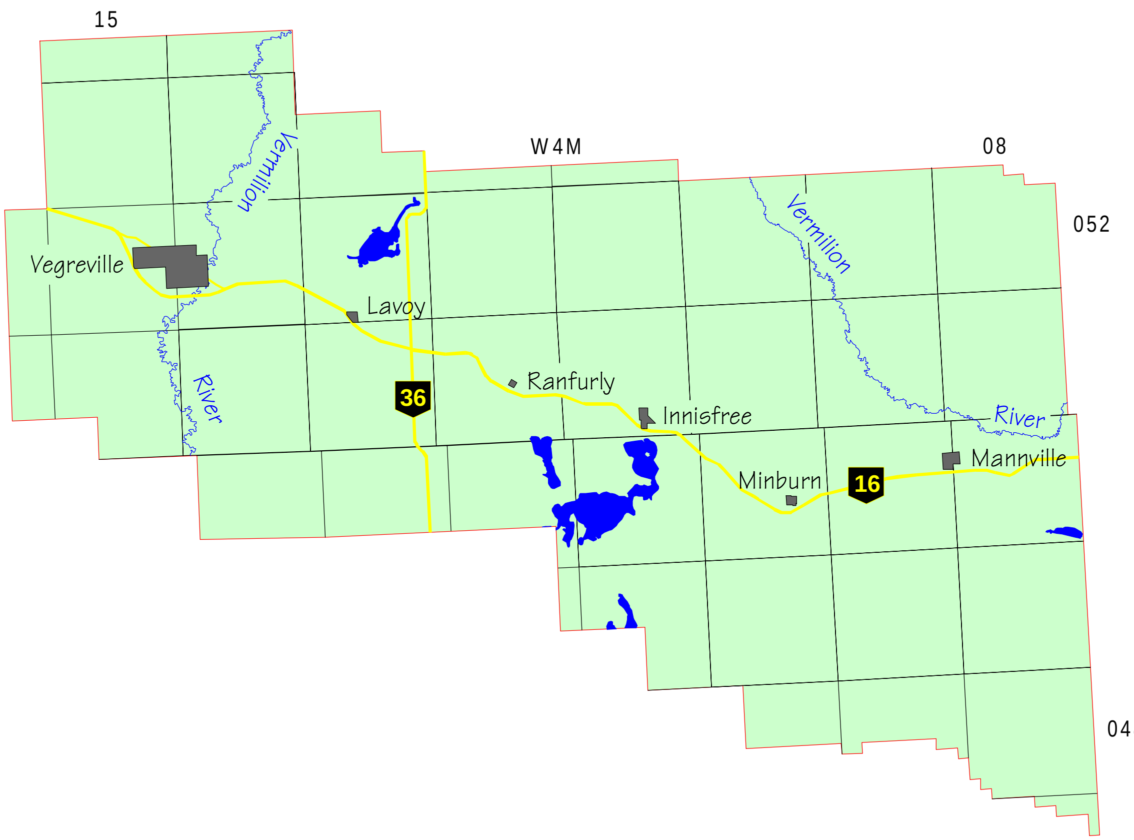
COUNTY OF MINBURN NO. 27

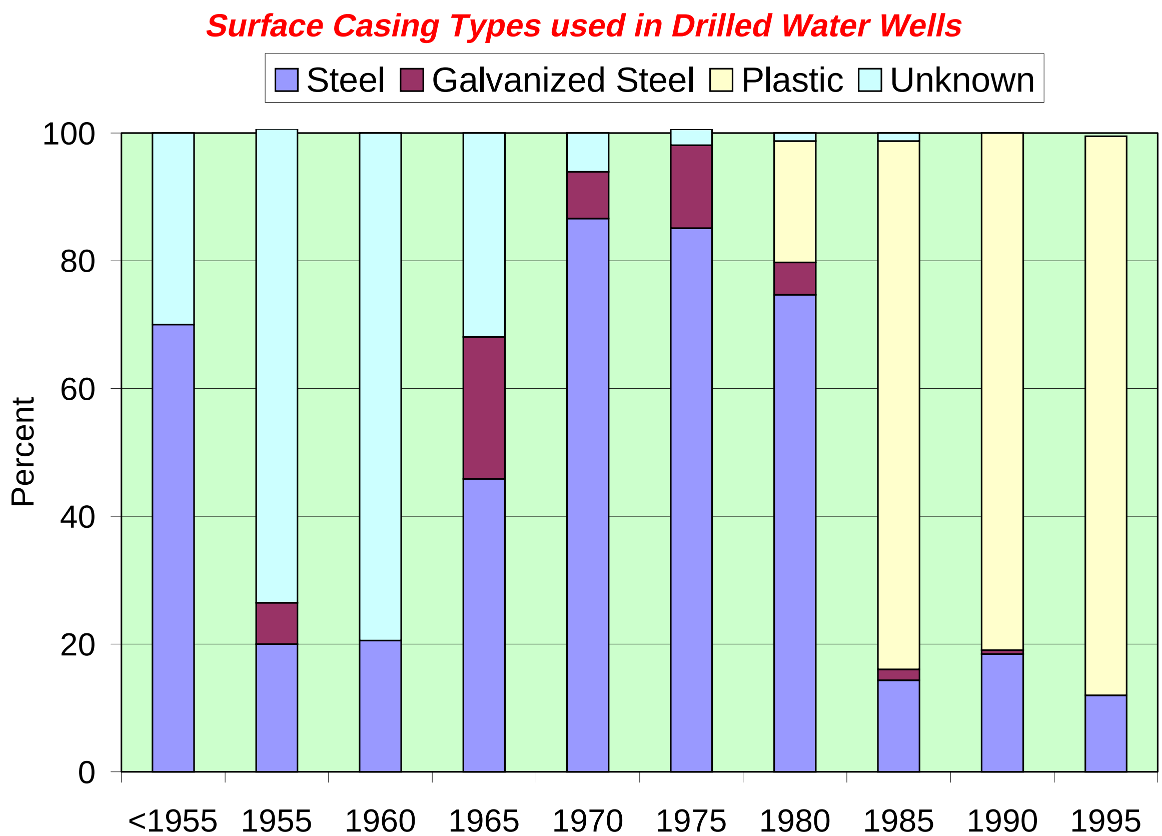
Appendix A

HYDROGEOLOGICAL MAPS AND FIGURES

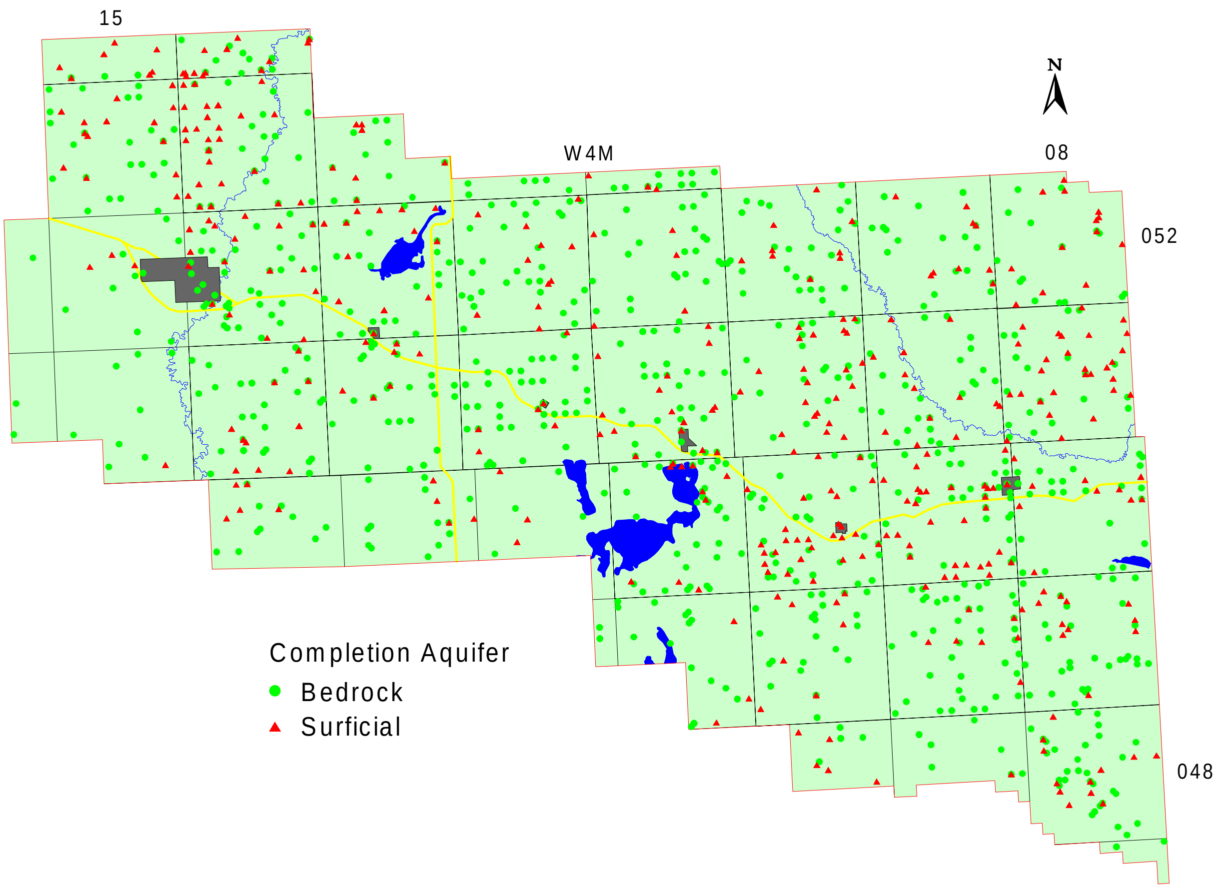
Index Map


N
Athabasca
Cold Lake
Saskatchewan
North
Sask.
River
16
Edmonton
Lloydminster

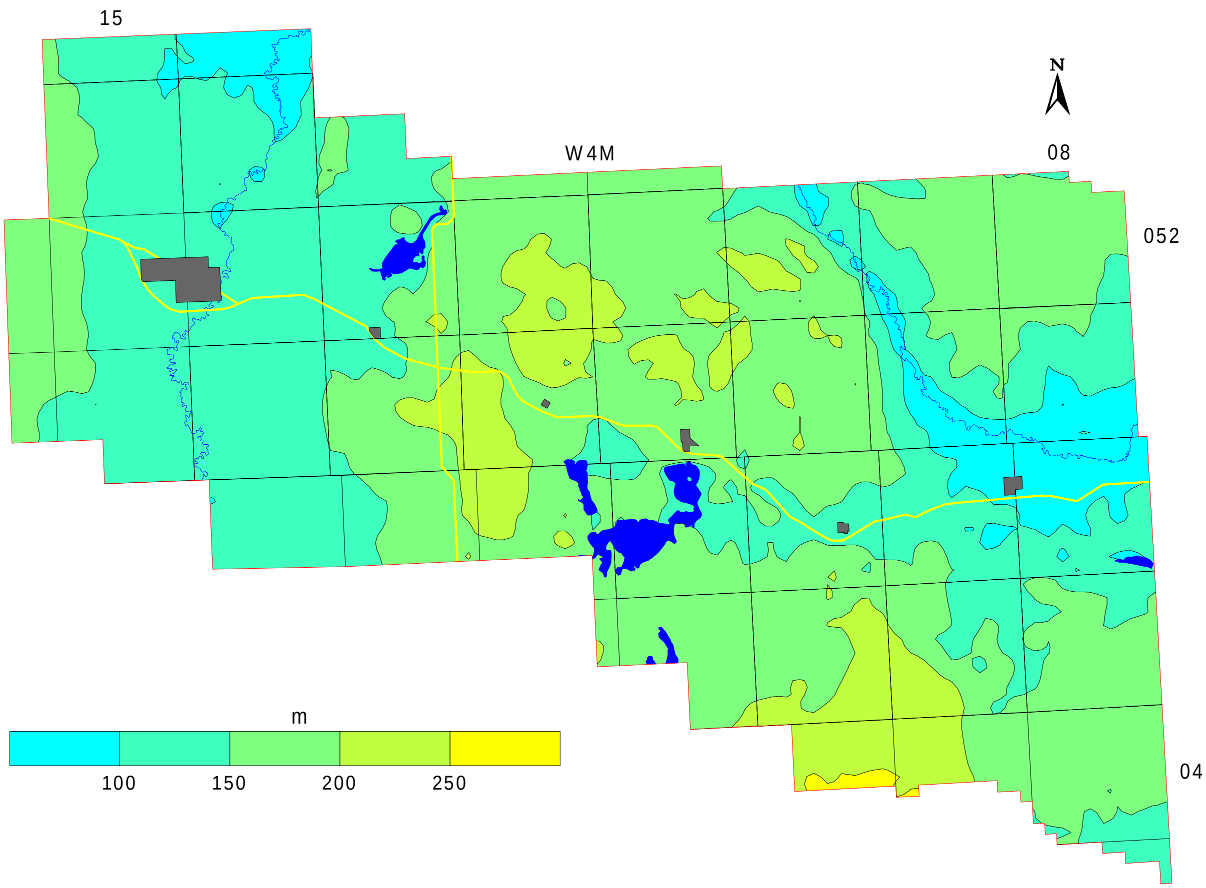

15
W4M
08
052
048
Vermilion
River
Vegreville
Lavoy
36
Ranfurly
Innisfree
Minburn
16
Mannville
Vermilion
River

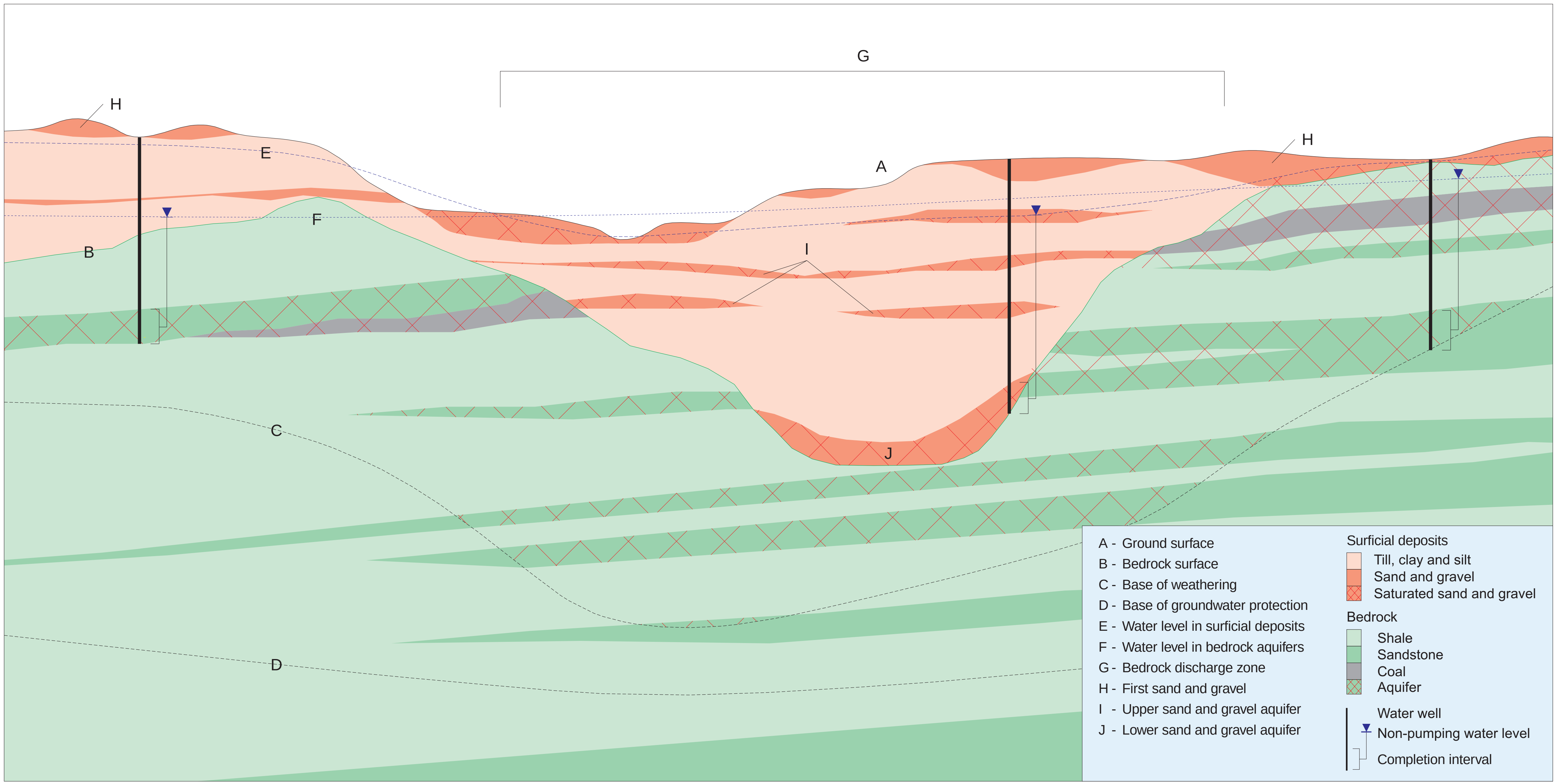

Surface Casing Types used in Drilled Water Wells
Steel
Galvanized Steel
Plastic
Unknown
Percent
100
80
60
40
20
0
<1955
1955
1960
1965
1970
1975
1980
1985
1990
1995

Location of Water Wells



Depth to Base of Groundwater Protection

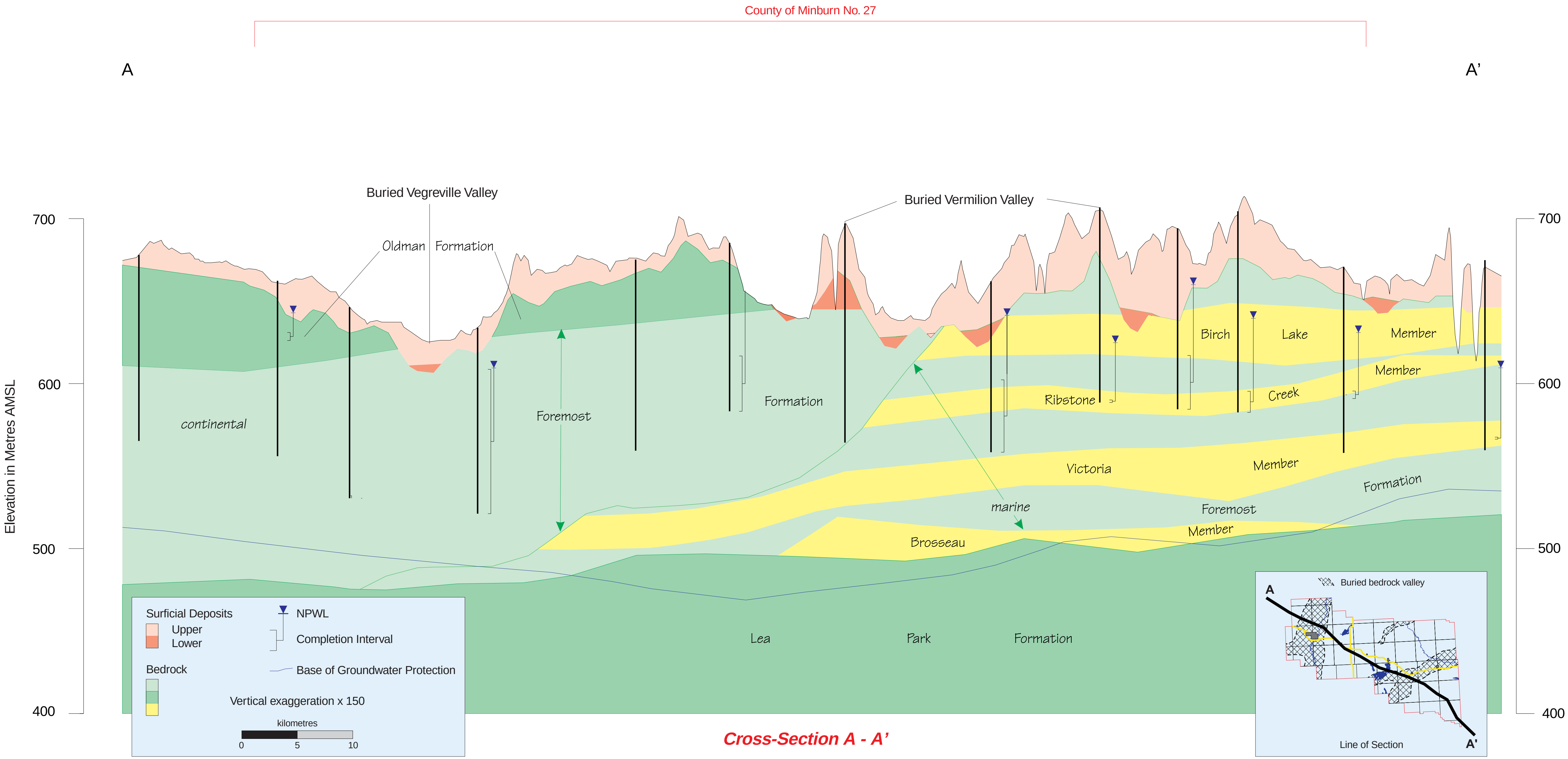




Generalized Cross-Section
(for terminology only)

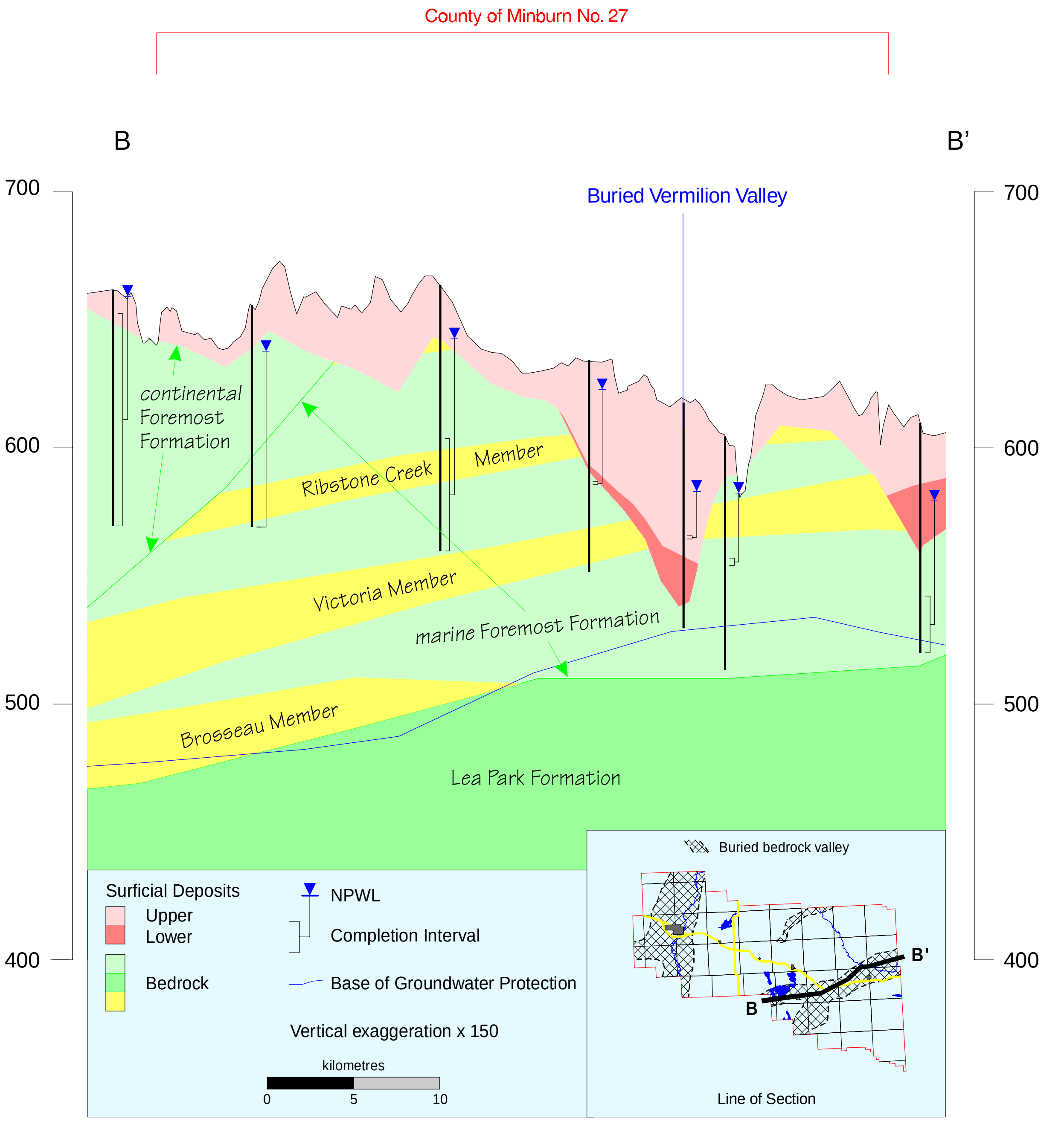
Lithology	Lithologic Description	Group and Formation: Thickness (m)	Group	Group and Formation: Designation	Member: Thickness (m)	Member: Designation	Zone: Thickness (m)	Zone: Designation
	sand, gravel, till, clay, silt	<80		Surficial Deposits	<80	Upper	<30	First Sand and Gravel
					<80	Lower		
	sandstone, 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		*continental* Foremost Formation			<20	Taber Coal Zone
							<20	McKay Coal Zone
	sandstone, shale	<200		*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

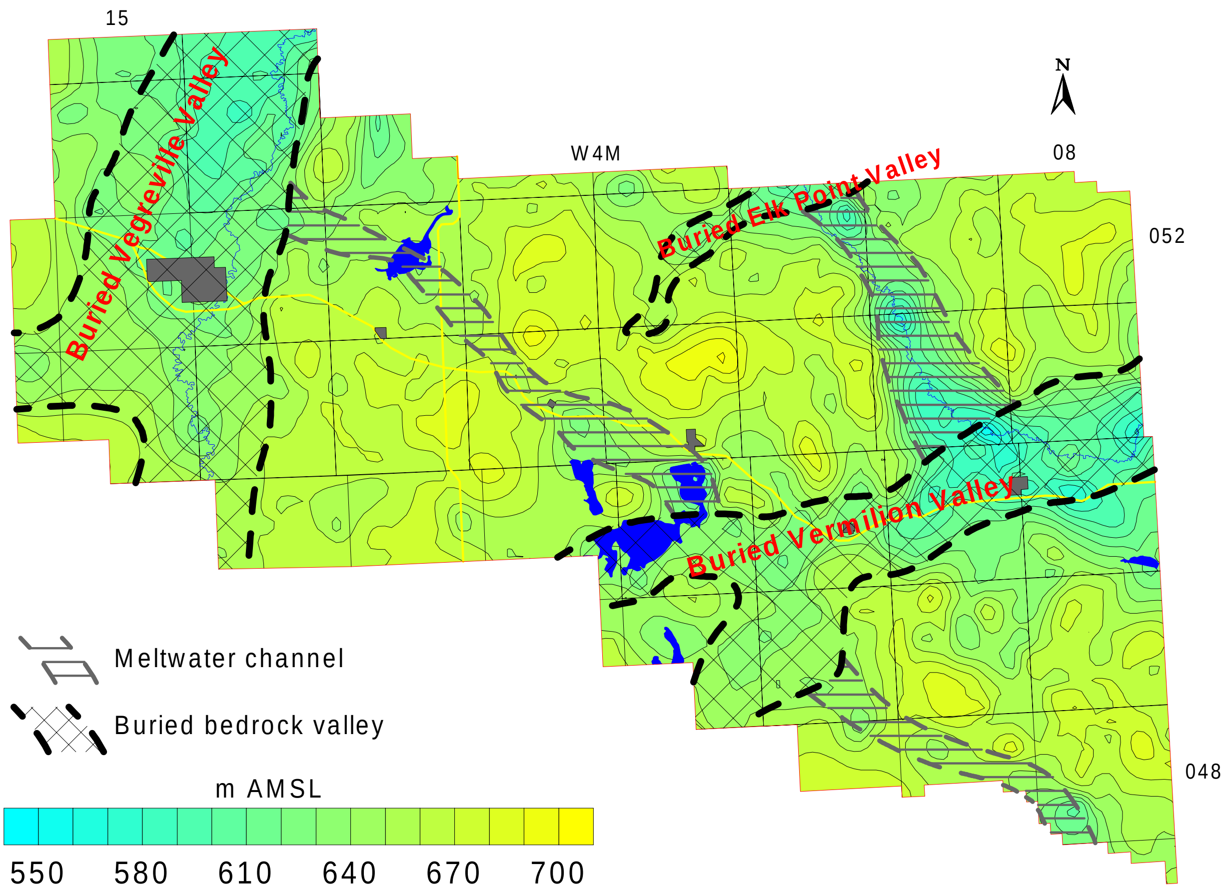


Cross-Section A - A'

Cross-Section B - B'



Bedrock Topography



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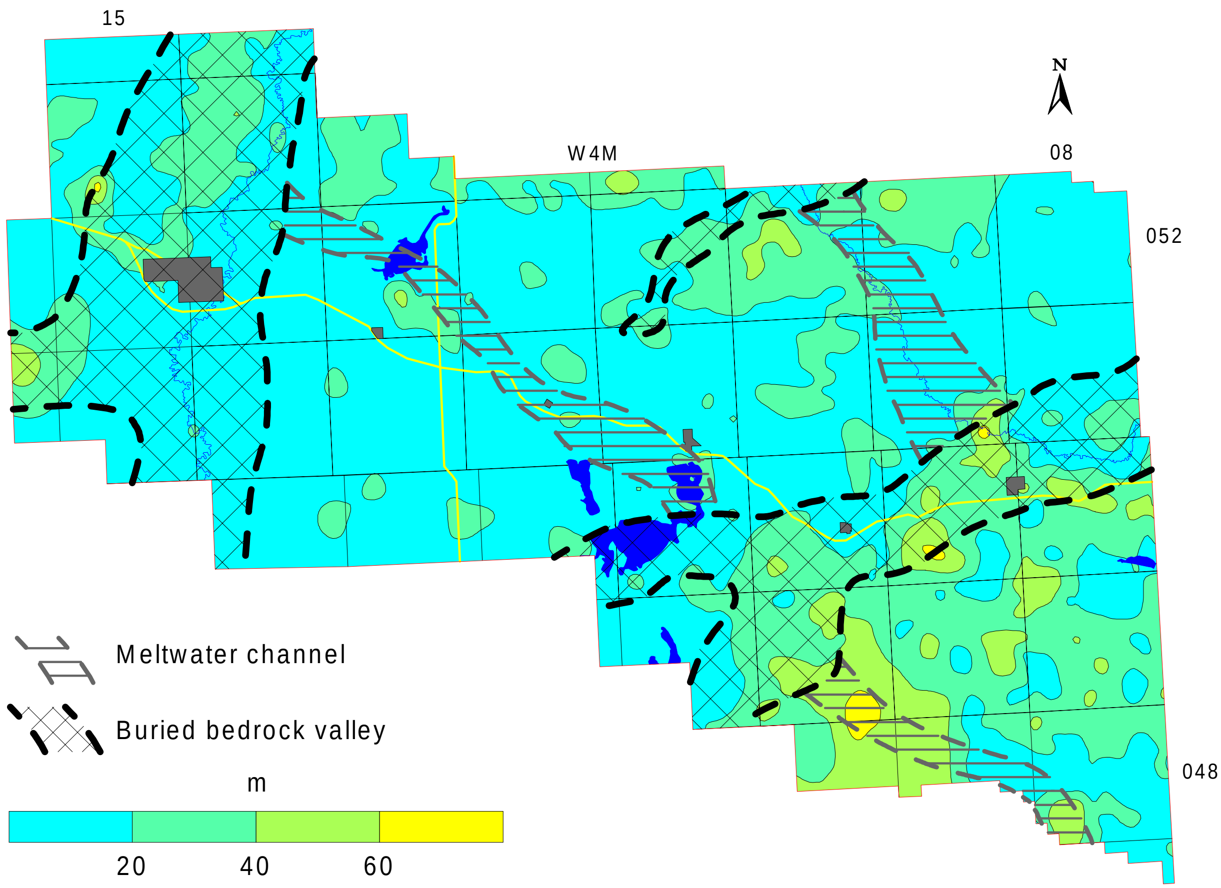
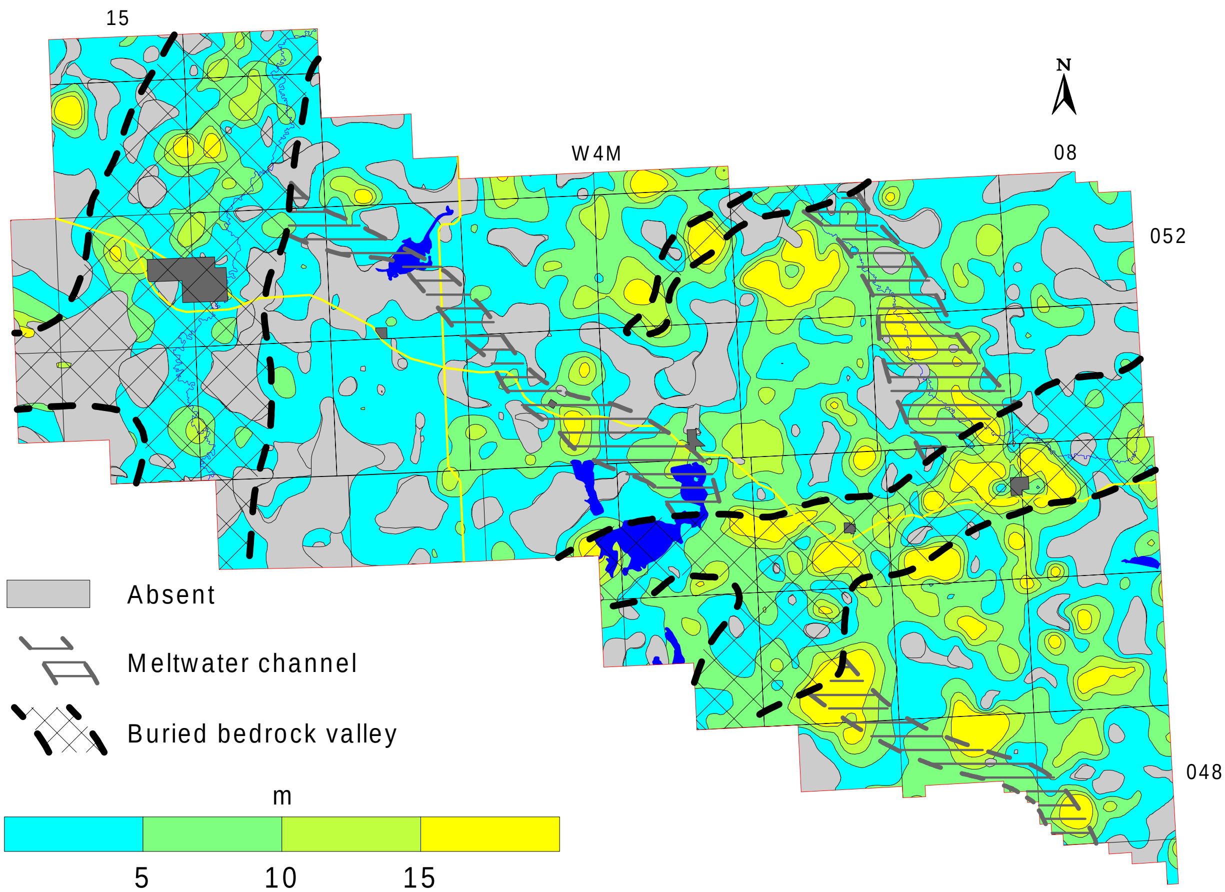
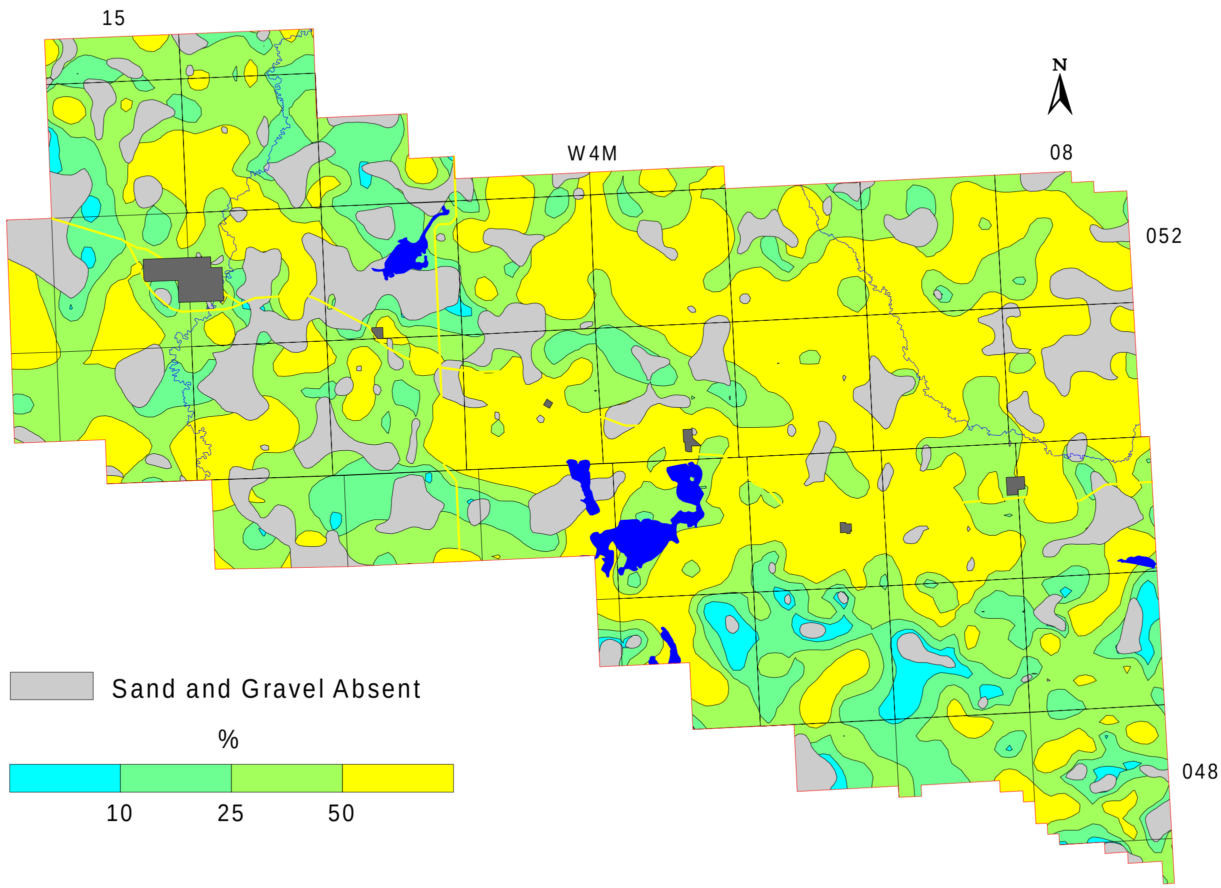
Thickness of Surficial Deposits



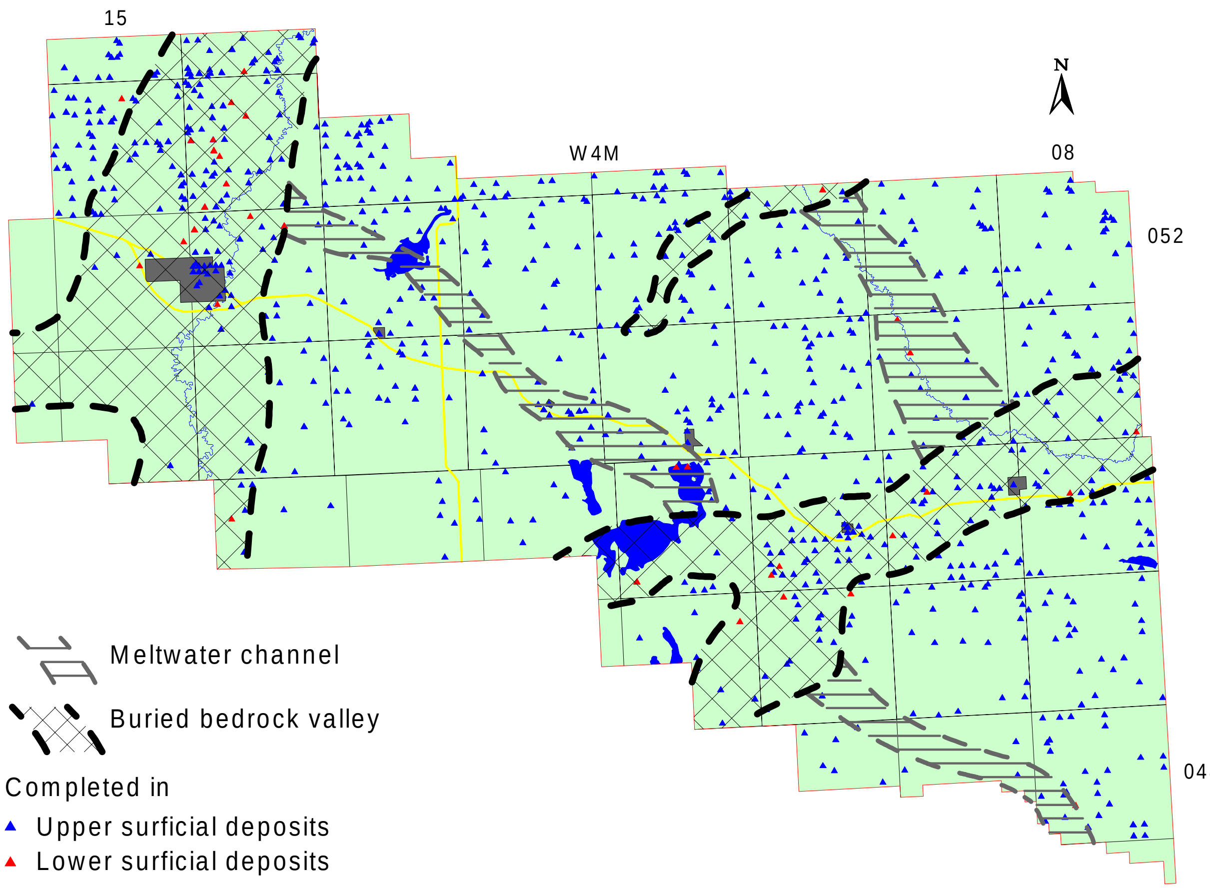
Thickness of Sand and Gravel Aquifer(s)



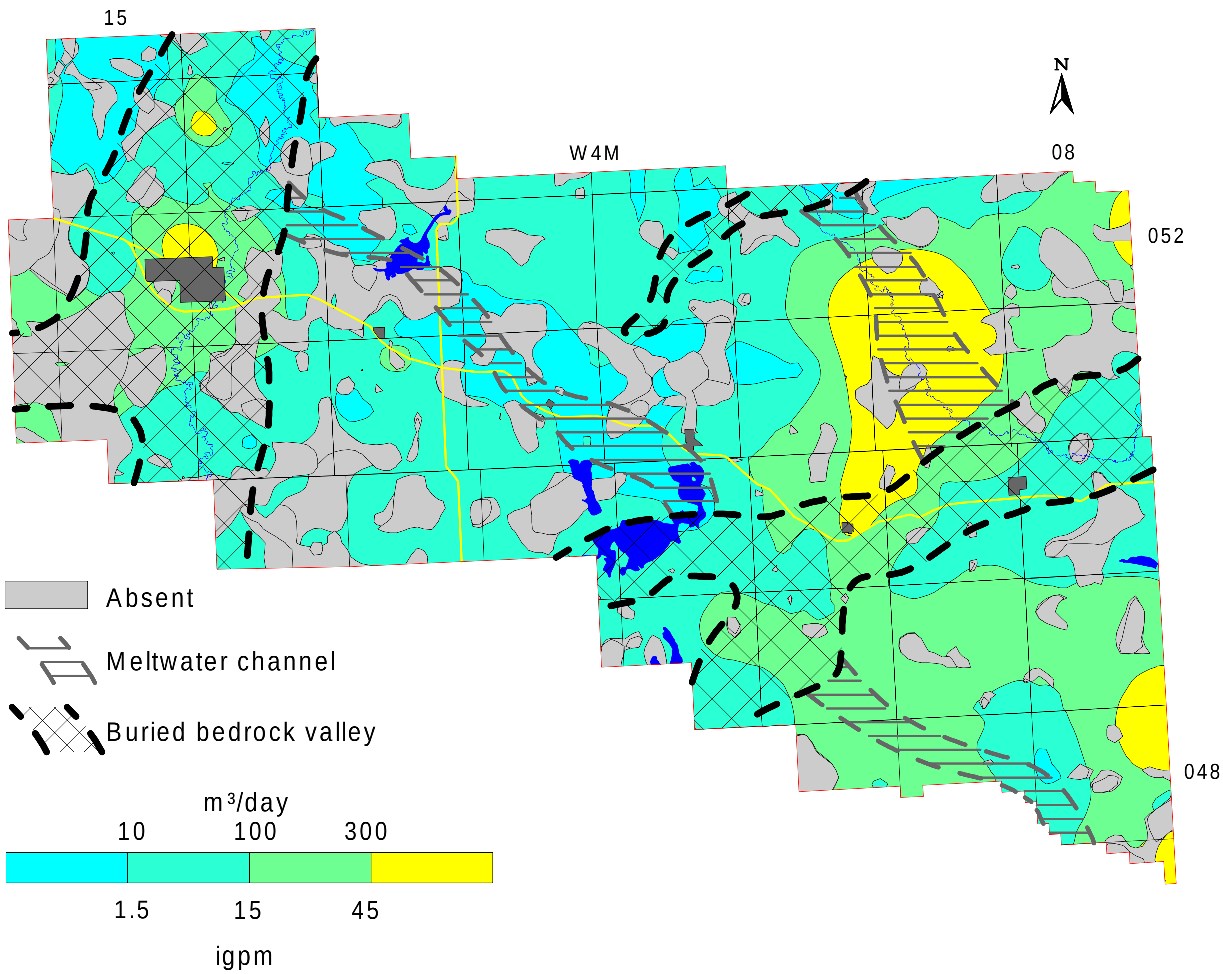
Amount of Sand and Gravel in Surficial Deposits



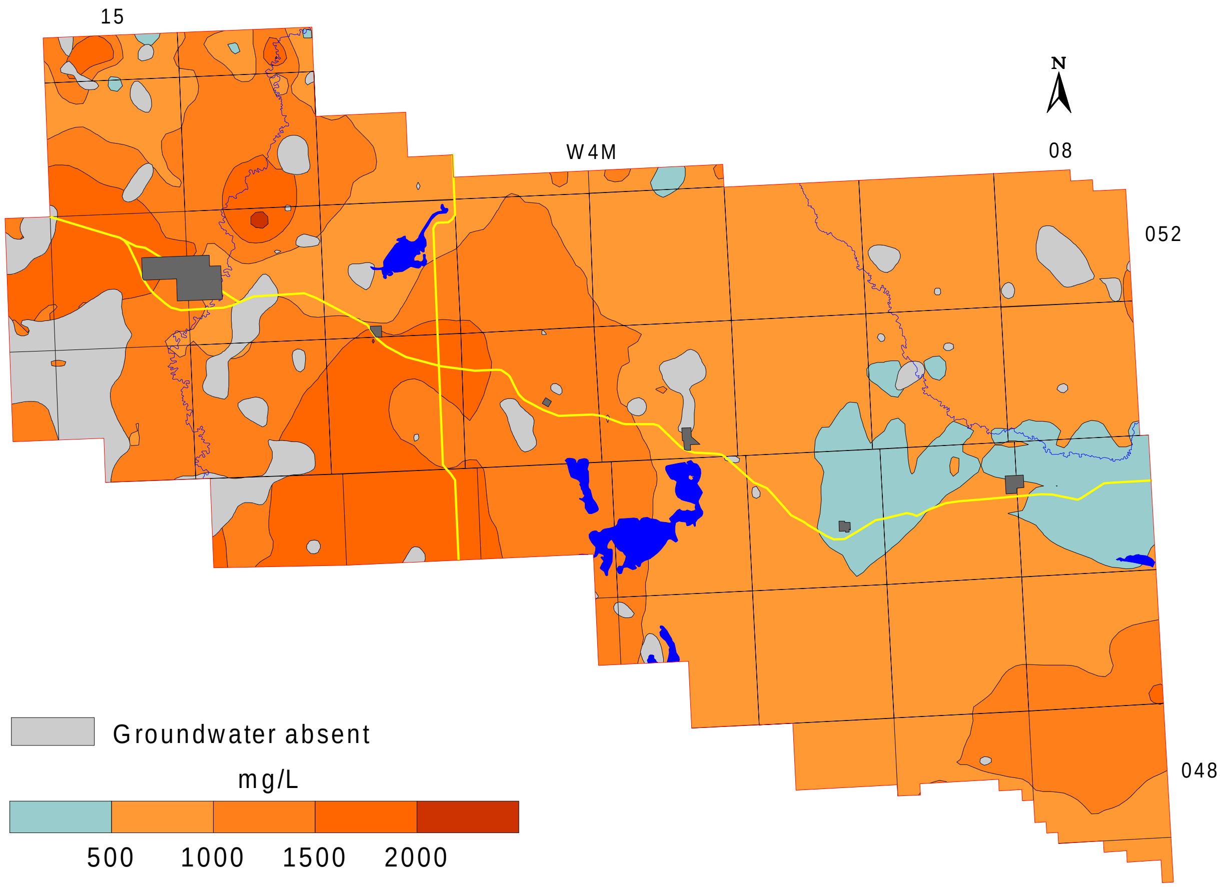
Water Wells Completed in Surficial Deposits



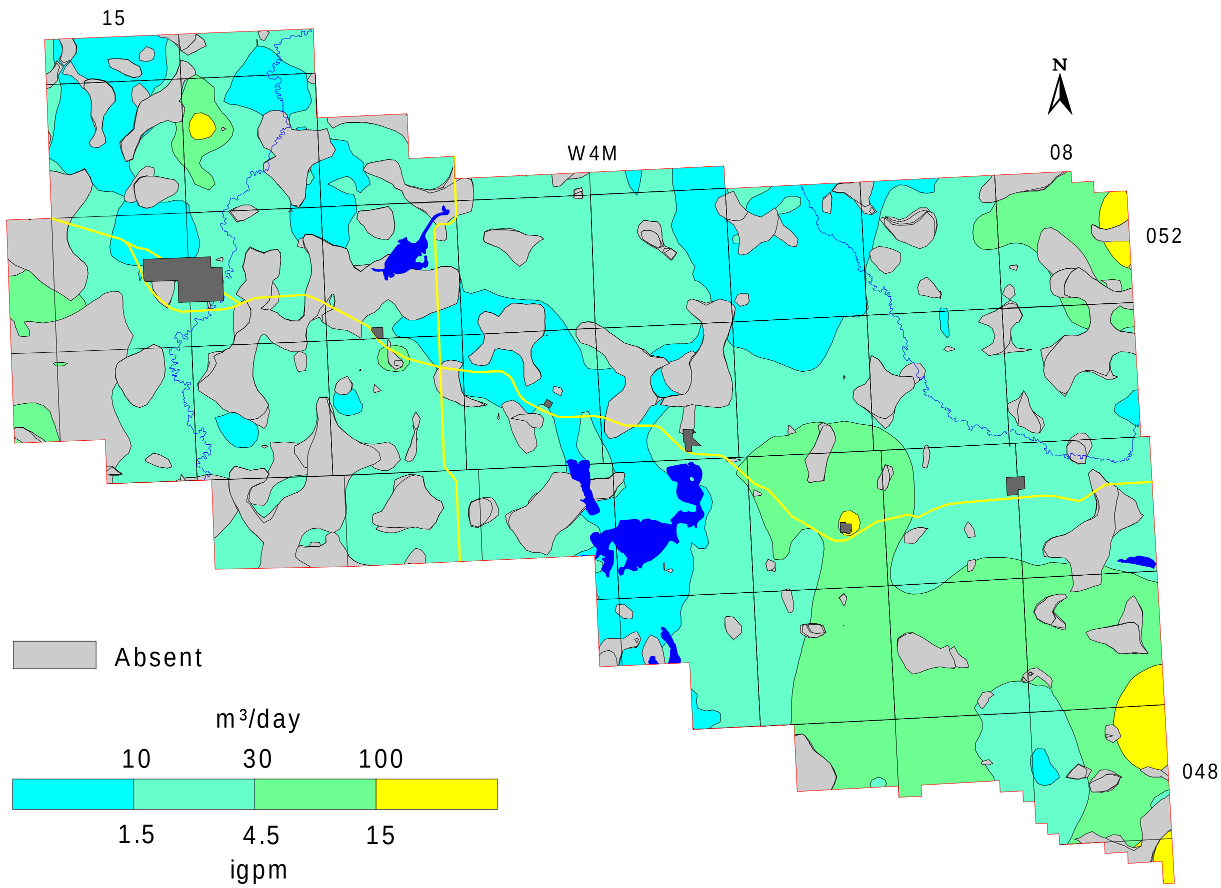
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)



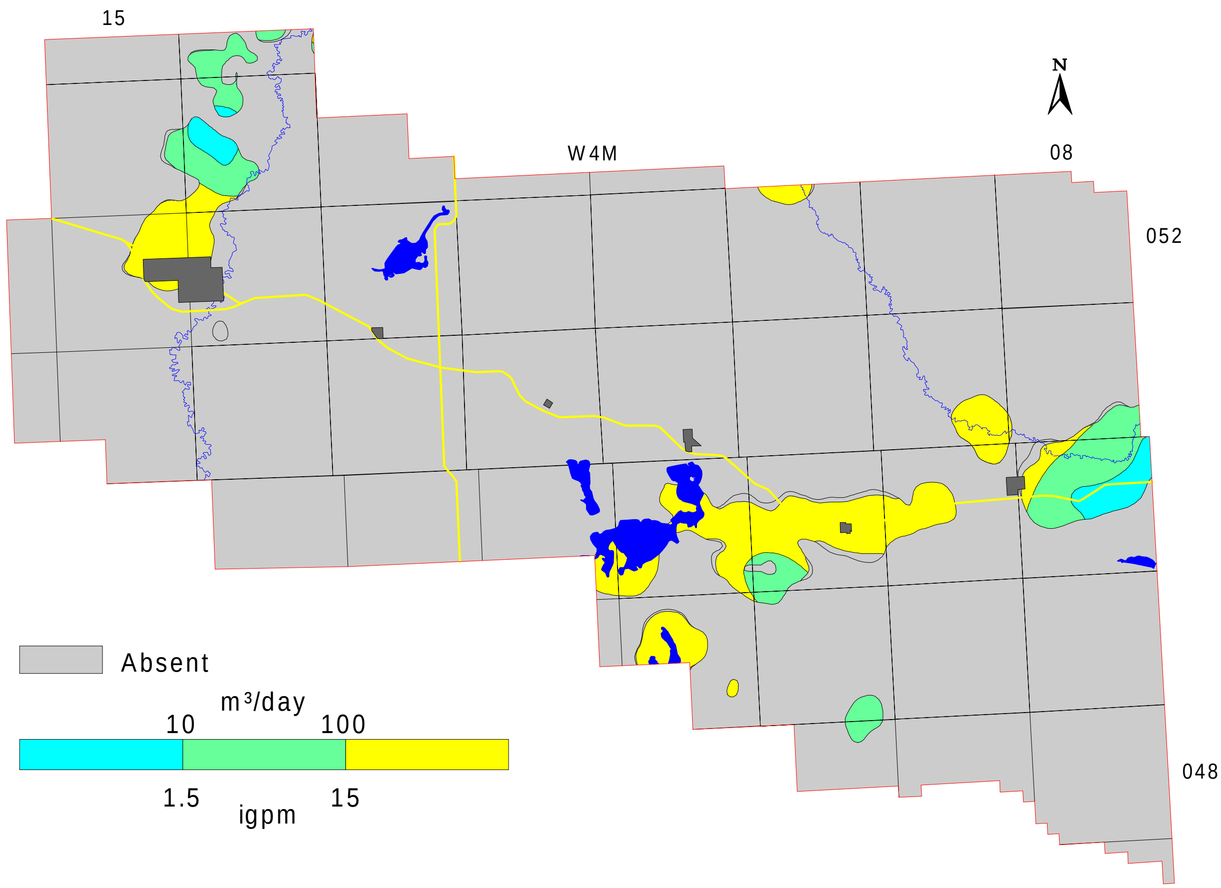
Total Dissolved Solids in Groundwater from Surficial Deposits



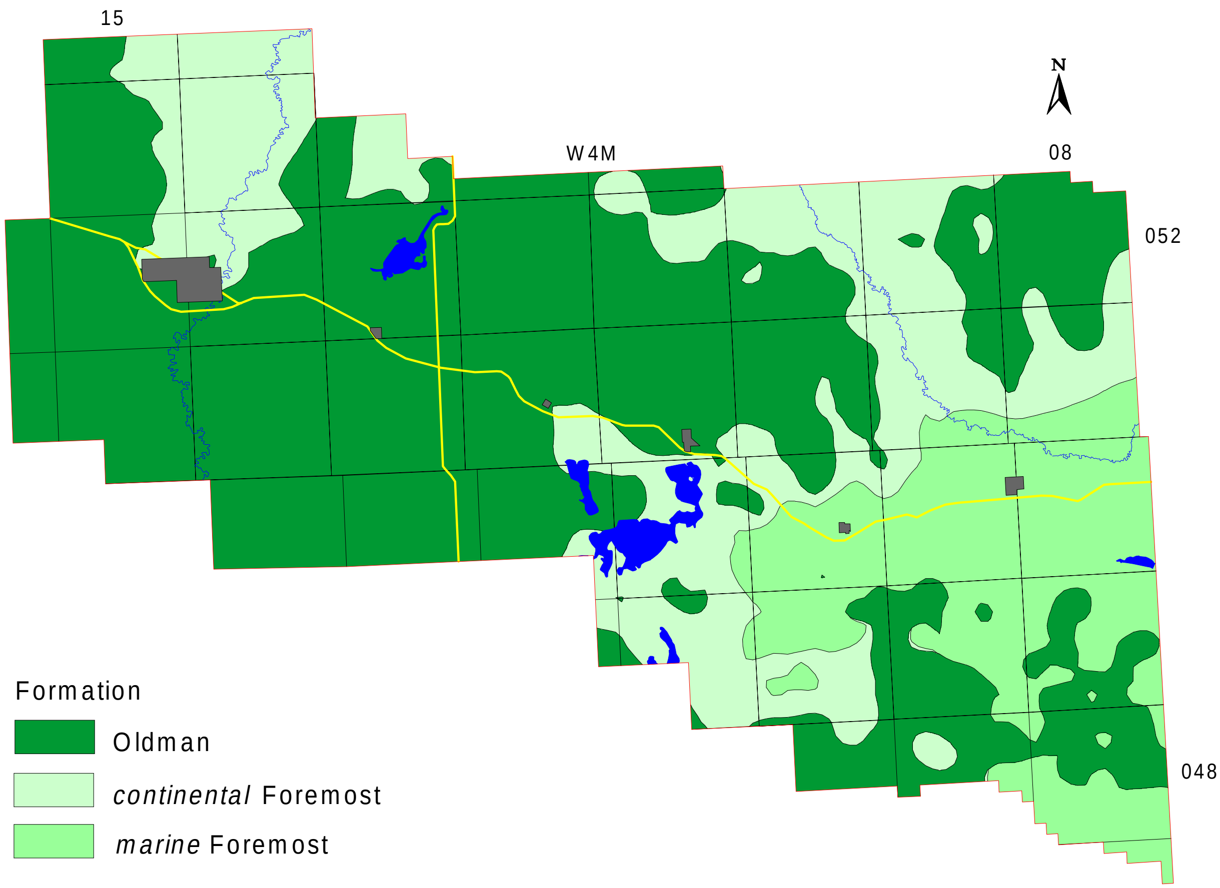
Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer



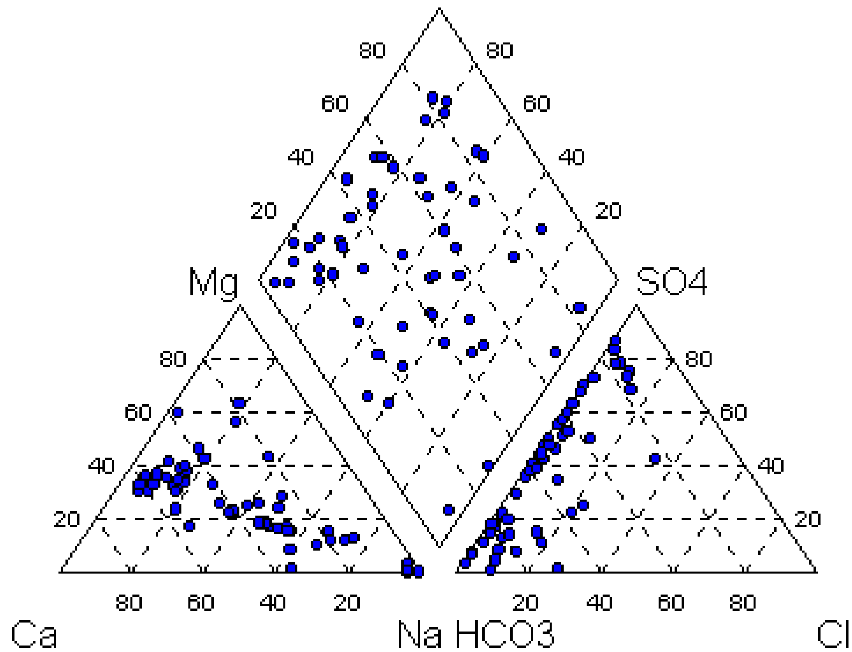
Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer



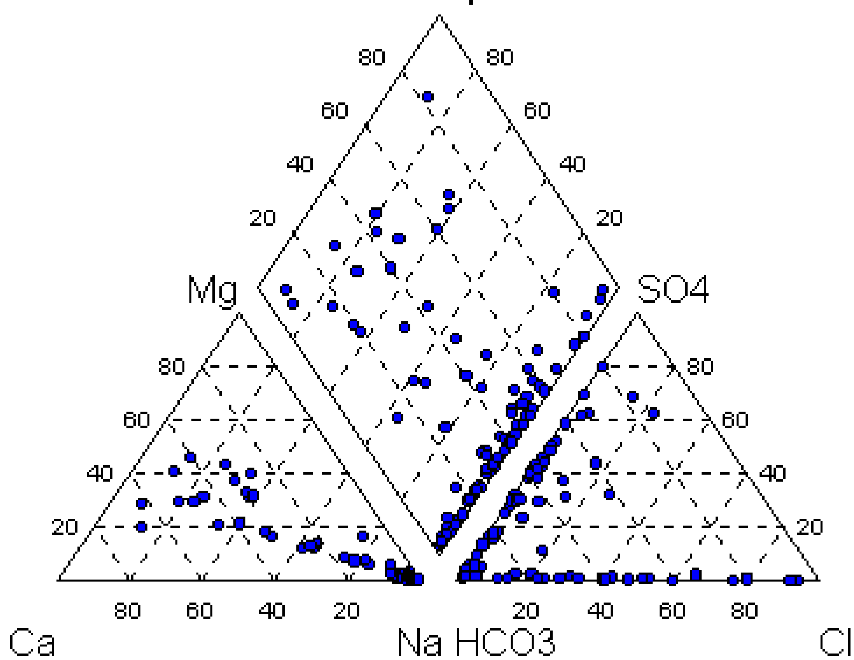
Bedrock Geology



Piper Diagrams

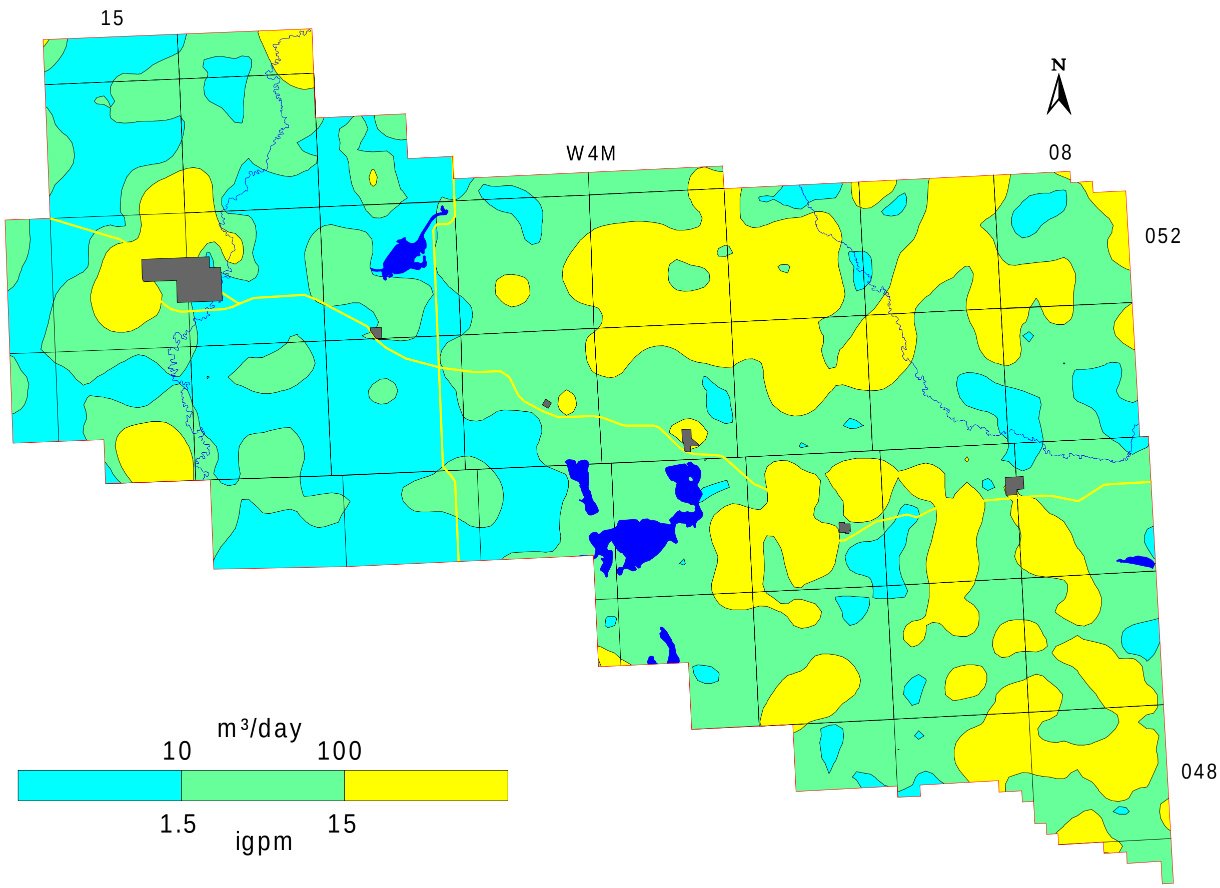


Surficial Deposits

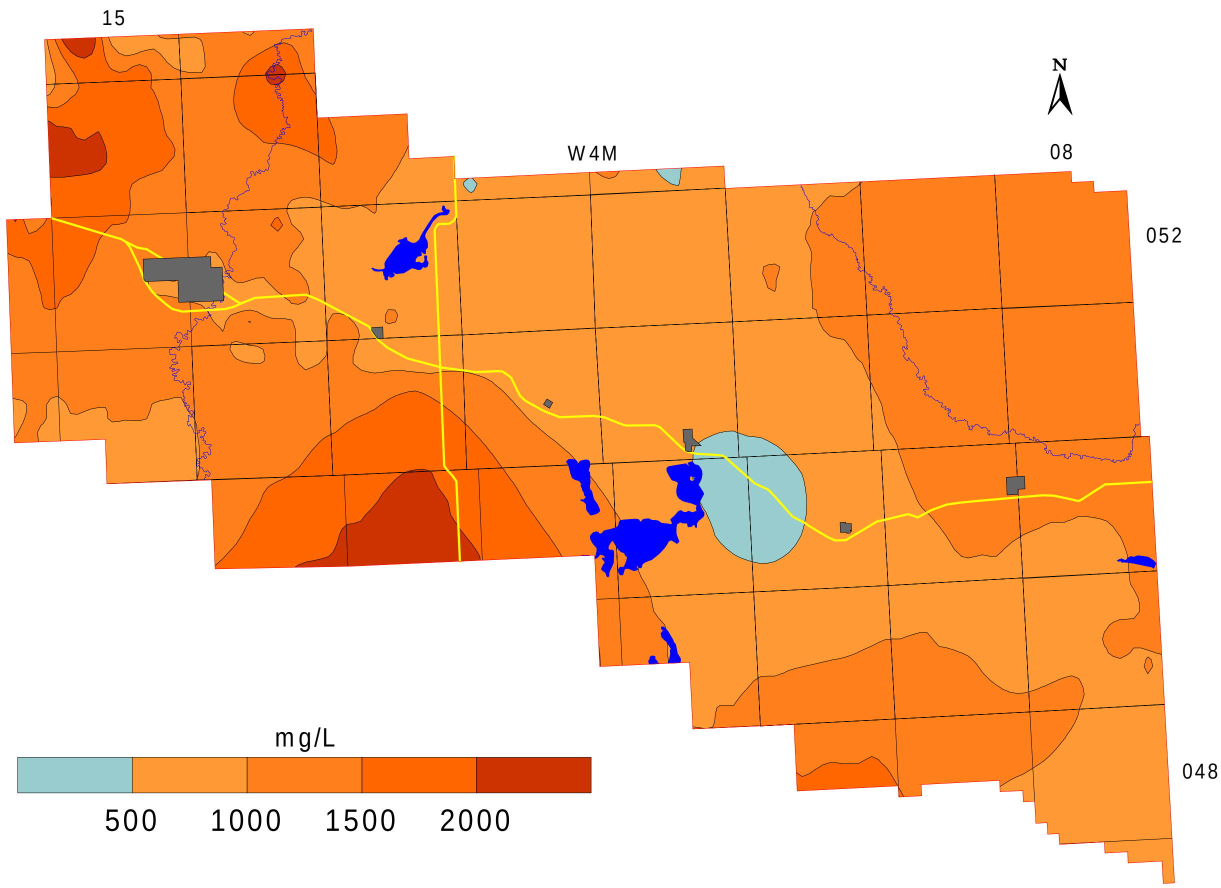


Bedrock Aquifers

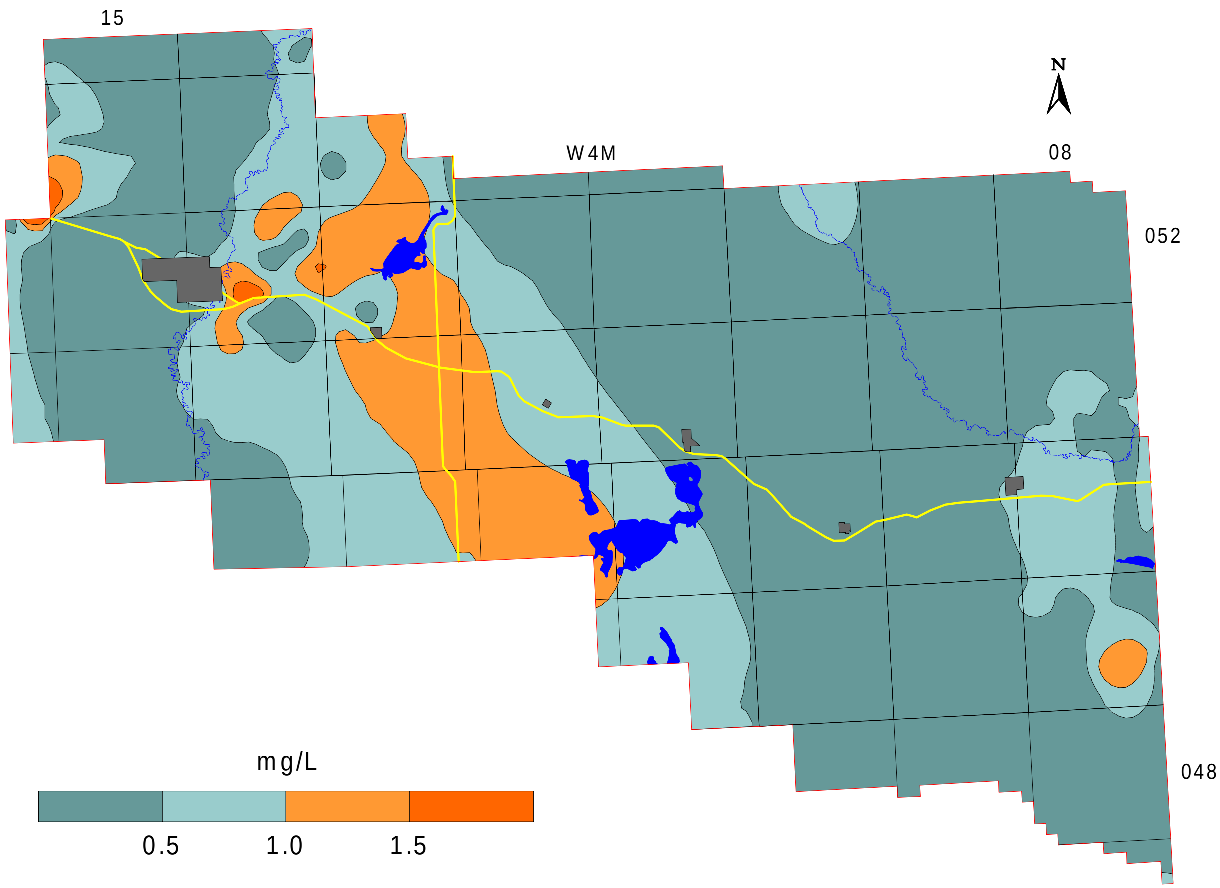
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



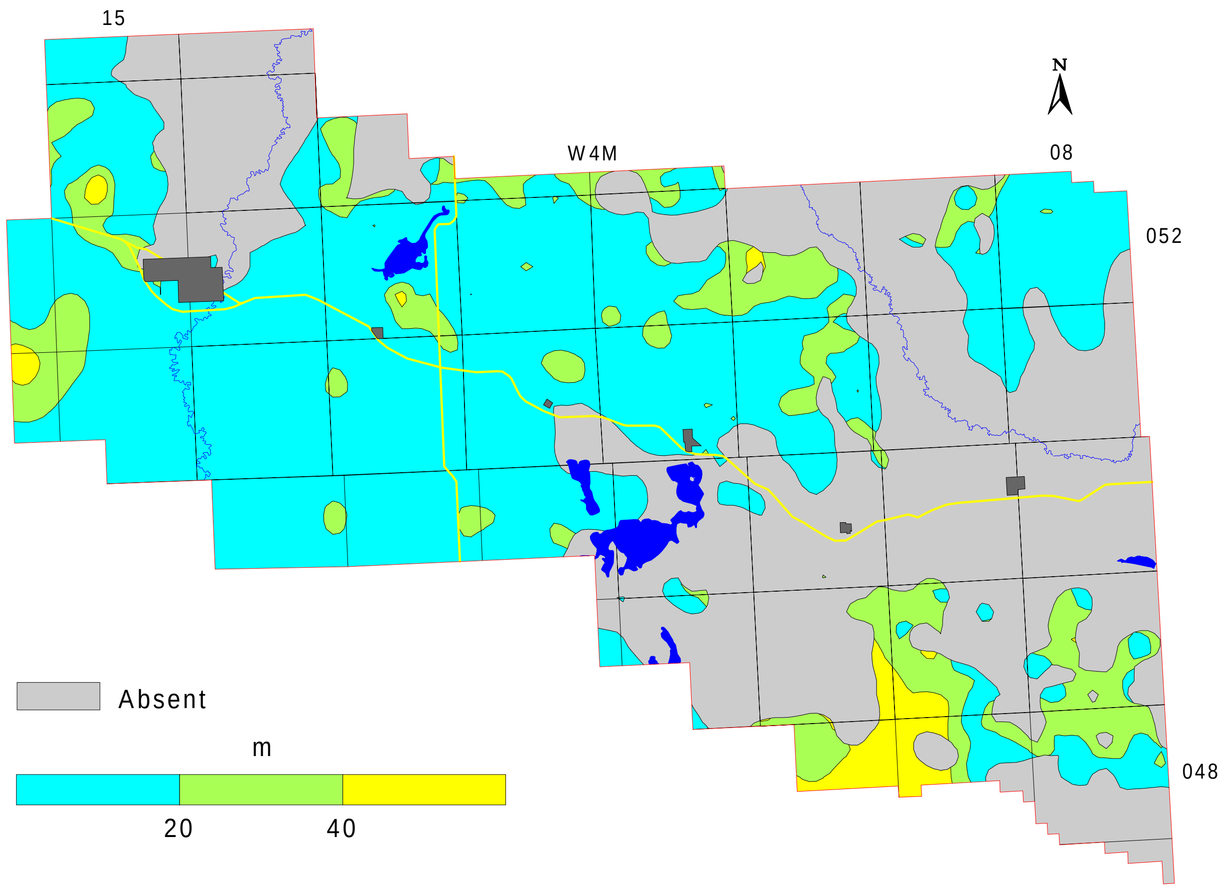
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



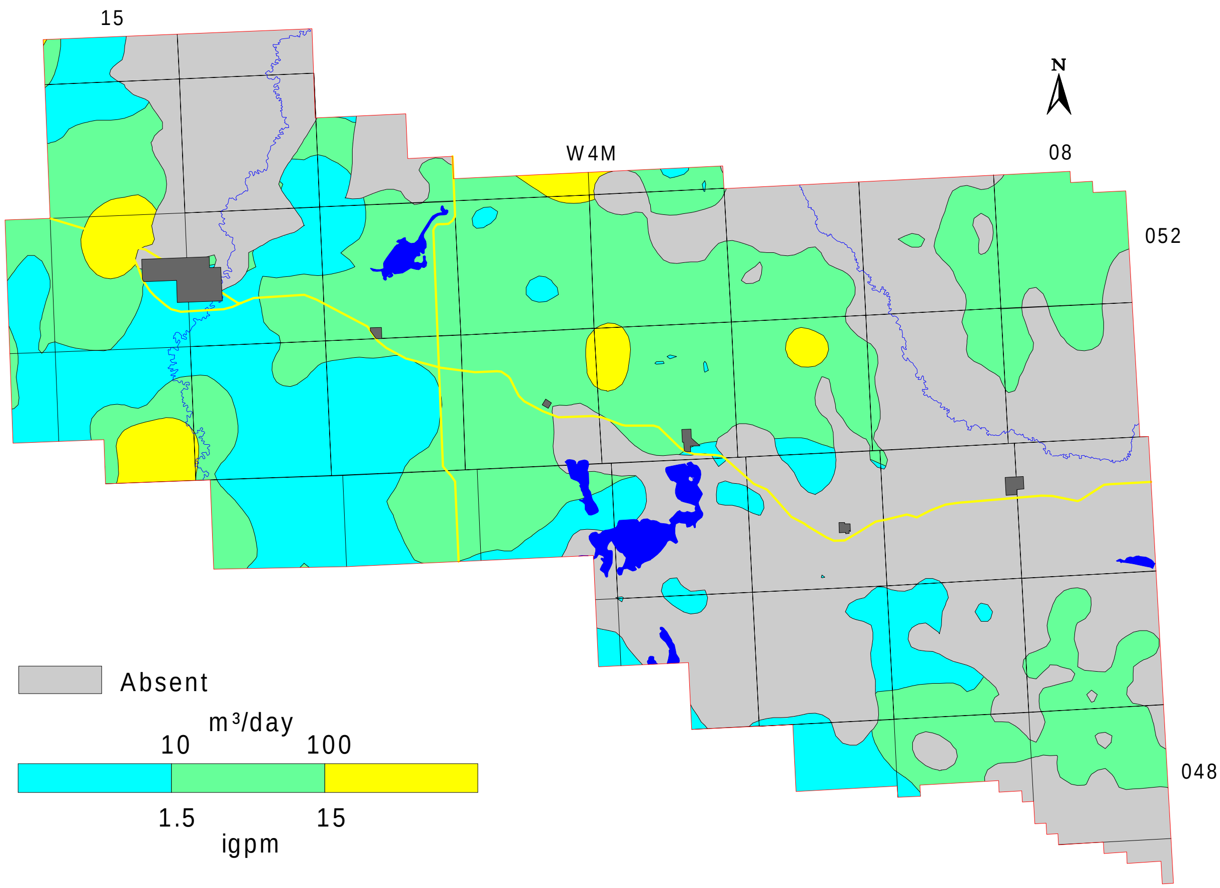
Fluoride in Groundwater from Upper Bedrock Aquifer(s)



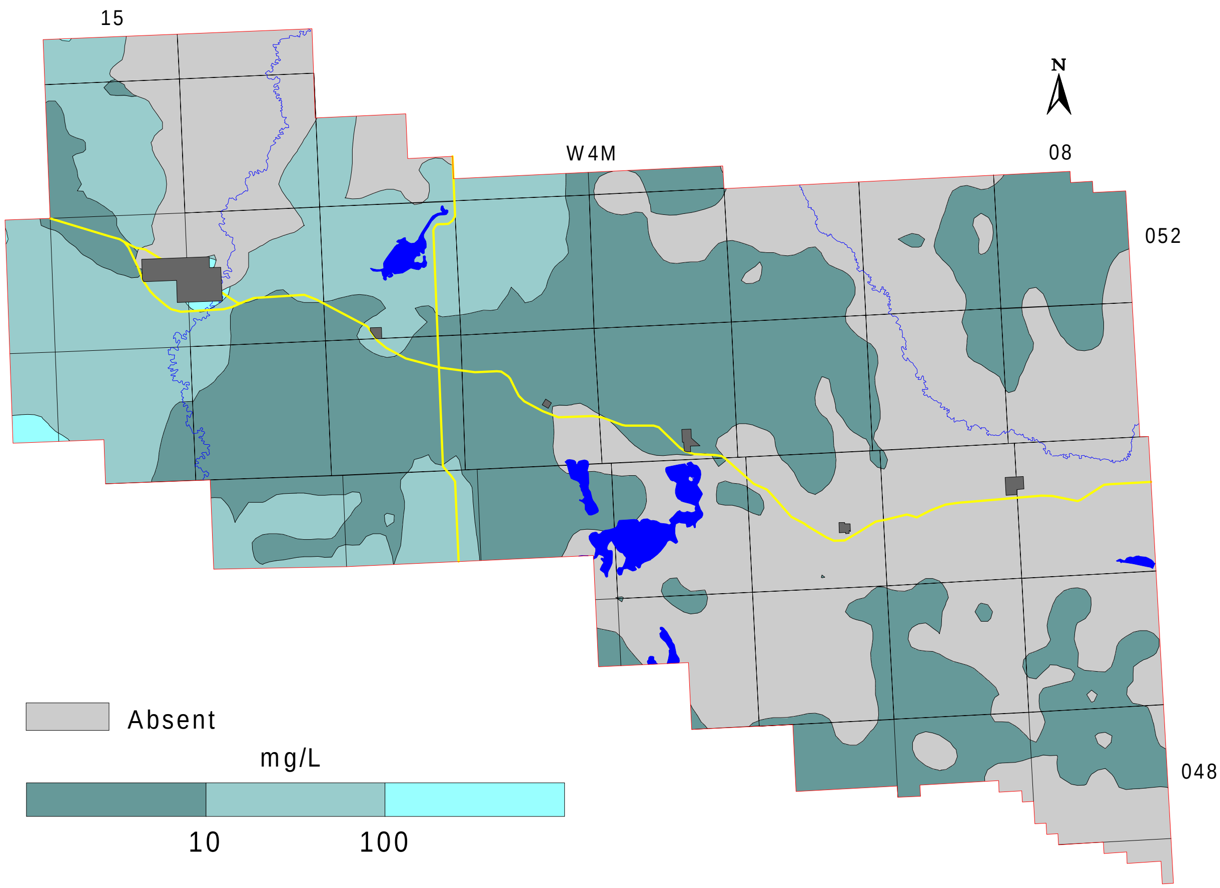
Depth to Top of Oldman Formation



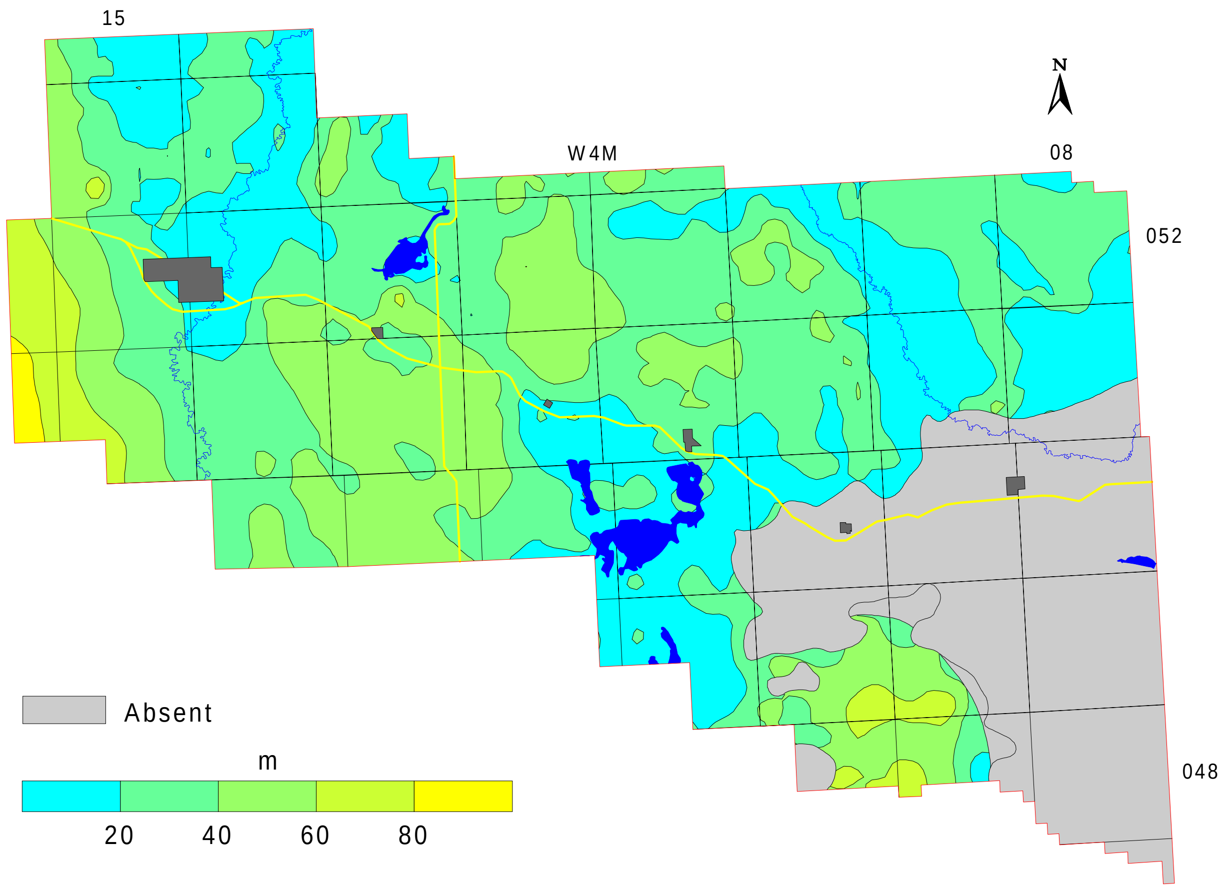
Apparent Yield for Water Wells Completed through Oldman Aquifer



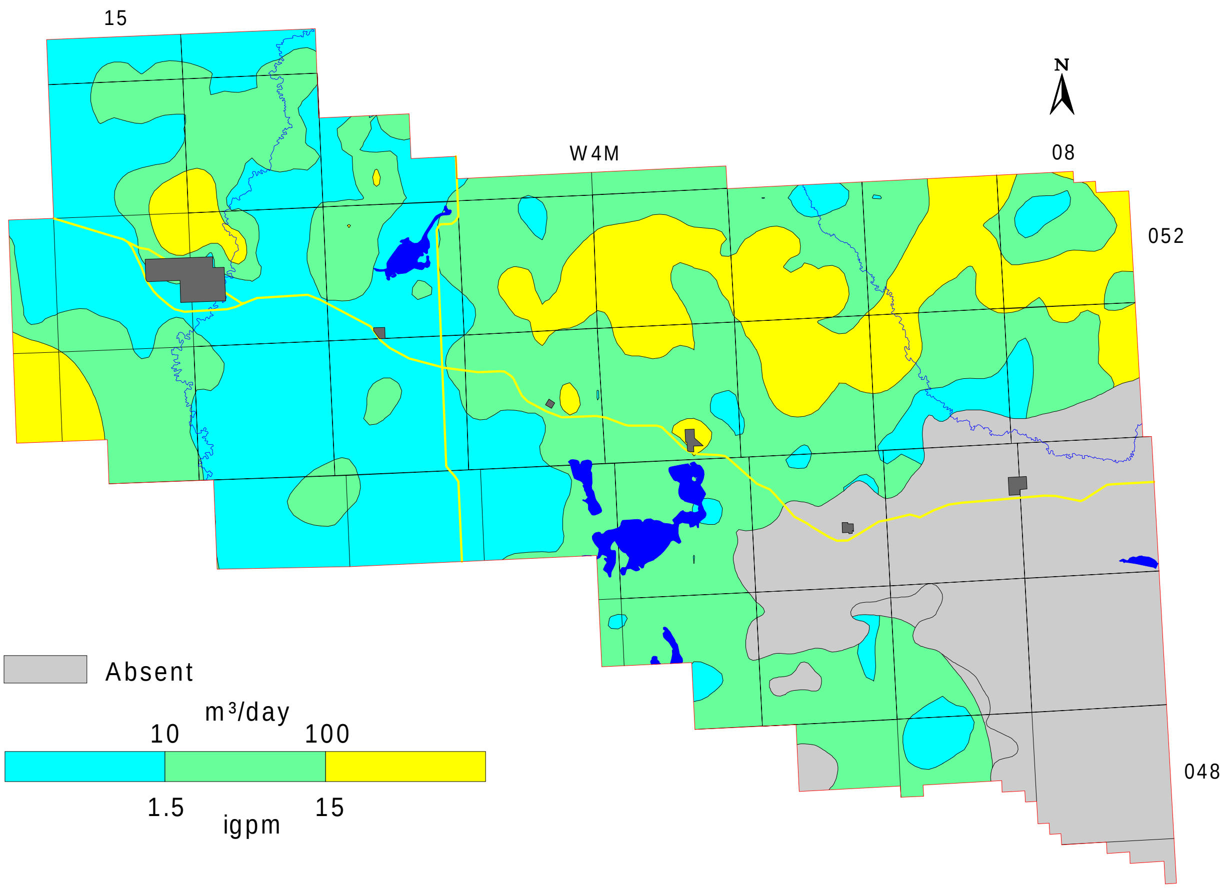
Chloride in Groundwater from Oldman Aquifer



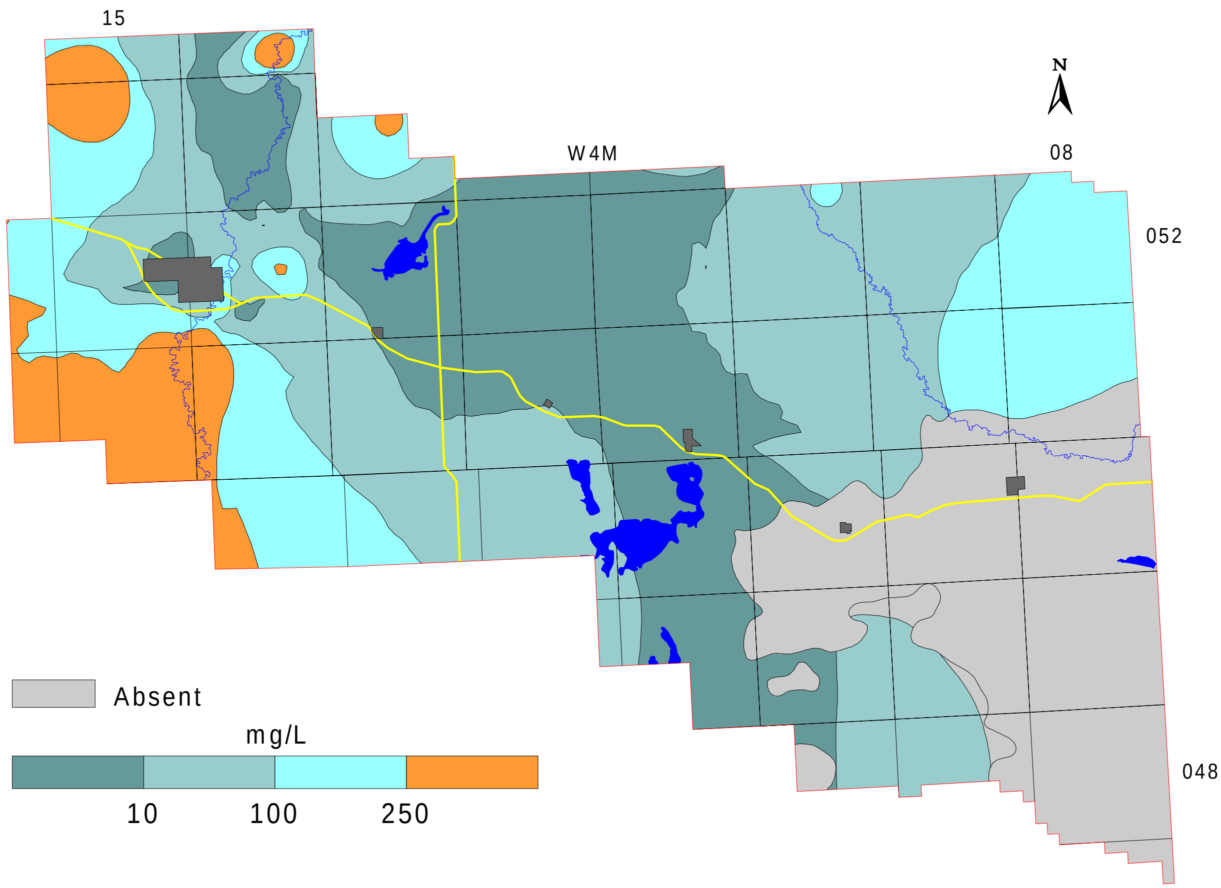
Depth to Top of continental Foremost Formation



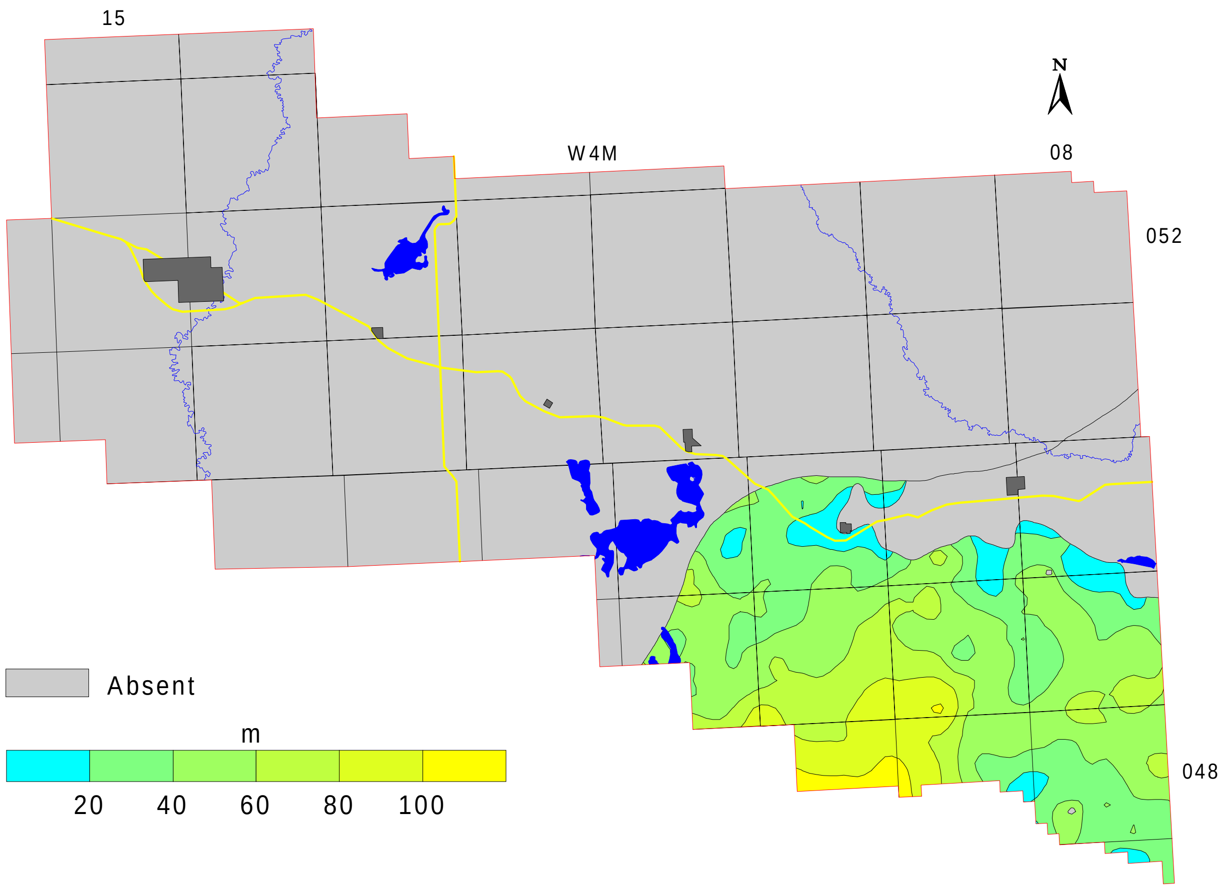
Apparent Yield for Water Wells Completed through continental Foremost Aquifer



Chloride in Groundwater from continental Foremost Aquifer



Depth to Top of Birch Lake Member



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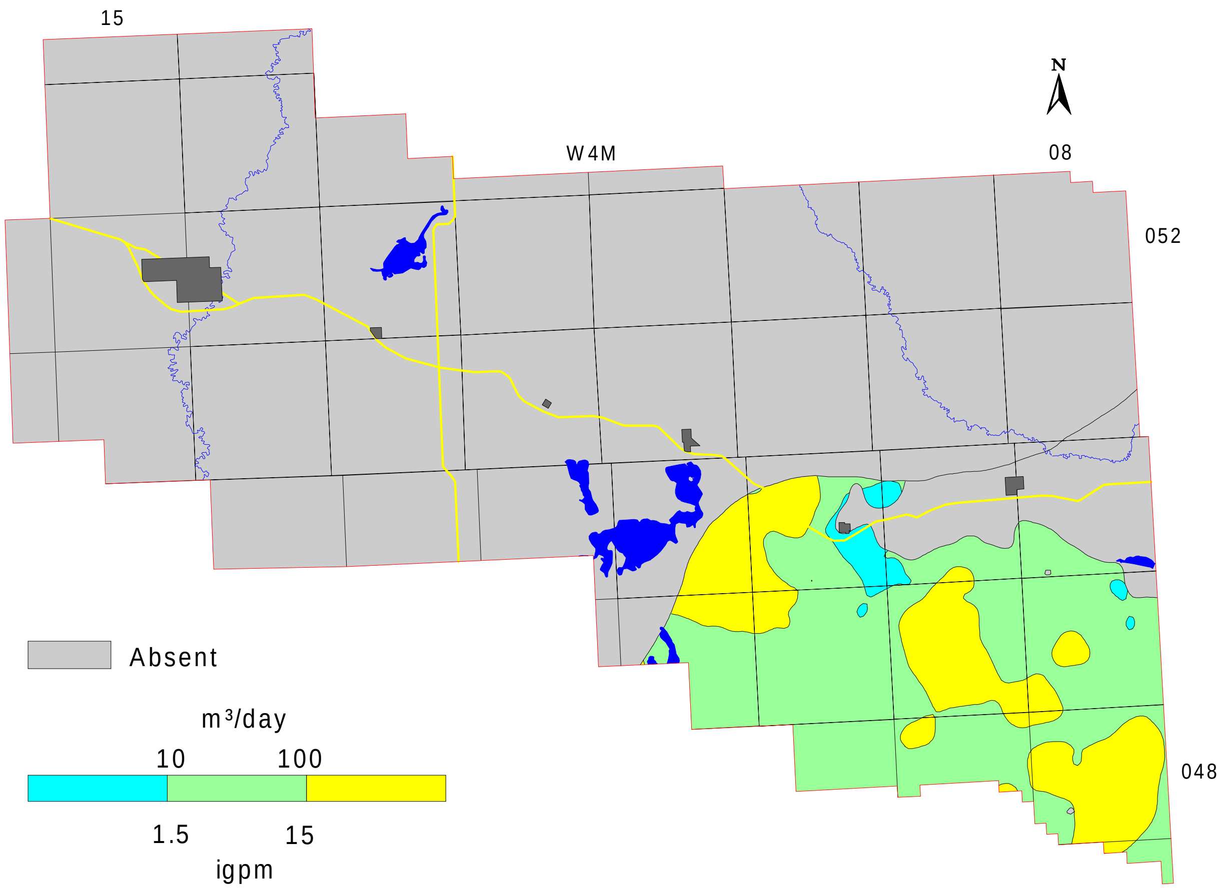
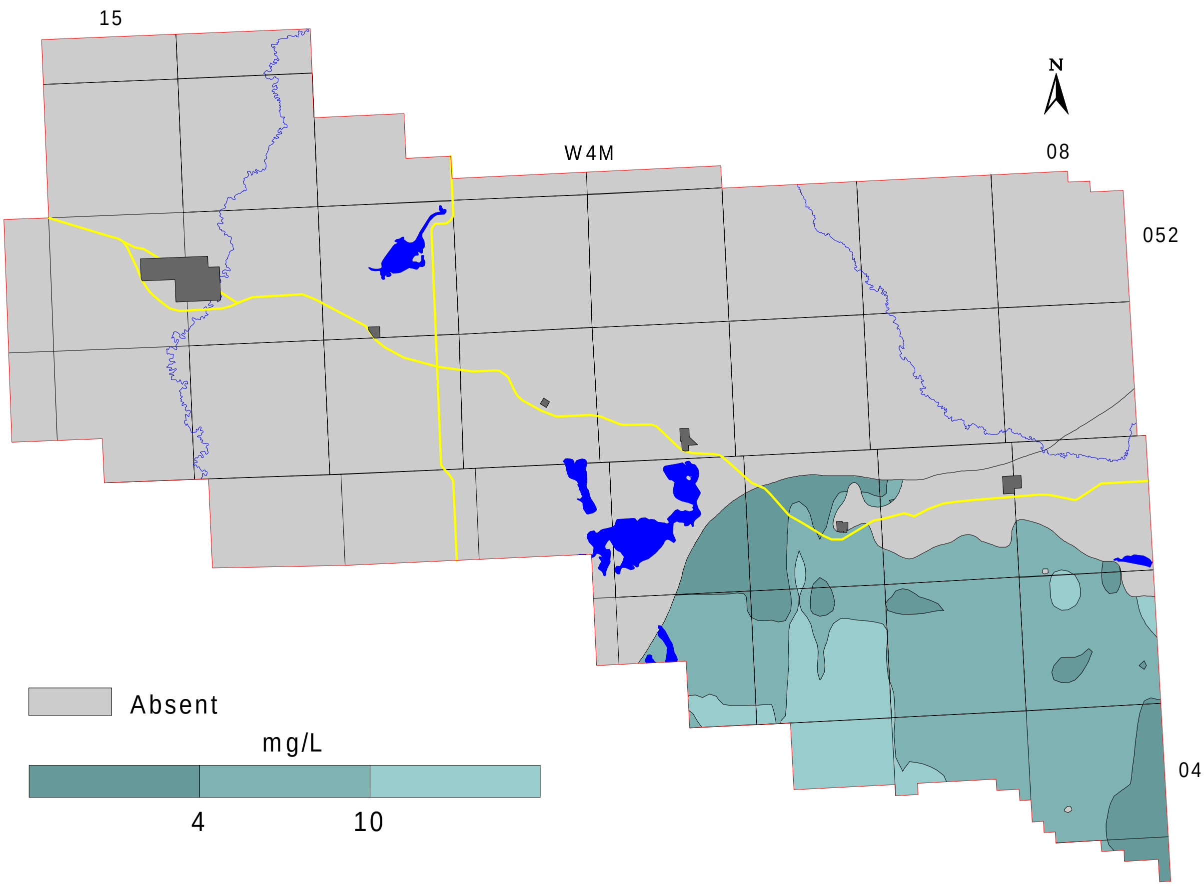
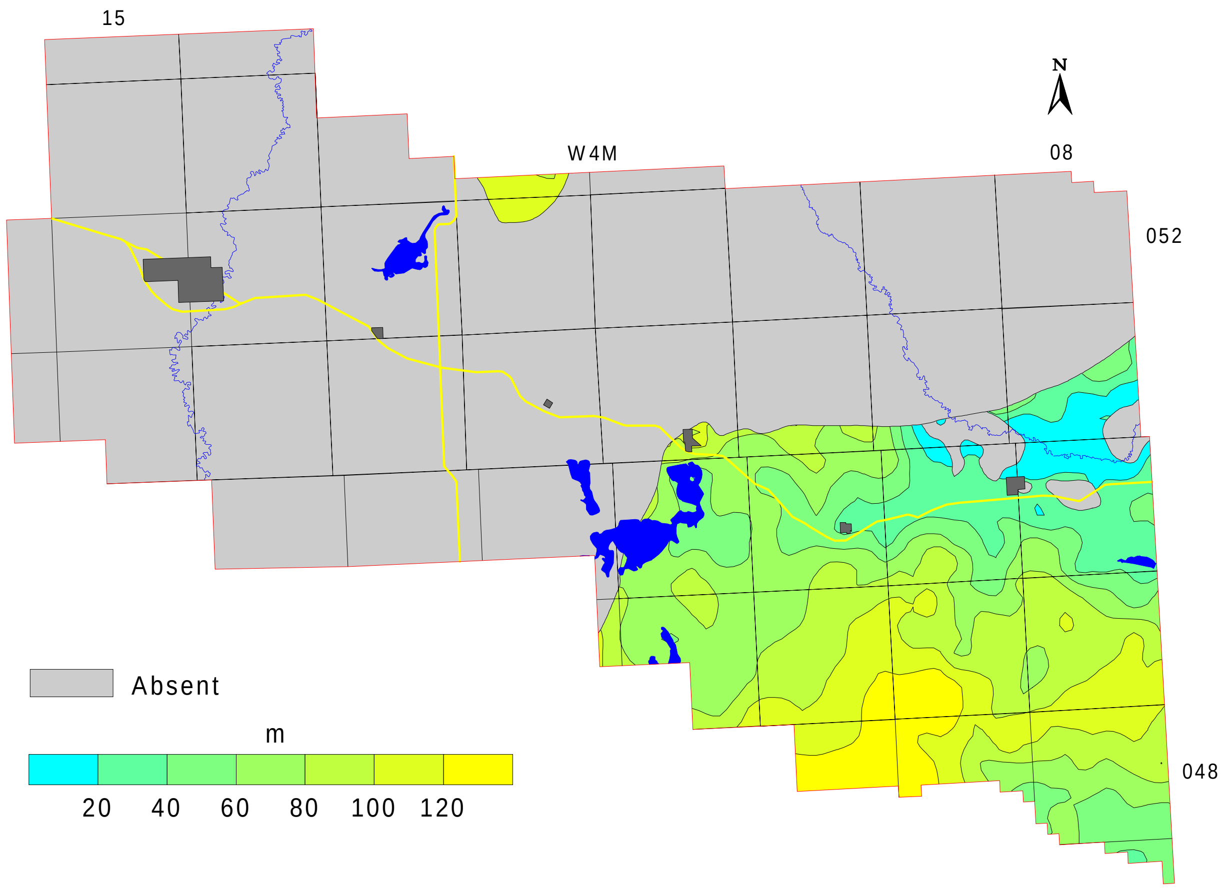
Apparent Yield for Water Wells Completed through Birch Lake Aquifer



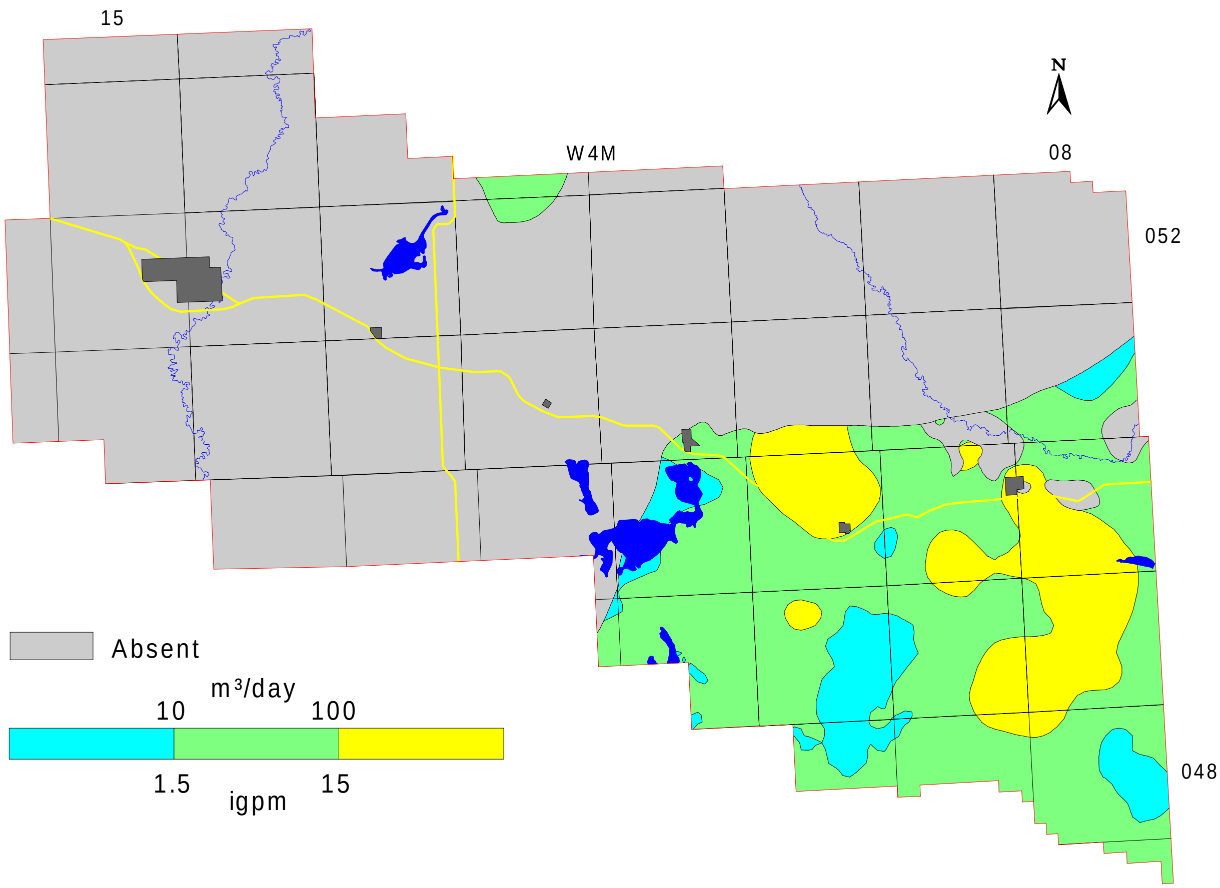
Chloride in Groundwater from Birch Lake Aquifer



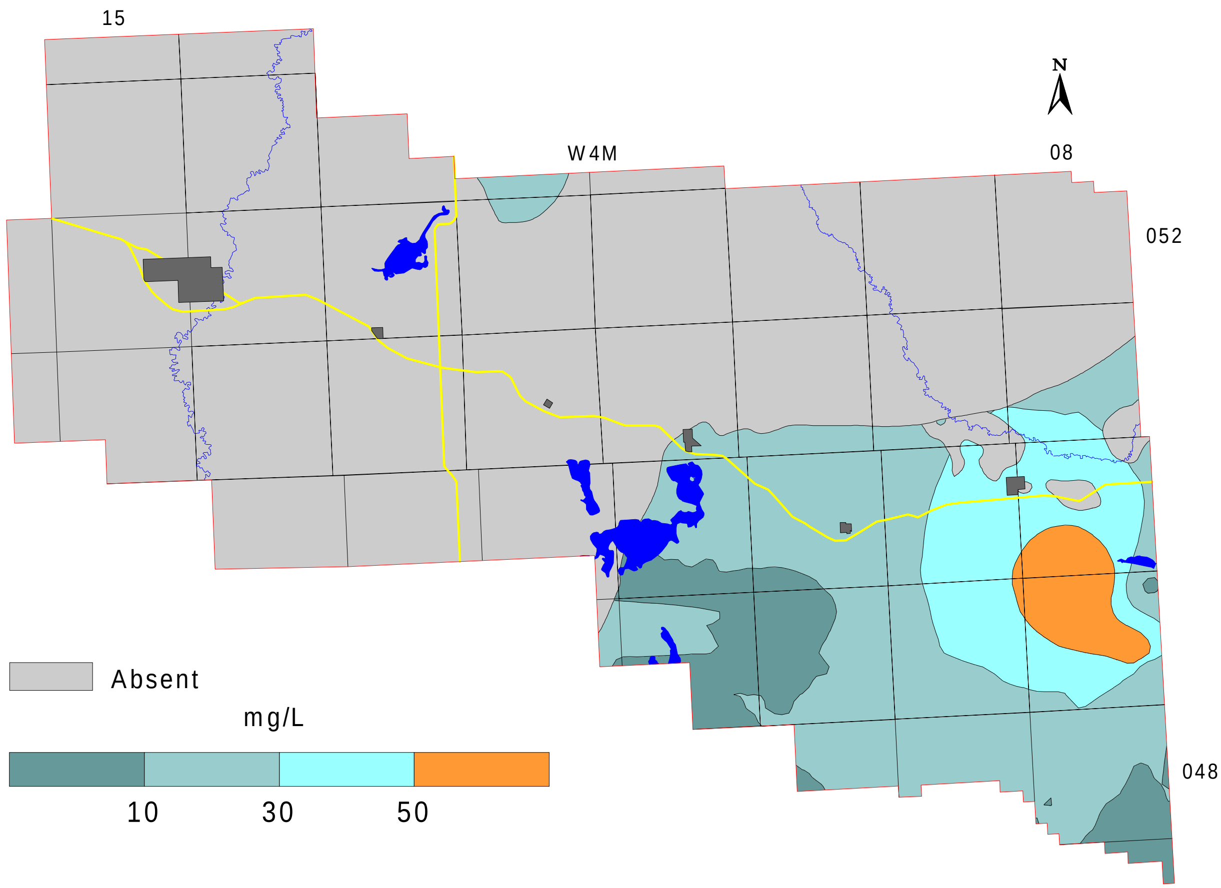
Depth to Top of Ribstone Creek Member



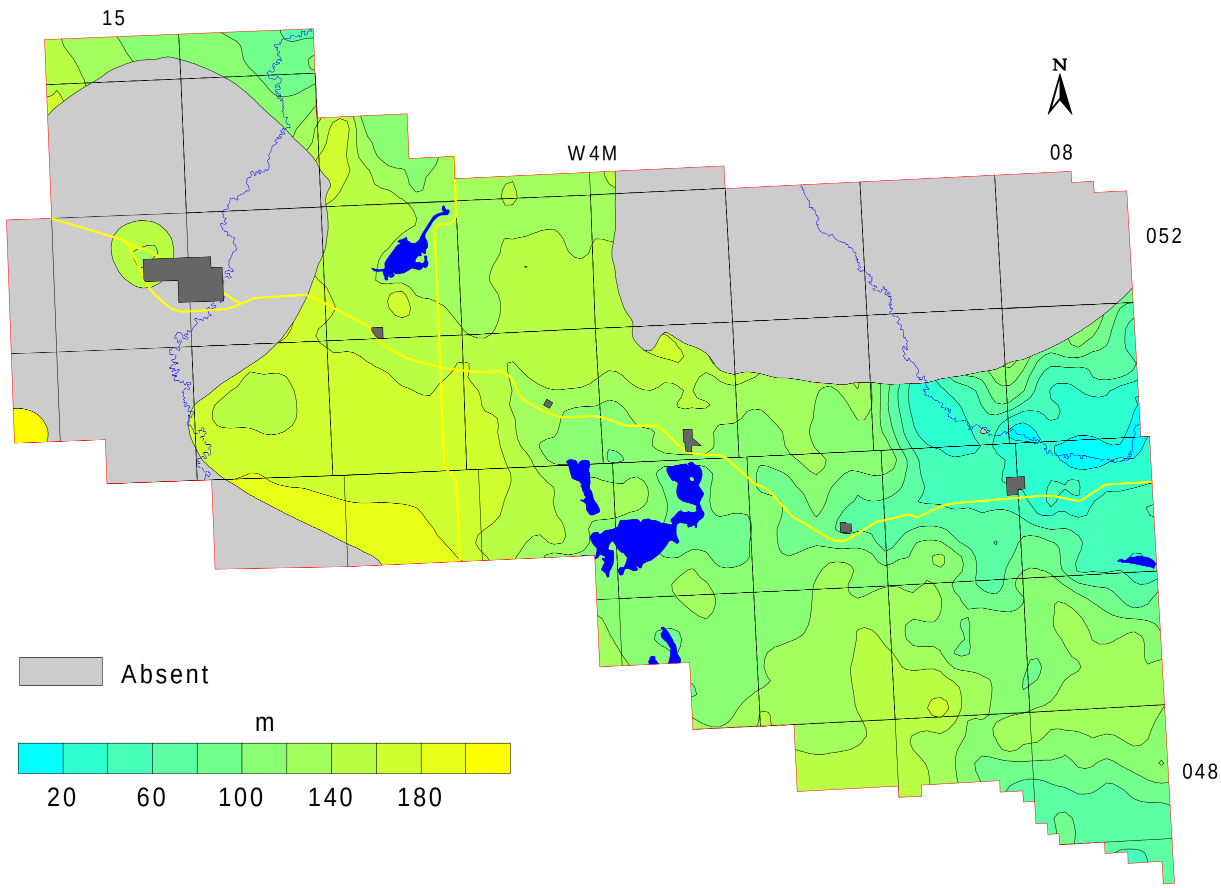
Apparent Yield for Water Wells Completed through Ribstone Creek Aquifer



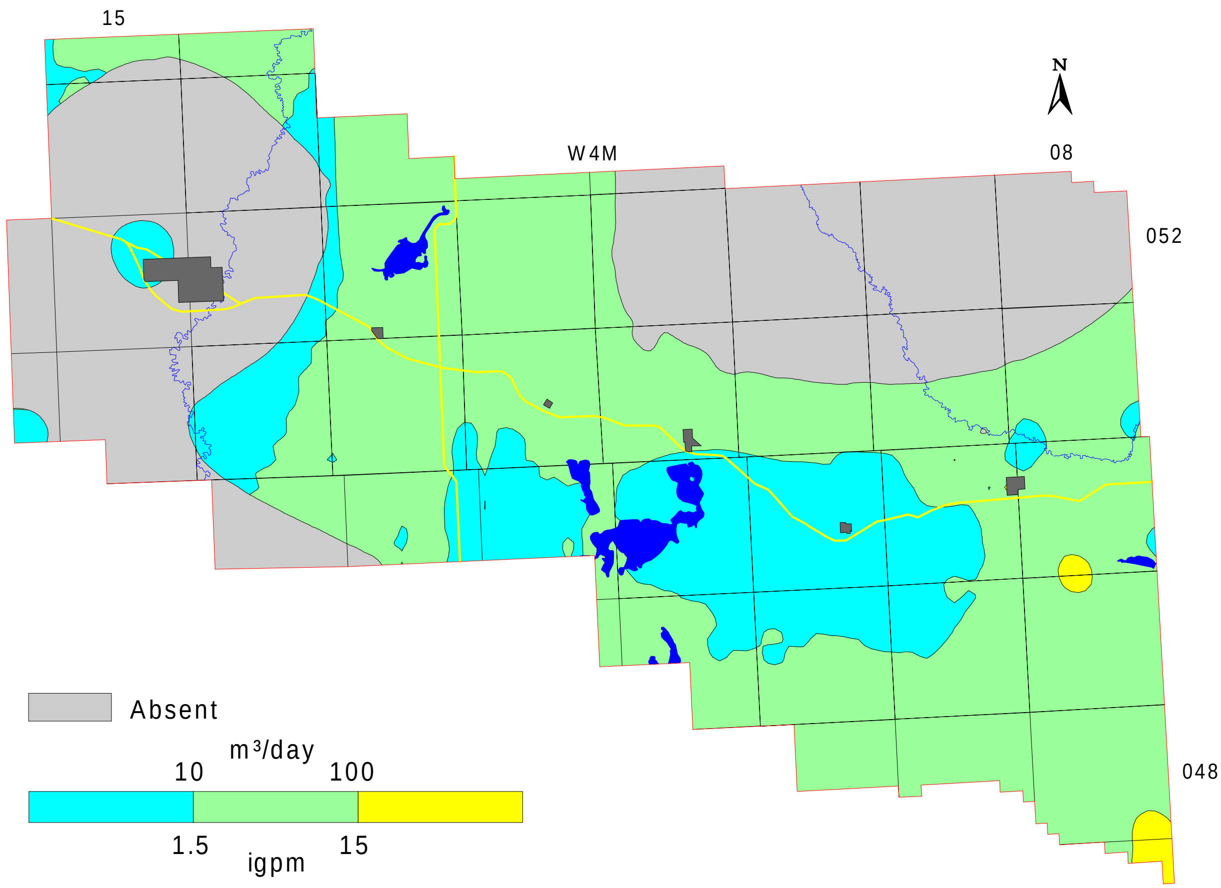
Chloride in Groundwater from Ribstone Creek Aquifer



Depth to Top of Victoria Member



Apparent Yield for Water Wells Completed through Victoria Aquifer



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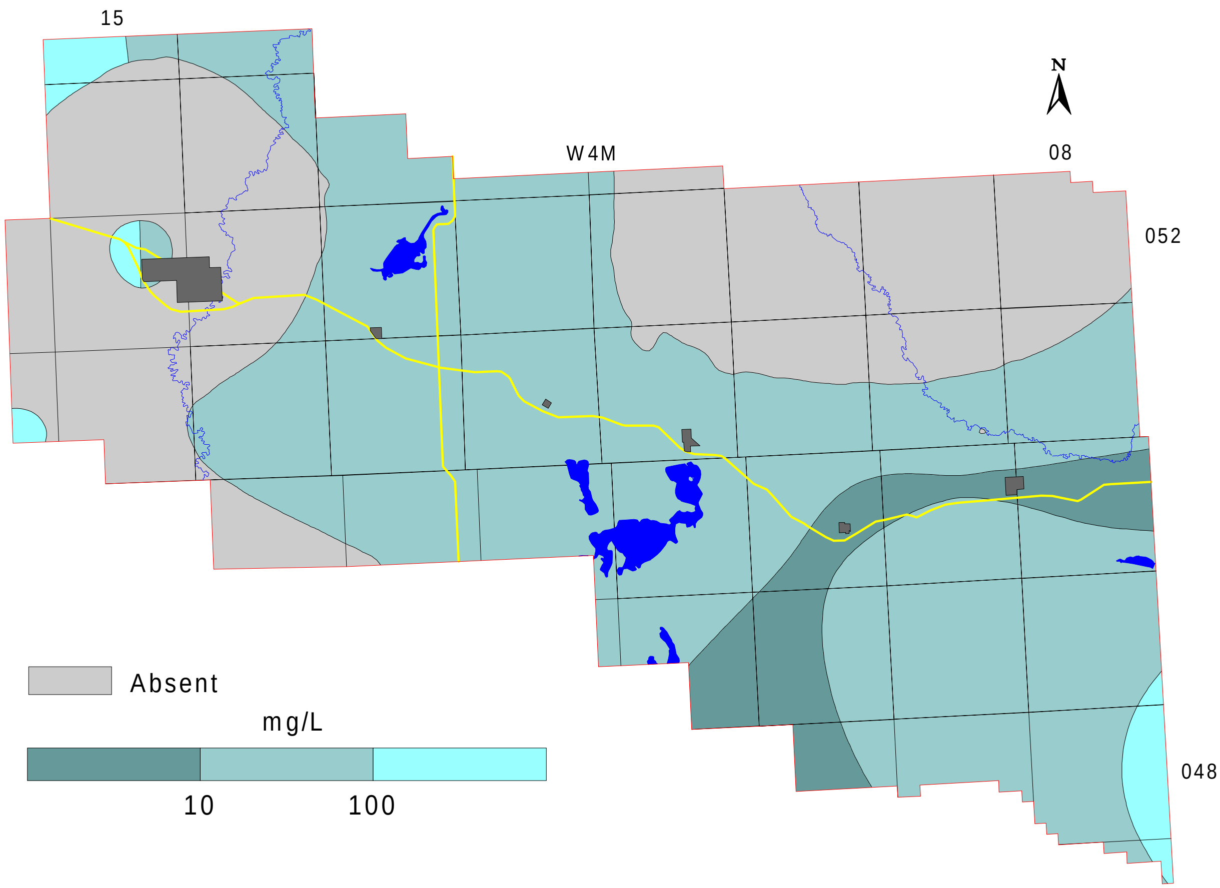
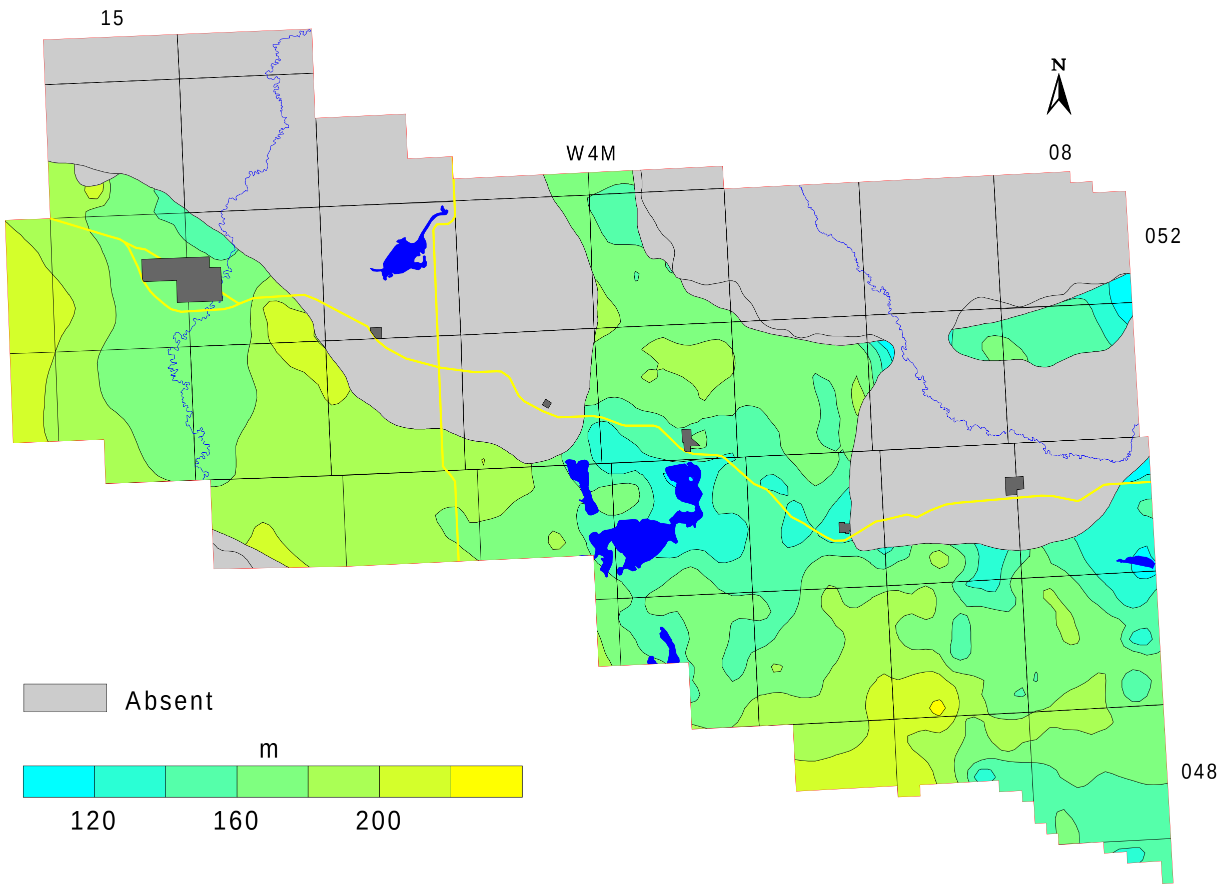
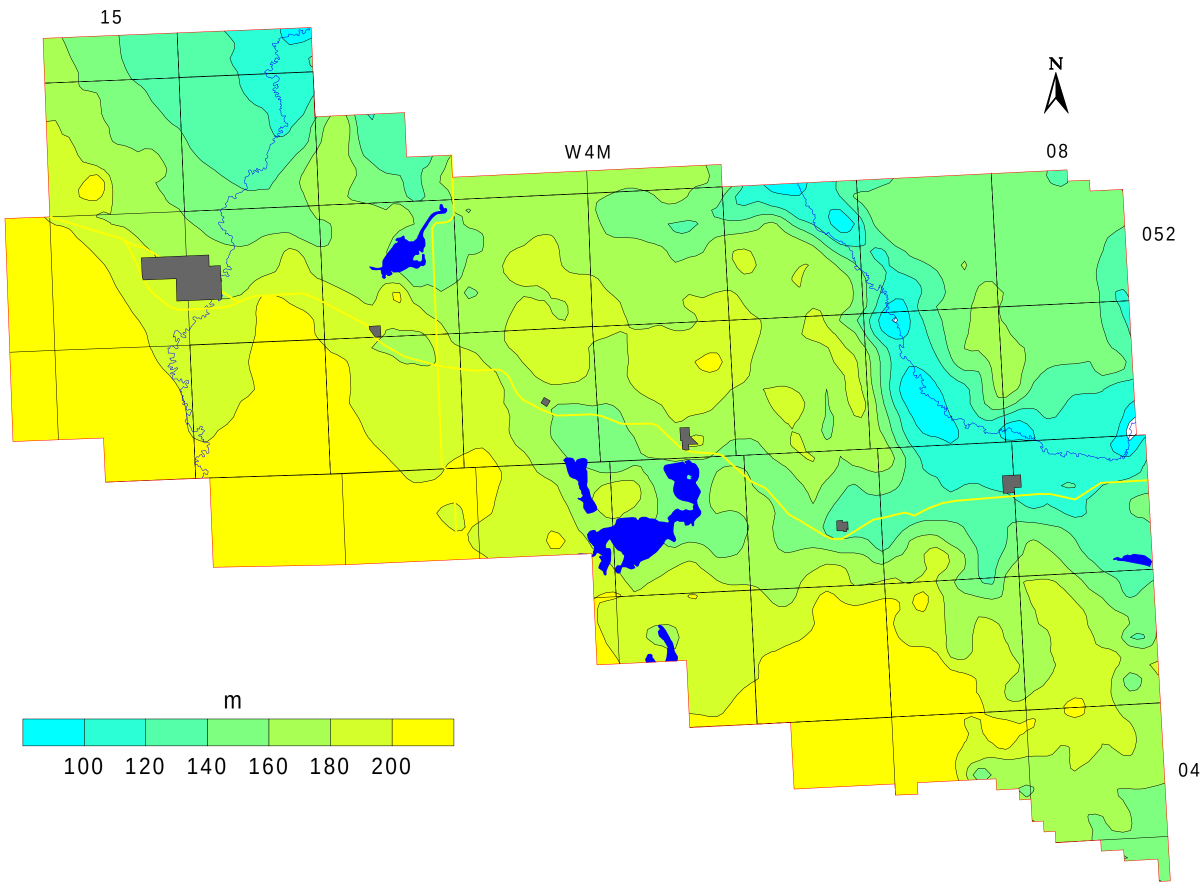
Chloride in Groundwater from Victoria Aquifer

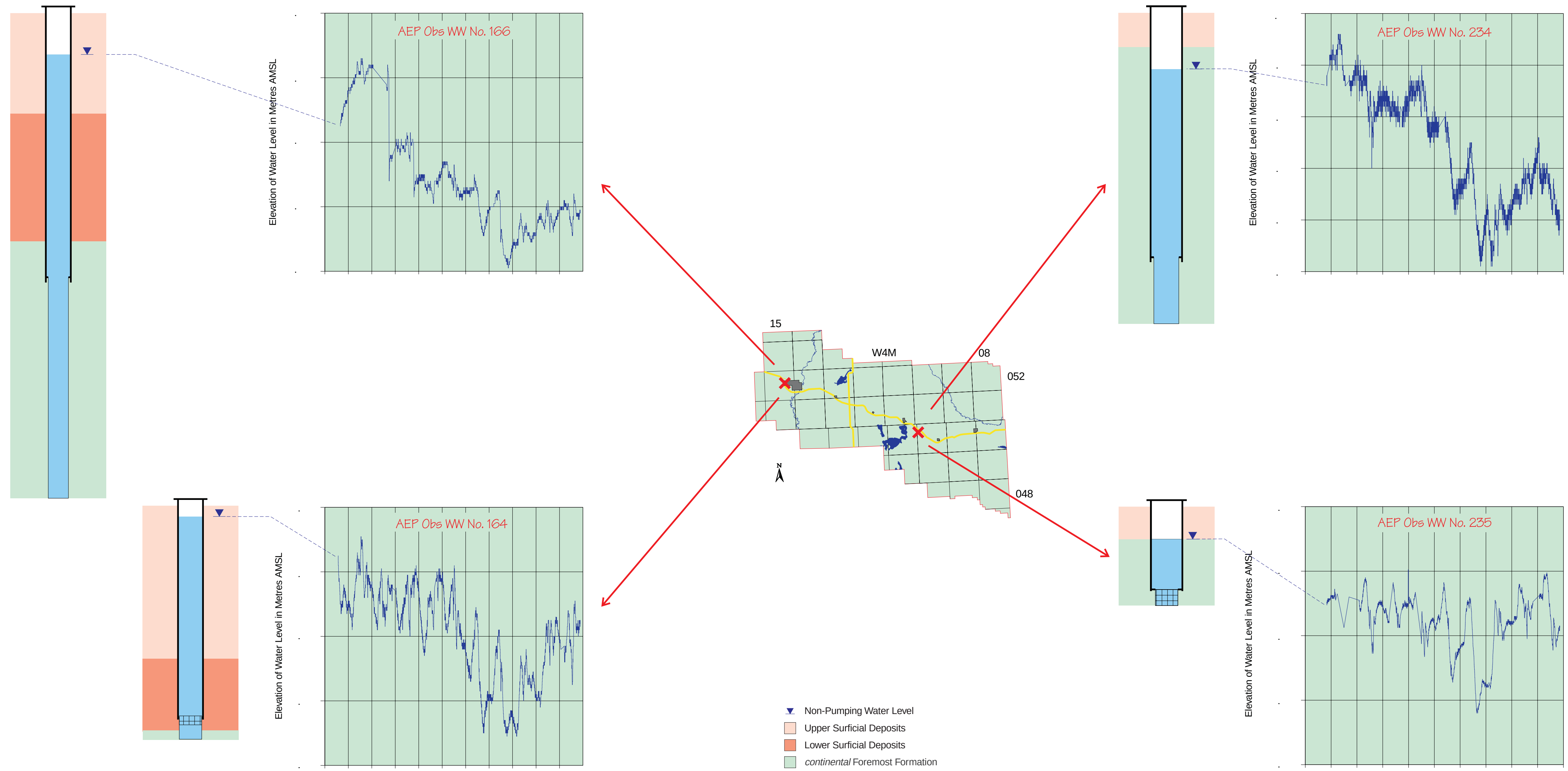


Depth to Top of Brosseau Member



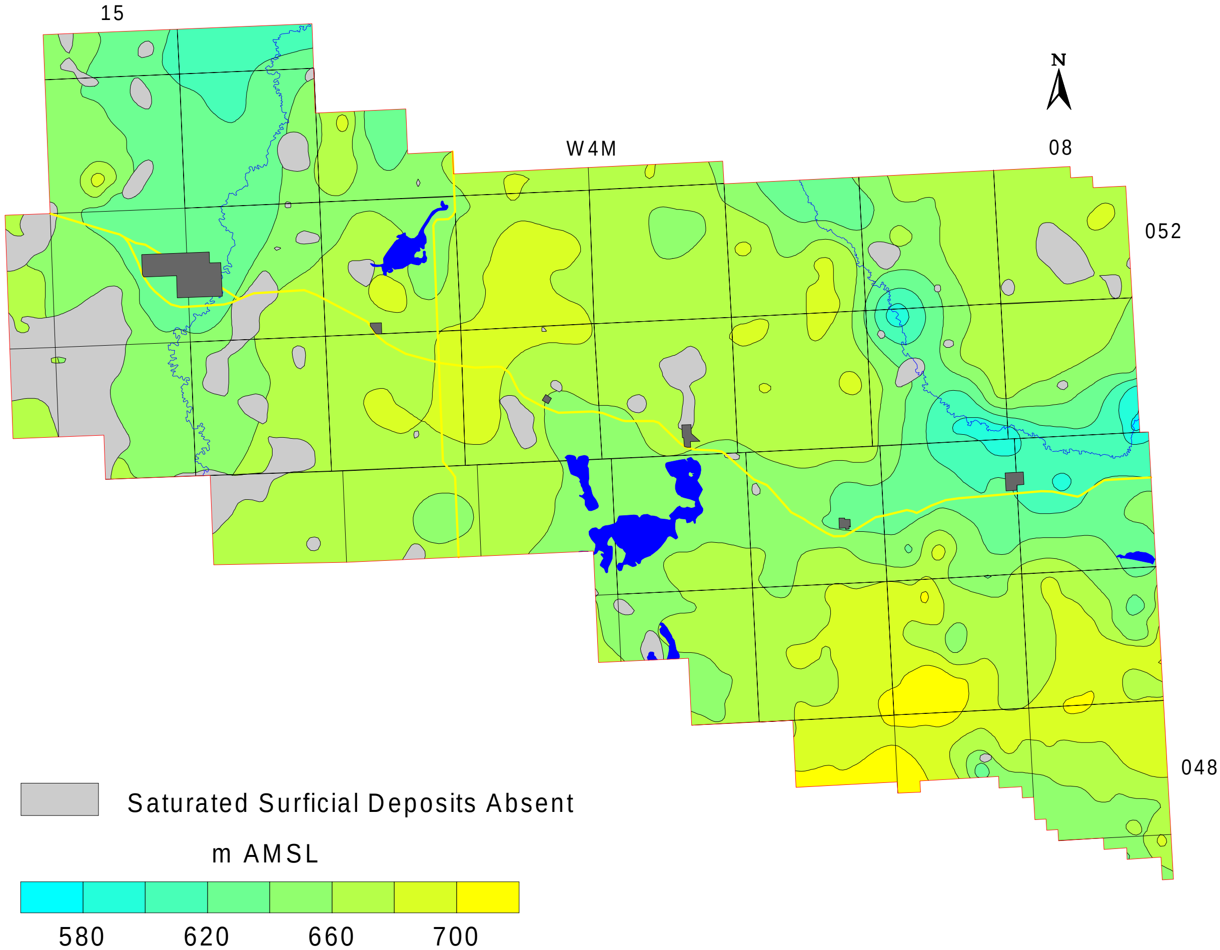
Depth to Top of Lea Park Aquitard



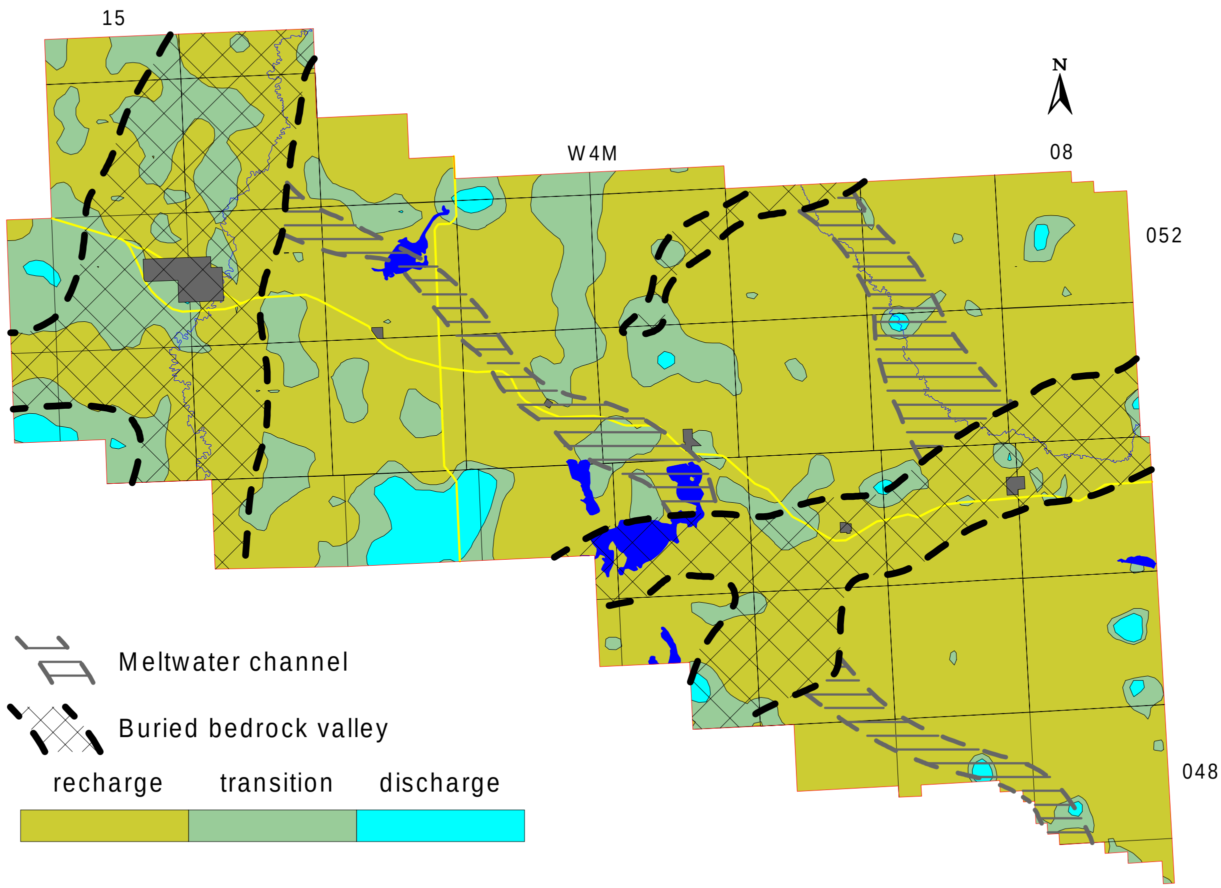


Hydrographs - AEP Observation Water Wells

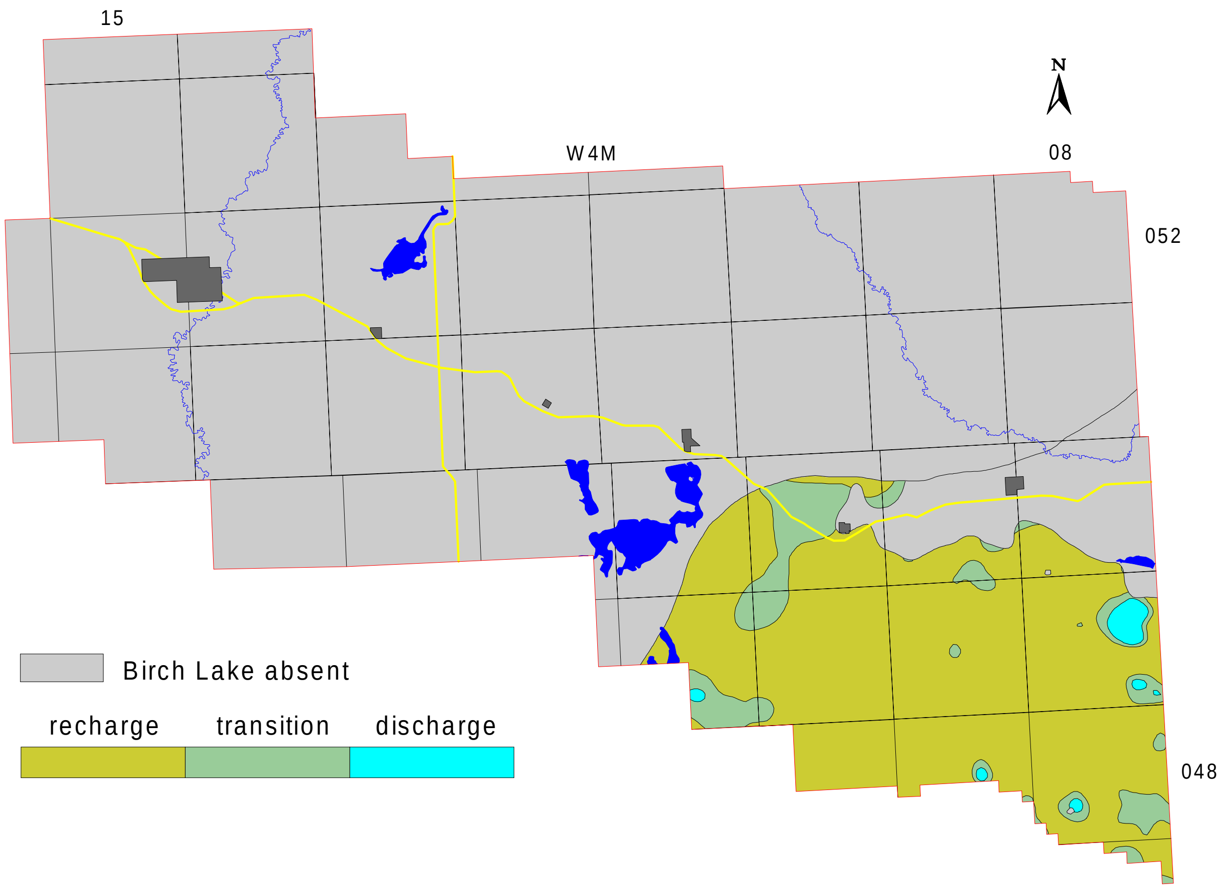
Non-Pumping Water-Level Surface in Surficial Deposits



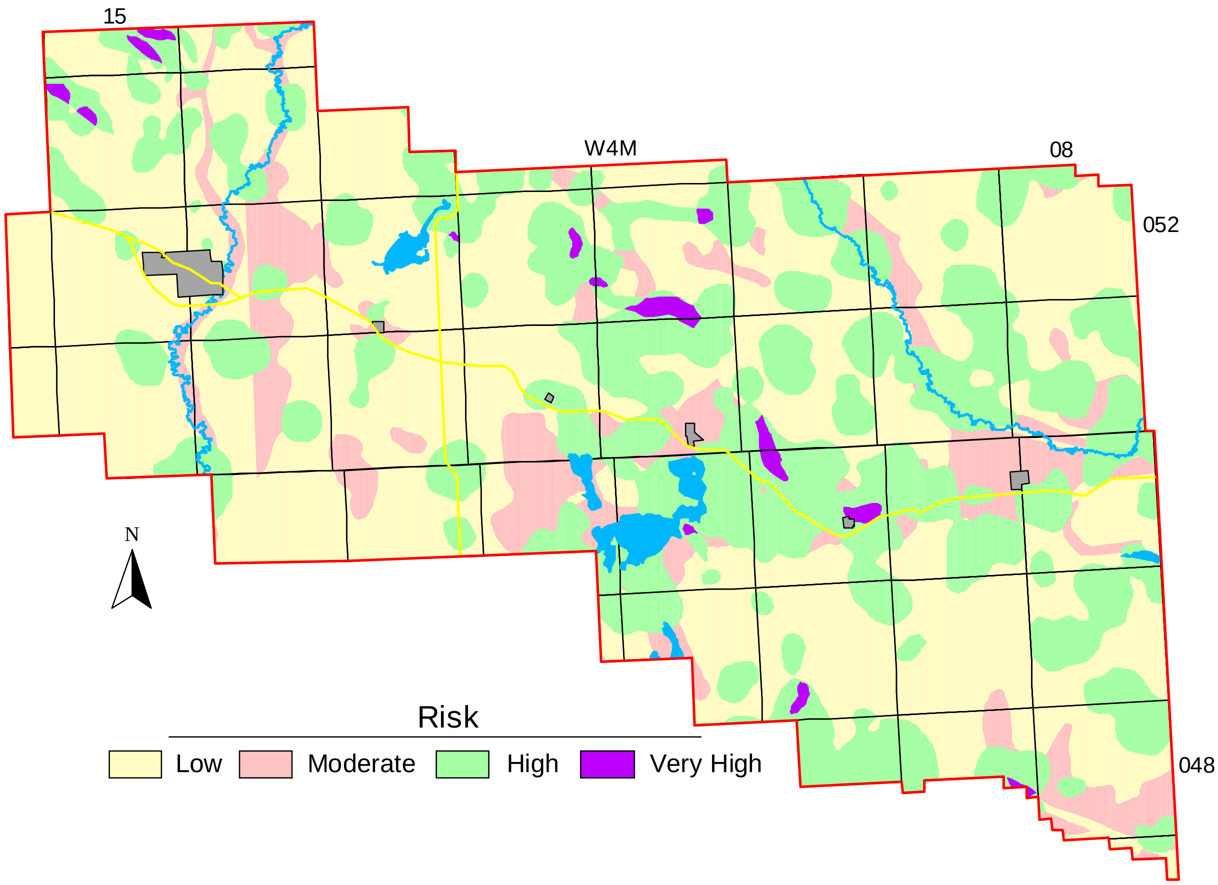
Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)



Recharge/Discharge Areas between Surficial Deposits and Birch Lake Aquifer



Risk of Groundwater Contamination



COUNTY OF MINBURN NO. 27

Appendix B

MAPS AND FIGURES ON CD-ROM

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COUNTY OF MINBURN NO. 27

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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Additional Information

VIDEOS

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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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PRAIRIE FARM REHABILITATION ADMINISTRATION

Keith Schick (Vegreville: 403-632-2919)

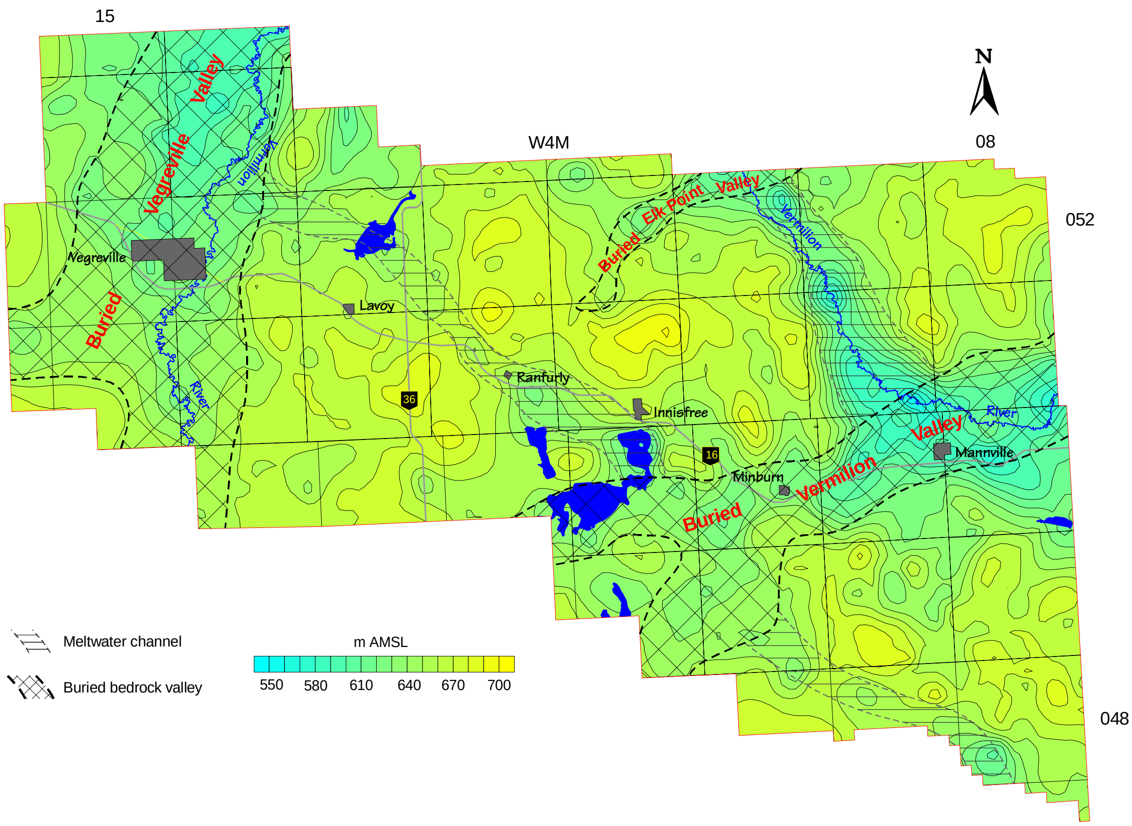
LOCAL HEALTH DEPARTMENTS

COUNTY OF MINBURN NO. 27

Appendix D

MAPS AND FIGURES INCLUDED AS LARGE PLOTS

County of Minburn No. 27
Bedrock Topography



Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada

PFRA Prairie Farm Rehabilitation Administration

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

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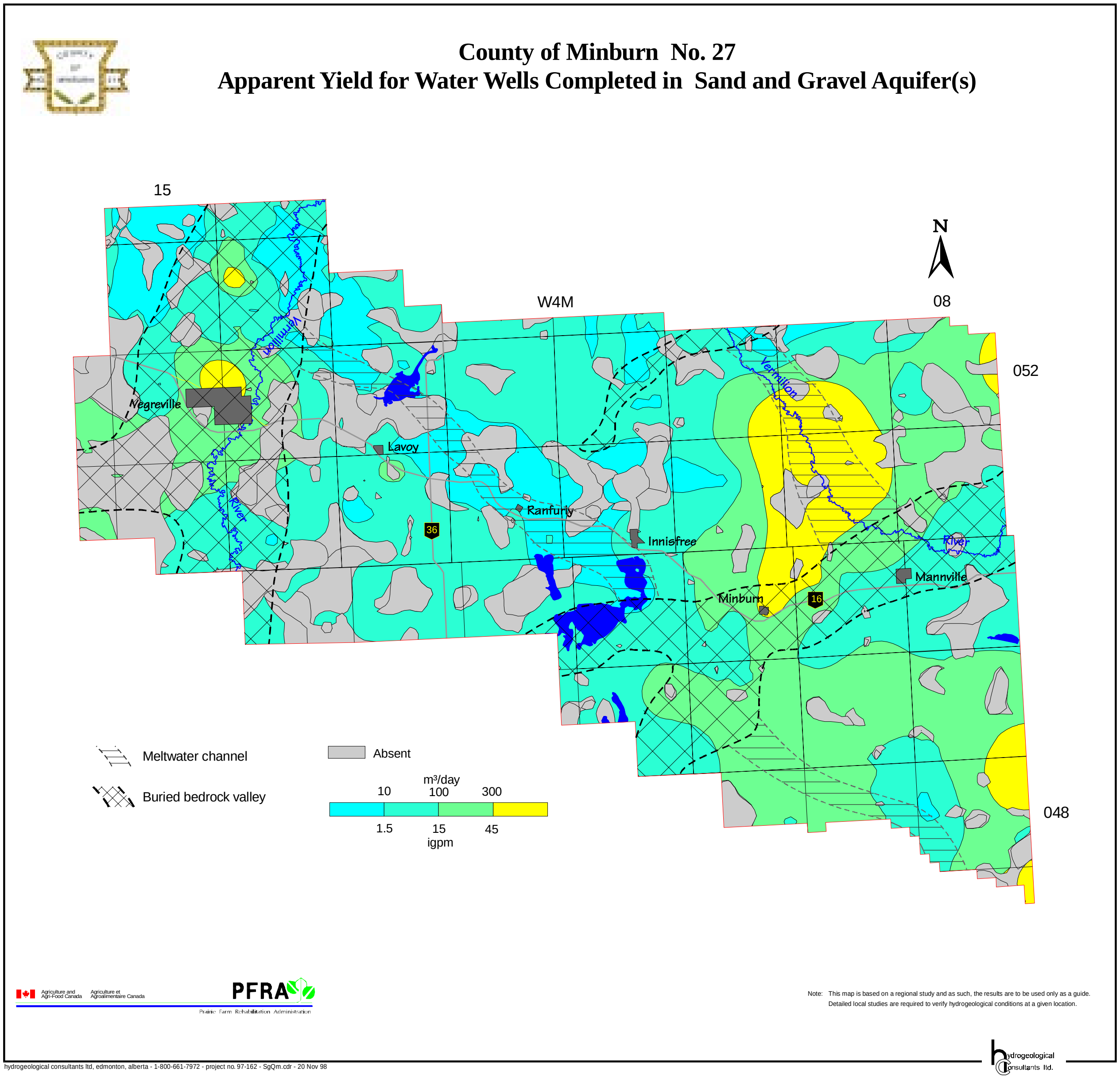
County of Minburn No. 27
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)
15
W4M
08
N
052
048
Vegreville
Lavoy
Ranfurly
Innisfree
Minburn
Mannville
Vermilion
River
36
16
Meltwater channel
Buried bedrock valley
Absent
m³/day
10
100
300
1.5
15
45
igpm
PFRA
Note: This map is based on a regional study and as such, the results are to be used only as a guide. Detailed local studies are required to verify hydrogeological conditions at a given location.
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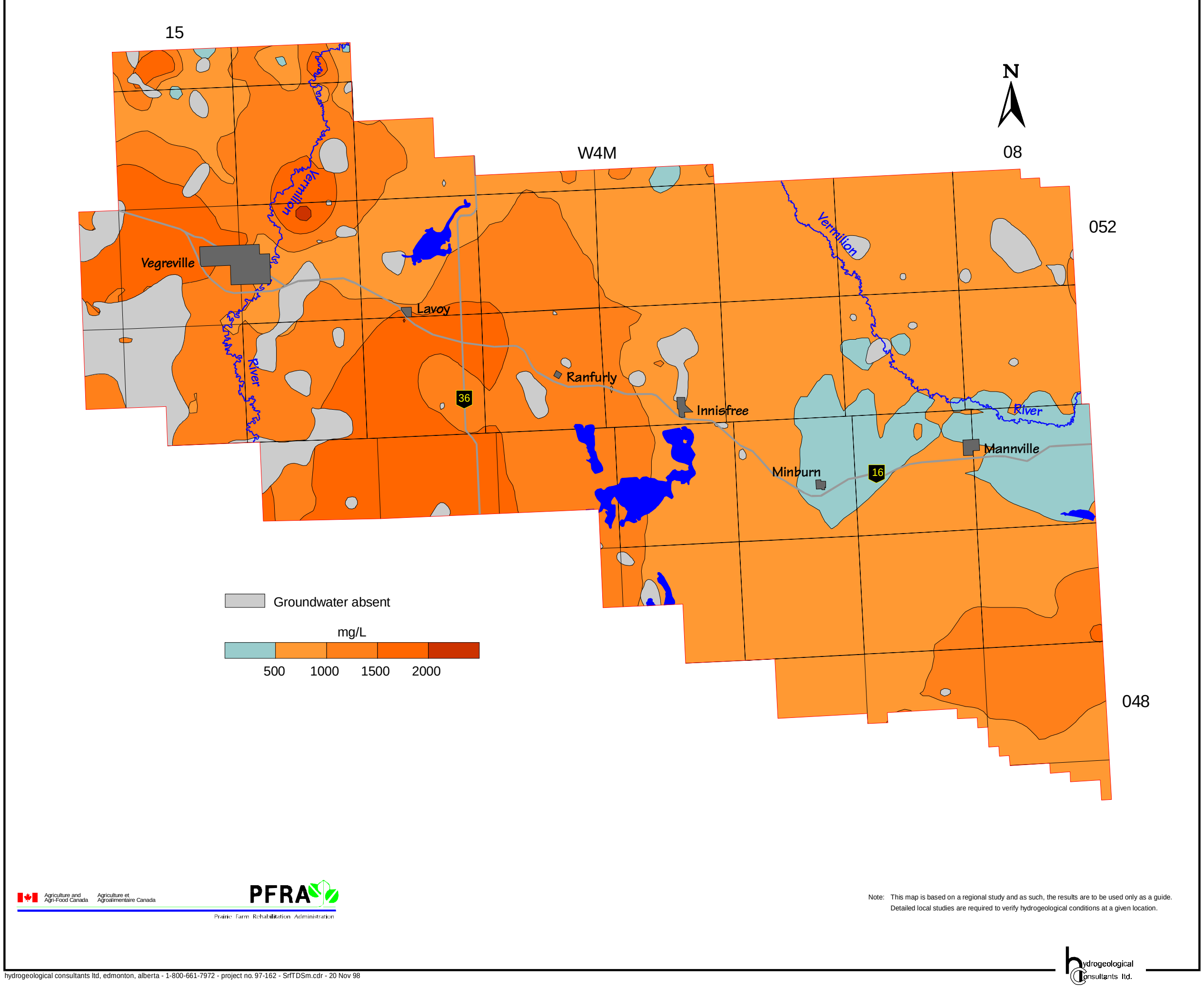
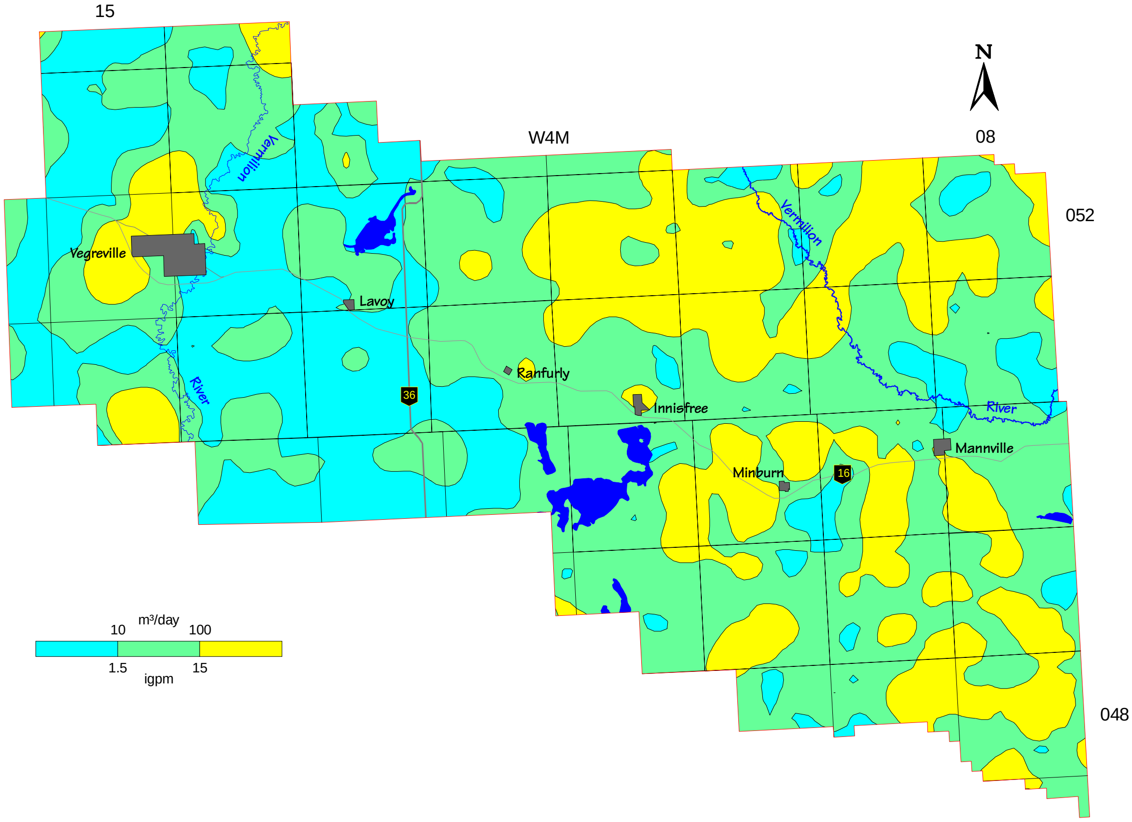
County of Minburn No. 27
Total Dissolved Solids in Groundwater from Surficial Deposits



County of Minburn No. 27
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



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

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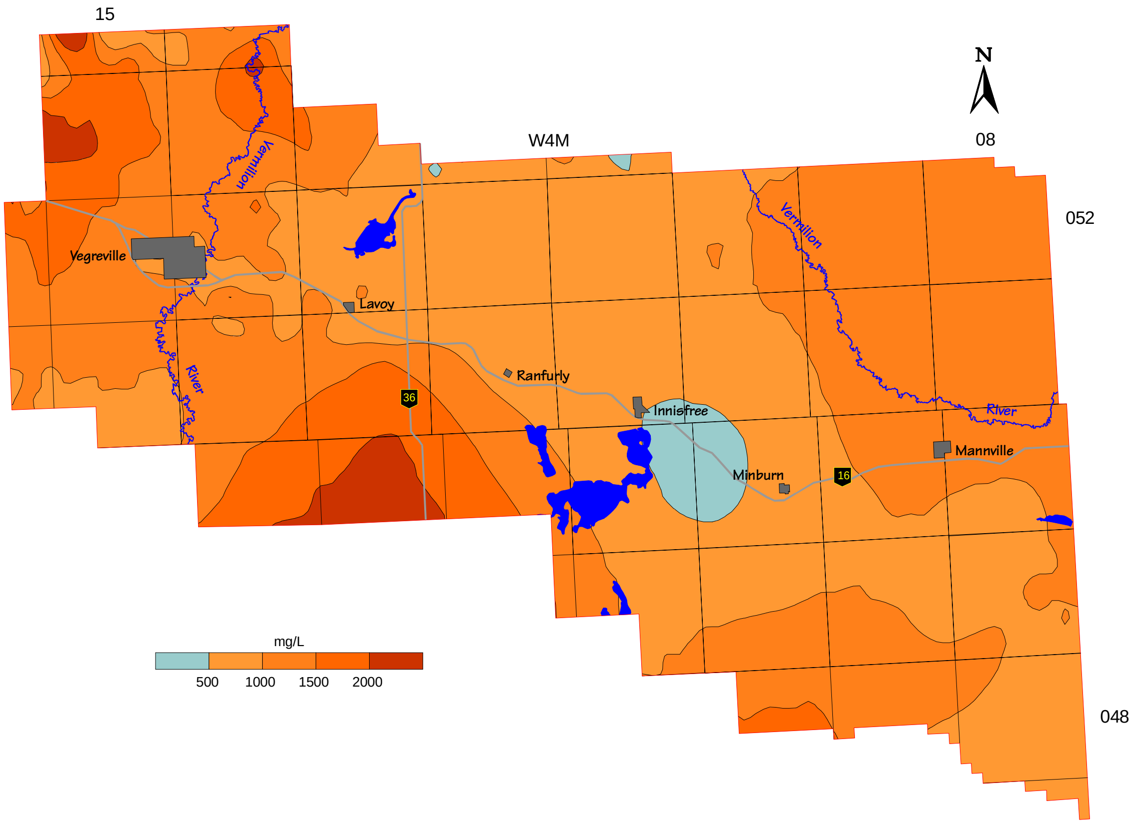
County of Minburn No. 27
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



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

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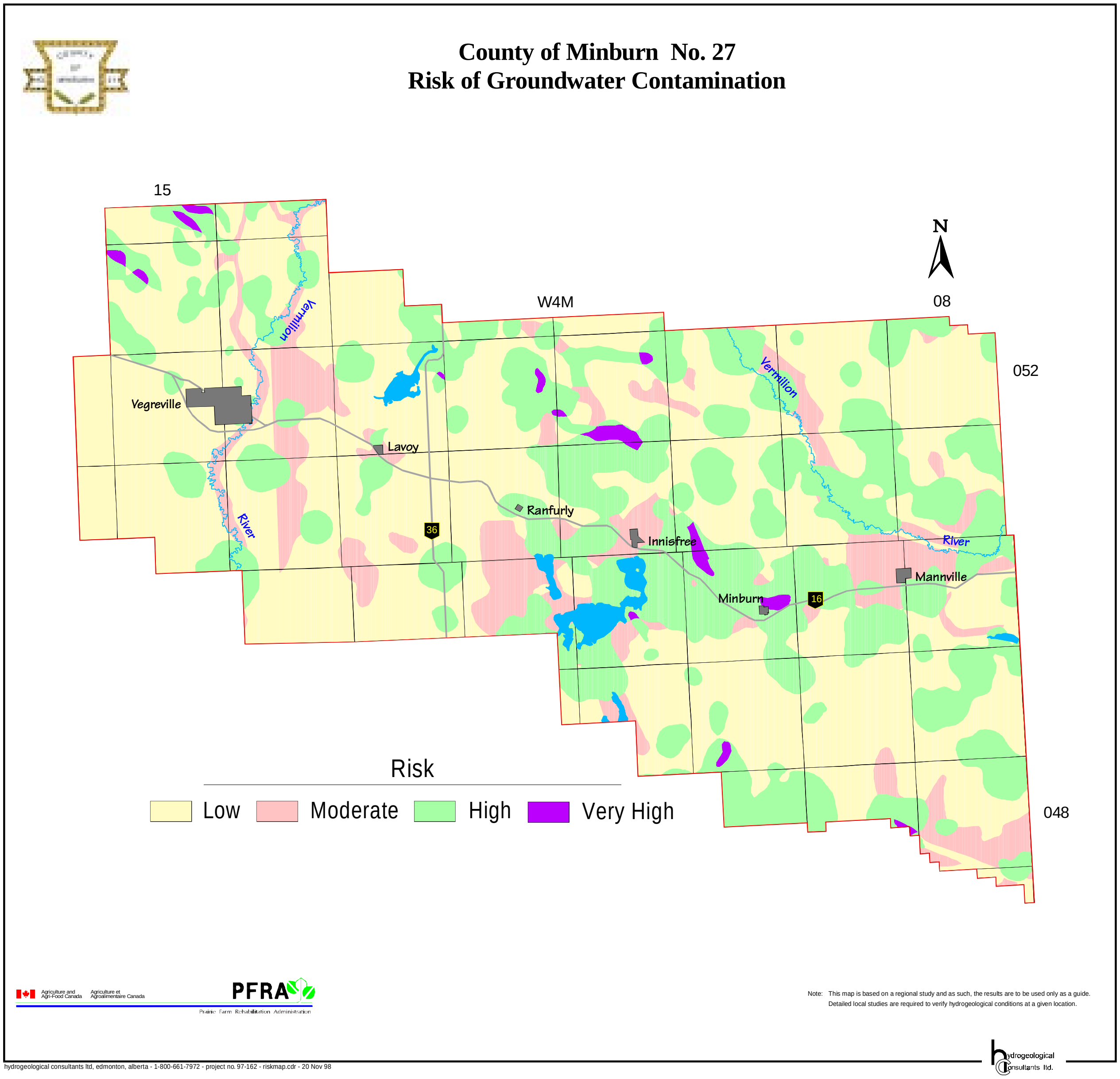
County of Minburn No. 27
Risk of Groundwater Contamination
15
W4M
08
052
048
N
Vegreville
Lavoy
Ranfurly
Innisfree
Minburn
Mannville
Vermilion
River
36
16
Risk
Low
Moderate
High
Very High
PFRA
Note: This map is based on a regional study and as such, the results are to be used only as a guide. Detailed local studies are required to verify hydrogeological conditions at a given location.
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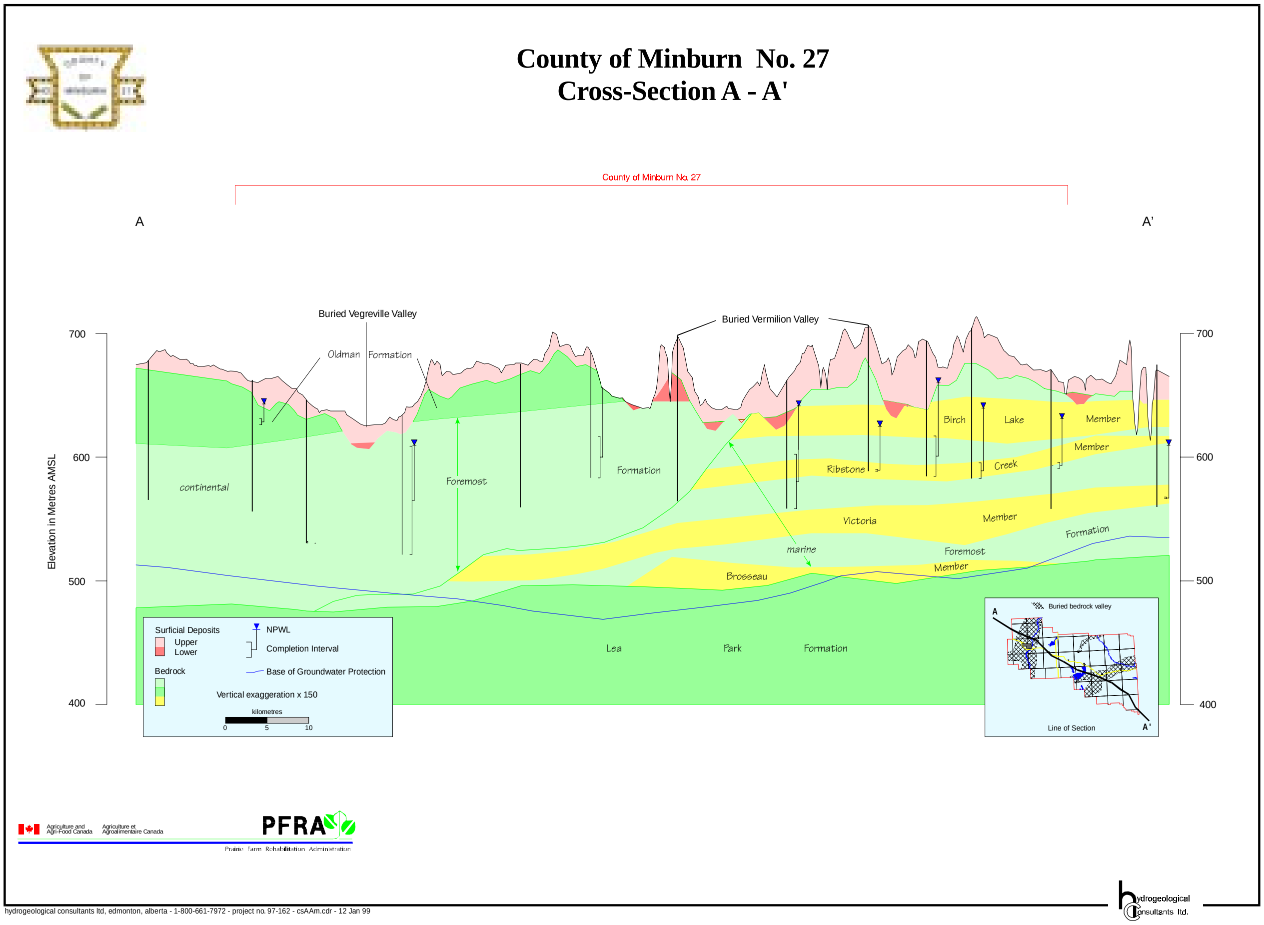
County of Minburn No. 27
Cross-Section A - A'
County of Minburn No. 27
A
A'
Buried Vegreville Valley
Buried Vermilion Valley
Oldman Formation
Foremost
Formation
continental
Birch
Lake
Member
Ribstone
Creek
Member
Victoria
Member
Formation
marine
Foremost
Member
Brosseau
Lea
Park
Formation
Elevation in Metres AMSL
700
600
500
400
Surficial Deposits
Upper
Lower
Bedrock
NPWL
Completion Interval
Base of Groundwater Protection
Vertical exaggeration x 150
kilometres
0
5
10
Buried bedrock valley
Line of Section
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
PFRA
Prairie Farm Rehabilitation Administration
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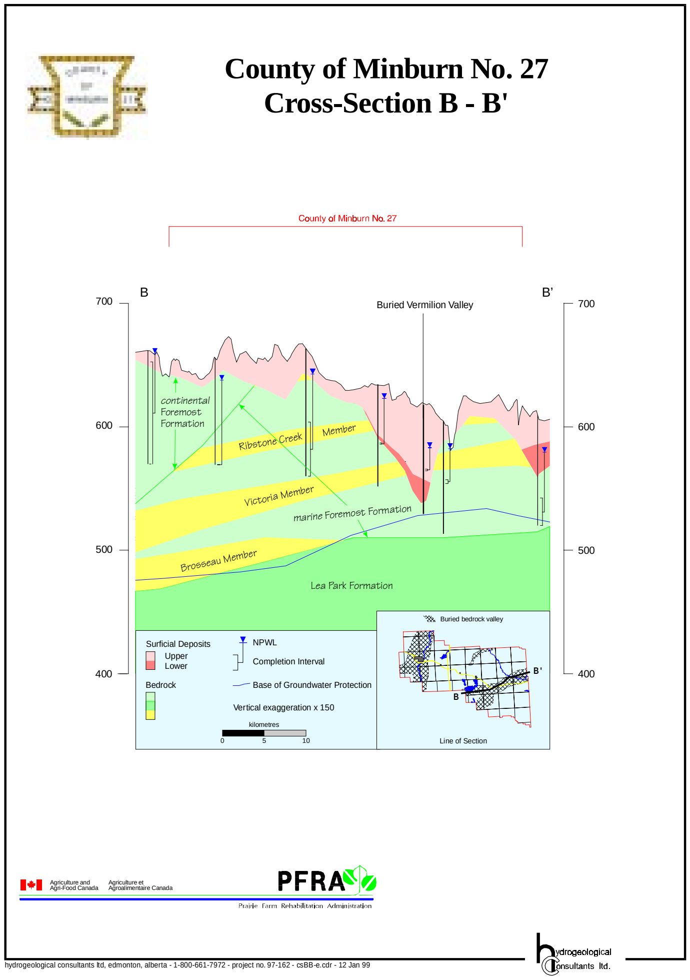
hydrogeological consultants ltd.


County of Minburn No. 27
Cross-Section B - B'
County of Minburn No. 27
B
B'
Buried Vermilion Valley
700
600
500
400
continental Foremost Formation
Ribstone Creek Member
Victoria Member
marine Foremost Formation
Brosseau Member
Lea Park Formation
Surficial Deposits
Upper
Lower
Bedrock
NPWL
Completion Interval
Base of Groundwater Protection
Vertical exaggeration x 150
kilometres
0
5
10
Buried bedrock valley
Line of Section
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
PFRA
Prairie Farm Rehabilitation Administration
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