M.D. of Provost No. 52

Part of the Battle River Basin
Parts of Tp 036 to 043, R 01 to 10, W4M
Regional Groundwater Assessment

Prepared for

In conjunction with

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Prairie Farm Rehabilitation Administration | Administration du rétablissement agricole des Prairies

Canada

Prepared by
hydrogeological consultants ltd.
1-800-661-7972
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The Association of Professional Engineers,
Geologists and Geophysicists of Alberta

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1 PROJECT OVERVIEW

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

How a Municipal District (M.D.) 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 M.D. of Provost No. 52 toward the management of the groundwater resource, which is a key component of the well-being of the M.D., 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 M.D. of Provost No. 52, (b) the processes used for the present project and (c) the groundwater characteristics in the M.D.

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 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 M.D. of Provost No. 52. The regional groundwater assessment provides the information to assist in the management of the groundwater resource within the M.D. Groundwater resource management involves determining the suitability of various areas in the M.D. 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 M.D.**

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 M.D. have been assembled. Where practical, the data have been digitized. These data are then being used in the regional groundwater assessment for the M.D.

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[1] See glossary
[2] See glossary

2 INTRODUCTION

2.1 Setting

The M.D. of Provost No. 52 is situated in east-central Alberta. This area is part of the Alberta Plains region. The M.D. exists within the Battle River basin. The northwestern boundary of the M.D. is the Battle River. The other boundaries follow township or section lines. The area includes some or all of townships 036 to 043, ranges 01 to 10, west of the 4th Meridian.

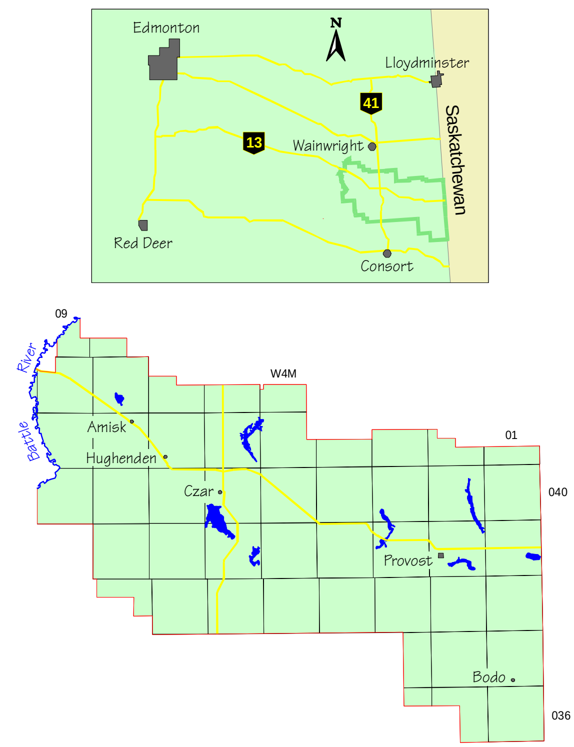

Figure 1. Index Map

The ground elevation varies between 580 and 820 metres above mean sea level (AMSL). Regionally the topographic surface generally decreases from west to east and from south to north. However, local drainage is toward the Battle River.

2.2 Climate

The M.D. 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 M.D. 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 M.D. measured 417 millimetres (mm), based on data from 1967 to 1985. The mean annual temperature averaged 2.3 °C, with the mean monthly temperature reaching a high of 17.1 °C in July, and dropping to a low of -15.6 °C in January. The calculated annual potential evapotranspiration is 530 millimetres.

2.3 Background Information

There are currently records for 2,980 water wells in the groundwater database for the M.D. Of the 2,980 water wells, 2,628 are for domestic/stock purposes. The remaining 352 water wells were completed for a variety of uses, including municipal, industrial and observation purposes. Based on a rural and hamlet population of 2,705, there are 3.9 domestic/stock water wells per family of four. The domestic or stock water wells vary in depth from less than one metre to 213.4 metres below ground level. Lithologic details are available for 1,537 water wells.

Data for casing diameters are available for 1,567 water wells, with 391 having a diameter of more than 300 mm and 1,176 having a diameter of less than 300 mm. The casing diameters of greater than 300 mm are mainly bored water wells and those with a surface casing of less than 300 mm are drilled water wells.

Steel, plastic and galvanized steel represent 97% 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 M.D. From before 1950 to the mid-1960s, the surface casing used was unknown in the majority of the water wells drilled. Steel casing was in use in the 1950s and is still used in 4% of the new water wells being drilled in the M.D. Galvanized steel surface casing was used in 4% of the new water wells in the early 1960s. By the 1970s, galvanized steel casing was being used in 30% of the water wells. From 1980 onward, there was a general decrease in the percentage of water wells using galvanized steel, with the last reported use in May 1992. Plastic casing was used for the first time in April 1972. The percentage of water wells with plastic casing has increased and in the mid-1990s, plastic casing was used in 96% of the water wells drilled in the M.D.

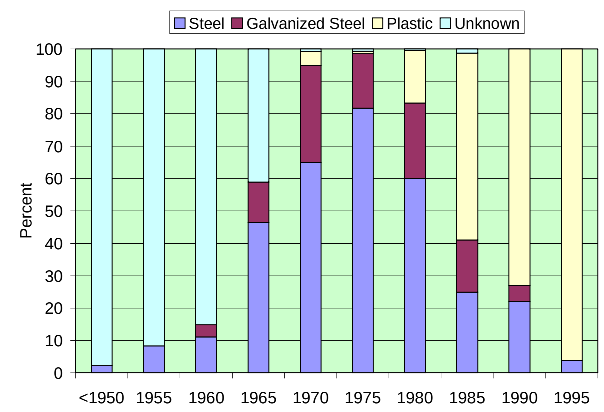

Figure 2. Surface Casing Types used in Drilled Water Wells

There are 1,272 water well records with sufficient information to identify the aquifer in which the water wells are completed. The water wells that were not drilled deep enough to encounter the bedrock plus water wells that have the bottom of their completion interval above the bedrock surface are water wells completed in surficial aquifers. The number of water wells completed in aquifers in the surficial deposits is 540. The adjacent map shows that these water wells occur over most of the M.D. Approximately 70% of the water wells completed in the surficial aquifers have a completion depth of less than 40 metres and 30% have a completion depth of more than 40 metres. The remaining 732 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 water wells completed in bedrock aquifers occur over most of the M.D.

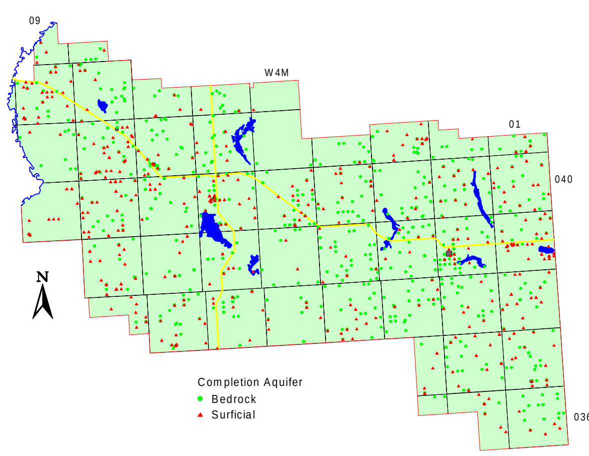

Figure 3. Location of Water Wells

Water wells not used for domestic needs must be licensed. At the end of 1996, 212 groundwater diversions were licensed in the M.D. The total maximum authorized diversion from these 212 water wells is 9,008 cubic metres per day (m³/day); 48% of the authorized groundwater diversion is allotted for industrial use. The largest licensed groundwater diversion within the M.D. not used for industrial purposes is for the Town of Provost, having a combined diversion of 957 m³/day from four water supply wells completed in a sand and gravel aquifer.

The largest licensed industrial groundwater diversion within the M.D. is 500 m³/day, for a PanCanadian Petroleum (PCP) water source well in 07-04-041-03 W4M. The water source well is completed at a depth of more than 800 metres below ground surface, in the Dina Member of the Mannville Group.

The adjacent table shows a breakdown of the 212 licensed groundwater diversions by the aquifer in which the water well is completed. The highest aquifer diversions are for licensed water wells completed in the Oldman Aquifer, of which most of the groundwater is used for agricultural and municipal purposes. The licensed water wells that are completed in the Ribstone Creek and Victoria aquifers are all used for industrial purposes. A detailed discussion of the individual aquifers can be found later in this report.

	Licensed Groundwater Diversions (m³/day)					
Aquifer	Agricultural	Domestic	Industrial	Municipal	Other	Total
Upper Sand and Gravel	564	3	0	1,024	54	1,645
Lower Sand and Gravel	47	0	0	0	0	47
Bearpaw	90	0	0	0	0	90
Oldman	1,877	0	3	110	10	2,000
continental Foremost	151	0	0	0	0	151
Milan	49	0	0	0	0	49
marine Foremost	96	0	0	9	0	105
Birch Lake	384	0	81	172	0	637
Ribstone Creek	0	0	730	0	0	730
Victoria	0	0	1,529	0	0	1,529
Unknown	0	0	2,025	0	0	2,025
Total	3,258	3	4,368	1,315	64	9,008

Table 1. Licensed Groundwater Diversions

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

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 M.D. are generally less than 1,000 milligrams per litre (mg/L). Groundwaters from the bedrock aquifers frequently are chemically soft with generally low concentrations of dissolved iron. The chemically soft groundwater is high in sodium concentration. Approximately 15% 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 would be for the most part the maximum drilling depth for a water supply well. Over approximately 30% of the Region, the depth to the Base of Groundwater Protection is more than 200 metres. There are only a few areas where the depth to the Base of Groundwater Protection is less than 100 metres.

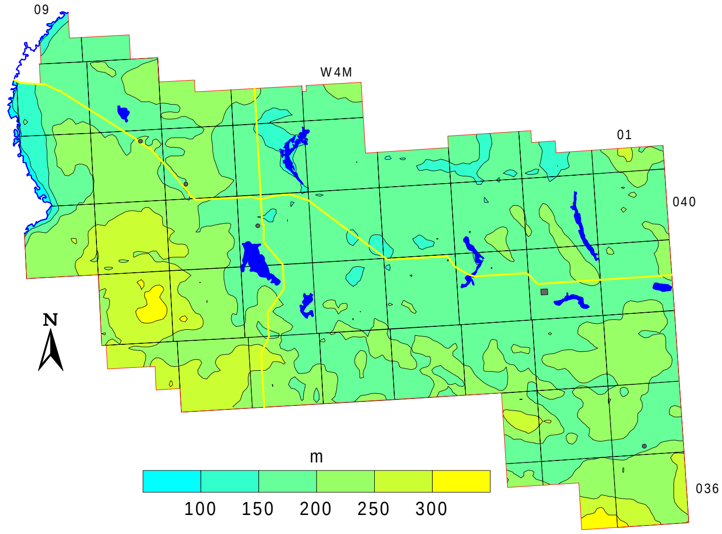

Figure 4. Depth to Base of Groundwater Protection

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 three AEP-operated observation water wells within the M.D. Additional data can be obtained from some of the licensed groundwater diversions. In the past, these data have been difficult to obtain from AEP, in part because of the failure of the licensee to provide the data.

However, even with the available sources of data, the number of water-level data points relative to the size of the M.D. 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

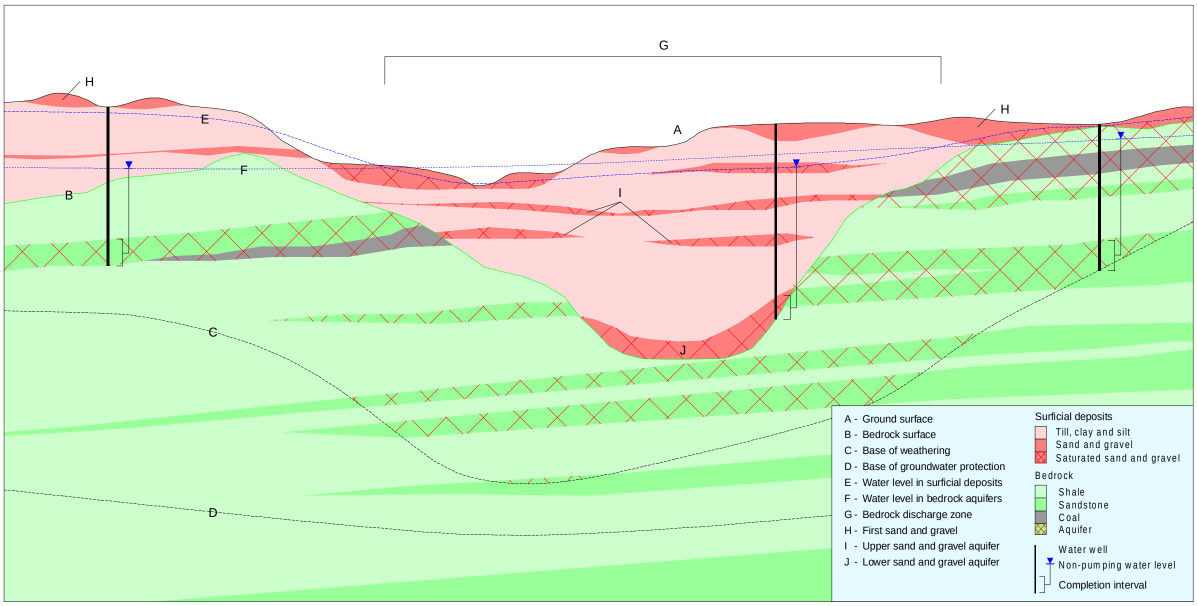

Figure 5. Generalized Cross-Section (for terminology only)

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	<100		Surficial Deposits	<100	Upper	<30	First Sand and Gravel
				<40	Lower		
shale, sandstone, siltstone	60-120		Bearpaw Formation				
sandstone, siltstone, shale, coal	40-80	Belly River Group	Oldman Formation	<30	Dinosaur Member	<25	Lethbridge Coal Zone
				<20	Upper Siltstone Member		
				8-20	Comrey Member		
shale, sandstone, coal	10-220		*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 SW ¼ of section 17, township 039, range 02, W4M would have a horizontal coordinate with an Easting of 322,500 metres and a Northing of 5,808,011 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 & Utilities Board (EUB) well database includes records for all of the wells drilled by the oil and gas industry. The information from this source includes:

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

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

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

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

4.2 Spatial Distribution of Aquifers

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

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

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

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

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

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

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

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

4.3 Hydrogeological Parameters

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

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

Once the values for the various parameters of the individual aquifers are established, the spatial distribution of the various parameters must be determined. The distribution of individual parameters involves the same process as the distribution of geological surfaces. This means establishing a representative data set and then preparing a grid.

4.3.1 Risk Criteria

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

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.

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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 from the digitally prepared surfaces to the cross-section.

Once the technical details of a cross-section are correct, the drawing file is moved to the software package CorelDRAW! for simplification and presentation in a hard-copy form. These cross-sections are presented in this report and 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 M.D. 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 M.D. are mainly less than 40 metres thick, except in areas of linear bedrock lows where the thickness of surficial deposits can exceed 80 metres. The Buried Wainwright and Bodo valleys are the two main linear bedrock lows in the M.D. The Buried Wainwright Valley is present in the northwestern and northern parts of the M.D. and trends generally from west to east. The Buried Bodo Valley is present in the southeastern part of the M.D. and trends from southwest to northeast. Cross-section A-A' passes across both the Buried Wainwright and Bodo valleys, and shows the thickness of the surficial deposits as being approximately 80 metres.

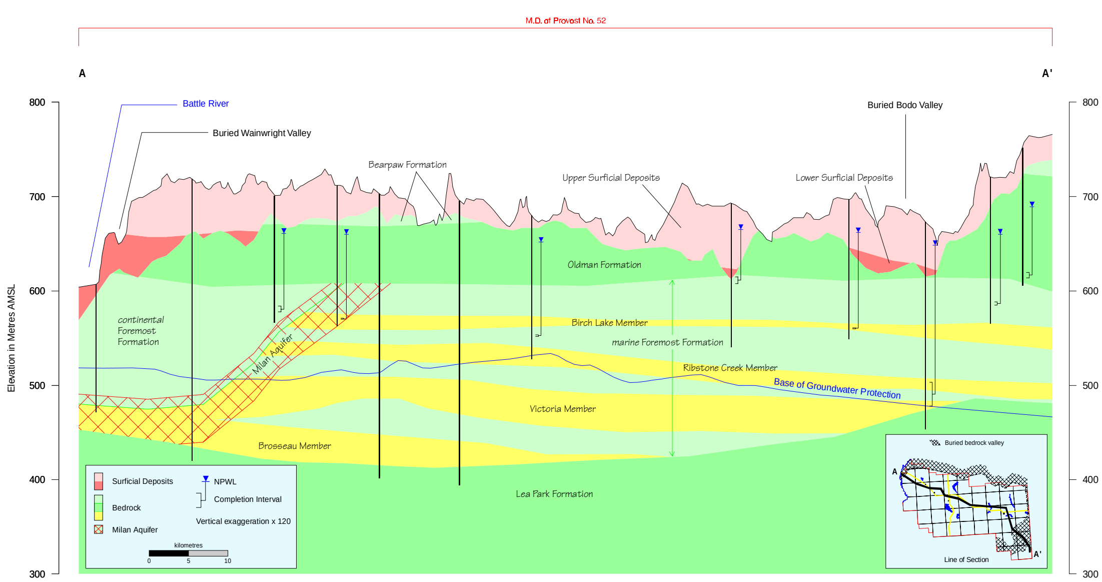

Figure 7. Cross-Section A - A'

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 must be treated before being used for domestic needs. Within the M.D., 38% of the water wells completed in the surficial deposits have a casing diameter of greater than 300 millimetres or no reported diameter for the surface casing, and are assumed to be dug or bored water wells.

5.1.2 Bedrock Aquifers

The upper bedrock includes rocks that are less than 200 metres below the bedrock surface. Some of this bedrock contains porous, permeable and saturated rocks that have a structure that is permeable enough for the rock to be an aquifer. Water wells completed in bedrock aquifers usually do not require water well screens, 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 732 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 732 water wells, more than 99% have surface casing diameters of less than 300 mm and 4% of these bedrock water wells have been completed with water well screens.

The upper bedrock includes parts of the Bearpaw Formation and the Belly River Group. The Lea Park Formation underlies the Belly River Group. The Bearpaw Formation is generally less than 100 metres thick. The Belly River Group has a maximum thickness of 250 metres and 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 upper part of the *marine* Foremost Formation is included in the Milan Aquifer. In the M.D., the Bearpaw and the Lea Park formations are regional aquitards[10].

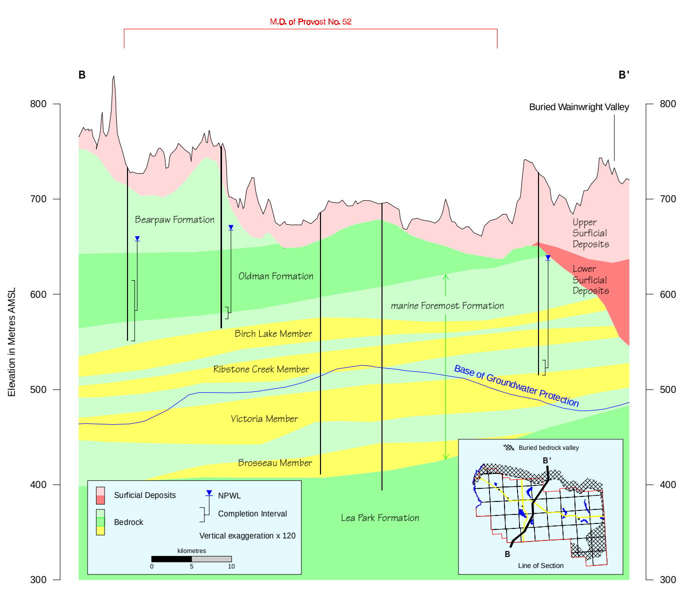

Figure 8. Cross-Section B - B'

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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 M.D., pre-glacial material would be expected to be present in association with the Buried Wainwright and Bodo 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 M.D., 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 M.D. have been designated as the Buried Wainwright Valley and the Buried Bodo Valley. The Buried Wainwright Valley is in the northwestern part of the M.D. as shown on the adjacent map. The Buried Wainwright Valley trends mainly easterly across parts of the northern border of the M.D. The Buried Wainwright Valley is approximately three to six kilometres wide within the M.D., 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, but the thickness of the sand and gravel deposits is expected to be mainly less than 30 metres.

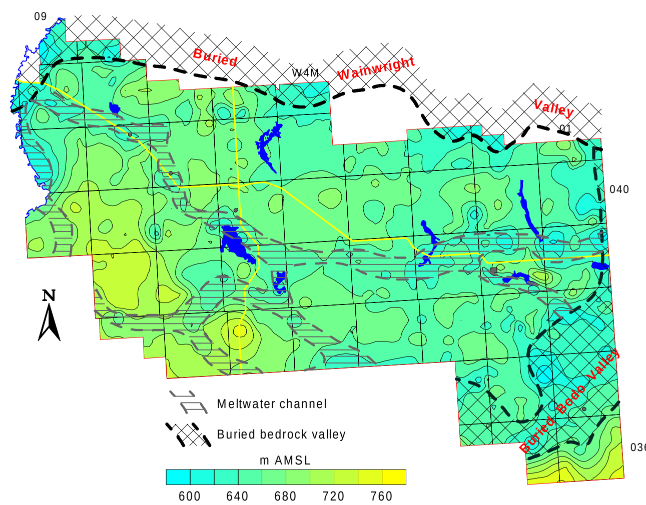


Figure 9. Bedrock Topography

The second linear bedrock low, the Buried Bodo Valley, trends from southwest to northeast along the southeastern edge of the M.D., mainly within townships 036, 037 and 038, ranges 01 and 02, W4M. The Buried Bodo Valley is approximately 5 to 11 kilometres wide, with local relief being less than 60 metres. Sand and gravel deposits can be expected to be present in association with this bedrock low, with the

[11] See glossary
[12] See glossary

thickness of the deposits expected to be less than 30 metres. The Town of Provost obtains its municipal water from water supply wells completed in the sand and gravel aquifer associated with the buried valley near St. Lawrence Lake (Geoscience Consulting Ltd., 1977).

There are other linear bedrock lows shown on the bedrock topography map. All of these lows trend northwest to southeast in the M.D. 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 Bodo Valley drainage system.

The lower surficial deposits are composed mainly of fluvial and lacustrine deposits. Lower surficial deposits occur over approximately 20% of the Region, in association with linear bedrock lows. The total thickness of the lower surficial deposits is mainly less than 20 metres, but ranges from 10 to more than 30 metres in parts of the Buried Wainwright and Bodo valleys. 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 Wainwright and Bodo valleys. The lowest sand and gravel deposits are of fluvial origin and are usually less than 10 metres thick.

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 40 metres. The greatest thickness of upper surficial deposits occurs mainly in association with the Buried Bodo 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 30 metres in the areas of the buried bedrock lows and meltwater channels.

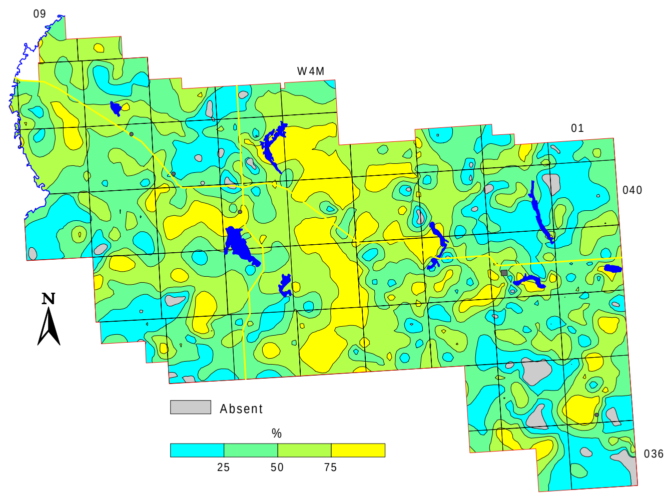


Figure 10. Amount of Sand and Gravel in Surficial Deposits

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 40% of the M.D., 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 in the north-central part of the M.D. and in association with linear bedrock lows. The other areas where sand and gravel deposits constitute more than 50% of the surficial deposits may 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 M.D. 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, 74 water wells are completed in aquifers in the lower surficial deposits and 1,112 are completed in aquifers in the upper surficial deposits. This situation occurs because of the limited areal extent of the lower surficial deposits. This number of 1,186 water wells completed in aquifers in the surficial deposits is more than double the number of water wells determined to be completed in aquifers in the surficial deposits based on lithology given on the water well drilling reports.

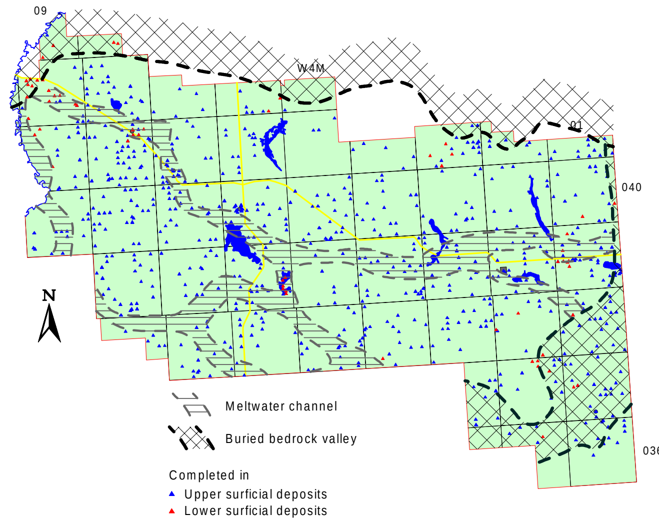


Figure 11. Water Wells Completed in Surficial Deposits

The water wells completed in the upper surficial deposits are located throughout the M.D., as shown in Figure 11. The majority of the water wells completed in the lower surficial deposits are located along the Buried Wainwright and Bodo valleys and bedrock lows of meltwater origin.

The adjacent map shows water well yields that are expected in the M.D., based on surficial aquifers that have been developed by existing water wells. These data show that water wells with yields of more than 100 m³/day from sand and gravel aquifer(s) can be expected in more than 30% of the M.D. The most notable areas where yields of more than 100 m³/day are expected are mainly in or adjacent to the areas of linear bedrock lows. Over the majority of the M.D., water wells completed in the sand and gravel aquifer(s) would be expected to mainly have long-term yields of less than 100 m³/day.

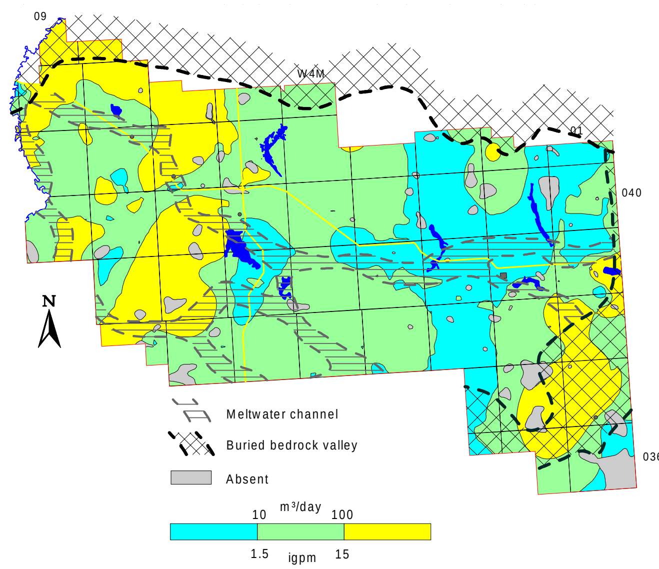


Figure 12. Apparent Yield for Water Wells Completed through Sand and Gravel Aquifer(s)

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 or 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-type waters, with 65% of groundwaters having a TDS of less than 1,000 mg/L. The groundwaters with a TDS of more than 1,500 mg/L occur mainly in the eastern part of the M.D. Groundwaters from the surficial deposits are expected to have dissolved iron concentrations of greater than 1 mg/L. Groundwater from the Town of Provost water supply wells completed in the Upper Sand and Gravel Aquifer has a TDS of approximately 500 mg/L and a hardness of less than 400 mg/L. Chloride concentrations were mainly below the detection limit (Geoscience Consulting Ltd., 1977).

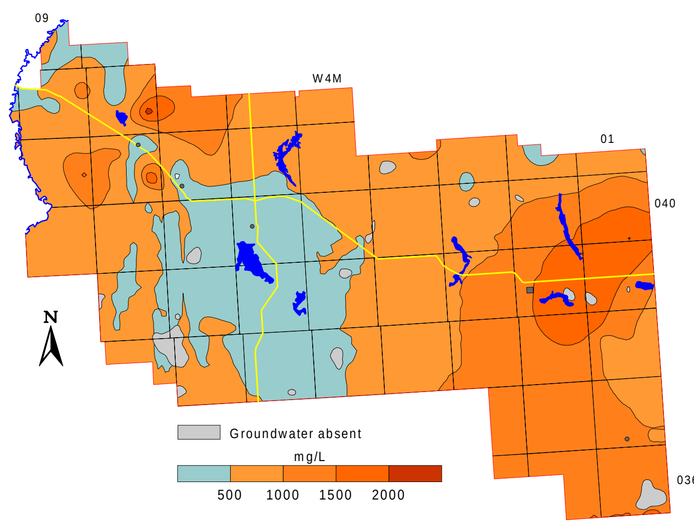


Figure 13. Total Dissolved Solids in Groundwater from Surficial Deposits

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 occur in areas where there are elevated levels of total dissolved solids. There are very few groundwaters from the surficial deposits with appreciable concentrations of the chloride ion and in most of the M.D., 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. These aquifers typically occur above an elevation of 650 metres AMSL. Saturated sand and gravel deposits are not continuous but are expected over approximately 95% of the M.D.

5.2.3.1 Aquifer Thickness

The thickness of the Upper Sand and Gravel Aquifer is in part a function of the elevation of the non-pumping water-level surface associated with the upper surficial deposits and in part a result of 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 30 metres thick in a few areas, but over the majority of the M.D., is less than ten metres thick; over 5% of the M.D., 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 long-term yields of the water wells are limited. The apparent yields for water wells completed in this Aquifer are expected to be mainly less than 100 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.

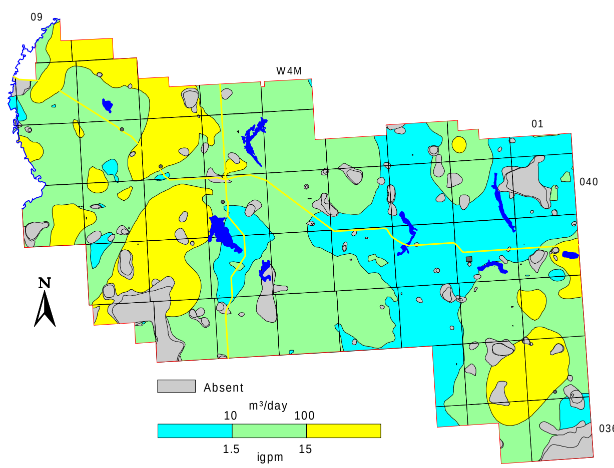


Figure 14. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

The highest yield from surficial deposits that has been developed in the M.D. is for the Town of Provost. The Town uses the Upper Sand and Gravel Aquifer associated with the Buried Bodo Valley in township 039, range 01, W4M. Extensive studies of this aquifer in 1966 by V.G. Beckie of J.D. Mollard & Associates indicated a long-term supply of in the order of 1,000 m³/day (Geoscience Consulting Ltd., 1977). A water test hole was completed in the Upper Sand and Gravel Aquifer associated with a bedrock low of meltwater origin for the Provost & District Golf Club in township 039, range 02, W4M. Studies of this aquifer indicated a long-term yield of 135 m³/day (Hydrogeological Consultants Ltd., November 1994).

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 Lower Sand and Gravel Aquifer may be a continuous aquifer in the Buried Wainwright Valley, where the thickness of the sand and gravel deposits is mainly between 10 and 30 metres. The Lower Sand and Gravel Aquifer is mostly restricted to the Buried Wainwright and Bodo valleys in the M.D.

5.2.4.1 Apparent Yield

Water wells completed in the Lower Sand and Gravel Aquifer may have yields in excess of 100 m³/day. The highest yields are expected in the Buried Wainwright Valley in the northwestern part of the M.D.

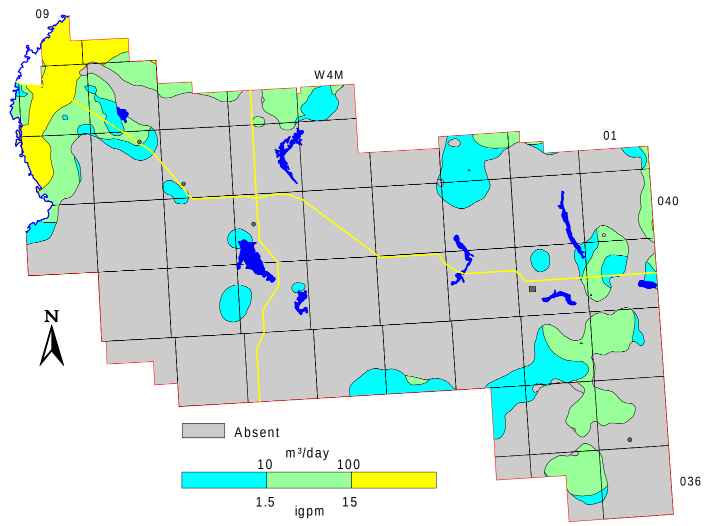


Figure 15. Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer

5.3 Bedrock

5.3.1 Geological Characteristics

The upper bedrock in the M.D. includes the Bearpaw Formation and the Belly River Group. The Lea Park Formation underlies the Belly River Group.

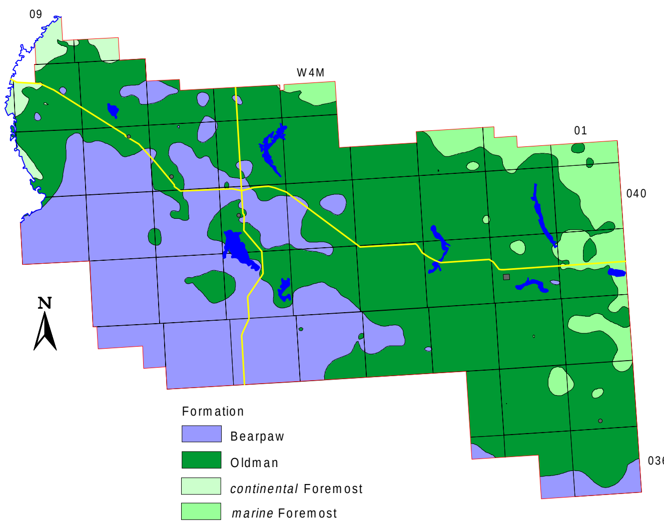


Figure 16. Bedrock Geology

The Bearpaw Formation is the upper bedrock mainly in the southwestern part of the M.D. and has been eroded in the northeastern half of the M.D. There are also subcrops of the Bearpaw Formation that occur as outliers within the area of the Oldman Formation. The Bearpaw Formation is generally less than 100 metres thick in the M.D. "The Bearpaw Formation consists of marine shale, siltstone and minor sandstone, and represents the final widespread marine unit in the Western Canada Foreland Basin" (Catuneanu, Miall and Sweet, 1997). The border between the bottom of the Bearpaw Formation and the uppermost part of the Belly River Group was used as a geological marker in the e-log interpretation. In the M.D., the Bearpaw Formation is composed mainly of shale and as such is a regional aquitard.

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

The uppermost part of the Belly River Group is the Oldman Formation. This Formation is the upper bedrock in the majority of the northeastern two-thirds of the M.D. The Oldman Formation has a maximum thickness of 100 metres within the M.D. and is composed of sandstone, siltstone, shale, and coal deposited in a continental environment. The Oldman Formation is composed of three parts: the Comrey, the Upper Siltstone and the Dinosaur members. The uppermost part of the Dinosaur Member is the Lethbridge Coal Zone. Sandstone is predominant in the Comrey Member, the Upper Siltstone is mainly siltstone, and the Dinosaur Member includes shale and coal deposits.

The *continental* Foremost Formation underlies the Oldman Formation and subcrops under the surficial deposits in the northwestern part of the M.D. The *continental* Foremost Formation has a maximum thickness of 140 metres within the M.D. 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 M.D. and underlies the *continental* Foremost Formation. The *marine* Foremost Formation can be separated into individual sandstone and shale members in parts of the M.D. The sandstone units from top to bottom are as follows: Birch Lake, Ribstone Creek, Victoria, and Brosseau members. In the northwestern part of the M.D., 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 western edge of the *marine* facies. With this change, distinguishing between the individual sandstone members is not possible. The upper part of the *marine* Foremost Formation is present in the northwestern part of the M.D. 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 10 metres into the overlying *continental* Foremost Formation and can occupy the upper 40 metres of the *marine* Foremost Formation. The westward extent of the Milan Aquifer coincides with the position where the Basal Belly River Sand can be distinguished. The Milan Aquifer is present under the *continental* Foremost Formation in the northwestern part of the M.D. but does not subcrop anywhere in the M.D.

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.

5.3.2 Aquifers

Of the 2,980 water wells in the database, 732 were defined as being completed in bedrock aquifers. This designation is based on the top of the completion interval being below the bedrock surface. The completion depth is available for the majority of water wells. In order to make use of additional information within the groundwater database, it was statistically determined that water wells typically have completion intervals equivalent to one quarter of their completed depth. This relationship was used to increase the number of water wells identified as completed in bedrock aquifers to 1,909 from 732. With the use of geological surfaces that were determined from the interpretation of geophysical logs, it has been possible to assign the water wells completed in bedrock aquifers to specific aquifers based on their completion intervals. Of the 1,909 bedrock water wells, 1,406 could be assigned a specific aquifer. The bedrock water wells are mainly completed in the Oldman and the *marine* Foremost aquifers as shown in the table above. The total given for the number of water wells completed in the *marine* Foremost Aquifer does not include water wells completed in the individual members of the *marine* Foremost Aquifer; however, the 415 water wells do include water wells completed through more than one member. The discussions related to specific aquifers, later in this report, do not include the Bearpaw, Milan or Lea Park aquifers due to the paucity of data available in the M.D. However, maps associated with these aquifers are included on the CD-ROM.

Bedrock Aquifer	No. of Water Wells
Bearpaw	76
Oldman	809
Continental Foremost	46
Milan	9
Marine Foremost	415
Birch Lake Member	18
Ribstone Creek Member	17
Victoria Member	16
Brosseau Member	0
Lea Park	0

Table 3. Completion Aquifer

There are 505 records for bedrock water wells that have apparent yield values. In the M.D., water well yields can be expected to be mainly less than 100 m³/day. The areas of higher yields that are indicated on the adjacent figure are mainly in the northern and eastern parts of the M.D. These higher yields may be a result of increased permeability that has resulted from the weathering process.

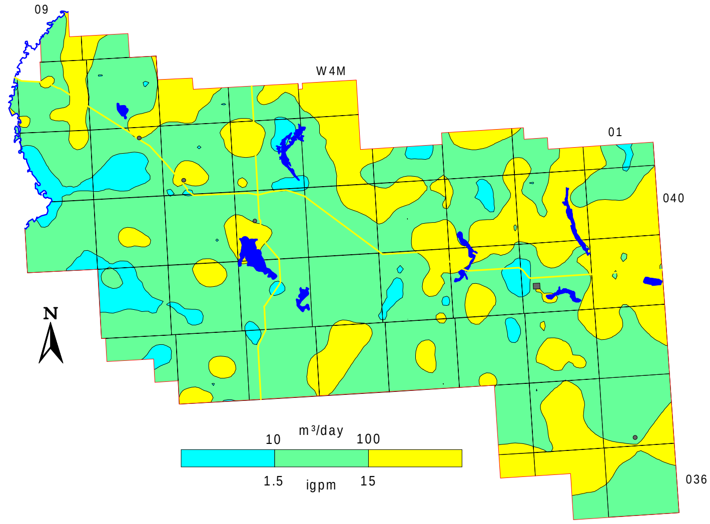


Figure 17. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

There are 490 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
Bearpaw	7	2	5	0
Oldman	231	43	159	29
Continental Foremost	19	2	10	7
Milan	8	2	4	2
Marine Foremost	180	14	87	79
Birch Lake Member	22	5	13	4
Ribstone	19	1	10	8
Victoria	4	1	2	1
Totals	490	70	290	130

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 1,000 mg/L, with only a few areas having TDS concentrations of less than 500 mg/L. The higher values are expected in the central parts of the M.D.

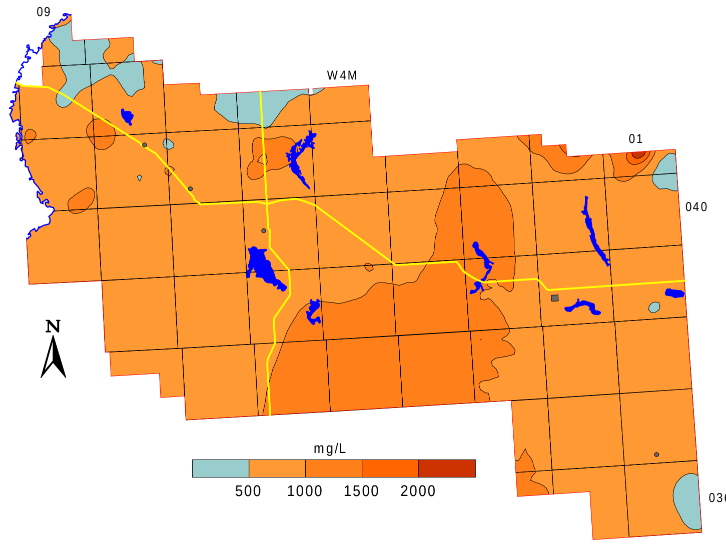


Figure 18. Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

The majority of the sulfate concentrations were less than 250 mg/L. The chloride concentration in groundwater from the upper bedrock aquifer(s) is less than 100 mg/L in 90% of the M.D.

In 95% of the M.D., the fluoride ion concentration in the groundwater from the upper bedrock aquifer(s) is less than 1.0 mg/L.

The Piper tri-linear diagrams (see Appendix A) show that all chemical types of groundwater occur in the upper bedrock aquifer(s). 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 and underlies the Bearpaw Formation and subcrops in the east-central part of the M.D. The thickness of the Oldman Formation increases to the southwest where it can be more than 100 metres. The thickness can be less than 20 metres along the northern and eastern edges of the Formation.

5.3.4.1 Depth to Top

The depth to the top of the Oldman Formation is mainly less than 40 metres in the northeastern part of the M.D., where it subcrops. In the western part of the M.D., where the Oldman is below the Bearpaw Formation, the depth to the top of the Oldman Formation can be more than 100 metres.

5.3.4.2 Apparent Yield

The apparent yields for individual water wells completed in the Oldman Aquifer are mainly less than 100 m³/day. The adjacent map indicates that water wells with apparent yields of more than 100 m³/day are expected toward the northern edge of the Oldman Formation and in the southern part of the M.D. A groundwater study conducted for the Hamlet of Metiskow indicated a long-term yield of 23 m³/day for a water supply well completed in the Oldman Aquifer (Geoscience Consulting Ltd., June 1984).

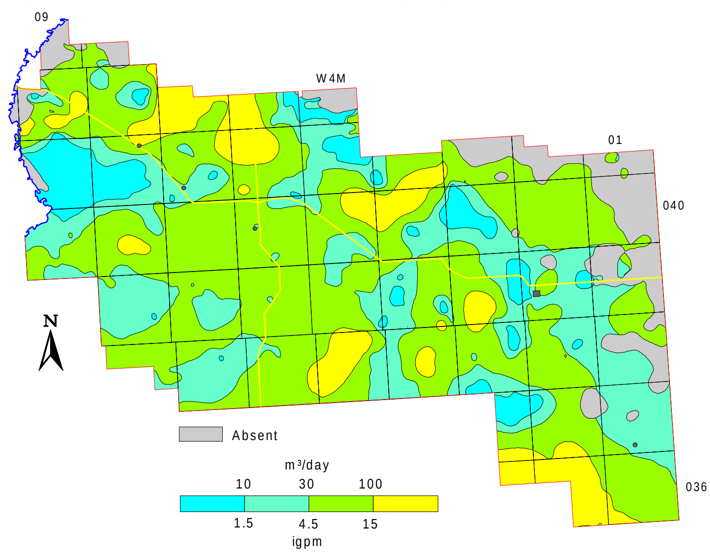


Figure 19. Apparent Yield for Water Wells Completed through Oldman Aquifer

5.3.4.3 Quality

Groundwaters from the Oldman Aquifer are mainly sodium-bicarbonate-type waters. TDS concentrations are expected to be mainly less than 1,000 mg/L, but can be more than 1,000 mg/L in the southern part of the M.D. The sulfate concentrations are mainly less than 300 mg/L.

Chloride concentrations in the groundwater from the Oldman Aquifer are mainly less than 10 mg/L in the northern half of the M.D. and between 10 and 100 mg/L in the southern part of the M.D.

5.3.5 *Continental* Foremost Aquifer

The *continental* Foremost Aquifer comprises the porous and permeable parts of the *continental* Foremost Formation and subcrops in the northwestern part of the M.D. The thickness of the *continental* Foremost Formation varies from zero at the edge of the subcrop to more than 100 metres in Tp 042, R 09, W4M. The thickness of the *continental* Foremost Formation decreases in the vicinity of the Battle River valley due to erosion by the Battle River. 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 where it subcrops in the northwestern part of the M.D., to more than 140 metres in the southern part of the M.D., where the *continental* Foremost Formation underlies the Bearpaw Formation.

5.3.5.2 Apparent Yield

The apparent yields for individual water wells completed in the *continental* Foremost Aquifer are mainly between 30 and 100 m³/day. The adjacent map indicates that apparent yields of more than 100 m³/day are expected northwest of the Village of Amisk in the vicinity of Highway 13.

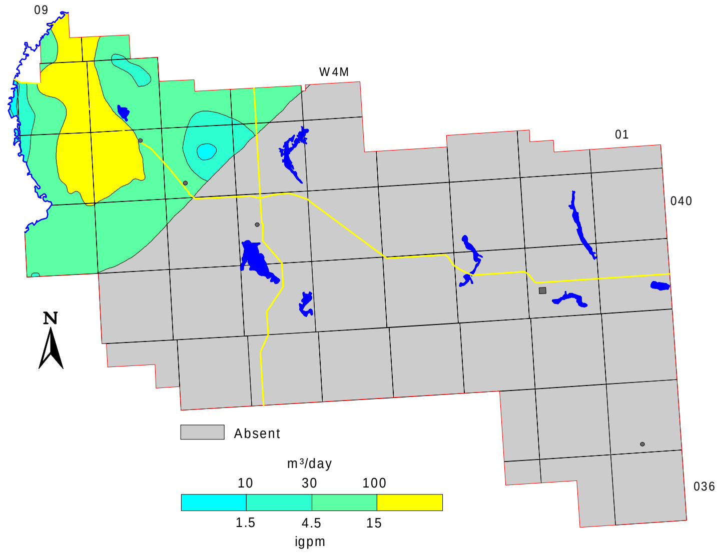


Figure 20. Apparent Yield for Water Wells Completed through continental Foremost Aquifer

5.3.5.3 Quality

There were only four water well records in the database with sufficient information to determine the chemical type of groundwaters from the *continental* Foremost Aquifer; they are mainly sodium-bicarbonate type. TDS concentrations are expected to be in the order of 500 to 1,000 mg/L. The sulfate concentrations are below 300 mg/L.

Chloride concentrations in the groundwater from the *continental* Foremost Aquifer are mainly between 10 and 50 mg/L. The indications are that in the northern part of the M.D. where the Formation is present, the chloride concentration is expected to be less than 10 mg/L.

The Milan Aquifer includes the lower 10 metres of the *continental* Foremost Formation. There is no detailed discussion for the Milan Aquifer in this report; however, maps for this Aquifer are provided on the CD-ROM.

5.3.6 *Marine* Foremost Aquifer

The thickness of the *marine* Foremost Formation, present in the entire M.D., can reach more than 180 metres in the north-central part of the M.D. The *marine* Foremost Formation can be separated into individual members in parts of the M.D. The sandstone units from top to bottom are as follows: Birch Lake, Ribstone Creek, Victoria, and Brosseau members. The following sections relating to the *marine* Foremost Aquifer include the available data from each of the four sandstone members. A discussion related specifically to the Birch Lake and Ribstone Creek members is included later in this report.

5.3.6.1 Depth to Top

The depth to the top of the *marine* Foremost Formation is mainly less than 80 metres below ground level, but can be more than 200 metres in the northwestern part of the M.D.

5.3.6.2 Apparent Yield

The apparent yields for individual water wells completed in the *marine* Foremost Aquifer are mainly in the range of 10 to 100 m³/day. The areas where water wells with higher yields are expected are mainly south of township 040. There is no apparent relationship between expected water well yield and thickness of the Aquifer.

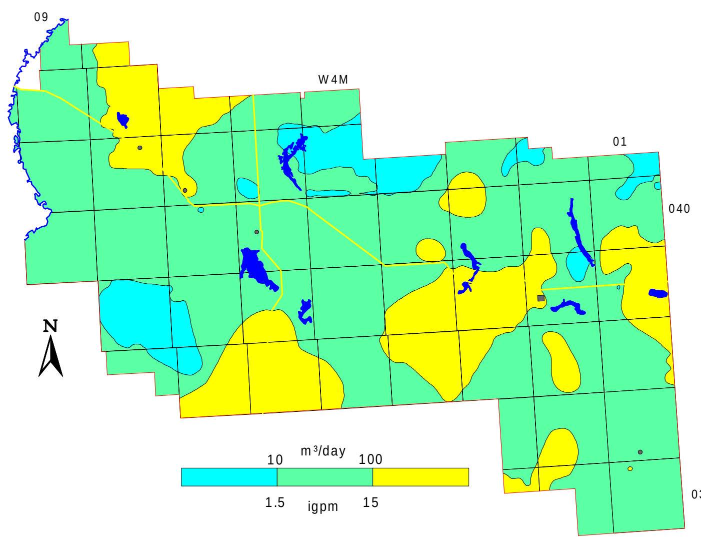


Figure 21. Apparent Yield for Water Wells Completed through marine Foremost Aquifer

5.3.6.3 Quality

The Piper tri-linear diagram shows that the majority of the groundwaters are sodium-bicarbonate or sodium-chloride types (see CD-ROM).

The TDS concentrations for groundwater from the *marine* Foremost Aquifer range mainly from 500 to 1,500 mg/L. There is a small area in township 041, range 01, W4M in the M.D. where the TDS of the groundwater from the *marine* Foremost Aquifer is less than 500 mg/L. The higher values of TDS mainly occur in the central part of the M.D., in townships 039 and 040, ranges 04 and 05, W4M. The sulfate concentrations are mainly less than 300 mg/L.

The chloride concentration of the groundwater from the *marine* Foremost Aquifer can be expected to be between 10 and 100 mg/L in the northeastern part of the M.D. In the southwestern part of the M.D., the chloride concentration is mainly between 100 and 250 mg/L. In a small area in the southwestern part of the M.D., the chloride concentration exceeds 250 mg/L.

5.3.7 Birch Lake Aquifer

The Birch Lake Aquifer comprises the porous and permeable parts of the Birch Lake Member and underlies the southeastern two-thirds of the M.D. The thickness of the Birch Lake Member is generally less than 30 metres; in parts of townships 038 and 039, ranges 07 and 08, W4M, the thickness can reach more than 30 metres. In ranges 02 to 04, the thickness of the Member is less than 10 metres, or is absent.

5.3.7.1 Depth to Top

The depth to the top of the Birch Lake Member is mainly less than 120 metres below ground level, but can be more than 200 metres in the southern part of the M.D.

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 the northeastern part of the M.D.

A groundwater program was completed for PanCanadian Petroleum Limited (PCP) in 1992 for their North Bodo site in 3C-21-038-01 W4M. A water test hole to be used as an observation water well was completed in the Birch Lake Aquifer. A four-hour aquifer test conducted with this water test hole indicated a long-term yield of 80 m³/day, based on an aquifer transmissivity of 2.3 m²/day (Hydrogeological Consultants Ltd., March 1995).

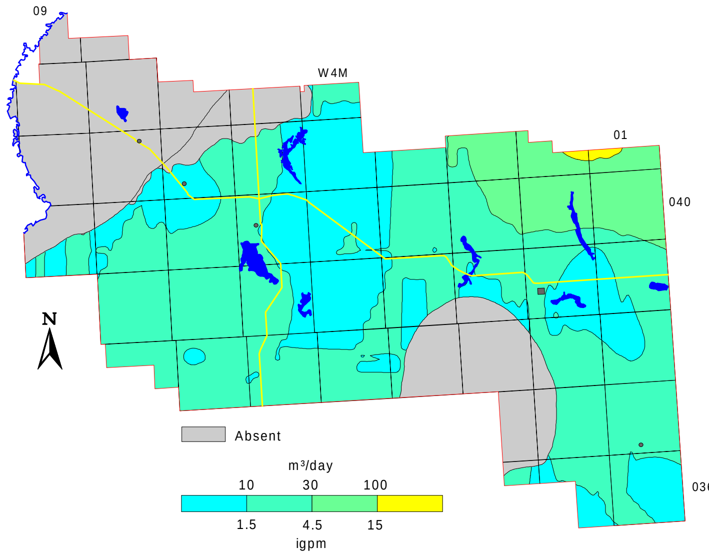


Figure 22. Apparent Yield for Water Wells Completed through Birch Lake Aquifer

5.3.7.3 Quality

The groundwater from the PCP observation water well is a sodium-bicarbonate-type water, with a TDS concentration of 893 mg/L and a chloride concentration of 95 mg/L.

5.3.8 Ribstone Creek Aquifer

The Ribstone Creek Aquifer comprises the porous and permeable parts of the Ribstone Creek Member and underlies the southeastern two-thirds of the M.D. The thickness of the Ribstone Creek Member is generally less than 20 metres.

5.3.8.1 Depth to Top

The depth to the top of the Ribstone Creek Member is mainly less than 200 metres below ground level. The greatest depth is in the areas along the southern edge of the M.D.

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 the northwestern and southeastern parts of the M.D.

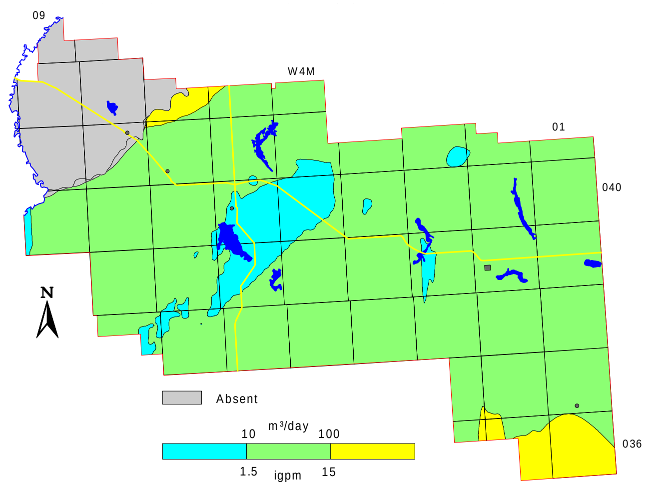


Figure 23. Apparent Yield for Water Wells Completed through Ribstone Creek Aquifer

A groundwater program was completed for PCP in 1992 for their North Bodo site in 3C-21-038-01 W4M. The result of the program was the development and licensing of a groundwater supply obtained from the Ribstone Creek Member. A long-term yield of 380 m³/day was determined based on an aquifer transmissivity of 8 m²/day. Since the PCP Bodo facility was put into service, the water levels and production have been monitored four times per day; analysis of the monitoring data has shown that the transmissivity of the aquifer is approximately 20% higher than the value determined from the aquifer testing. The calculated long-term yield is in the order 450 m³/day, based on the revised aquifer transmissivity of 10 m²/day determined from the monitoring data (Hydrogeological Consultants Ltd., March 1995).

A groundwater program was also completed for Elan Energy Inc. (Elan) in 1995 for their Bodo site in 08-32-036-01 W4M. The results of aquifer testing of a water test hole completed in the Ribstone Creek Member indicated a long-term yield of 250 m³/day based on an aquifer transmissivity of 23 m²/day (Hydrogeological Consultants Ltd., September 1996).

5.3.8.3 Quality

The groundwater from the Ribstone Creek Member at the PCP Bodo location is a sodium-chloride type, with a TDS concentration of approximately 3,900 mg/L (Hydrogeological Consultants Ltd., March 1995). Significant quantities of gas are present with the groundwater in the Aquifer.

5.3.9 Other *marine* Foremost Sandstone Members

The Victoria Member is present in most of the M.D. There are nine water wells completed through the Victoria Member in ranges 03, 04 and 05, W4M. The water well yields are in the order of 100 to 200 m^3/day. The groundwater from the Victoria Aquifer in the northern part of the M.D. has 6,600 mg/L of TDS and in the southern part has TDS concentrations in the order of 8,000 mg/L.

There is no detailed discussion for the Brosseau Member in this report; however, maps for this Member are provided on the CD-ROM.

6 GROUNDWATER BUDGET

6.1 Hydrographs

There are five locations in the M.D. where water levels are being measured and recorded with time. Three sites are observation water wells (Obs WWs) that are part of the AEP regional groundwater-monitoring network. The three observation water wells are located in 11-01-040-05 W4M in the vicinity of the Hamlet of Metiskow; their hydrographs are shown in the adjacent figure. The two other groundwater monitoring sites are part of the PanCanadian Petroleum Limited (PCP) facility.

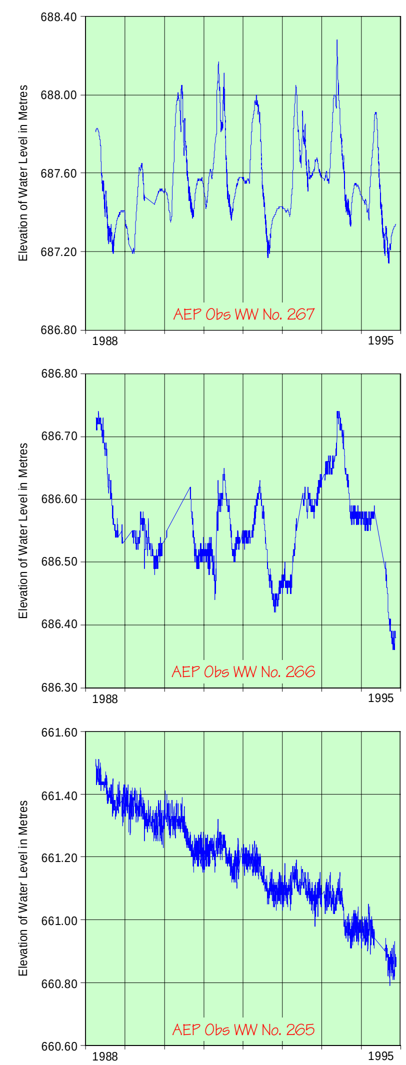


Figure 24. Hydrographs - AEP Observation Water Wells

AEP Obs WW No. 267 is completed at a depth of 6 metres below ground level in the Upper 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 50 to 60 cm.

AEP Obs WW No. 266 is completed at a depth of 37.5 metres below ground level in the Oldman Aquifer. This hydrograph also reflects an annual cycle similar to Obs WW No. 267, but with a smaller water-level fluctuation. The annual fluctuations in Obs WW No 266 are approximately 10 to 15 cm.

AEP Obs WW No. 265 is completed at a depth of 129 metres below ground level and is believed to be completed in the Birch Lake Aquifer. Despite the main characteristic of a water-level decline of 60 cm over the eight years from 1988 to 1995, there is a distinct annual cycle of approximately 10 to 15 cm. The PCP Obs WW Shallow in 21-038-01 W4M is also completed in the Birch Lake Aquifer and the water level showed no decline in 1993, 1994 and 1995. Since 1995 the water level in the PCP Obs WW Shallow has declined approximately 40 cm.

The PCP water source well in 21-038-01 W4M is completed in the Ribstone Creek Aquifer. The water source well has been used to divert 200,000 cubic metres of groundwater from the Ribstone Creek Aquifer between January 1992 and February 1996. Since February 1996 there has been no significant diversion from the water source well. In September 1998, the non-pumping water level in the water source well was 0.15 metres higher than the water level on 01 Nov 92, before any significant diversion from the water source well occurred.

The three AEP observation water wells indicate the generally downward hydraulic gradient that occurs throughout most of the M.D. The vertical gradient between AEP Obs WW Nos. 267 and 266 is 0.03 m/m while the downward gradient between AEP Obs WW Nos. 266 and 265 is much higher, at 0.28 m/m.

6.2 Groundwater Flow

A direct measurement of groundwater recharge or discharge is not possible from the data that are available for the M.D. One indirect method of measuring recharge is to determine the quantity of groundwater flowing through each individual aquifer. This method assumes that there is sufficient recharge to the aquifer to maintain the flow through the aquifer and that 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 M.D.

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

Aquifer Designation	Transmissivity (m^2/day)	Gradient (m/m)	Width (km)	Main Direction of Flow	Quantity (m^3/day)	Diversion (m^3/day)
Upper Surficial Deposits	40	0.002	80	Northeast	6,400	1,645
Buried Bodo Valley	30	0.001	10	Northeast	300	47
Oldman					800	2,000
	6	0.003	40	Northwest	600	
	6	0.0007	40	Southeast	200	
continental Foremost					300	151
	4	0.003	30	Northwest	300	
Birch Lake					200	637
	3	0.001	30	Northeast	90	
	3	0.001	15	North	60	
	3	0.0005	20	Northwest	30	
Ribstone Creek					1000	730
	10	0.001	75	Northeast	800	
	10	0.0005	40	Northwest	200	
Victoria					200	1,529
	5	0.0005	40	Northwest	100	
	5	0.0004	40	Northeast	100	

The main area of recharge to the aquifers is the high land in the western part of the M.D. and along the southern boundary. The above table indicates that there may be more groundwater authorized to be diverted from the Oldman, Birch Lake and Victoria aquifers than there is flowing through the individual aquifers. However, because of the 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 1.5 to 9 cubic kilometres. This volume is based on an areal extent of 3,800 square kilometres and a saturated sand and gravel thickness of eight 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 aquifers in the surficial deposits. The map shows the highest level of groundwater in surficial deposits, and this level was used for the calculation of saturated surficial deposits and for calculations of recharge/discharge areas.

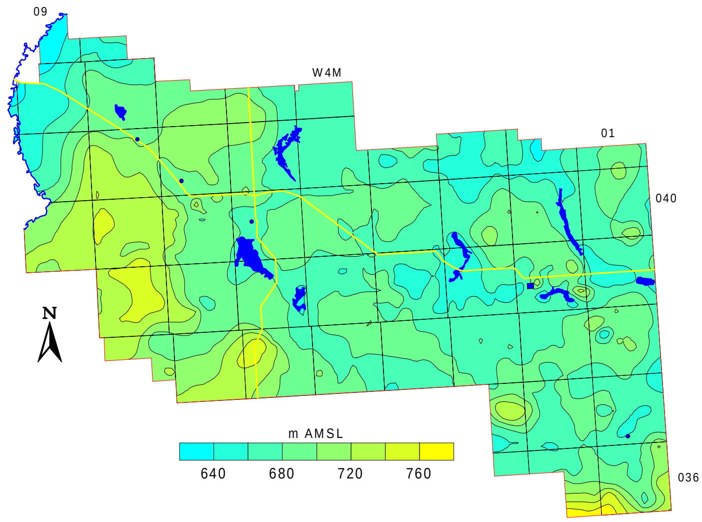


Figure 25. Non-Pumping Water-Level Surface in Surficial Deposits

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 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 90% of the M.D., there is a downward hydraulic gradient, or discharge from the surficial deposits. There are very few areas where there is an upward hydraulic gradient, or discharge from the bedrock; these areas are mainly in the vicinity of lows in the bedrock surface. The remaining parts of the M.D. are areas where there is a transition condition.

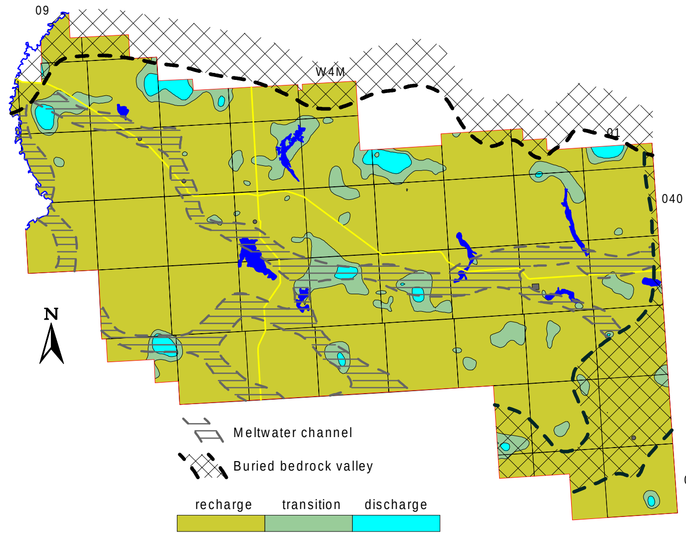


Figure 26. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)

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

6.4.1.2 Bedrock Aquifers

Recharge to the bedrock aquifers within the M.D. takes place from the overlying surficial deposits and from flow in the aquifer from outside the M.D. The recharge/discharge maps show that generally for most of the M.D., there is a downward hydraulic gradient from the surficial deposits to the bedrock, i.e. discharge from the surficial deposits. 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 the 70% of the M.D. where the Oldman Formation is present, there is a downward hydraulic gradient. Discharge and transition areas for the Oldman Aquifer are either in or adjacent to the bedrock lows. For the Bearpaw Aquifer, the discharge areas are mainly at the extent of the Aquifer. The hydraulic relationship between the surficial deposits and the remainder of the bedrock aquifers present in the M.D. indicates there is mainly a downward hydraulic gradient.

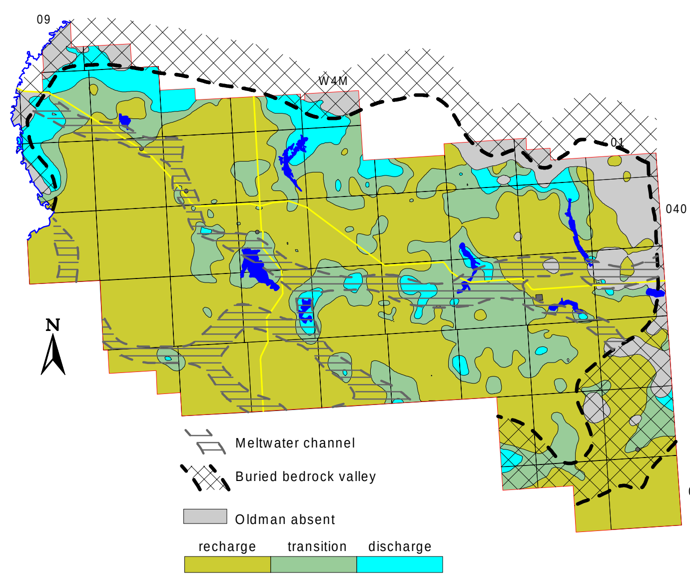


Figure 27. Recharge/Discharge Areas between Surficial Deposits and Oldman Aquifer

A second method to determine recharge is to monitor water levels in an aquifer close to a groundwater diversion point. Data are available form the PCP North Bodo water source well and the deep observation water well completed in the Ribstone Creek Aquifer. From late 1992 to early 1996, there was a groundwater diversion of 200,000 cubic metres. By the end of 1996, the non-pumping water level in the Ribstone Creek Aquifer had returned to its pre-diversion level. Therefore, it can be concluded that recharge to the Aquifer offset the diversion. A detailed analysis would be required to understand the nature of the recharge.

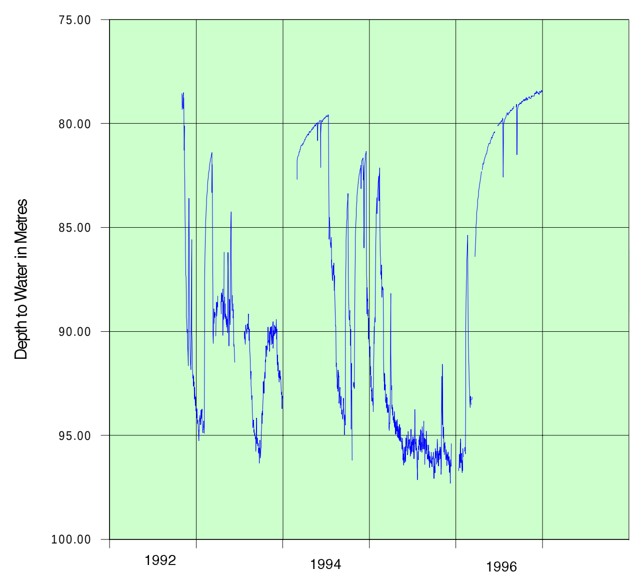


Figure 28. Water-Level Summary – PCP North Bodo Deep Obs WW

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 1,672 records in the area of the M.D. with lithological descriptions, 395 have sand and gravel within one metre of ground level. In the remaining 1,277 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 65% of the M.D., 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.

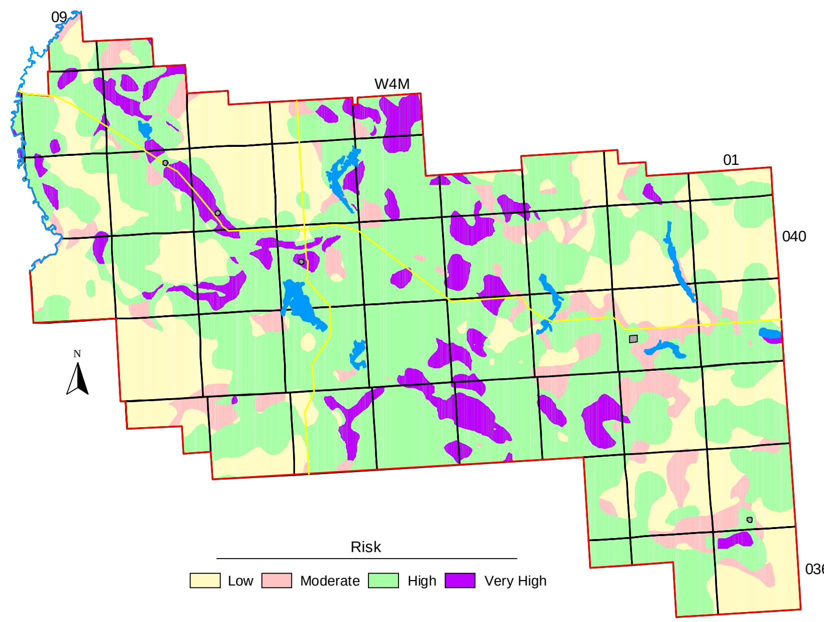


Figure 29. Risk of Groundwater Contamination

At all locations, good environmental practices should be exercised in order to ensure that groundwater contamination would not affect groundwater quality.

8 RECOMMENDATIONS

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

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

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

The present analysis has shown that the groundwater flow in three aquifers may not be sufficient to sustain the diversions authorized 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 Oldman and the Birch Lake aquifers. The study would need to obtain all of the data for individual water wells authorized to divert groundwater from the two aquifers, document the quantity of groundwater being diverted, establish the water-level trends, and evaluate the hydraulic parameters for the two aquifers. 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 M.D. 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 M.D. 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.

9 REFERENCES

Carrigy, M. A. 1971. Lithostratigraphy of the Uppermost Cretaceous (Lance) and Paleocene Strata of the Alberta Plains. Research Council of Alberta. Bulletin 27.

Catuneanu, Octavian, Andrew D. Miall and Arthur R. Sweet. 1997. Reciprocal Architecture of Bearpaw T-R Sequences, Uppermost Cretaceous, Western Canada Sedimentary Basin. Bulletin of Canadian Petroleum Geology. Vol. 45, No. 1 (March 1997), P. 75-94.

Geoscience Consulting Ltd. March 1977. Evaluation of Water Supply. Provost, Alberta. Prepared for Alberta Department of Environment.

Geoscience Consulting Ltd. June 1984. New Well. Hamlet of Metiskow, Alberta. SE 03-040-04 W4M. Prepared for Municipal District of Provost No. 52.

Hackbarth, D. A. 1975. Hydrogeology of the Wainwright area, Alberta. Earth Sciences Report No. 75-1. Alberta Research Council.

Hydrogeological Consultants Ltd. March 1976. Groundwater Supplies for the Village of Amisk. Unpublished Contract Report.

Hydrogeological Consultants Ltd. September 1977. Ashland Oil Canada Ltd. Provost Water Wells Nos. 1 and 2. Prepared for Webster Drilling Ltd. Unpublished Contract Report.

Hydrogeological Consultants Ltd. October 1983. Village of Hughenden. 1983 Groundwater Program. Water Well No. 4-83. Unpublished Contract Report.

Hydrogeological Consultants Ltd. November 1992. PanCanadian Petroleum Limited. North Bodo Groundwater Supply. Tp 038, Rg 01, W4M. 1992 Exploration and Development Program. Unpublished Contract Report.

Hydrogeological Consultants Ltd. August 1993. Discovery West Corporation. Provost Area. Tp 038, R 04, W4M. Groundwater Prognosis. Unpublished Contract Report.

Hydrogeological Consultants Ltd. November 1994. Provost & District Golf Club. SW 17-039-02 W4M. Application for Groundwater Licence. Unpublished Contract Report.

Hydrogeological Consultants Ltd. March 1995. PanCanadian Petroleum Limited. Hayter Area. 15-33-040-01 W4M. 1995 Groundwater Review. Unpublished Contract Report.

Hydrogeological Consultants Ltd. April 1995. Renaissance Energy Ltd. Sounding Lake Area. 11-16-038-04 W4M. 1995 Groundwater Program. Unpublished Contract Report.

Hydrogeological Consultants Ltd. September 1996. Elan Energy Inc. Bodo Area. Sec 32, Tp 036, R 01, W4M. 1995 Groundwater Program. Unpublished Contract Report.

Hydrogeological Consultants Ltd. June 1998. PanCanadian Petroleum Limited. North Bodo. Tp 038, Rg 01, W4M. 1997 Annual Monitoring Report. Unpublished Contract Report.

Le Breton, E. Gordon. 1971. Hydrogeology of the Red Deer Area, Alberta. Research Council of Alberta. Report 71-1.

Mossop, G. and I. Shetsen (co-compilers). 1994. Geological Atlas of the Western Canada Sedimentary Basin. Produced jointly by the Canadian Society of Petroleum Geology, Alberta Research Council, Alberta Energy, and the Geological Survey of Canada.

Ozoray, G., M. Dubord and A. Cowen. 1990. Groundwater Resources of the Vermilion 73E Map Area, Alberta. Alberta Environmental Protection.

Pettijohn, F. J. 1957. Sedimentary Rocks. Harper and Brothers Publishing.

Shetsen, I. 1990. Quaternary Geology, Central Alberta. Produced by the Natural Resources Division of the Alberta Research Council.

Strong, W.L. and K. R. Legatt, 1981. Ecoregions of Alberta. Alta. En. Nat. Resour., Resour. Eval. Plan Div., Edmonton as cited in Mitchell, Patricia and Ellie Prepas (eds.). 1990. Atlas of Alberta Lakes. The University of Alberta Press. Page 12.

Thornthwaite, C. W. and J. R. Mather. 1957. Instructions and Tables for Computing Potential Evapotranspiration and the Water Balance. Drexel Institute of Technology. Laboratory of Climatology. Publications in Climatology. Vol. 10, No. 3, P. 181-289.

10 GLOSSARY

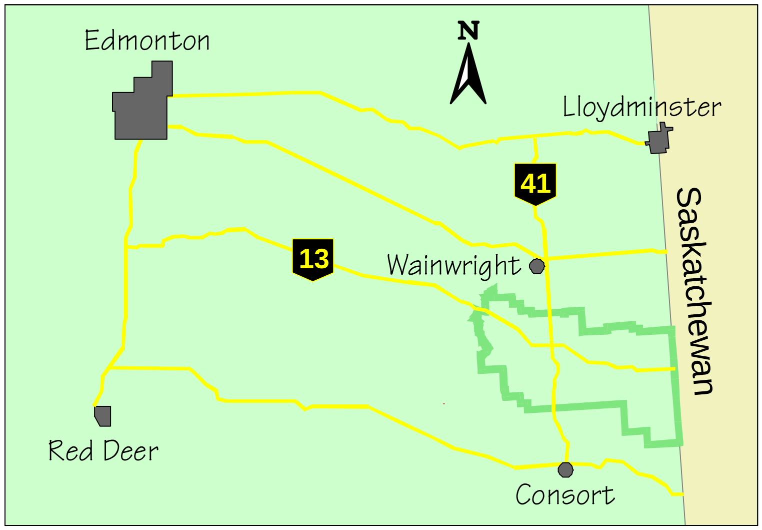
Aquifer	a formation, group of formations, or part of a formation that contains saturated permeable rocks capable of transmitting groundwater to water wells or springs in economical quantities.
Aquitard	a confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer.
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.

M.D. OF PROVOST NO. 52

Appendix A

HYDROGEOLOGICAL MAPS AND FIGURES

Index Map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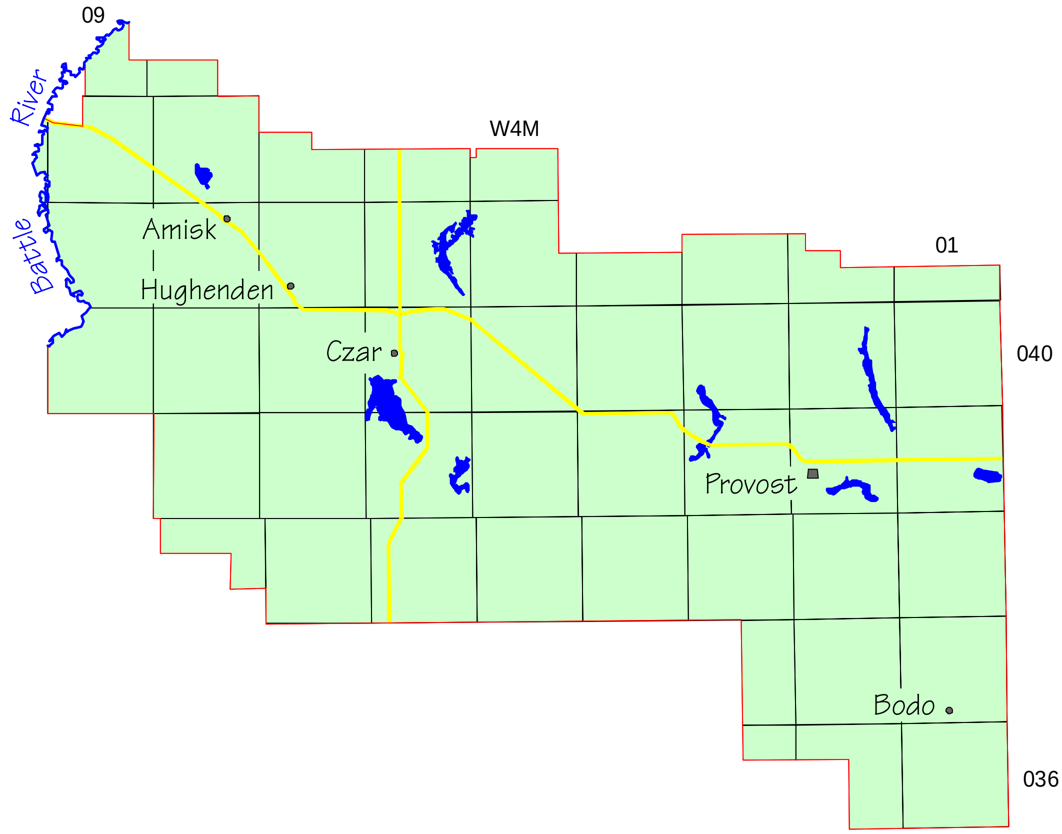
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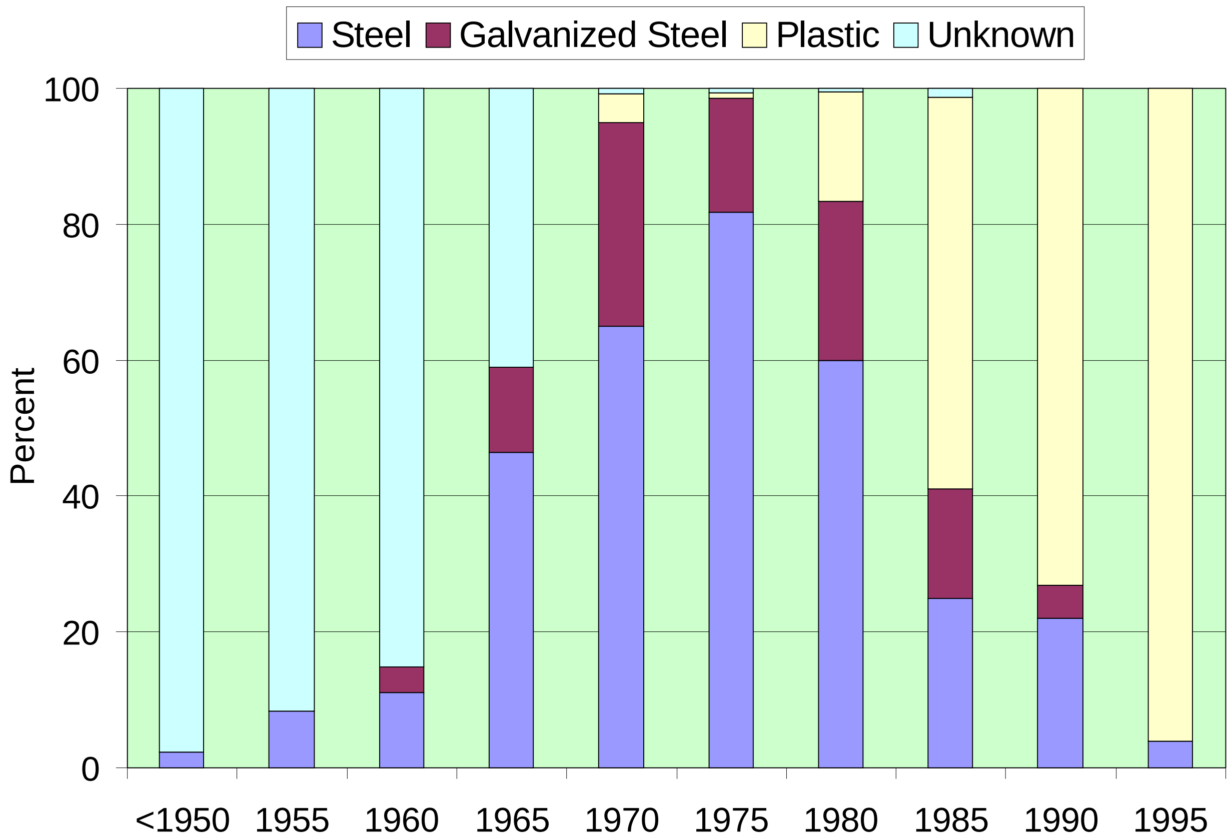
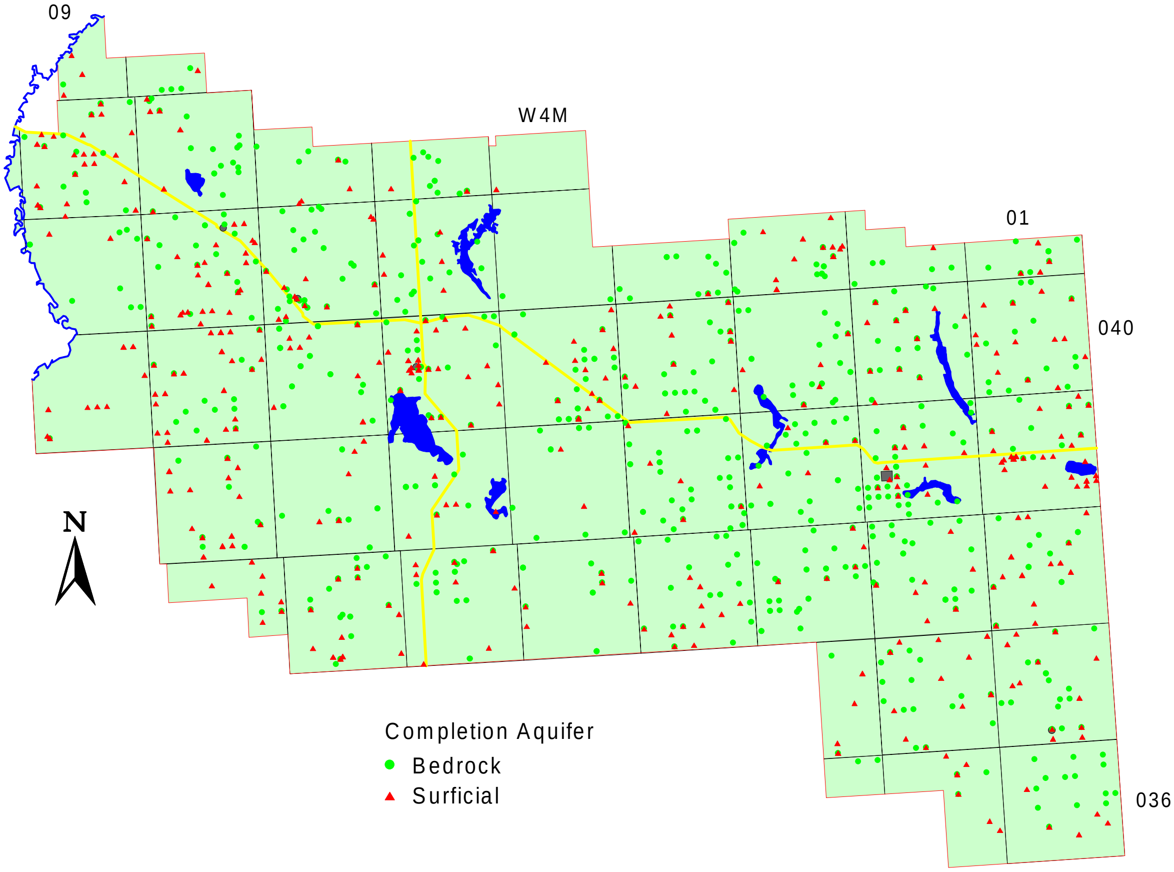
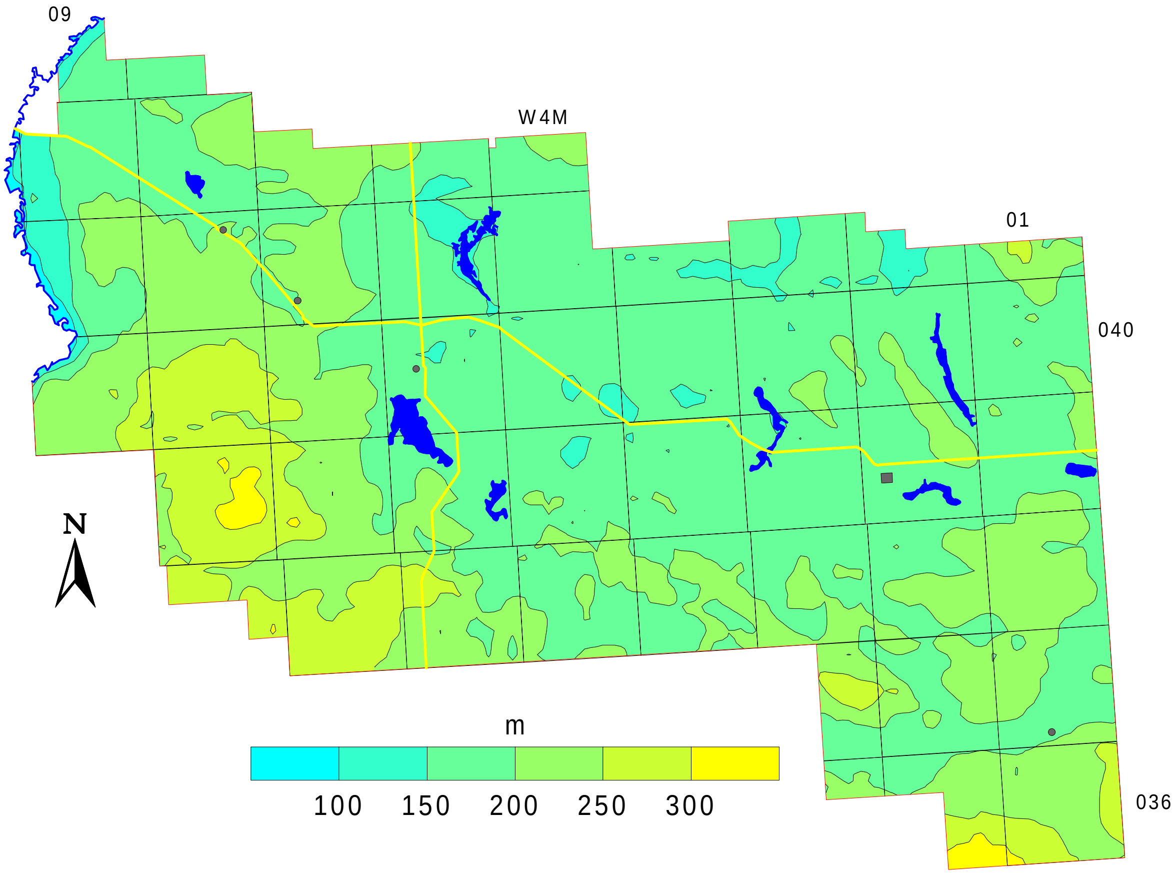
Surface Casing Types used in Drilled Water Wells

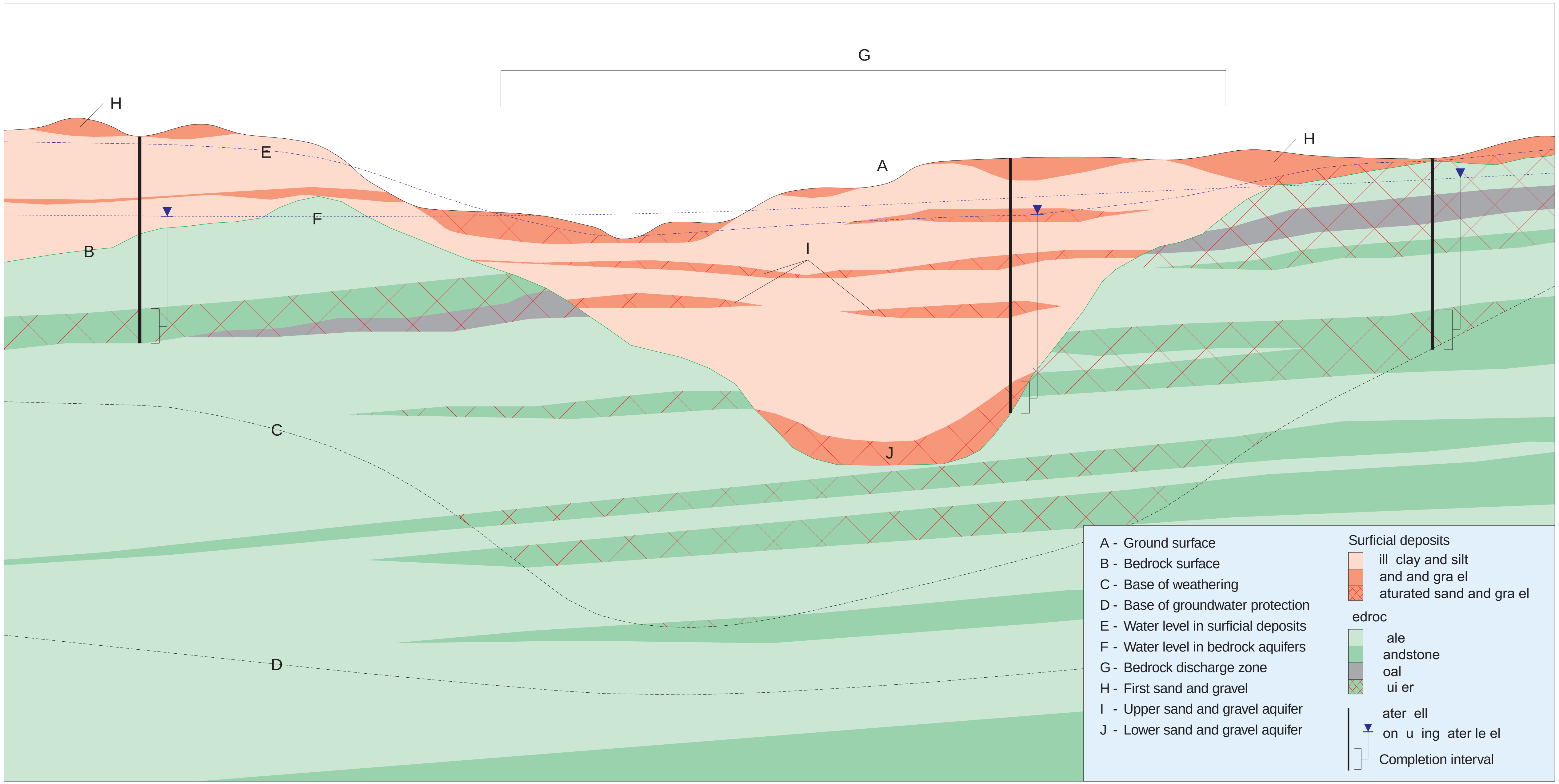


Location of Water Wells



Depth to Base of Groundwater Protection

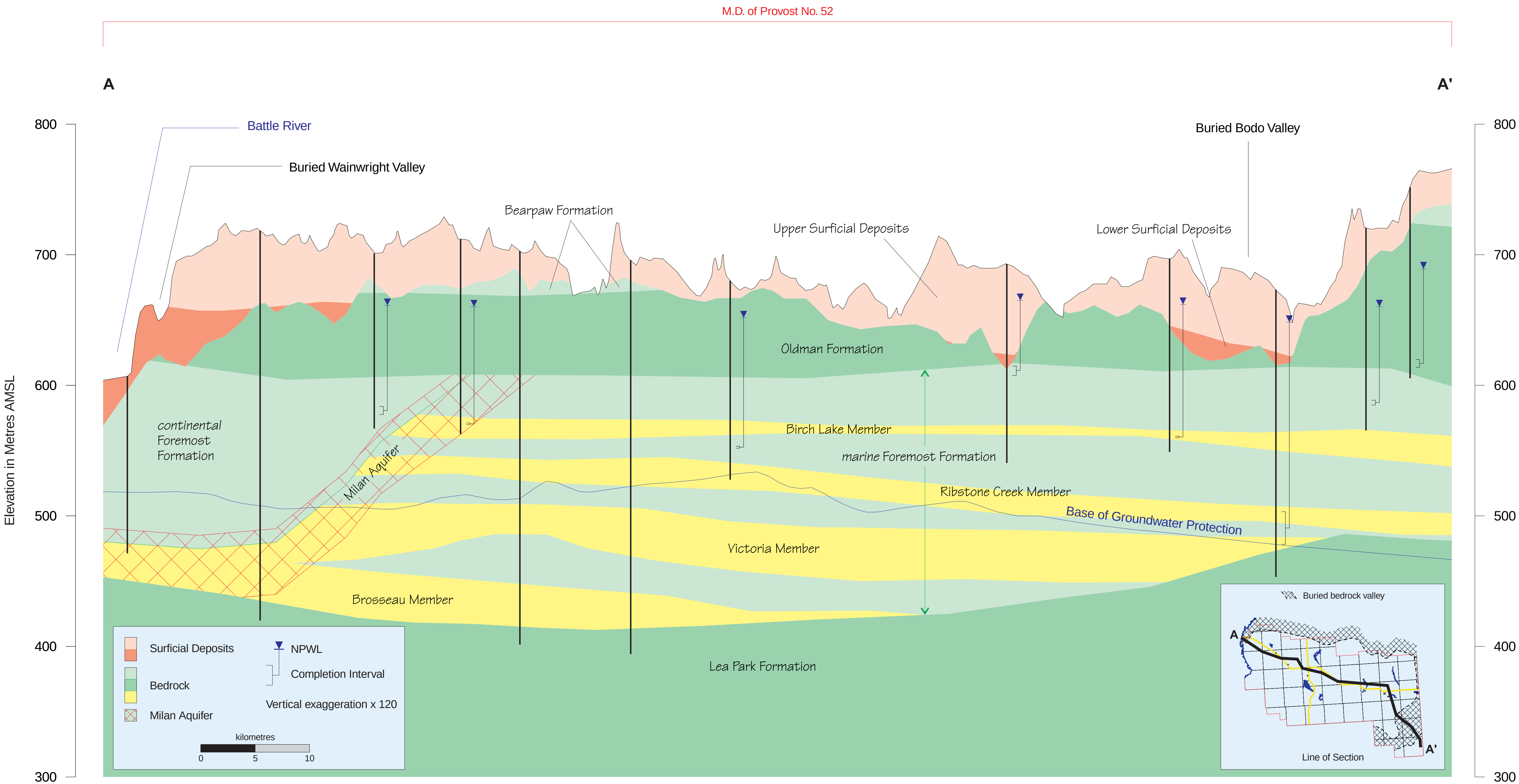




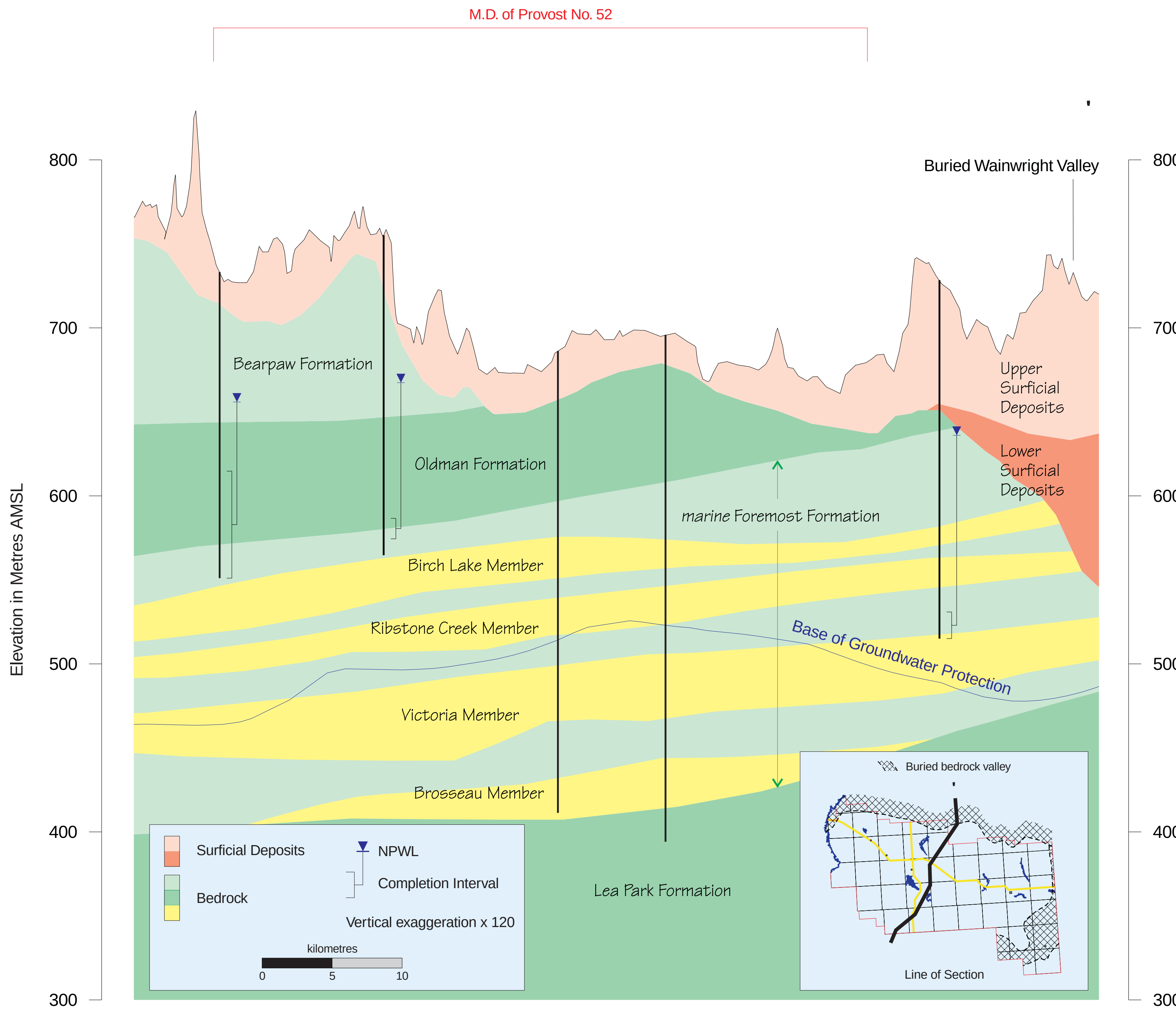
Generalized Cross-Section
(for terminology only)

Depth (m)	Lithologic Description	Group and Formation: Thickness (m)	Group and Formation: Designation	Member: Thickness (m)	Member: Designation	Zone: Thickness (m)	Zone: Designation
0–100	sand, gravel, till, clay, silt	<100	Surficial Deposits	<100	Upper	<30	First Sand and Gravel
				<40	Lower		
100–200	shale, sandstone, siltstone	60-120	Bearpaw Formation				
200–300	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		
300	shale, sandstone, coal	10-220	Belly River Group: *continental* Foremost Formation			<20	Taber Coal Zone
						<20	McKay Coal Zone
300–500	sandstone, shale	<200	Belly River Group: *marine* Foremost Formation (Basal Belly River Sandstone)	<30	Birch Lake Member		Milan Aquifer
				<30	Ribstone Creek Member		
				<30	Victoria Member		
				<30	Brosseau Member		
500–600	shale, siltstone	100-200	Lea Park Formation	50-100	Upper		
				50-100	Lower		

Geologic Column

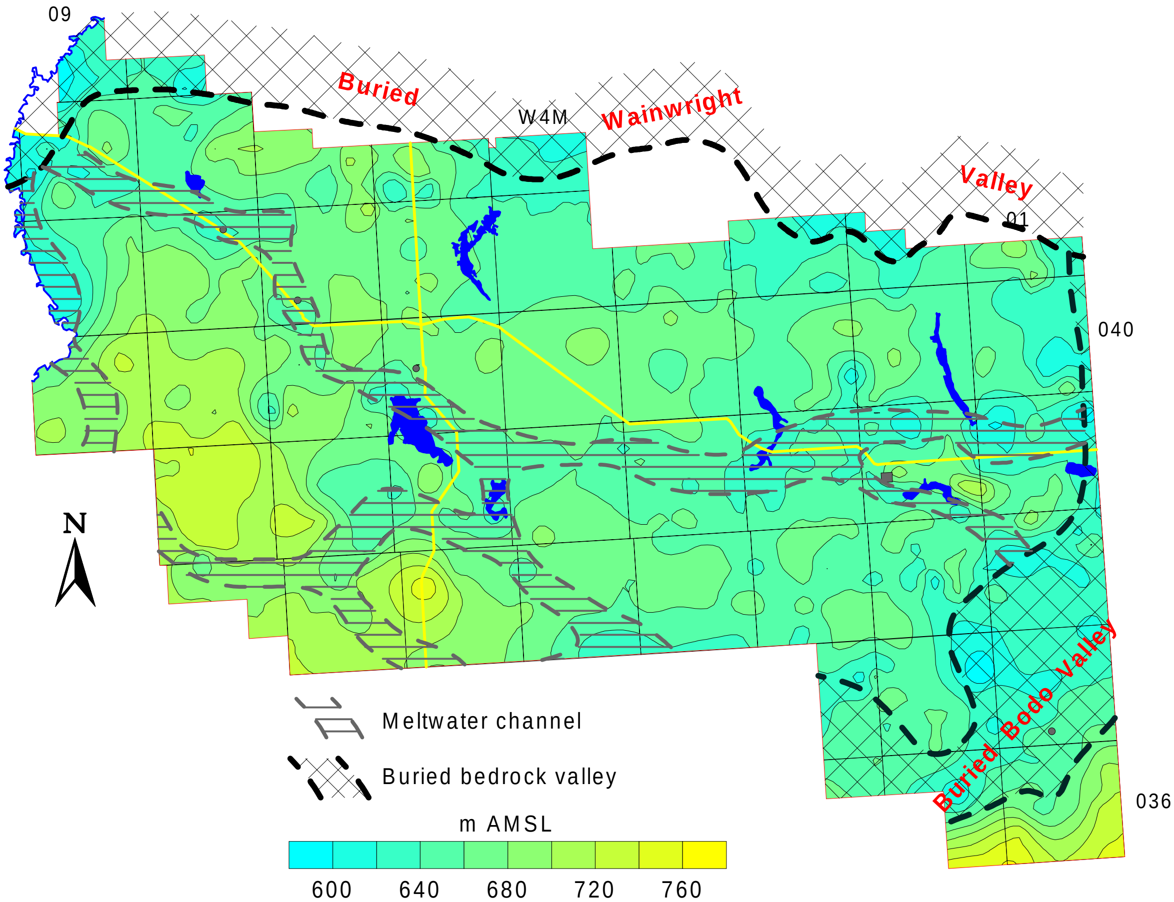


Cross-Section A - A'

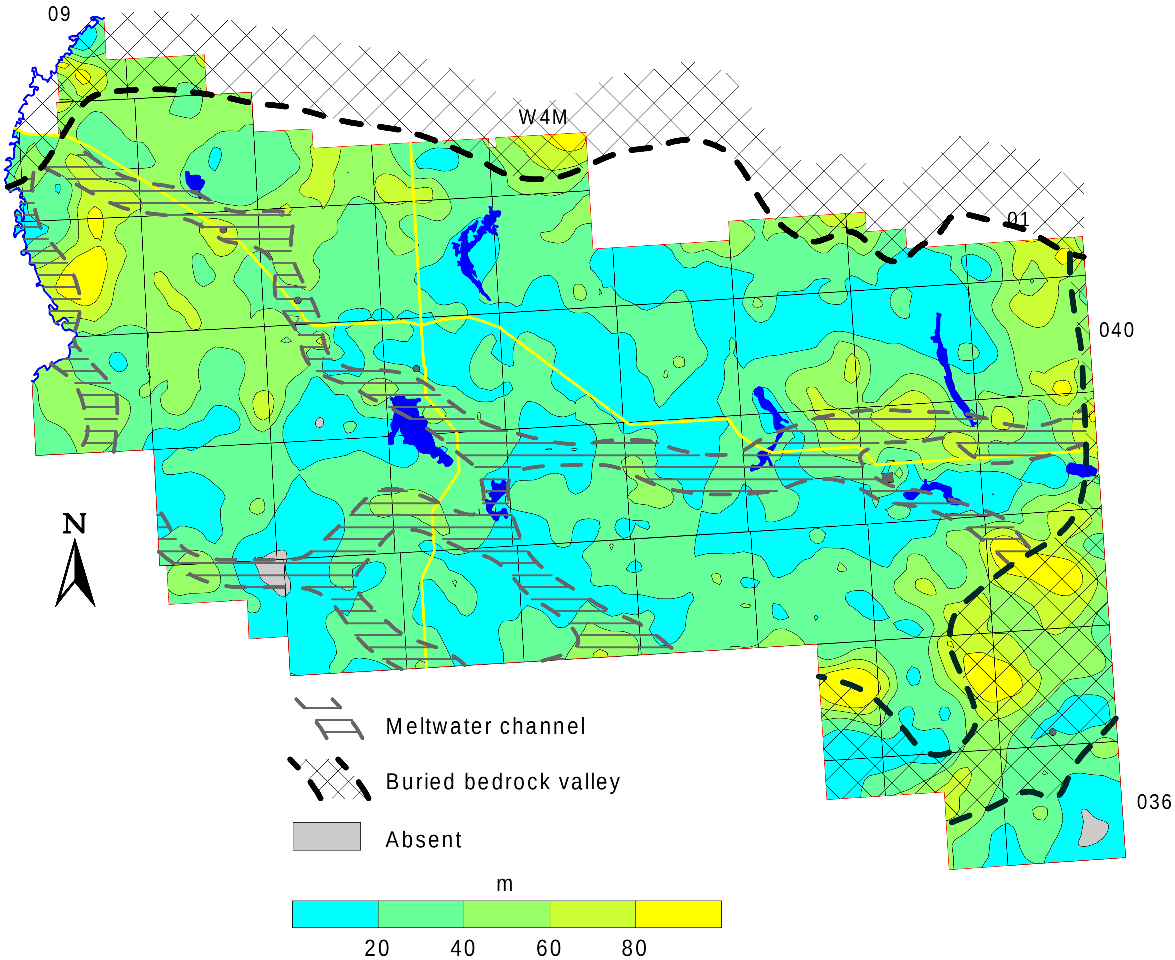


Cross-Section B - B'

Bedrock Topography



Thickness of Surficial Deposits



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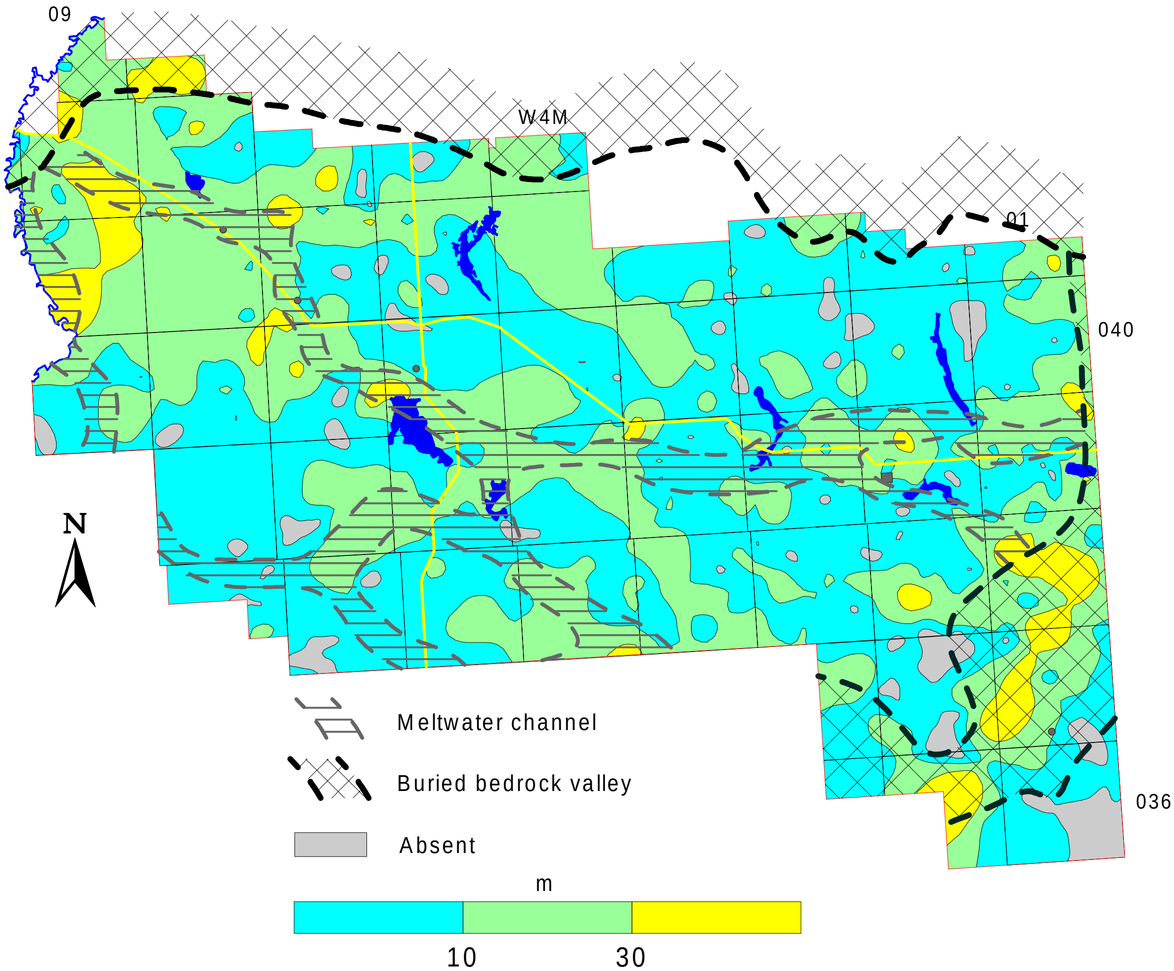
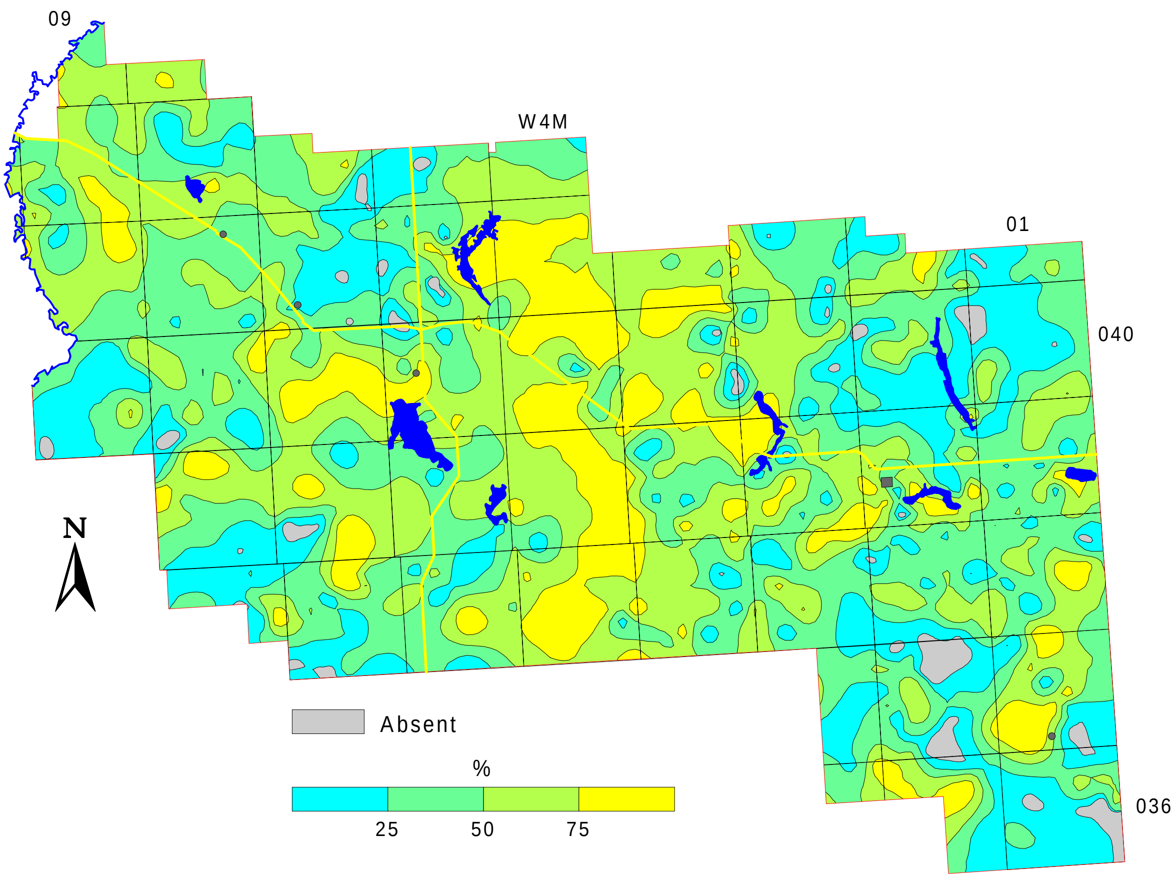
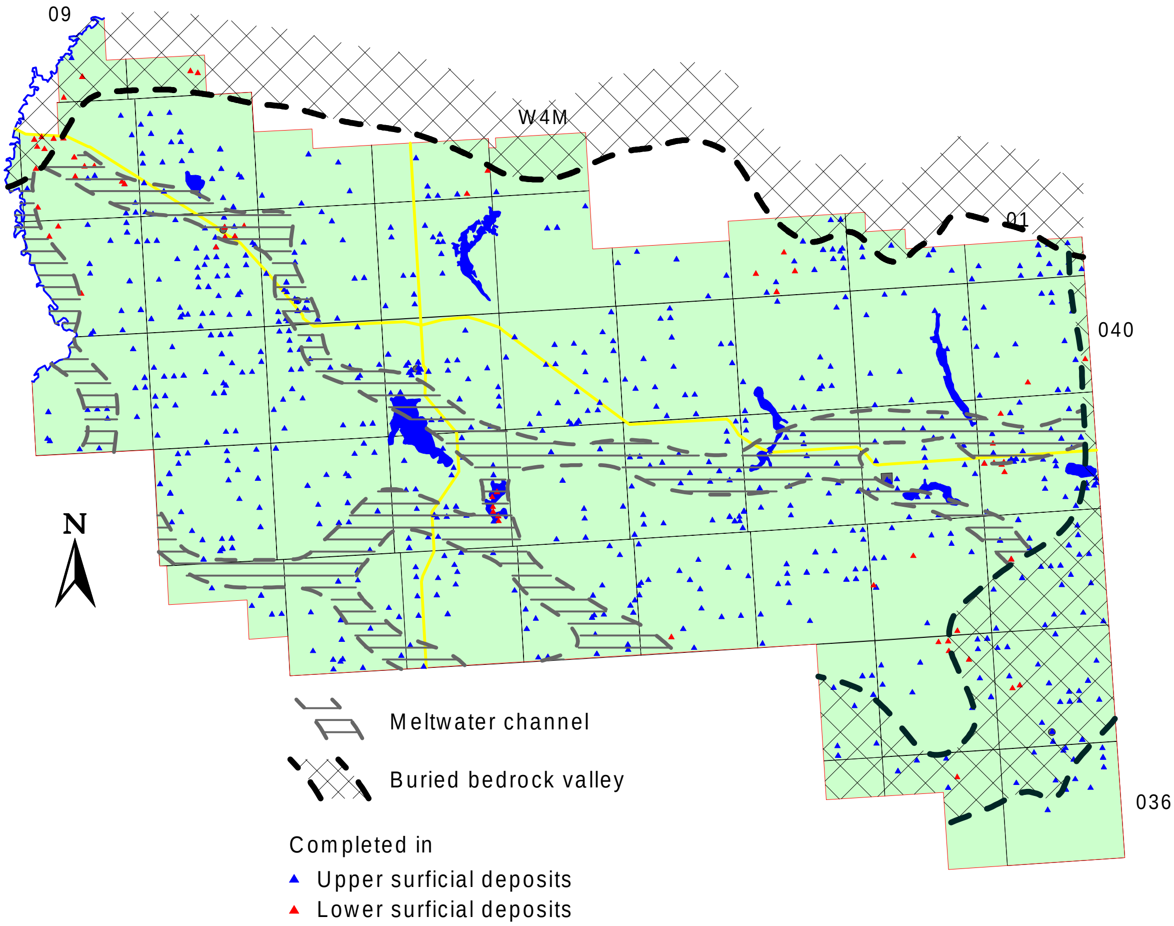
Thickness of Sand and Gravel Aquifer(s)



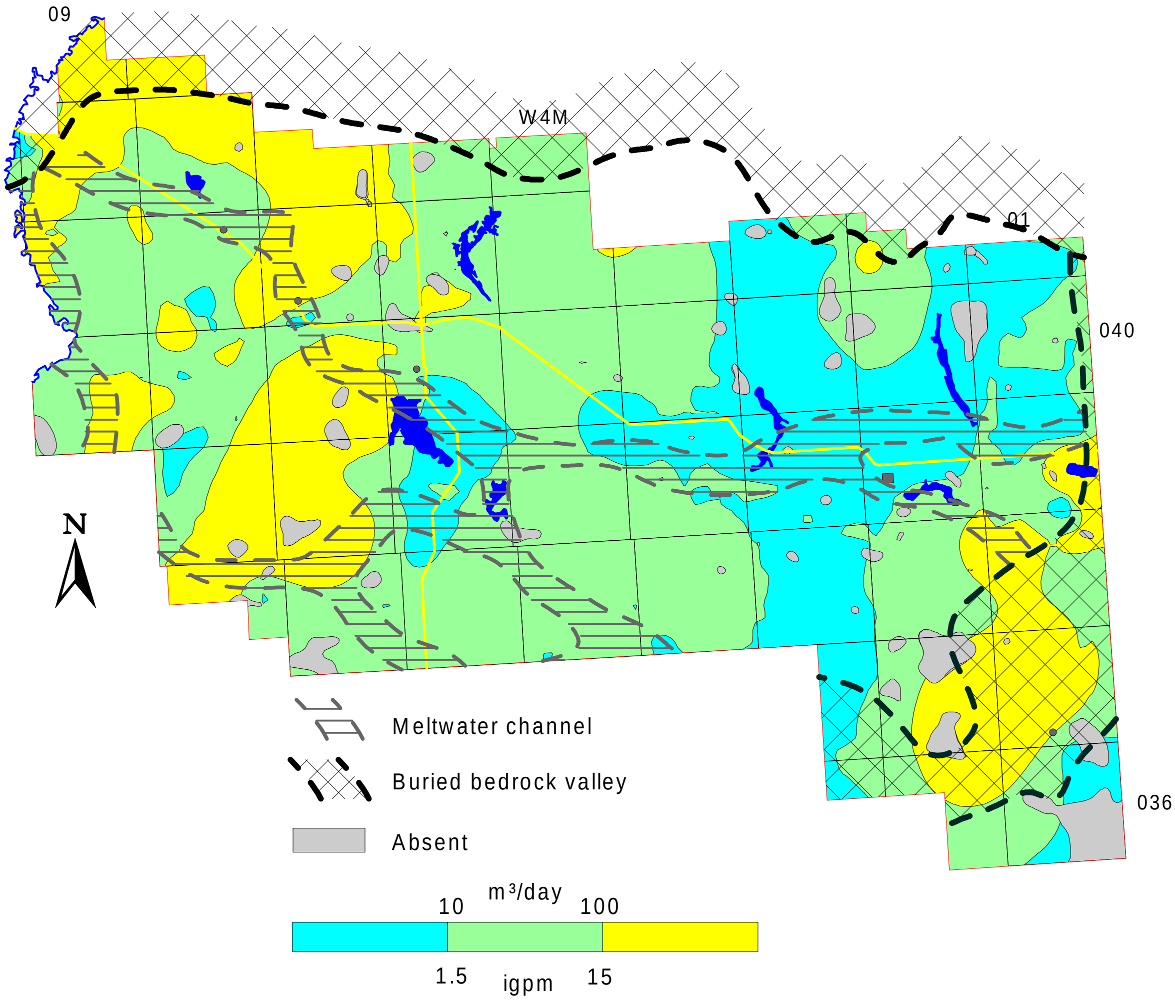
Amount of Sand and Gravel in Surficial Deposits



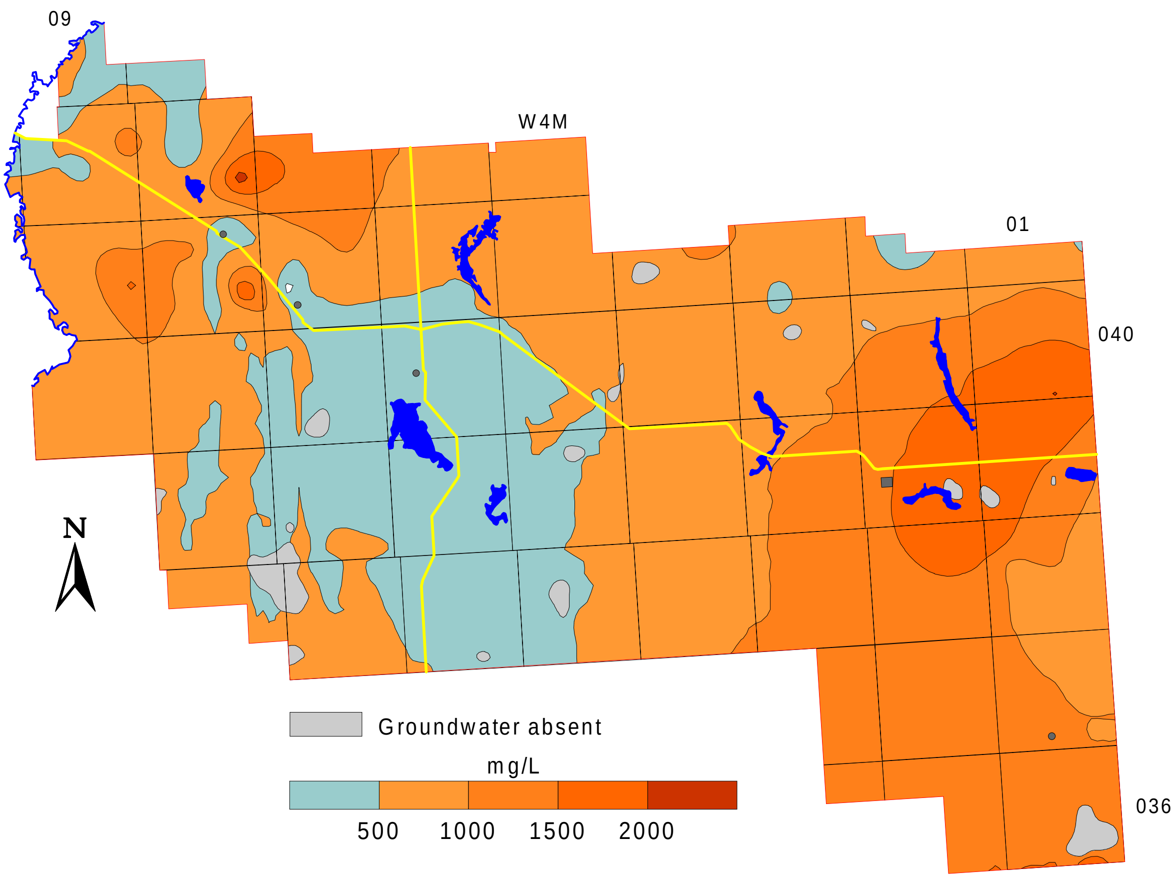
Water Wells Completed in Surficial Deposits



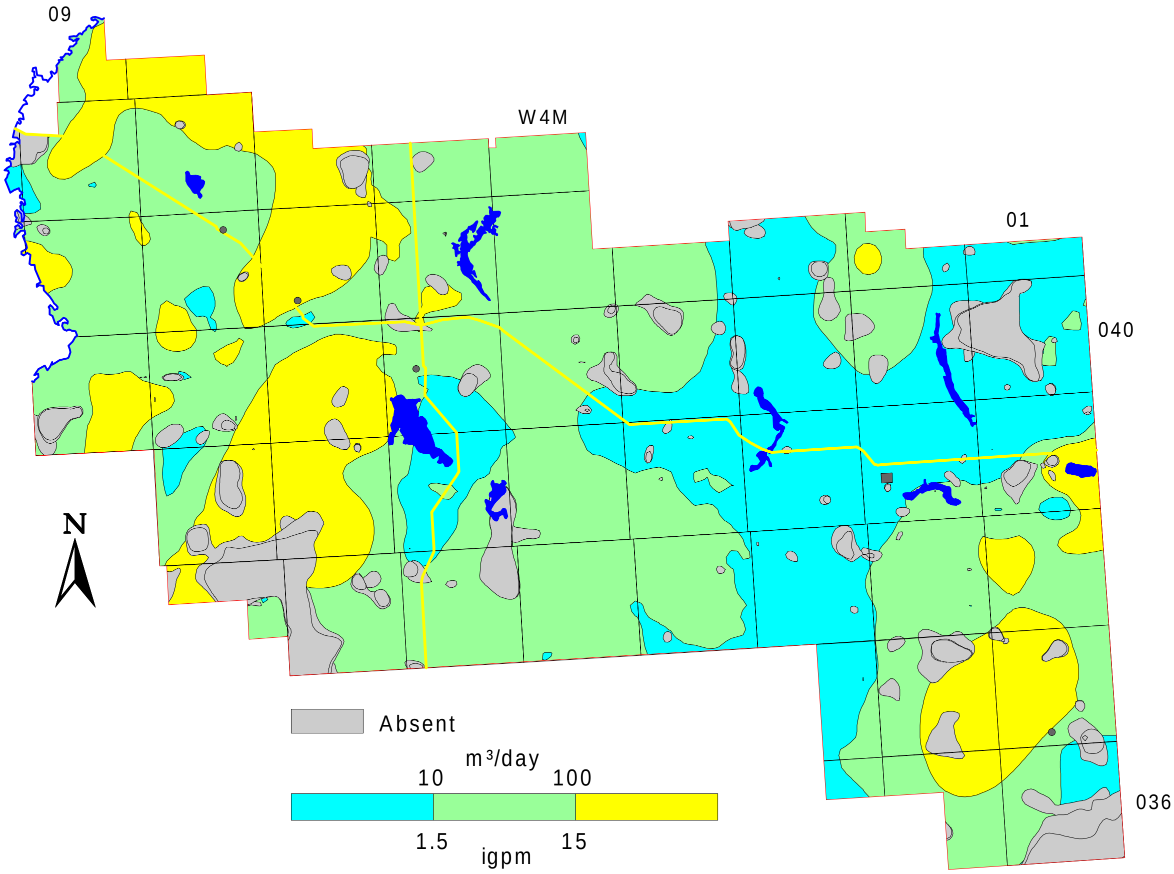
Apparent Yield for Water Wells Completed through Sand and Gravel Aquifer(s)



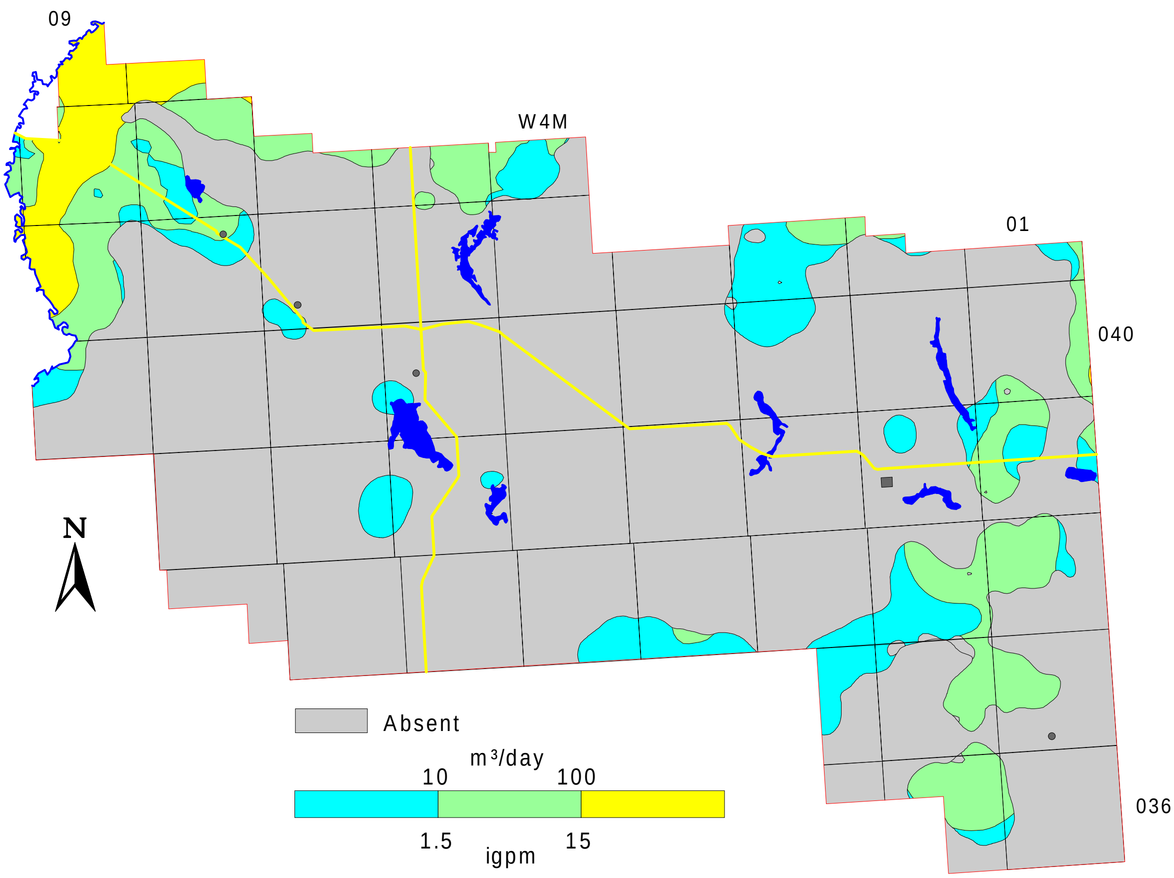
Total Dissolved Solids in Groundwater from Surficial Deposits



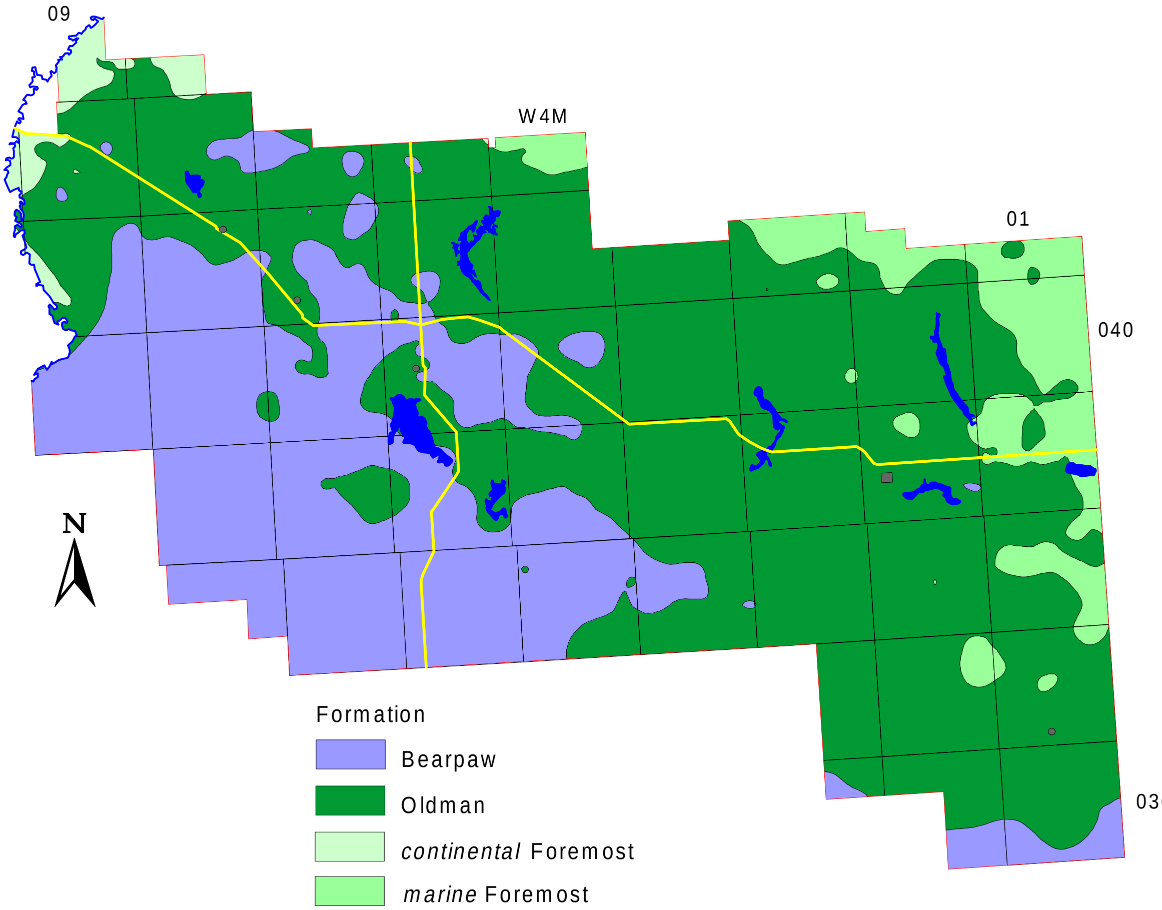
Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer



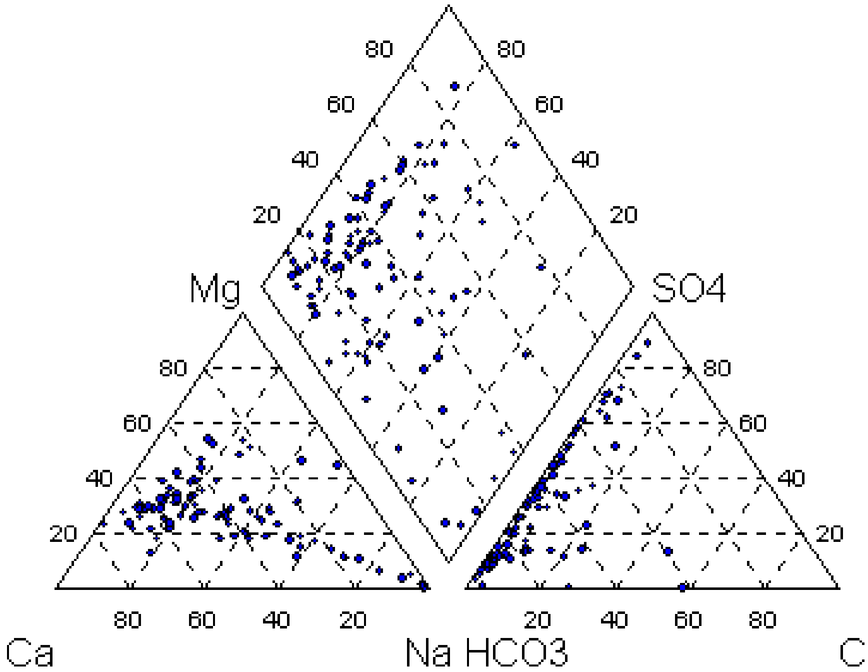
Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer



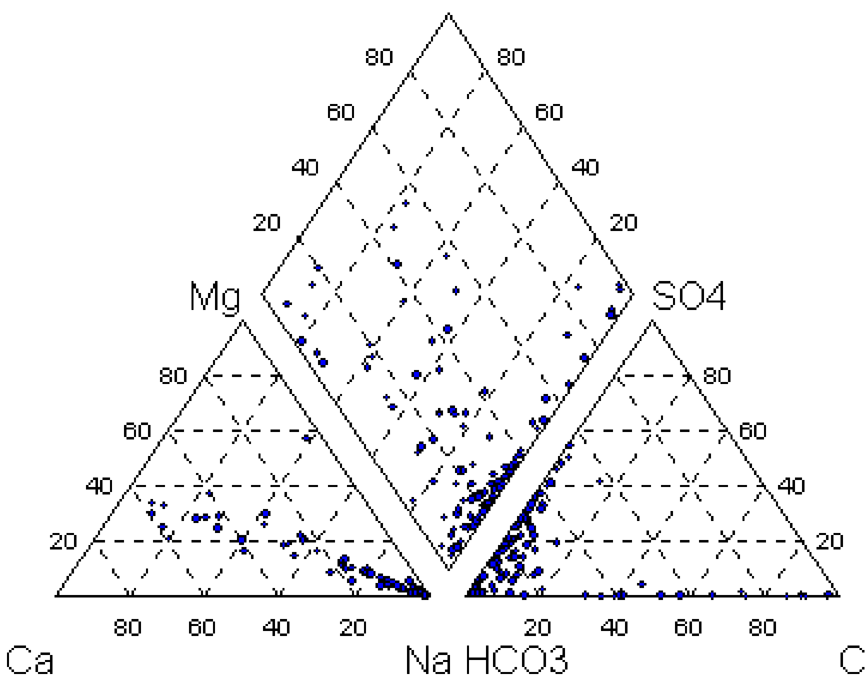
Bedrock Geology



Piper Diagrams



Surficial Deposits



Bedrock Aquifers

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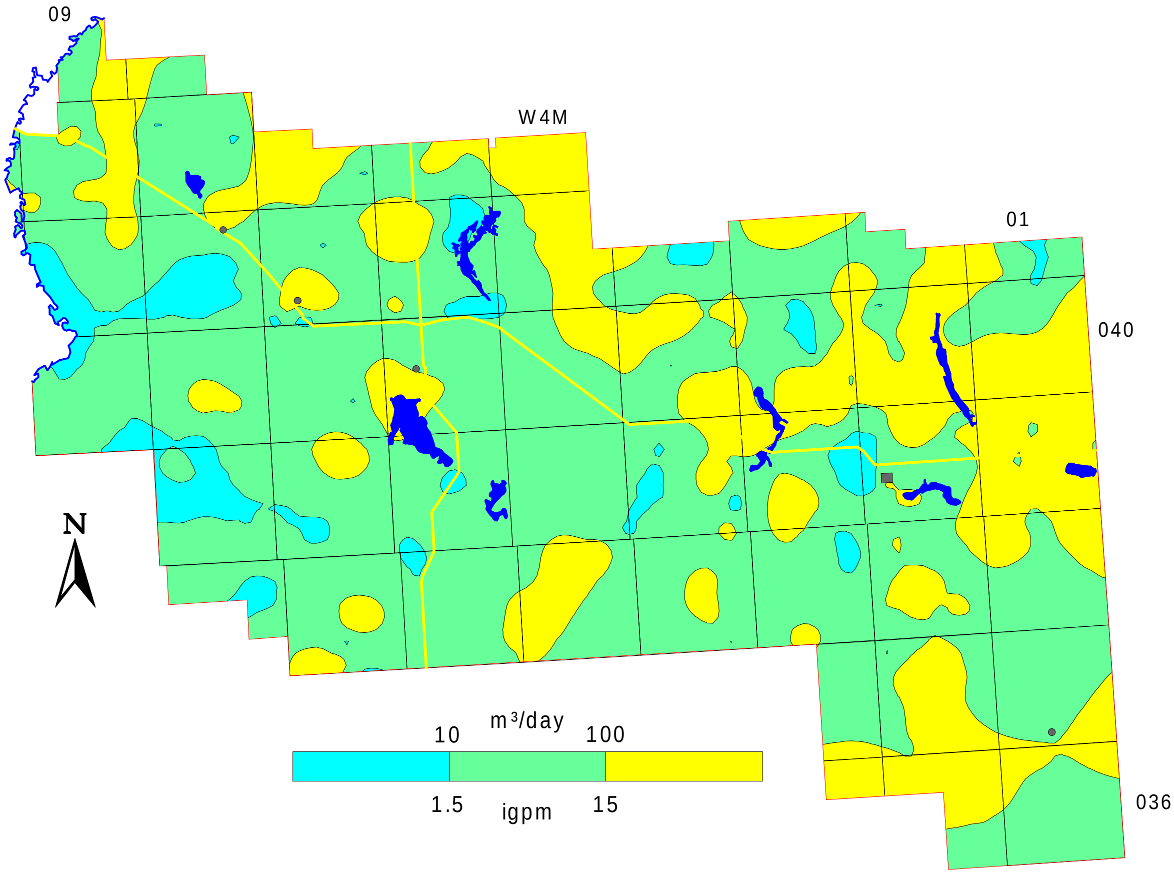
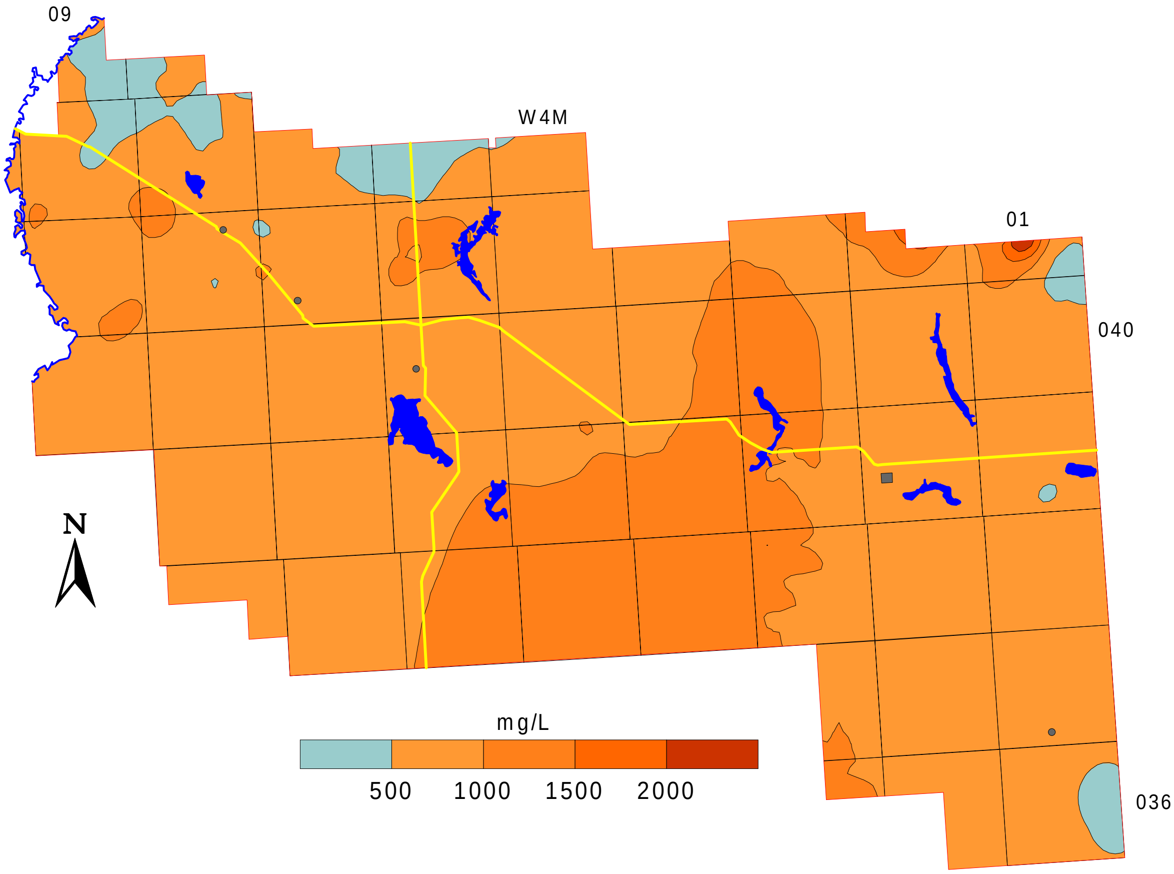
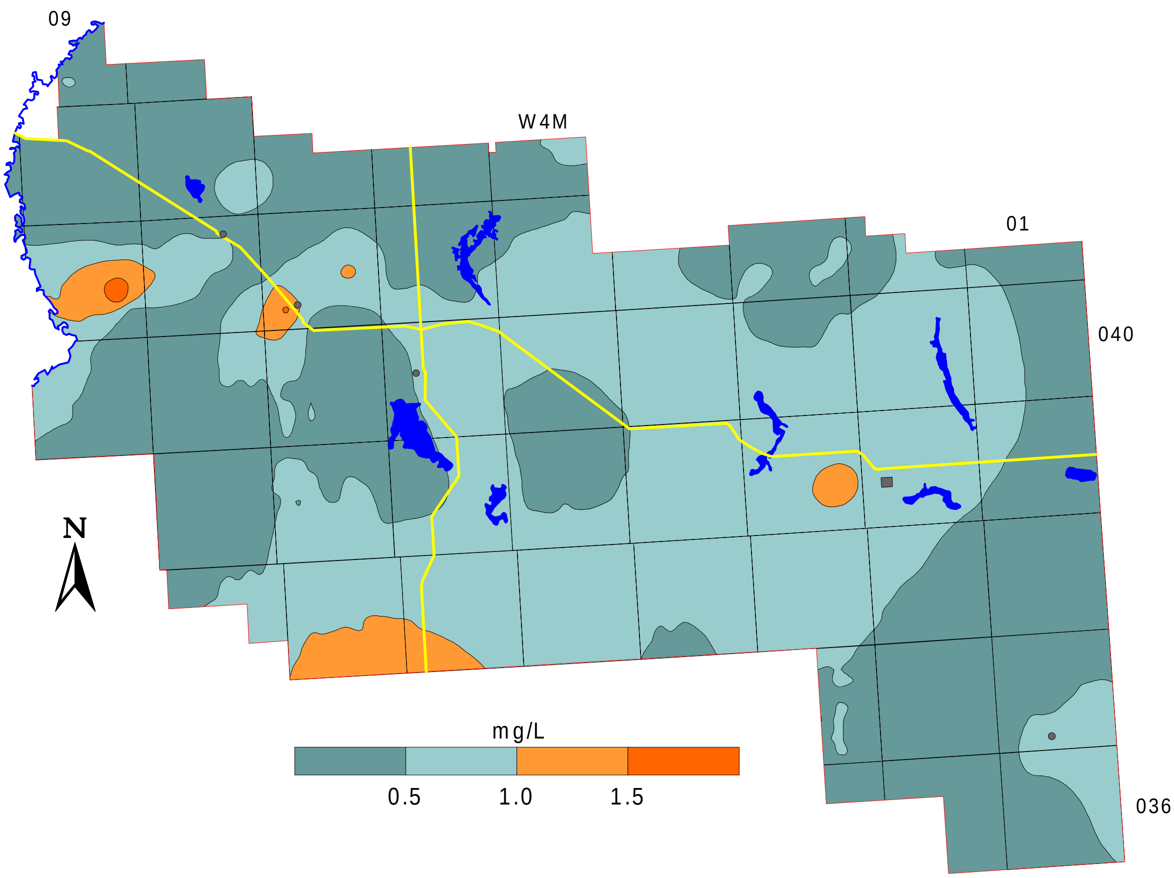
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



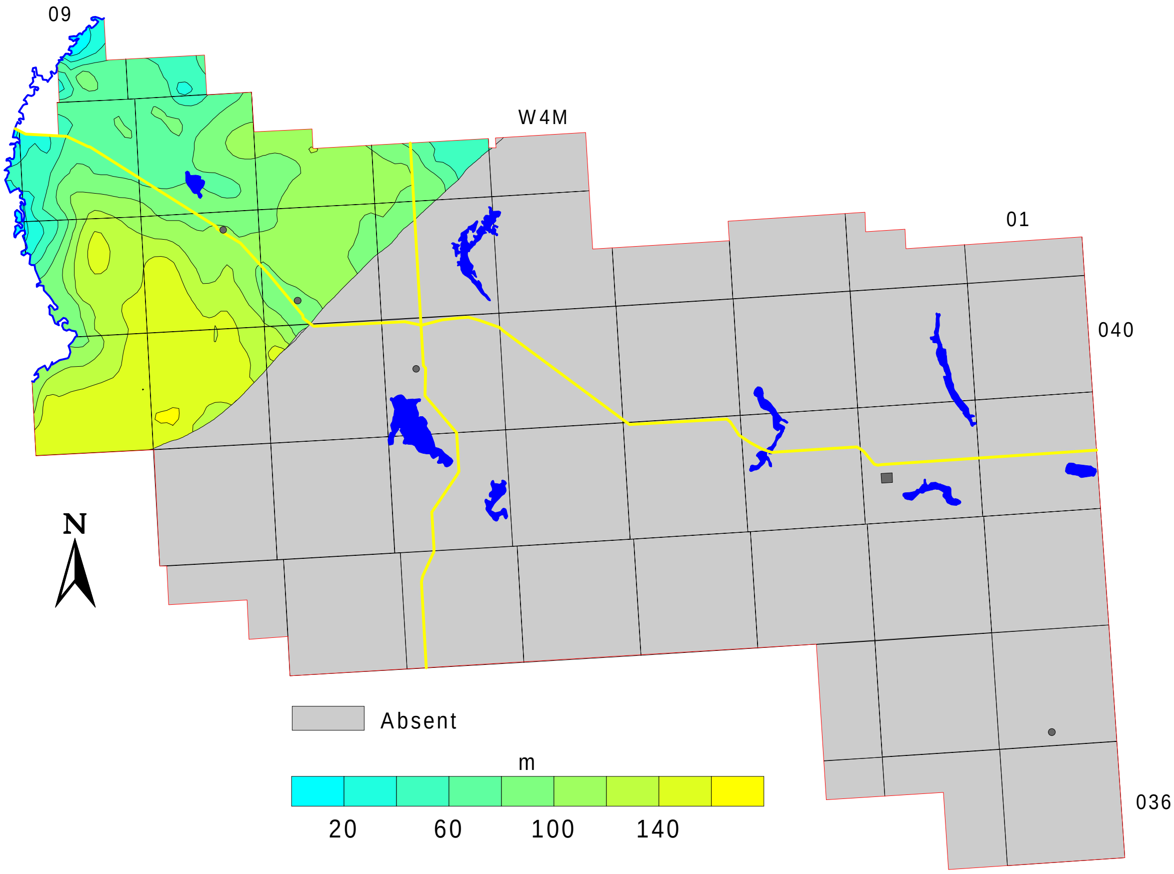
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



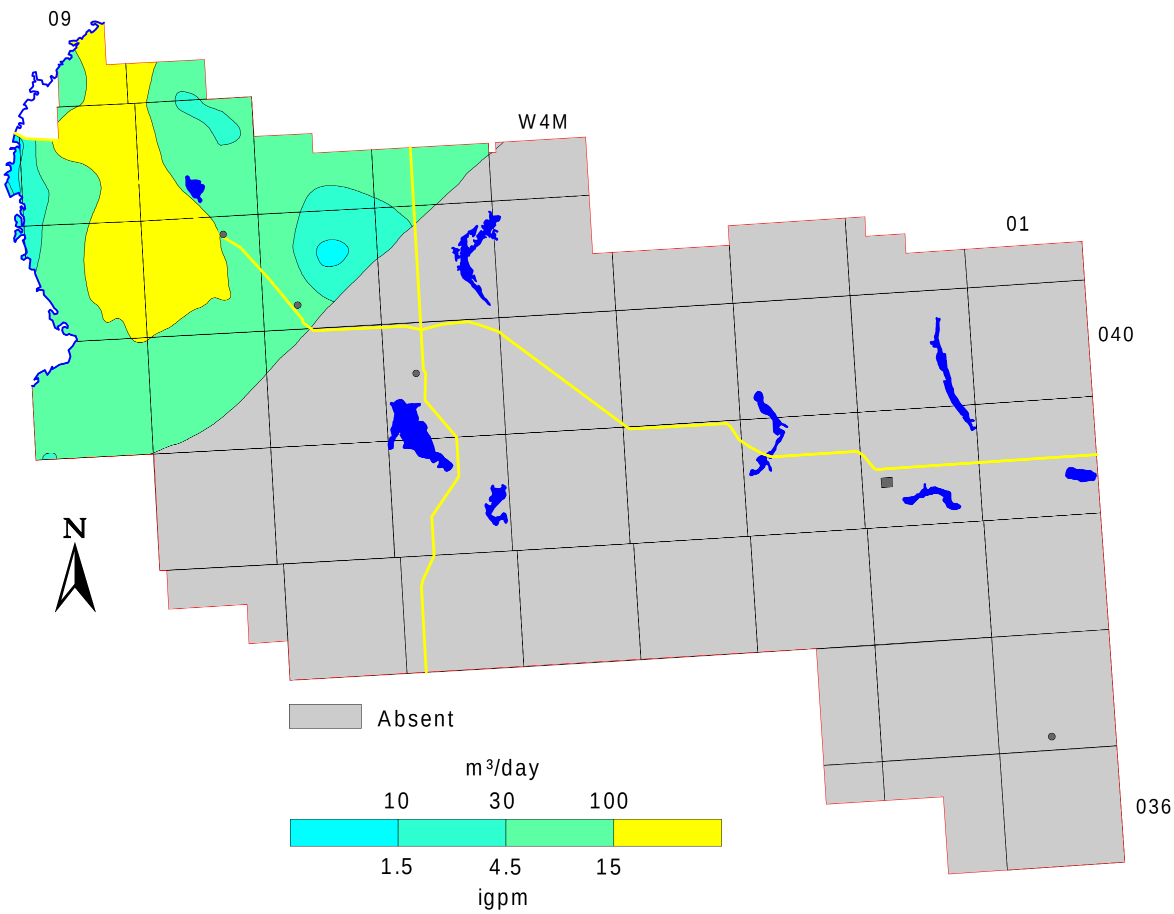
Fluoride in Groundwater from Upper Bedrock Aquifer(s)



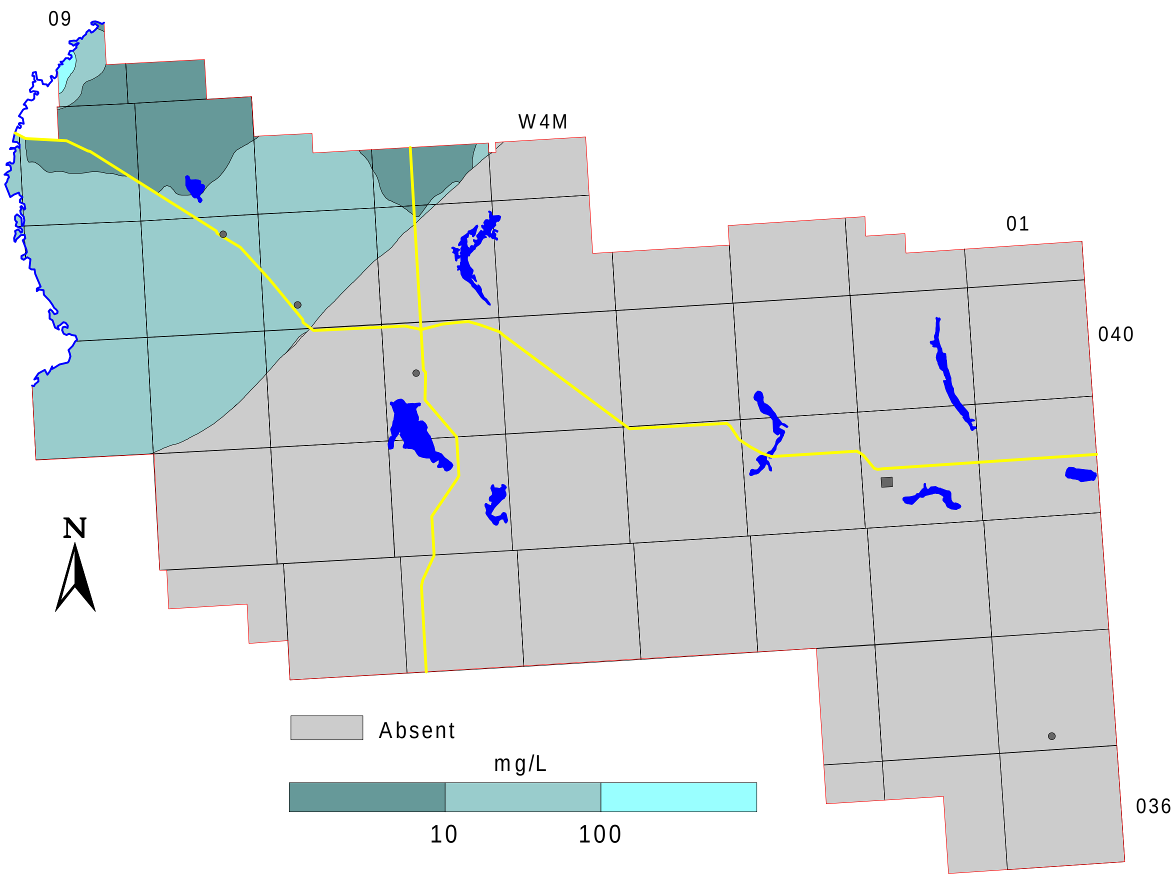
Depth to Top of continental Foremost Formation



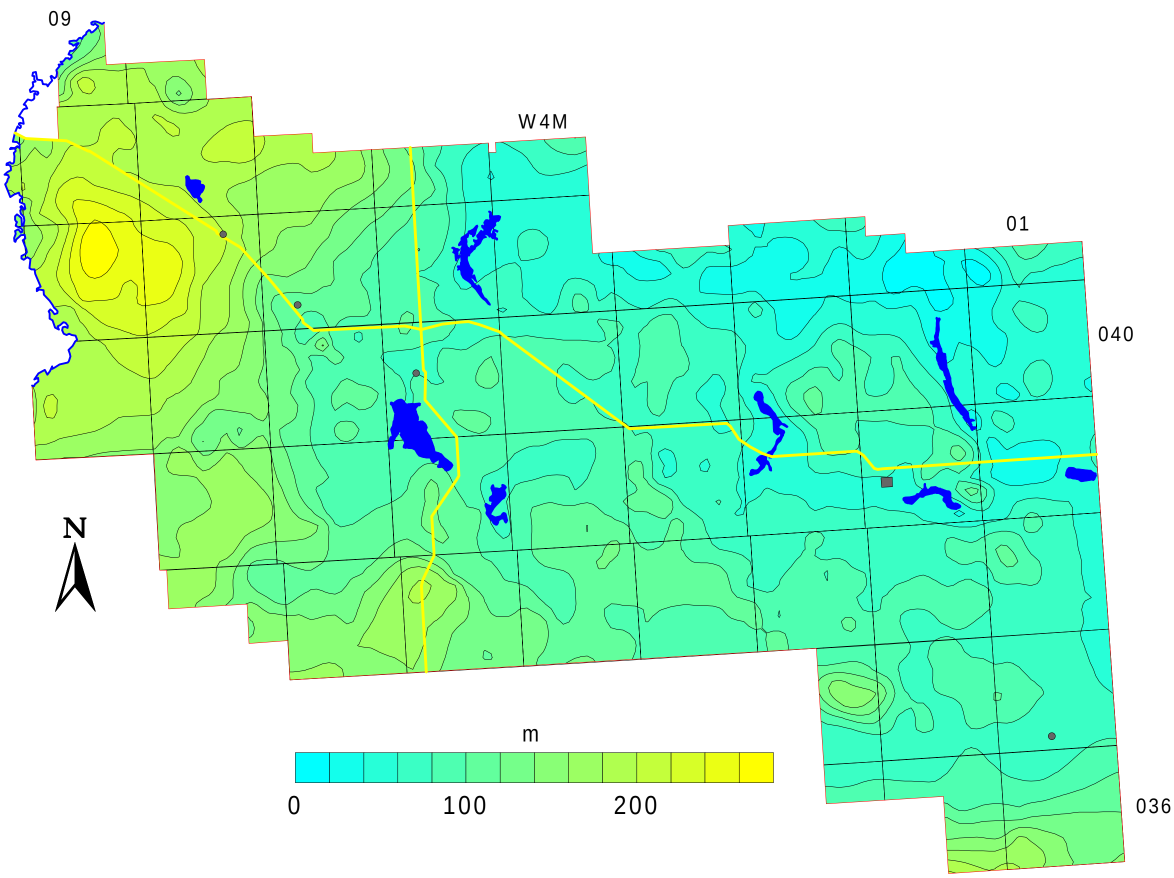
Apparent Yield for Water Wells Completed through continental Foremost Aquifer



Chloride in Groundwater from continental Foremost Aquifer



Depth to Top of marine Foremost Formation



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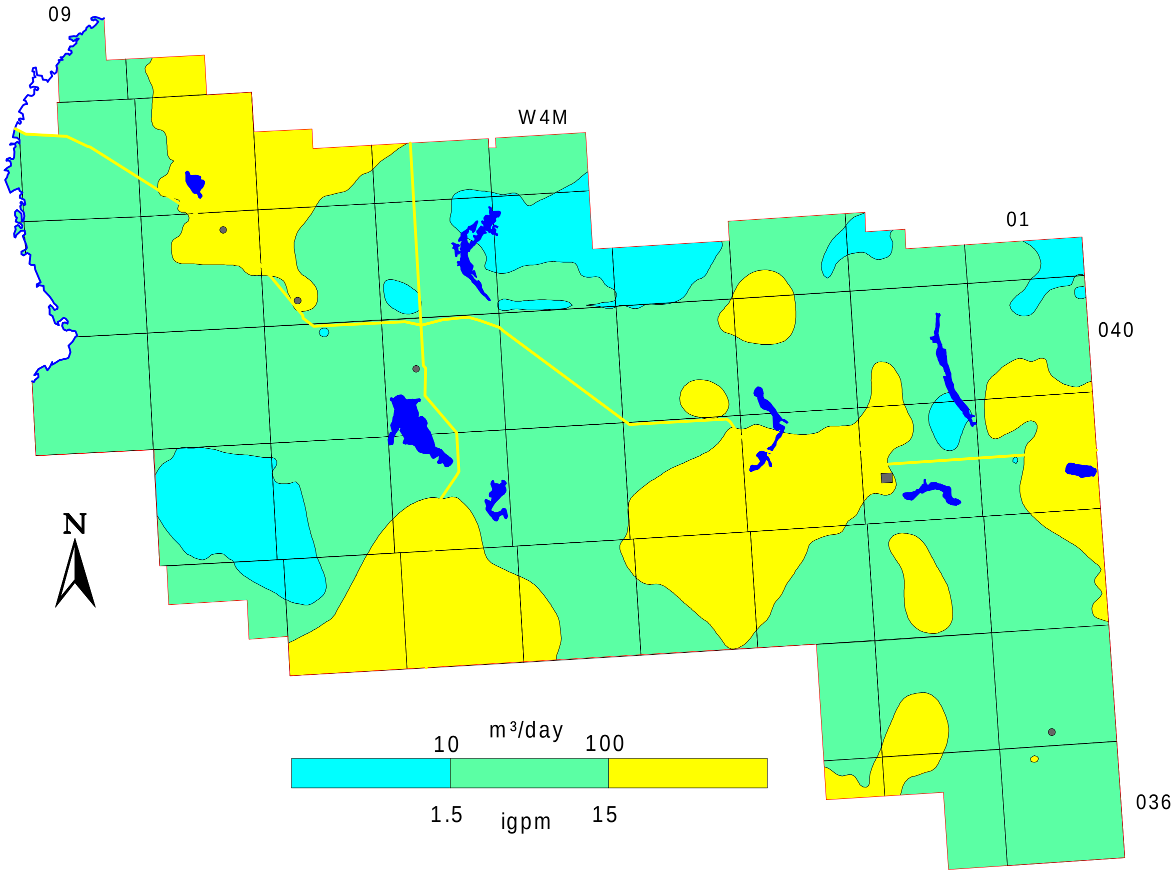
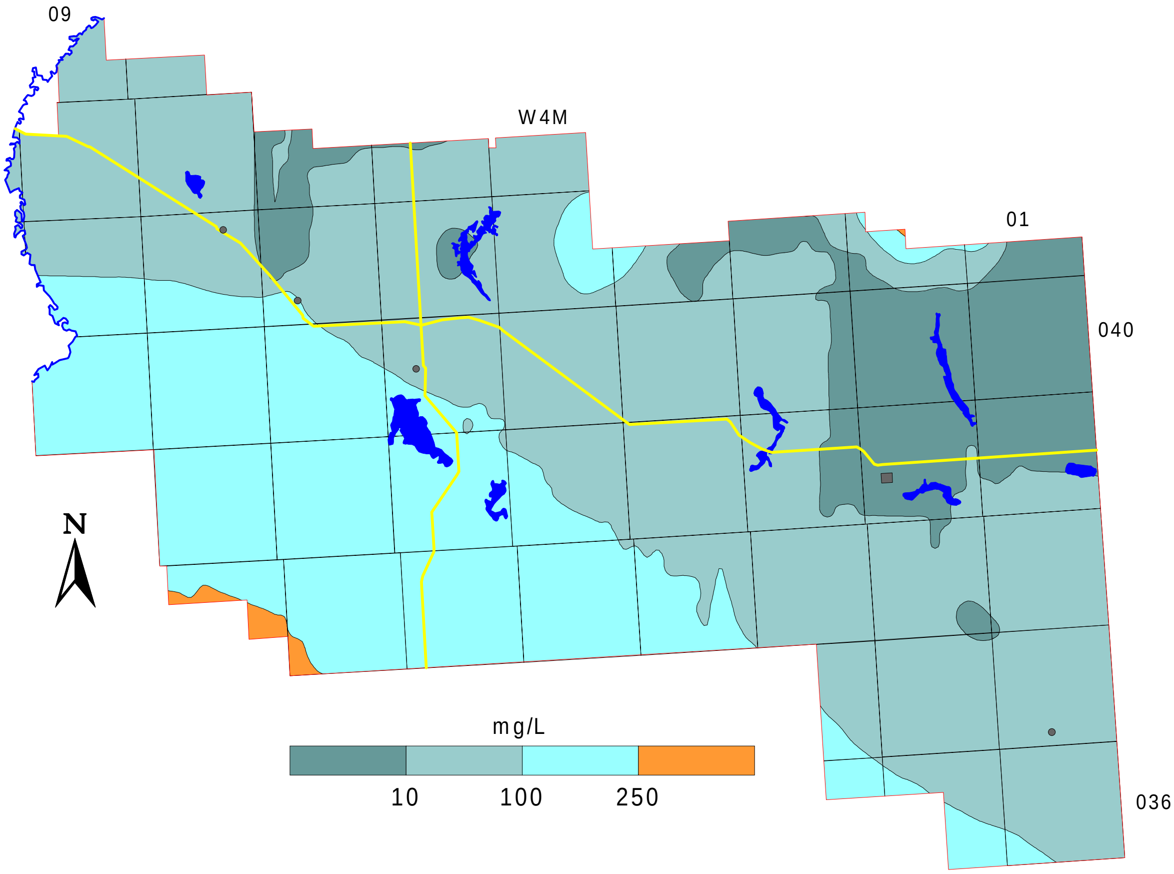
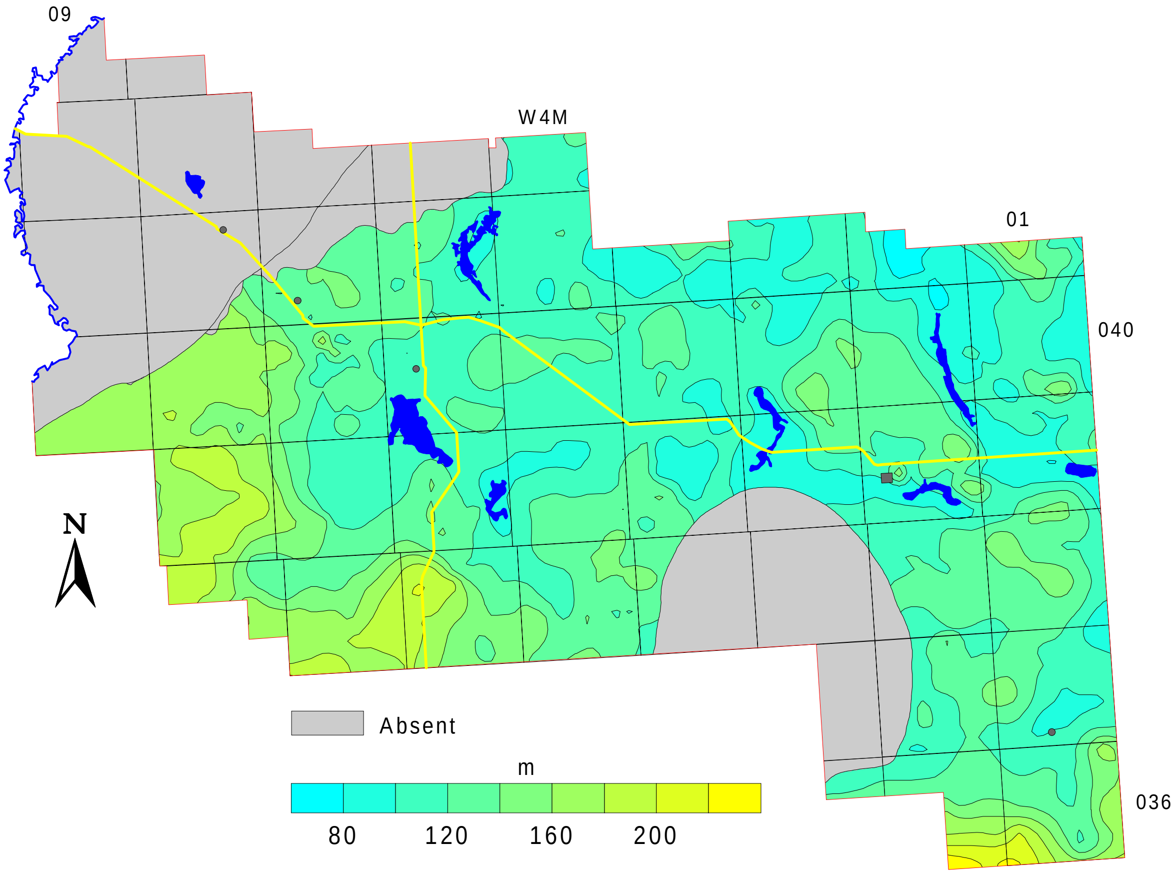
Apparent Yield for Water Wells Completed through marine Foremost Aquifer



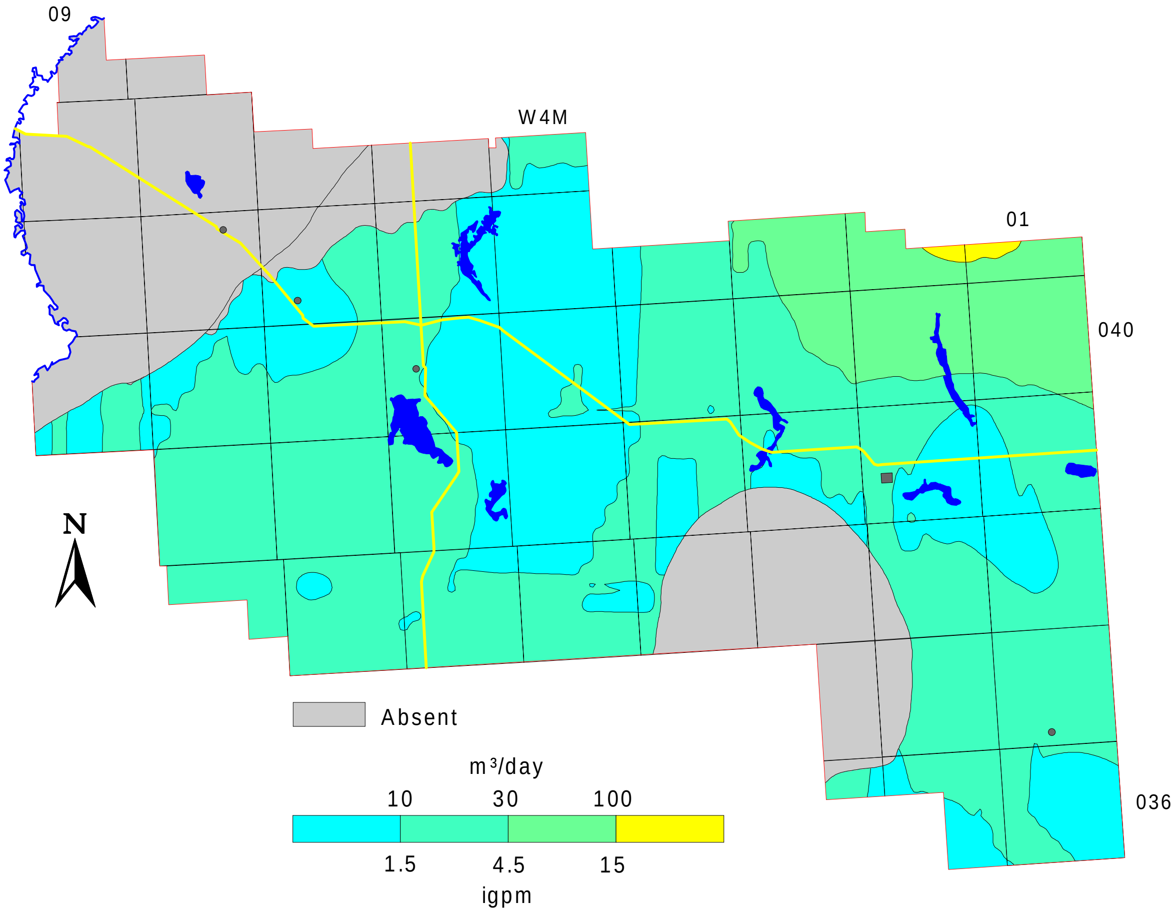
Chloride in Groundwater from marine Foremost Aquifer



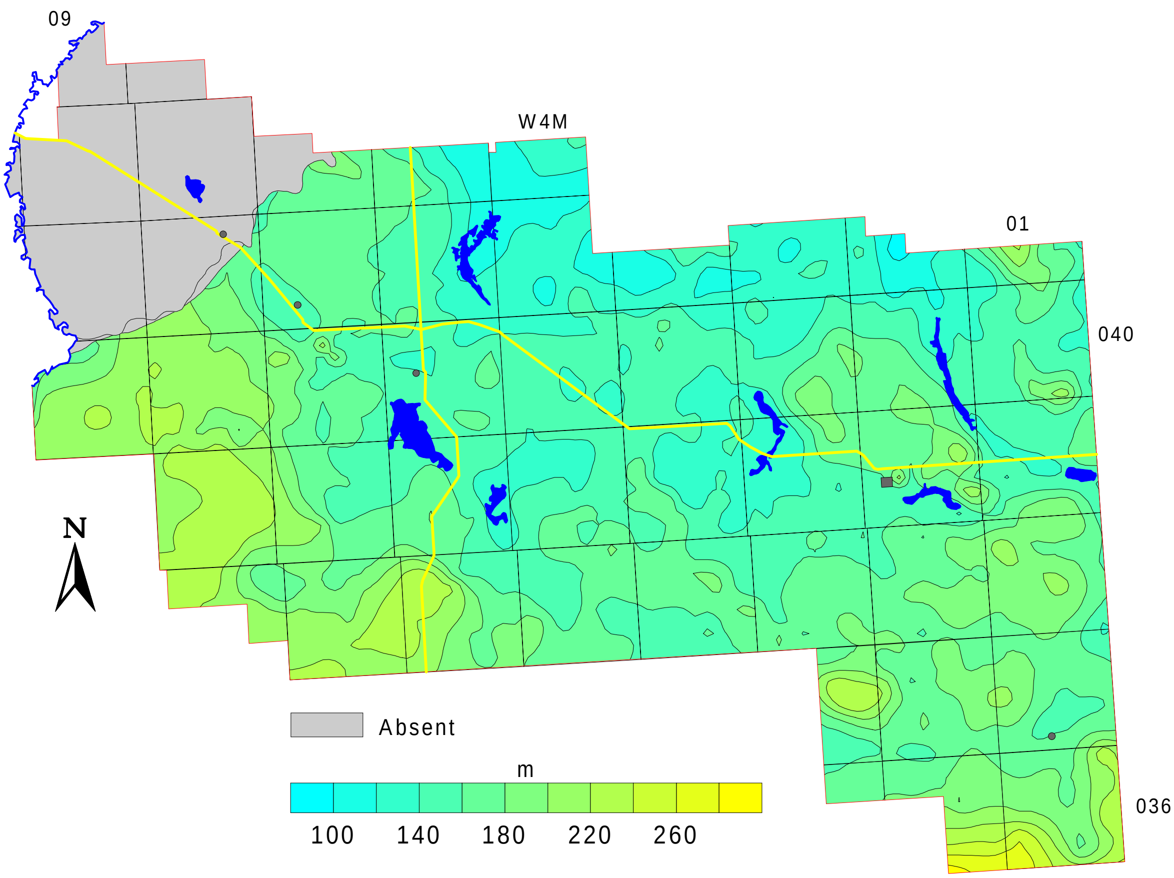
Depth to Top of Birch Lake Formation



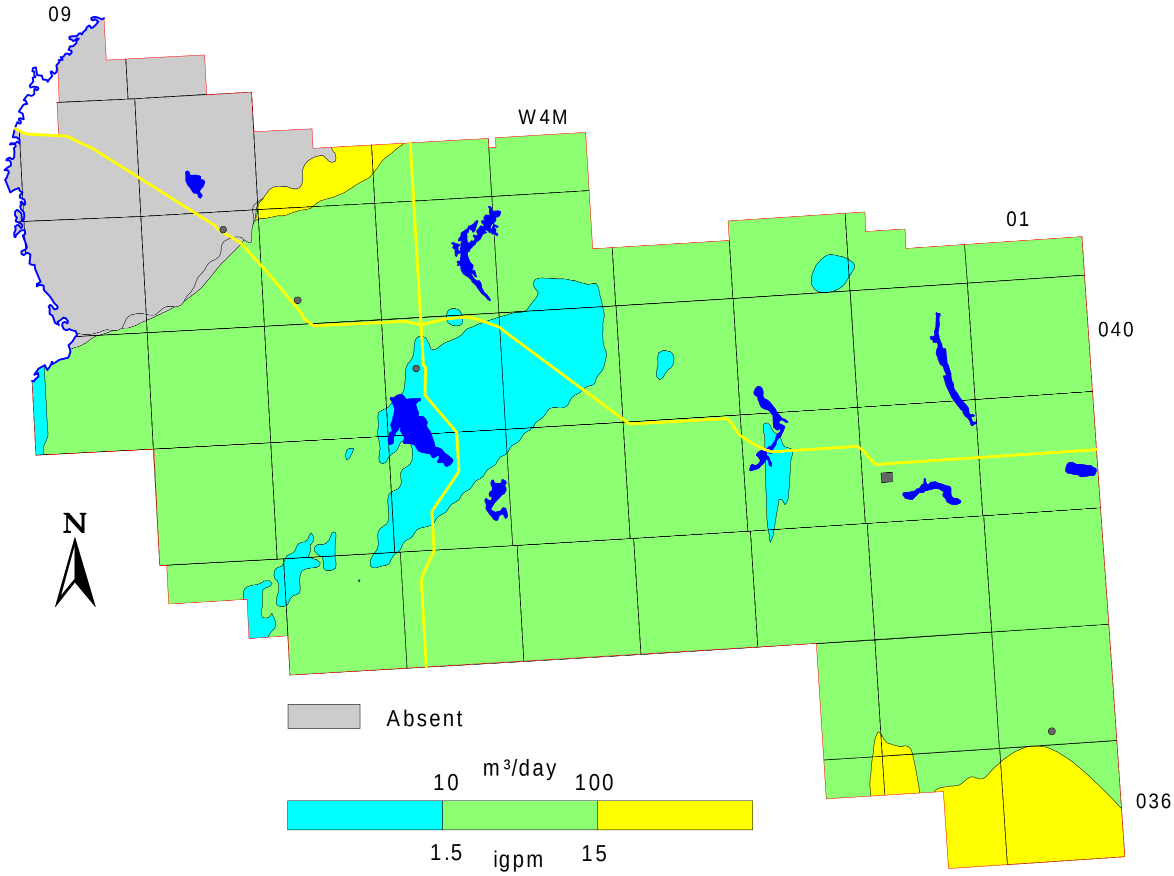
Apparent Yield for Water Wells Completed through Birch Lake Aquifer



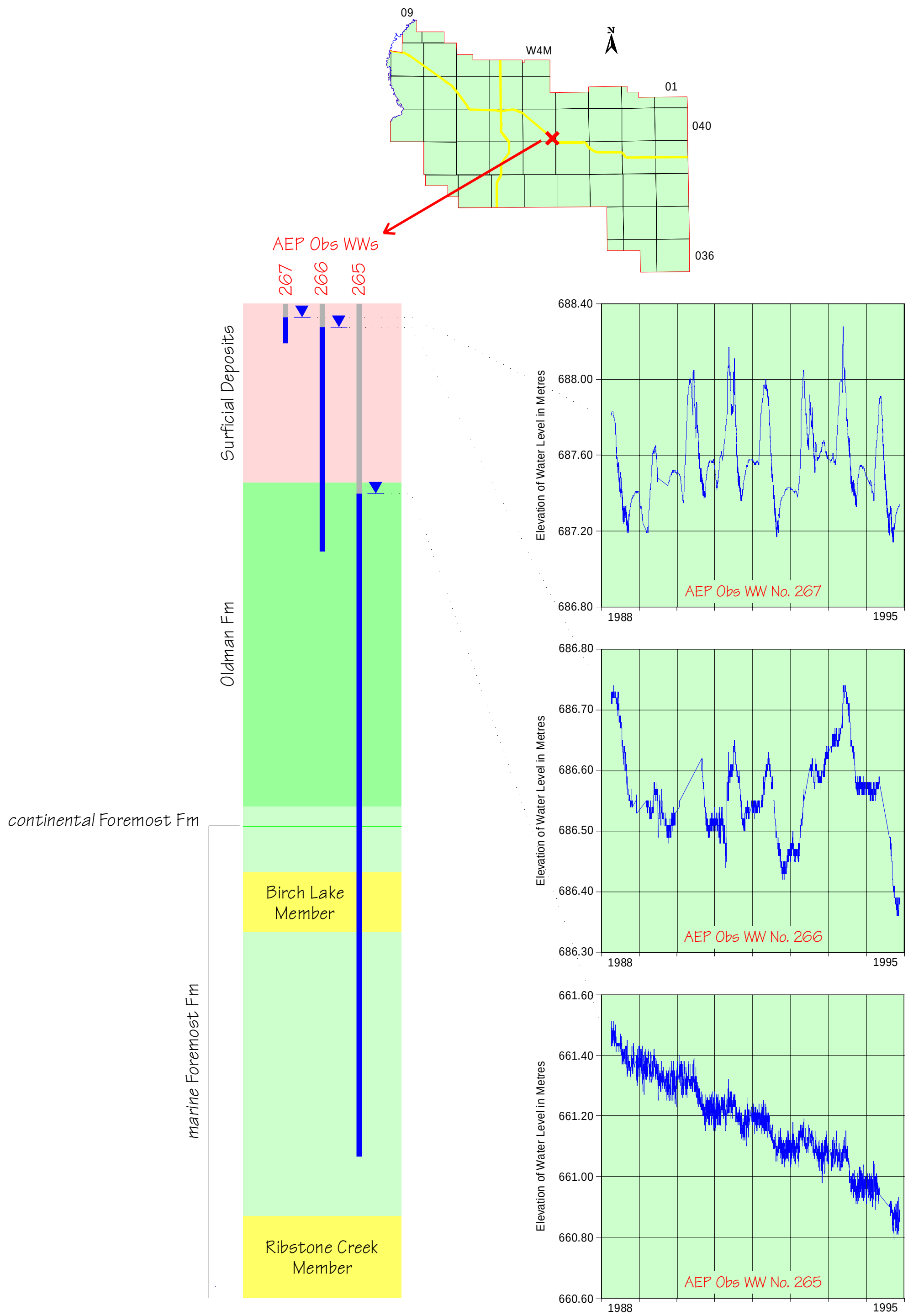
Depth to Top of Ribstone Creek Formation



Apparent Yield for Water Wells Completed through Ribstone Creek Aquifer

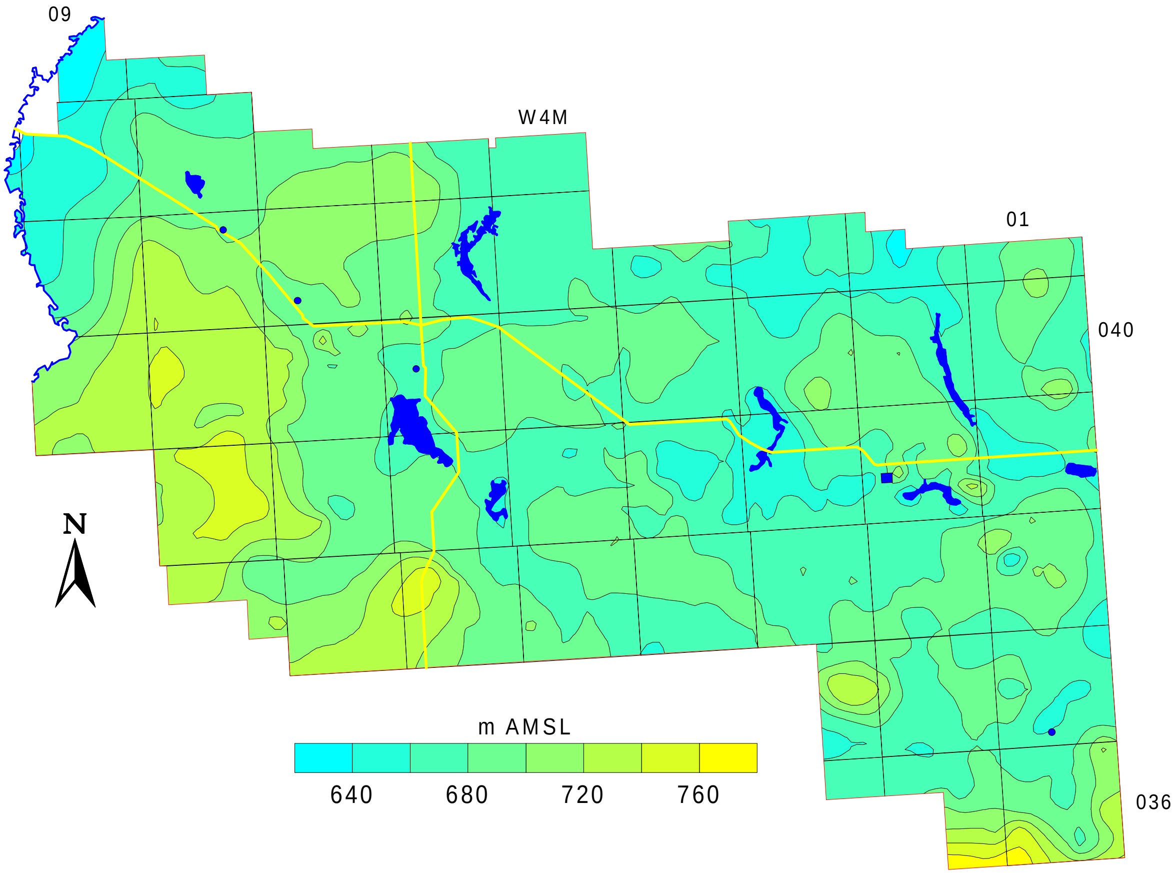


Hydrographs - AEP Observation Water Wells

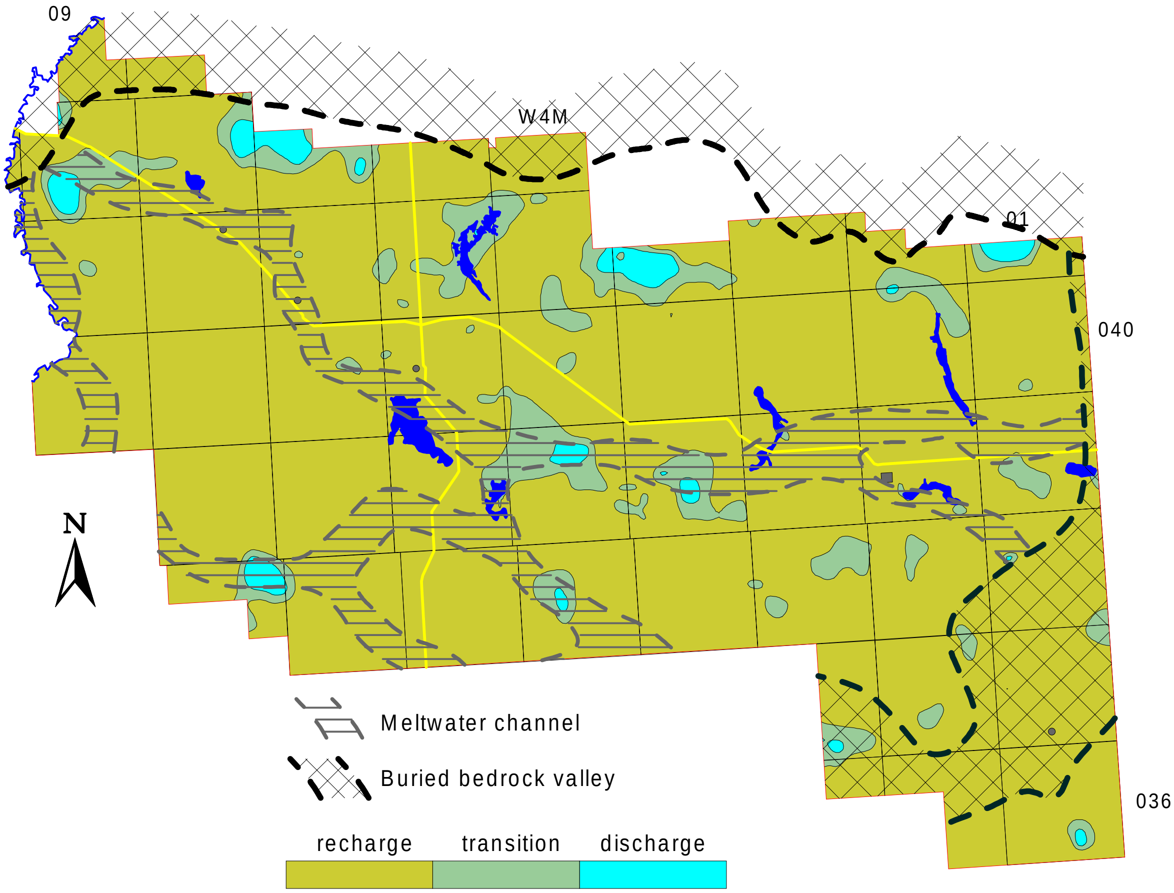


(Based on regional analysis;
no drilling reports available)

Non-Pumping Water-Level Surface in Surficial Deposits



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



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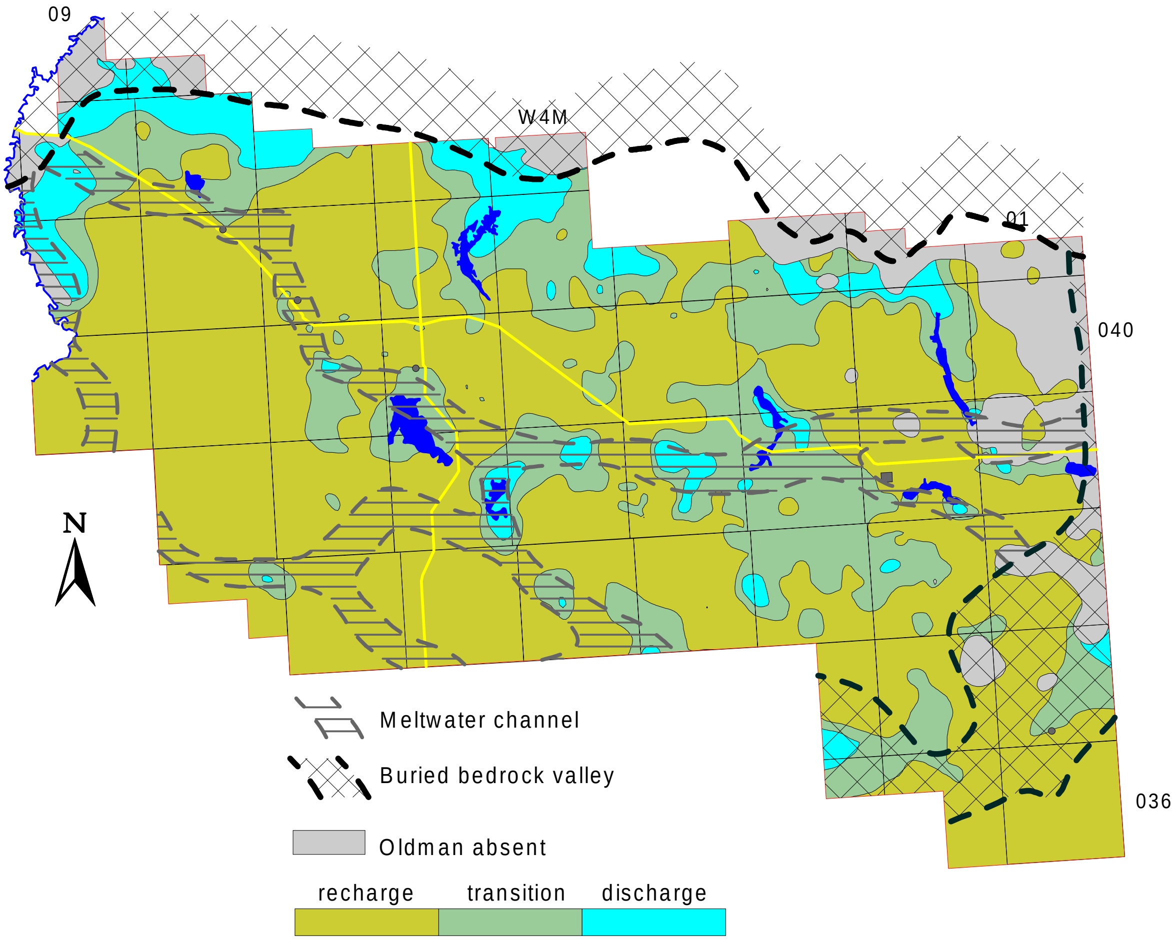
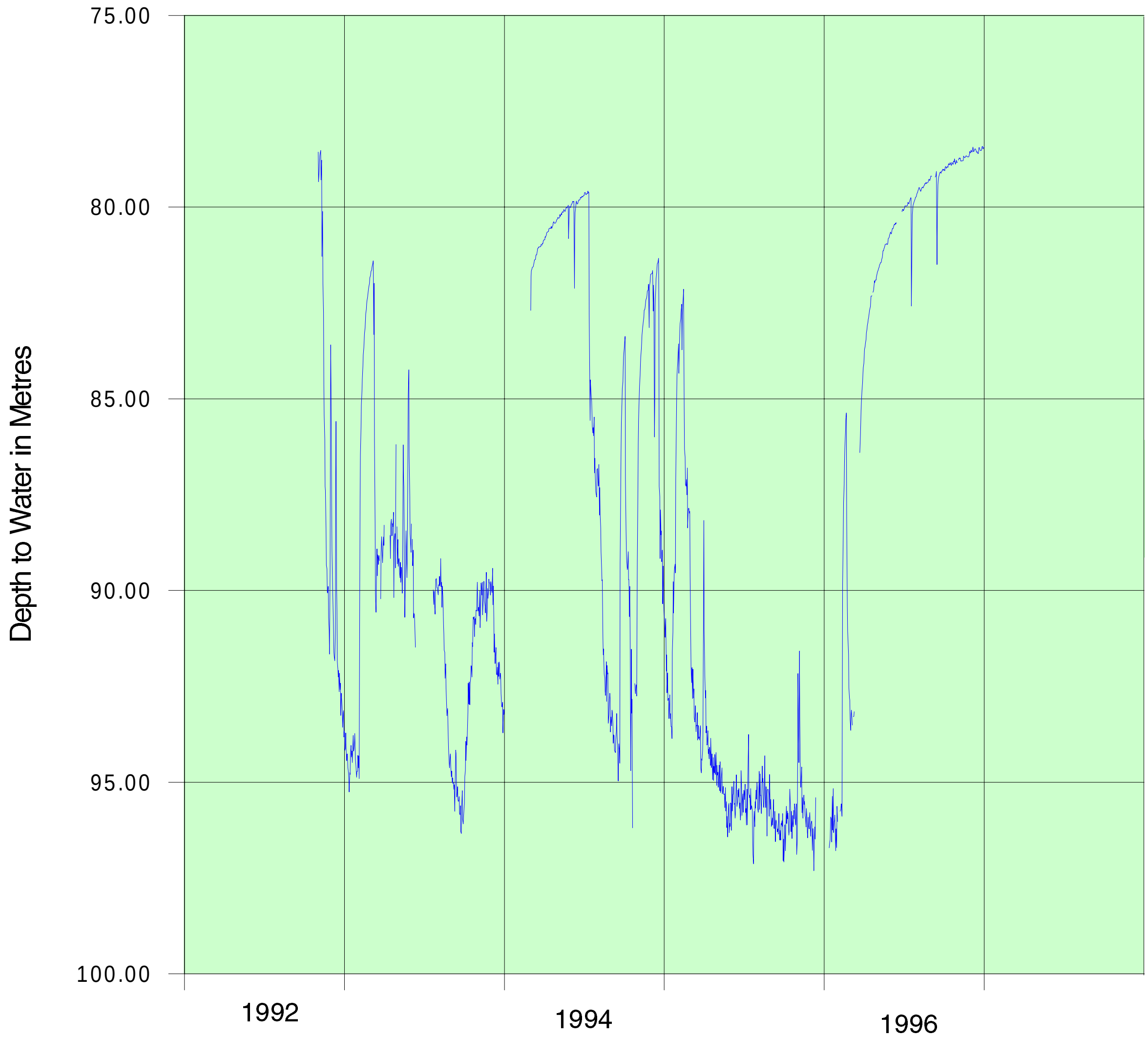
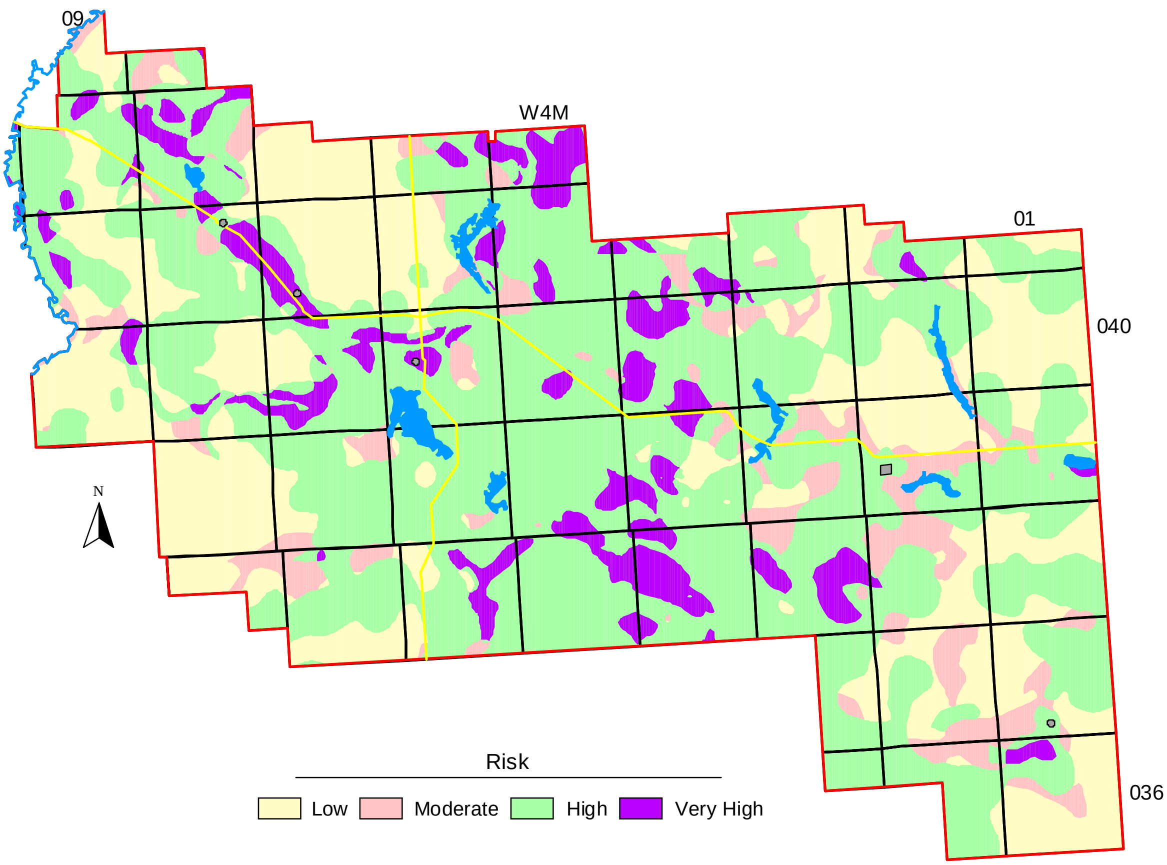
Recharge/Discharge Areas between Surficial Deposits and Oldman Aquifer



Water-Level Summary - PCP North Bodo Deep Obs WW



Risk of Groundwater Contamination



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Appendix B

MAPS AND FIGURES ON CD-ROM

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B) ArcView Files
C) Query
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Thickness of First Sand and Gravel
First Sand and Gravel - Saturation

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Thickness of Upper Sand and Gravel (not all drill holes fully penetrate surficial deposits)
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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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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)

ALBERTA ENVIRONMENTAL PROTECTION

WATER WELL INSPECTORS

Jennifer McPherson (Edmonton: 403-427-6429)
Colin Samis (Lac La Biche: 403-623-5235)

GEOPHYSICAL INSPECTION SERVICE

Edmonton: 403-427-3932

COMPLAINT INVESTIGATIONS

Blair Stone (Red Deer: 403-340-5310)

UNIVERSITY OF ALBERTA – Department of Earth and Atmospheric Sciences - Hydrogeology

Carl Mendosa (Edmonton: 403-492-2664)

UNIVERSITY OF CALGARY – Department of Geology and Geophysics - Hydrogeology

Larry Bentley (Calgary: 403-220-4512)

FARMERS ADVOCATE

Paul Vasseur (Edmonton: 403-427-2433)

PRAIRIE FARM REHABILITATION ADMINISTRATION

Dave Seitz (Hanna: 403-854-4448)

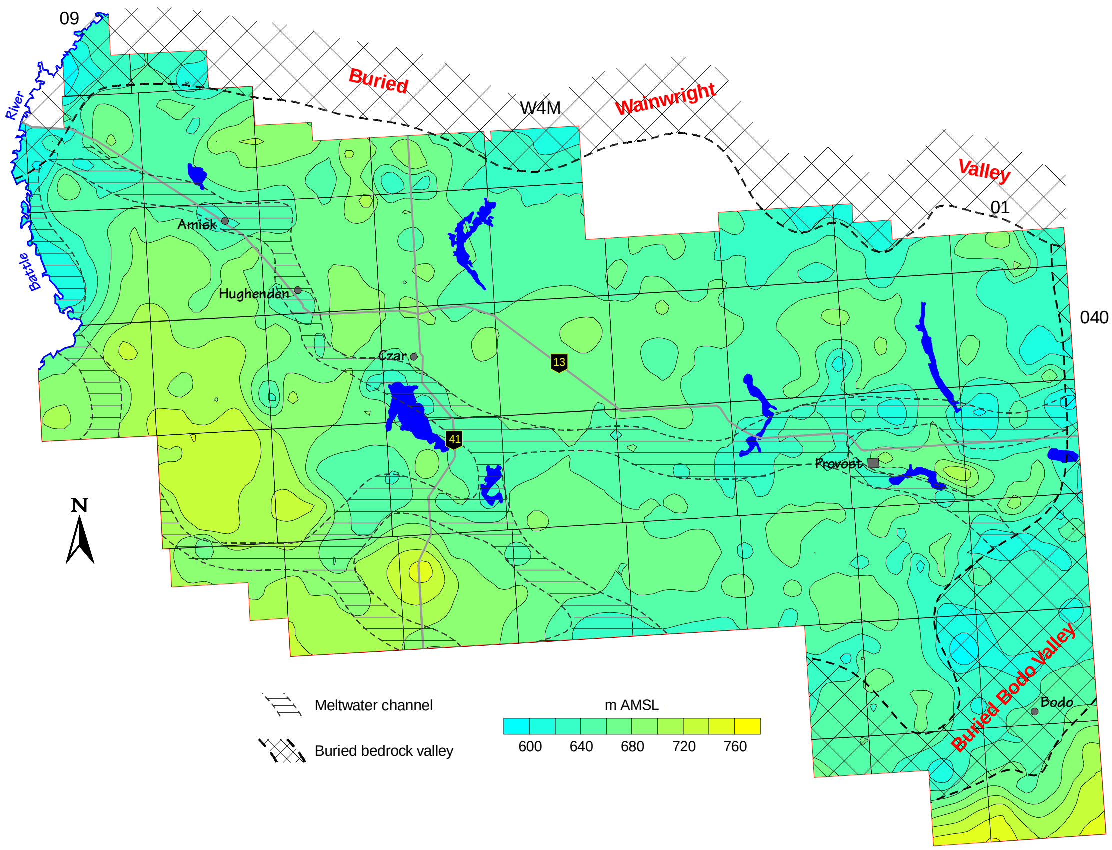
LOCAL HEALTH DEPARTMENTS

M.D. OF PROVOST NO. 52

Appendix D

MAPS AND FIGURES INCLUDED AS LARGE PLOTS

M.D. of Provost No. 52
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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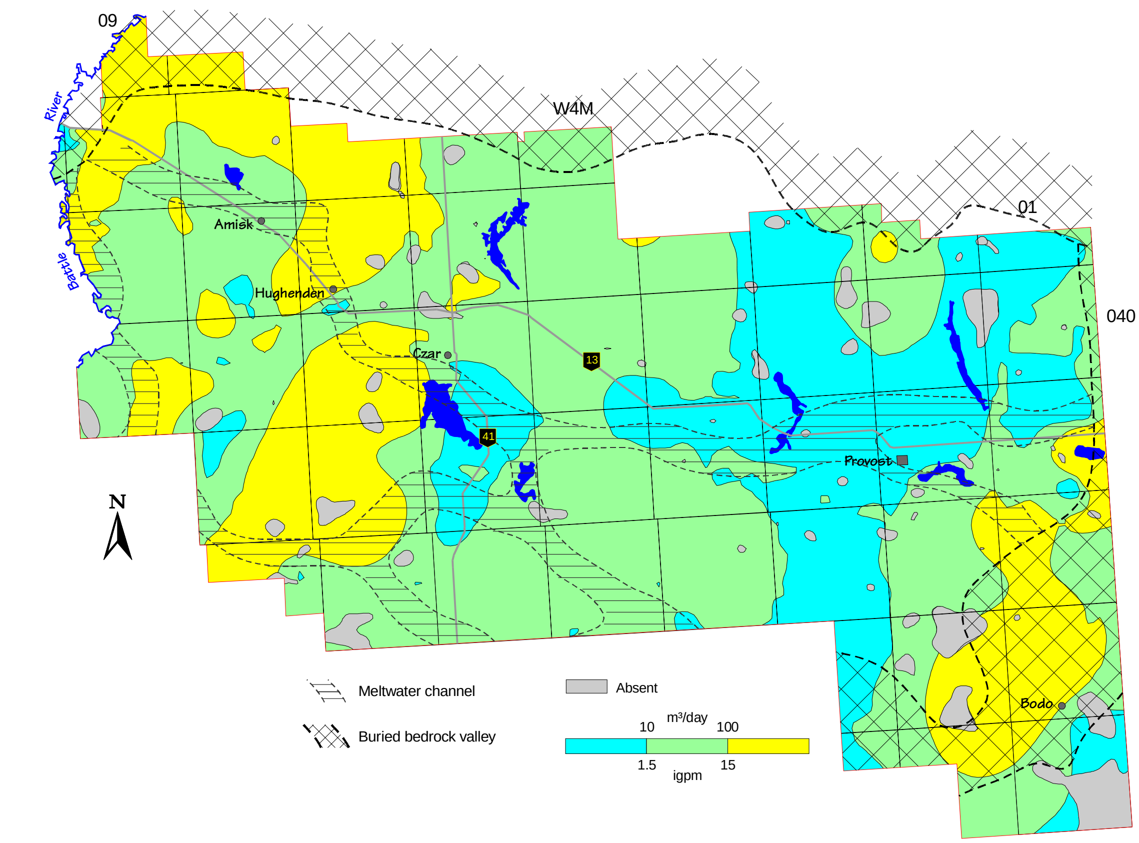
M.D. of Provost No. 52
Apparent Yield for Water Wells Completed through Sand and Gravel Aquifer(s)



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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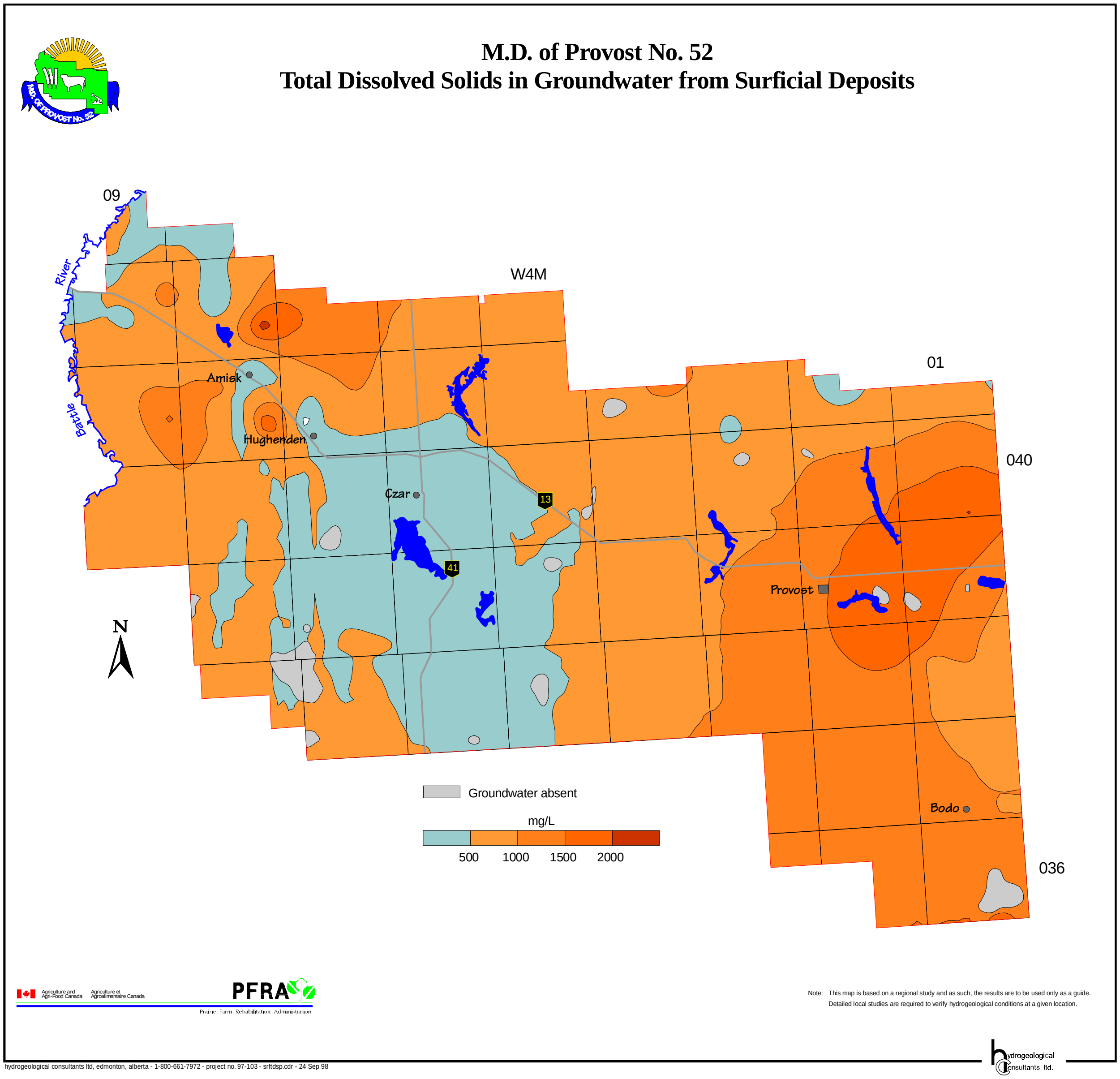
M.D. of Provost No. 52
Total Dissolved Solids in Groundwater from Surficial Deposits
09
W4M
01
040
036
Battle River
Amisk
Hughenden
Czar
13
41
Provost
Bodo
N
Groundwater absent
mg/L
500
1000
1500
2000
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
PFRA
Prairie Farm Rehabilitation 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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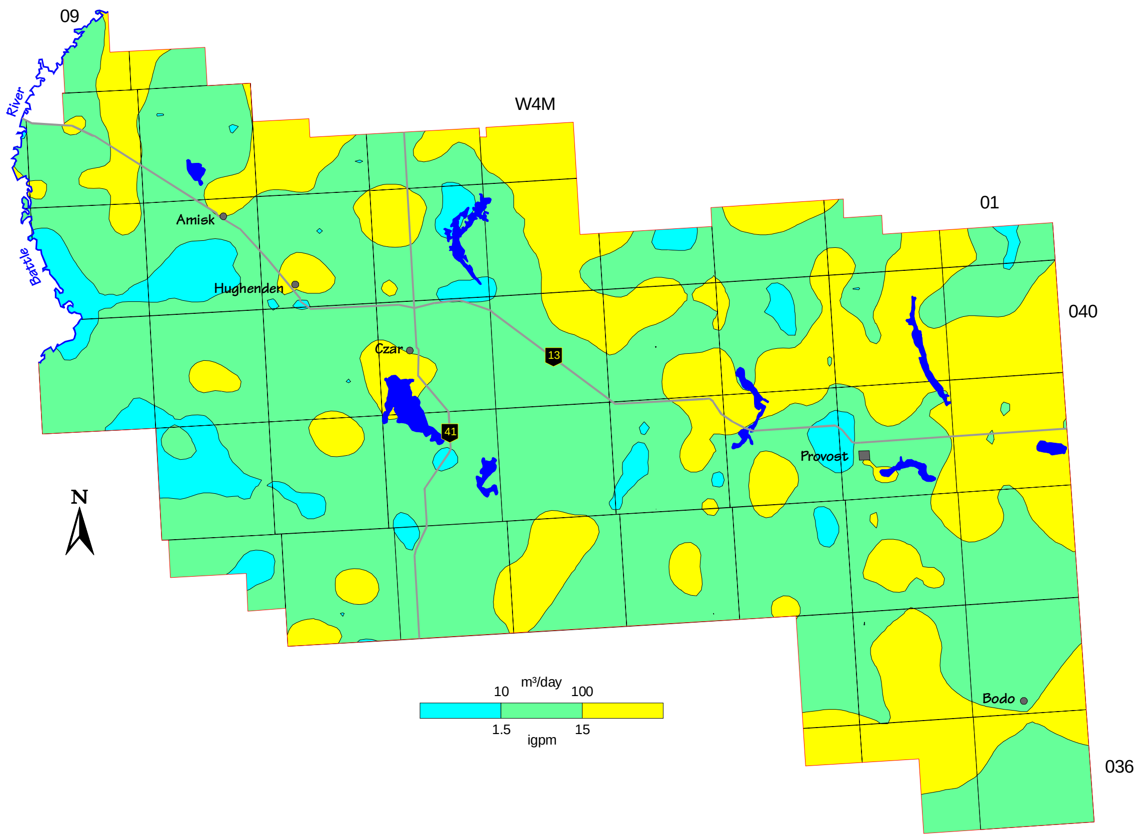
M.D. of Provost No. 52
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



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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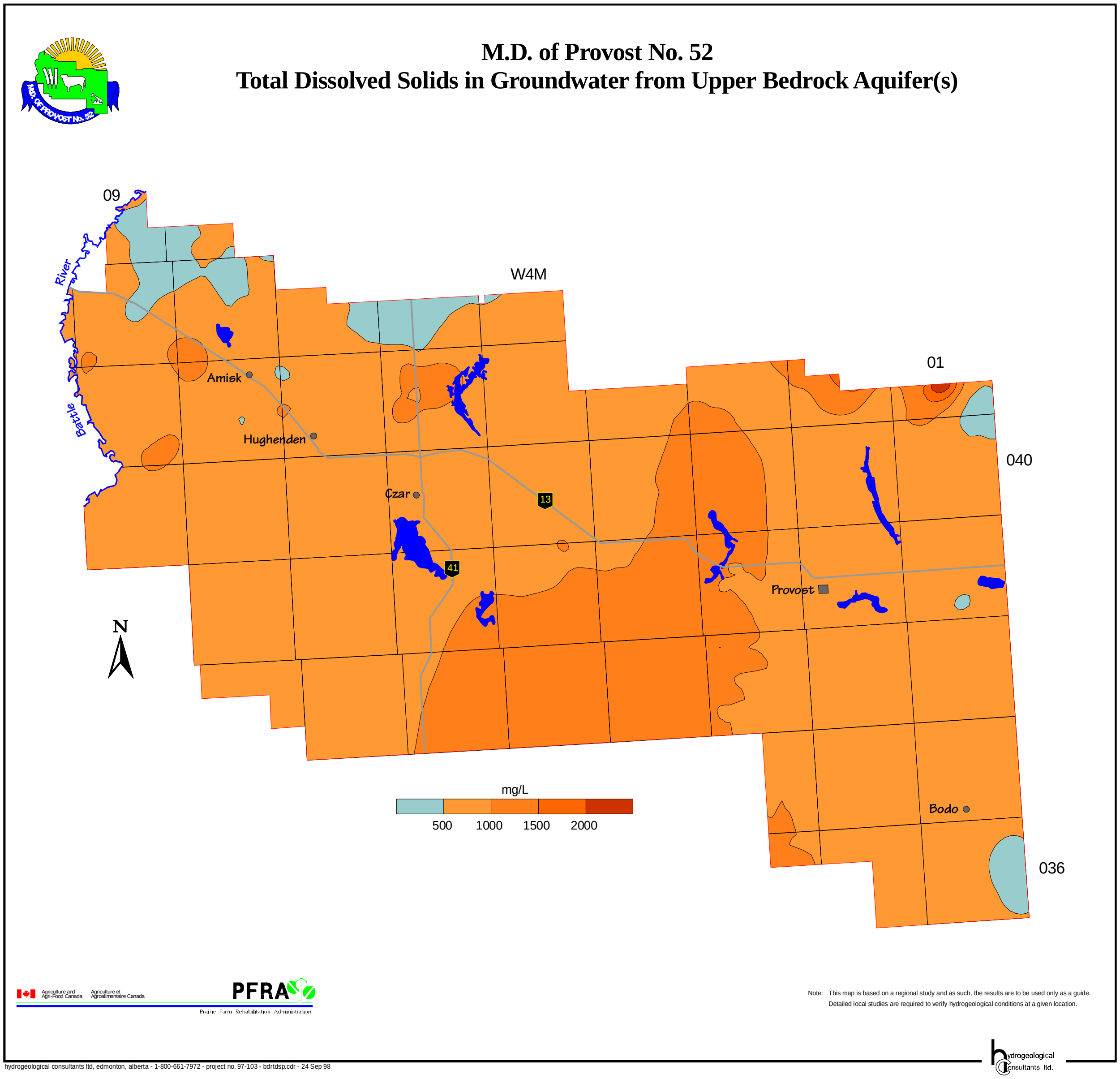
M.D. of Provost No. 52
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)
09
W4M
01
040
036
Battle River
Amisk
Hughenden
Czar
13
41
Provost
Bodo
N
mg/L
500
1000
1500
2000
PFRA
Note: This map is based on a regional study and as such, the results are to be used only as a guide.
Detailed local studies are required to verify hydrogeological conditions at a given location.
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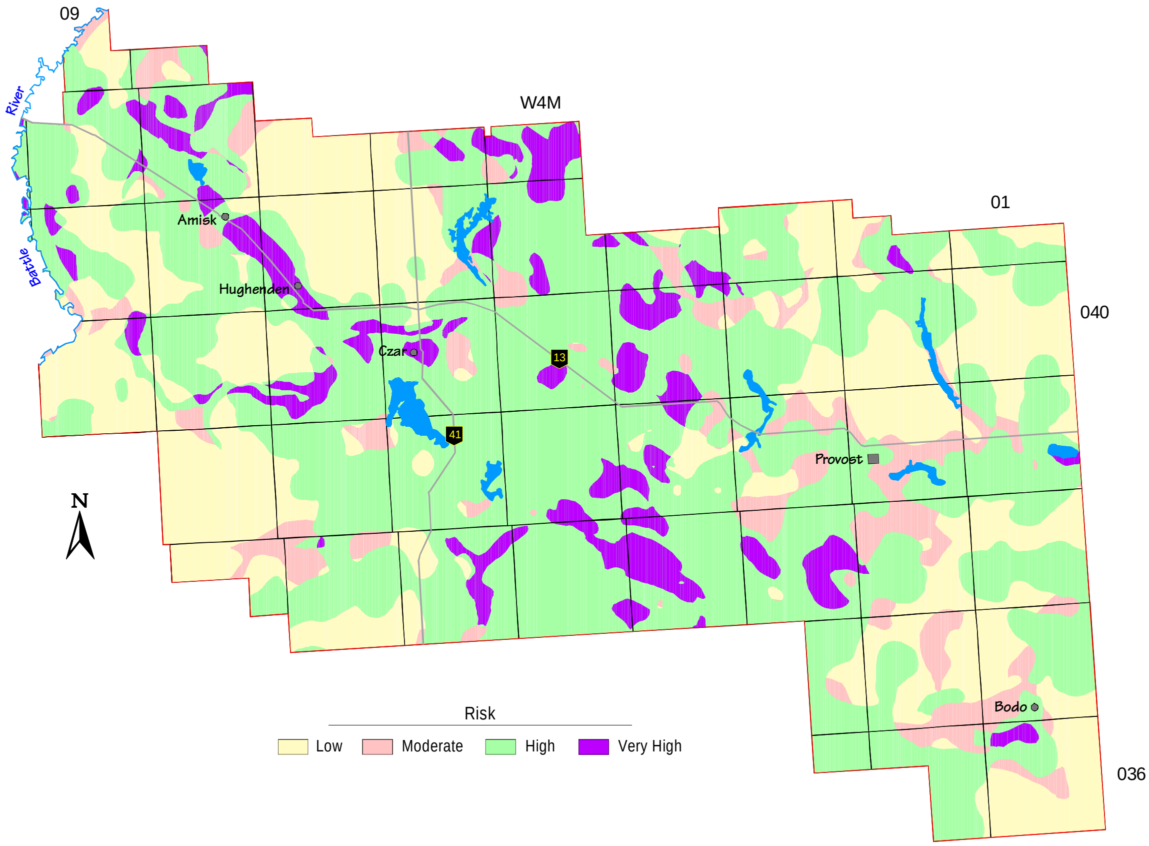
M.D. of Provost No. 52
Risk of Groundwater Contamination



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

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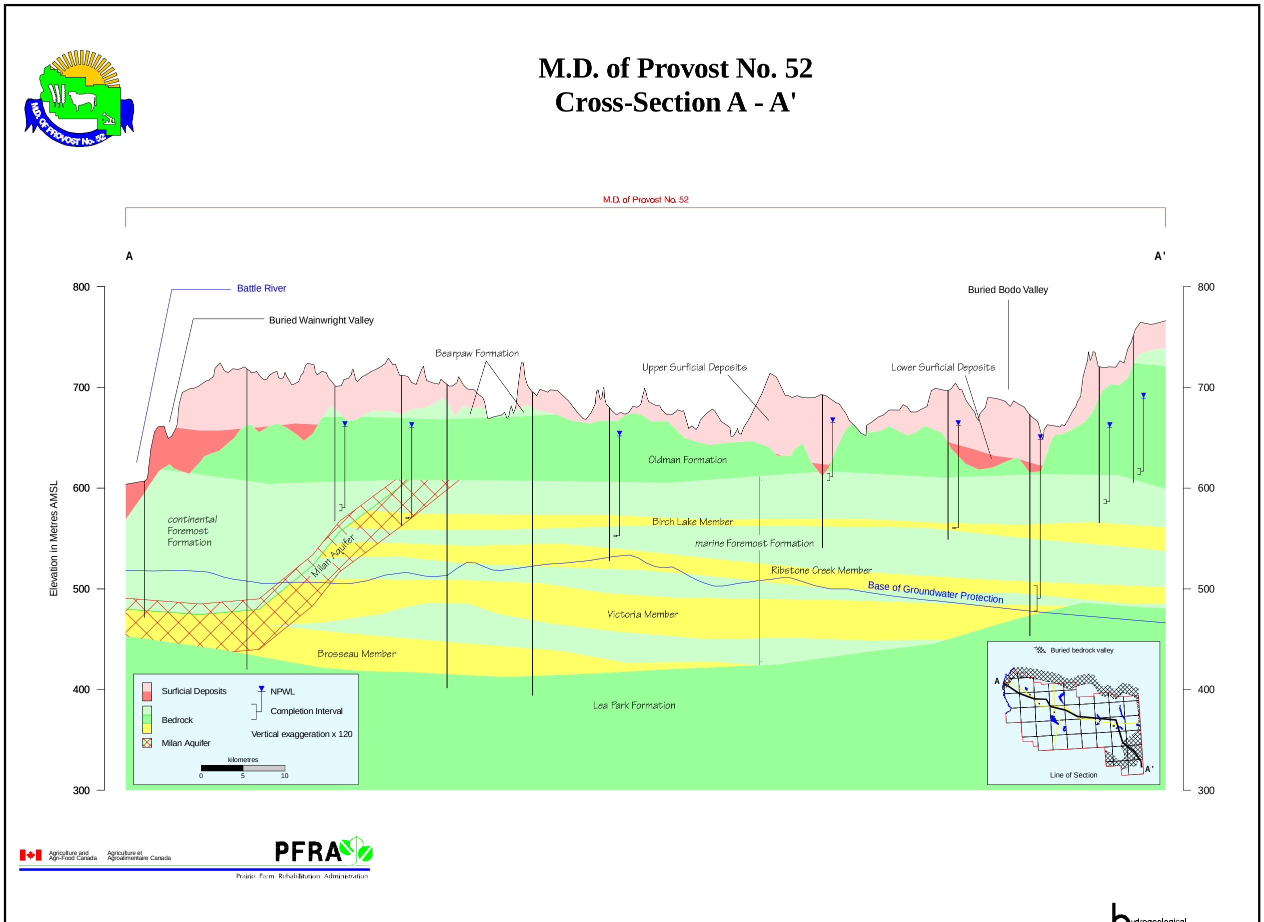

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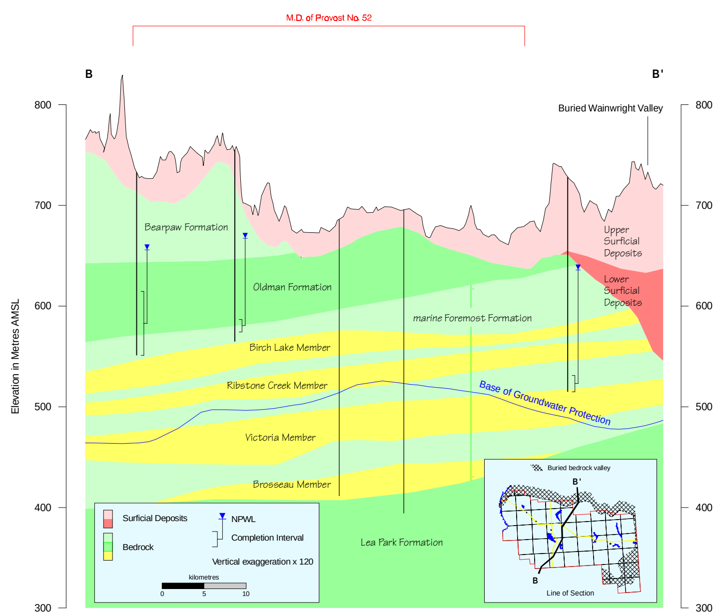
M.D. of Provost No. 52
Cross-Section B - B'



hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 97-103 - csBB-e.cdr - 25 Sep 98