County of Paintearth No. 18

Part of the Battle River Basin
Parts of Tp 035 to 041, R 08 to 16, W4M
Regional Groundwater Assessment

Prepared for

In conjunction with

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada
Prairie Farm Rehabilitation Administration | Administration du rétablisseme agricole des Prairies

Canada

Prepared by
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1 Project Overview

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

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

1.1 About This Report

This report provides an overview of (a) the groundwater resources of the County of Paintearth, (b) the processes used for the present project and (c) the groundwater characteristics in the County.

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

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

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

Appendix C includes the following:

1) a procedure for conducting aquifer tests with water wells;
2) a table of contents for the Water Well Regulation under the Environmental Protection and Enhancement Act;
3) a flow chart showing the licensing of a groundwater diversion under the new Water Act; and
4) 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. The new Water Act was proclaimed 10 Jan 1999.

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

1.2 The Project

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

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

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

This report and the accompanying maps represent Modules 2 and 3.

1.3 Purpose

This project is a regional groundwater assessment of the County of Paintearth. The regional groundwater assessment provides the information to assist in the management of the groundwater resource within the County. Groundwater resource management involves determining the suitability of various areas in the County for particular activities. These activities can vary from the development of groundwater for agricultural or industrial purposes, to the siting of waste storage. **Proper management ensures protection and utilization of the groundwater resource for the maximum benefit of the people of the County.**

The regional groundwater assessment includes:

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

Under the present program, the groundwater-related data for the County have been assembled. Where practical, the data have been digitized. These data are then being used in the regional groundwater assessment for the County.

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[1] See glossary
[2] See glossary

2 Introduction

2.1 Setting

The County of Paintearth is situated in east-central Alberta. This area is part of the Alberta Plains region. The County is within the Battle River basin; a part of the County's northern boundary is the Battle River. The other County boundaries follow township or section lines. The area includes parts of the area bounded by township 041, range 16, W4M in the northwest and township 035, range 08, W4M in the southeast.

Regionally, the topographic surface varies between 600 and 850 metres above mean sea level (AMSL). The lowest elevations occur in the Battle River Valley in the northern part of the County and the highest are in the southwestern part of the County as shown in Figure 1.

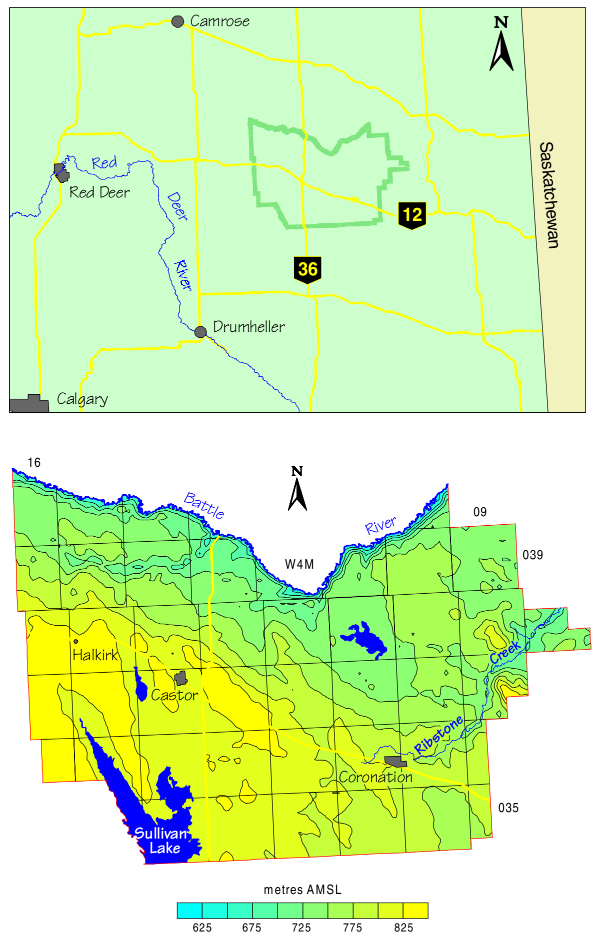

Figure 1. Index Map

2.2 Climate

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

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

The mean annual precipitation averaged from three meteorological stations within the County measured 422 millimetres (mm), based on data from 1961 to 1993. The annual temperature averaged 2.9 °C, with the mean monthly temperature reaching a high of 17.1 °C in July, and dropping to a low of -13.6 °C in January. The calculated annual potential evapotranspiration is 529 millimetres.

2.3 Background Information

There are currently records for 2,136 water wells in the groundwater database for the County. Of the 2,136 water wells, 1,914 are for domestic/stock purposes. The remaining 222 water wells were completed for a variety of uses, including industrial, municipal and observation. Based on a rural population of 2,316, there are 3.7 domestic/stock water wells per family of four. The domestic or stock water wells vary in depth from 0.22 metres to 289.8 metres below ground level. Lithologic details are available for 1,180 water wells.

Data for casing diameters are available for 972 water wells, with 739 indicated as having a diameter of less than 275 mm and 201 having a diameter of more than 300 mm. The casing diameters of greater than 300 mm are mainly bored or dug water wells and those with a surface casing diameter of less than 275 mm are drilled water wells. Large diameter water wells are mainly present where the Lower Horseshoe Canyon Formation subcrops.

Steel, galvanized steel and plastic represent 99% of the materials that have been used for surface casing in drilled water wells over the last 40 years in the County. Until the 1970s, the type of surface casing used in drilled water wells was largely undocumented. Steel casing was in use in the 1950s and is still used in 45% of the water wells being drilled in the County. Steel and galvanized steel were the main casing types until the start of the 1980s, when plastic casing and steel casing replaced the use of galvanized steel.

Galvanized steel surface casing was used in a maximum of 8% of the new water wells from the 1950s to the early 1990s. Galvanized steel was last used in October 1991.

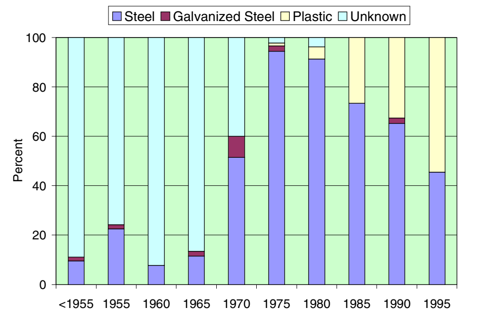

Figure 2. Surface Casing Types used in Drilled Water Wells

There are 1,130 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 285. The adjacent map shows that these water wells occur mostly in the northeastern part of the County. Approximately 70% of the water wells completed in surficial aquifers have a completion depth of less than 30 metres.

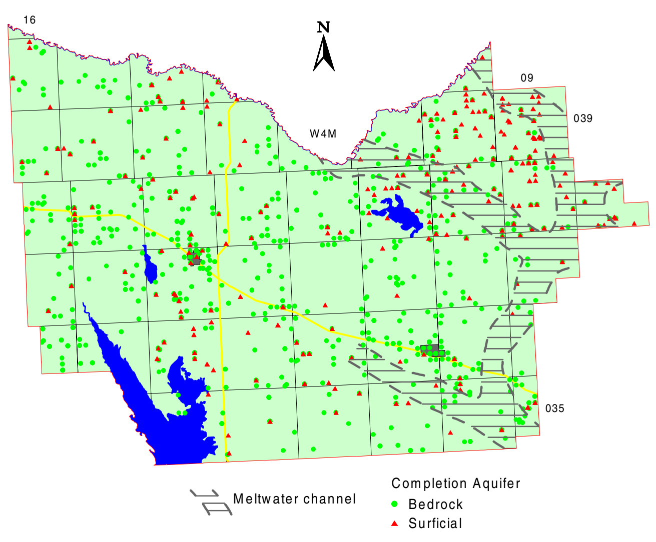

Figure 3. Location of Water Wells

The remaining 845 water wells have the top of their completion interval deeper than the top to the bedrock surface. From Figure 3, it can be seen that water wells completed in bedrock aquifers occur over most of the County, but percentage wise, there are fewer water wells completed in bedrock aquifers in the northeastern part of the County.

Water wells not used for domestic needs and providing groundwater with total dissolved solids (TDS) of less than 4,000 milligrams per litre (mg/L) must be licensed. At the end of 1996, 76 groundwater diversions were licensed in the County. Of the 76 licensed groundwater users, 45 are for agricultural purposes, and the remaining 31 are for industrial, municipal and other purposes. The total maximum authorized diversion from the water wells associated with these licences is 3,050 cubic metres per day (m^3/day); 48% percent of the authorized groundwater diversion is allotted for industrial use, 37% is allotted for municipal use, and 14% is allotted for agricultural use. The largest potable groundwater diversion licensed within the County is for the Town of Coronation, having a diversion of 483.5 m^3/day. The largest licensed industrial groundwater diversion within the County is for a saline water source well in 11-03-031-10 W4M owned by Fletcher Challenge Petroleum.

The adjacent table shows a breakdown of the 76 licensed groundwater diversions by the aquifer in which the water well is completed. With the exception of the saline source wells, the highest licensed diversions are for water wells completed in the Lower Horseshoe Canyon and Bearpaw aquifers; the majority of the groundwater is used for industrial and municipal purposes.

	Licensed Groundwater Users (m^3/day)					
Aquifer	Agricultural	Industrial	Municipal	Other	Total	Percentage
Upper Sand and Gravel	61	0	0	0	61	2
Lower Horseshoe Canyon	274	3	592	0	869	28
Bearpaw	95	47	531	10	683	22
Oldman	0	433	0	0	433	14
Foremost	0	0	0	0	0	0
Saline Source Wells	0	994	0	0	994	33
Unknown	10	0	0	0	10	0
Total	440	1,477	1,123	10	3,050	
Percentage	14	48	37	0		

Table 1. Licensed Groundwater Diversions

Based on the 1996 Agriculture Census, the water requirement for livestock for the County is in the order of 8,798 m^3/day, which is twenty times the amount of the groundwater diversion that is licensed for agricultural purposes.

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

Groundwaters from the surficial deposits can be expected to be chemically hard with a high dissolved iron content. The TDS concentrations in the groundwaters from the upper bedrock in the County are generally less than 1,500 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 10% of the chemical analyses indicate a fluoride concentration above 1.5 mg/L.

The minimum, maximum and average concentrations of TDS, sodium, sulfate, chloride and fluoride in the groundwaters from water wells completed in the upper bedrock in the County have been compared to the Guidelines for Canadian Drinking Water Quality (GCDWQ) in Table 2. Of the five constituents compared to the GCDWQ, only average values of TDS and sodium concentrations exceed the guidelines.

	Groundwater Concentrations from Bedrock Water Wells in the County			Recommended Maximum Concentration
Constituent	Minimum	Maximum	Average	GCDWQ
Total Dissolved Solids	335	5652	1414	500
Sodium	20	1723	486	200
Sulfate	4	3509	342	500
Chloride	1.0	1712	157	250
Fluoride	0.1	5.6	0.7	1.5

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives

GCDWQ - Guidelines for Canadian Drinking Water Quality, Sixth Edition
Minister of Supply and Services Canada, 1996

Table 2. Concentrations of Constituents in Groundwaters from Upper Bedrock Aquifer(s)

Alberta Environmental Protection (AEP) defines the Base of Groundwater Protection as the elevation below which the groundwater is expected to have more than 4,000 mg/L of total dissolved solids. By using the ground elevation, the bedrock surface and the Base of Groundwater Protection provided by the Alberta Energy and Utilities Board (EUB), a depth to the Base of Groundwater Protection can be determined. This depth, for the most part, would be the maximum drilling depth for a water well for agricultural purposes or for a potable water supply. If a water well is completed below the Base of Protection with the total dissolved solids of the groundwater exceeding 4,000 mg/L, then the groundwater use does not require licensing by AEP.

Over approximately 60% of the County, the depth to the Base of Groundwater Protection is more than 250 metres. There are only a few areas where the depth to the Base of Groundwater Protection is less than 100 metres; these areas are mainly within a few kilometres of the Battle River as shown on the adjacent map.

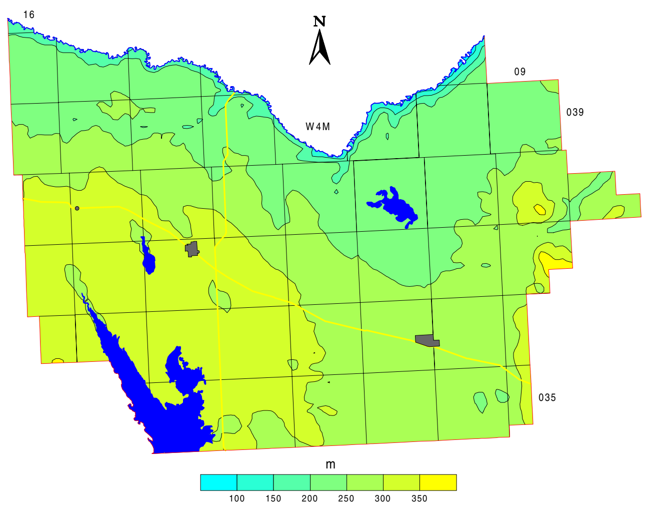

Figure 4. Depth to Base of Groundwater Protection (after EUB, 1995)

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

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

3 Terms

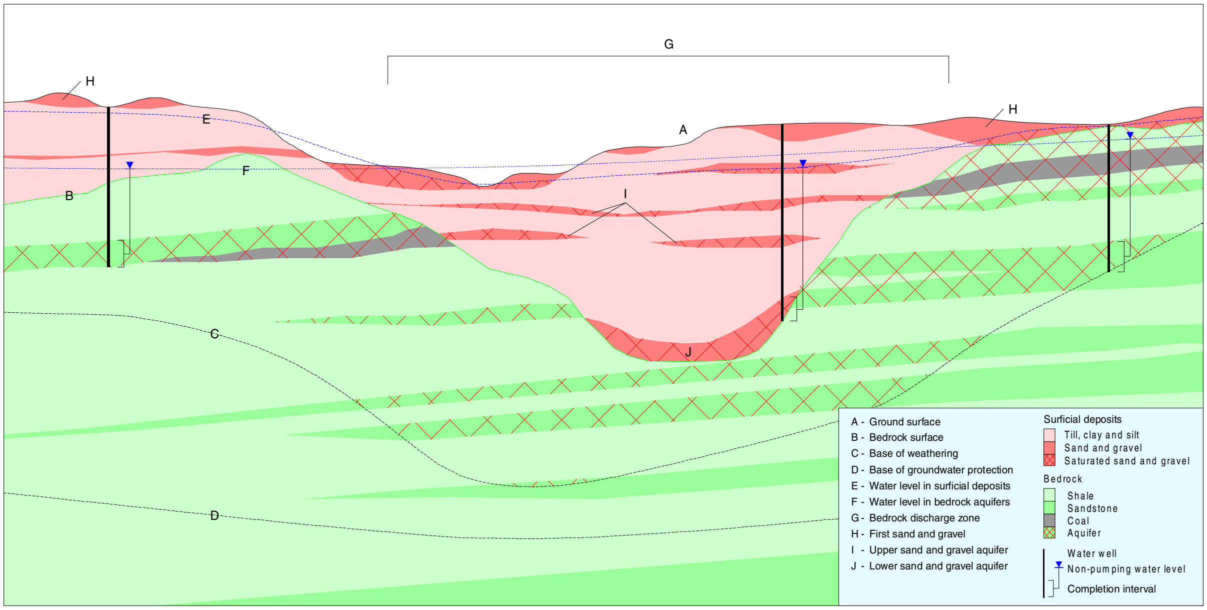

Figure 5. Generalized Cross-Section (for terminology only)

		Group and Formation			Member		Zone	
Lithology	Lithologic Description	Thickness (m)		Designation	Thickness (m)	Designation	Thickness (m)	Designation
	sand, gravel, till, clay, silt	<50	Surficial Deposits		<50	Upper	<15	First Sand and Gravel
	shale, sandstone, siltstone, coal, bentonite, limestone, ironstone	300-380	Edmonton Group	Horseshoe Canyon Formation	~100	Upper		
					~100	Middle		
					~170	Lower		
	shale, sandstone, siltstone	60-120	Bearpaw Formation					
	sandstone, siltstone, shale, coal	40-130	Belly River Group	Oldman Formation		Dinosaur Member	<0-25	Lethbridge Coal Zone
						Upper Siltstone Member		
						Comrey Member		
	sandstone, shale, coal	<200	Belly River Group	Foremost Formation	<70	Birch Lake Member		Taber Coal Zone
					<60	Ribstone Creek Member		
					<70	Victoria Member		
					<30	Brosseau Member		McKay Coal Zone
	shale, siltstone	30-60	Lea Park Formation					
	sandstone, siltstone, shale, coal	90-120	Milk River Formation					

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. However, unlike other areas in the Province where there are numerous duplicate records, the present database for the County contains less than 50 duplicate water well IDs.

The AEP groundwater database uses a land-based system with only a limited number of records having a value for ground elevation. The locations for records usually include a quarter section description; a few records also have a land description that includes a Legal Subdivision (Lsd). For digital processing, a record location requires a horizontal coordinate system. In the absence of an actual location for a record, the record is given the coordinates for the centre of the land description.

The present project uses the 10TM coordinate system. This means that a record for the SE ¼ of section 13, township 036, range 11, W4M, would have a horizontal coordinate with an Easting of 243883 metres and a Northing of 5774310 metres, the centre of the quarter section. If the water well has been positioned by the Prairie Farm Rehabilitation Administration (PFRA), the location will be more accurate, possibly within several 10s of metres of the actual location. Once the horizontal coordinates are determined for a record, a ground elevation for that record is obtained from the 1:20,000 Digital Elevation Model (DEM) from the Resource Data Division of AEP.

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

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

1) depth to bedrock;
2) total thickness of sand and gravel;
3) thickness of first sand and gravel when present within one metre of ground surface;
4) total thickness of saturated sand and gravel; 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. Where valid detailed aquifer test results exist, the interpreted data provide values for aquifer transmissivity and effective transmissivity.

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

The EUB well database includes records for all of the wells drilled by the oil and gas industry. The information from this source includes:

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

Values for apparent transmissivity, apparent yield and hydraulic conductivity[5] 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 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.

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5 See glossary
6 See glossary

4.3 Hydrogeological Parameters

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

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

Once the values for the various parameters of the individual aquifers are established, the spatial distribution of these parameters must be determined. The distribution of individual parameters involves the same process as the distribution of geological surfaces. This means establishing a representative data set and then preparing a grid. Even when only limited data are available, grids are prepared. However, the data from these grids must be used with extreme caution because the gridding process can be unreliable.

4.3.1 Risk Criteria

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

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

Table 3. Risk of Groundwater Contamination Criteria

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 outline and the thickness of the geological unit. The thickness of the porous and permeable part(s) of the geological unit is used to determine the aquifer transmissivity by multiplying the hydraulic conductivity by the thickness.

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

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

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

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

4.5 Software

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

- Acrobat 4.0
- ArcView 3.1
- AutoCAD 14.01
- CorelDRAW! 8.0
- Microsoft Professional Office 97
- Surfer 6.04

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7 See glossary

5 Aquifers

5.1 Background

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

5.1.1 Surficial Aquifers

Surficial deposits in the County are mainly less than ten metres thick, except in areas of linear bedrock lows where the thickness of the surficial deposits can exceed 30 metres. There are a series of linear bedrock lows in the eastern part of the County that trend generally from northwest to southeast. Cross-section A-A' passes across these linear bedrock lows, and shows the thickness of the surficial deposits varying from less than five to more than 30 metres.

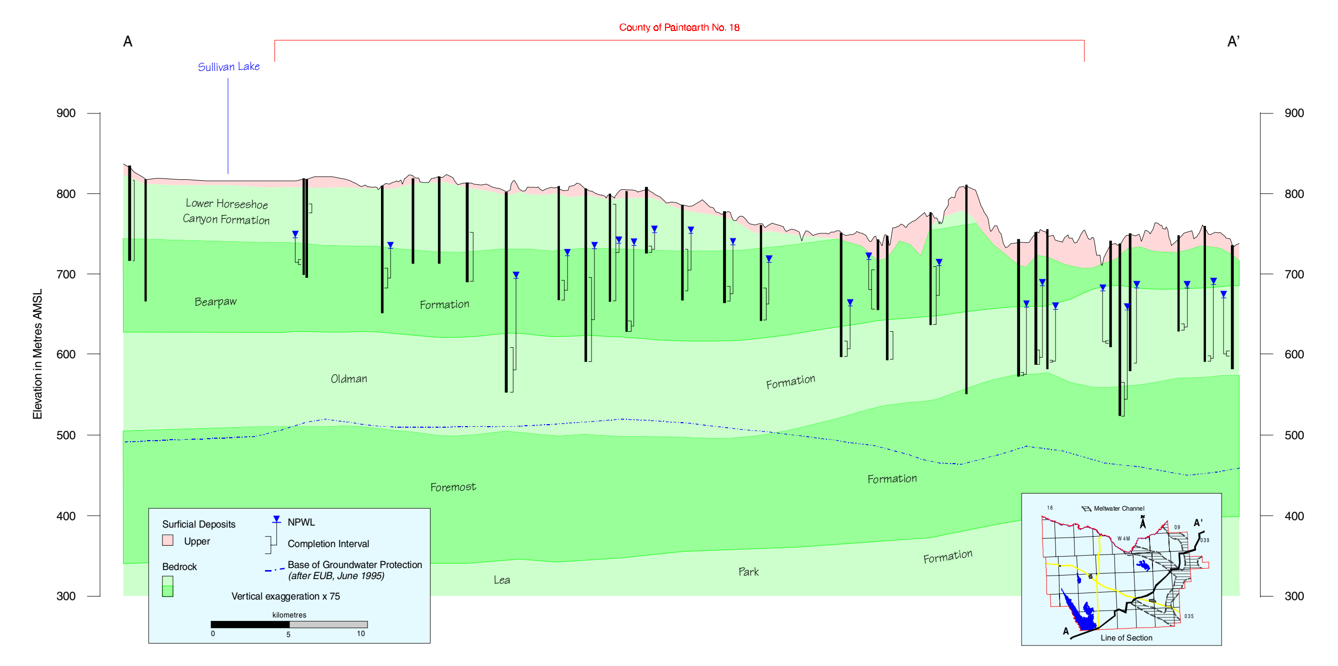

Figure 7. Cross-Section A - A'

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

For a water well with a small-diameter casing to be effective in surficial deposits and to provide sand-free groundwater, the water well must be completed with a water well screen. Some water wells completed in the surficial deposits are completed in low-permeability aquifers and have a large-diameter casing. The large-diameter water wells may have been hand dug or bored and because they are completed in very low permeability aquifers, most of these water wells would not benefit from water well screens. The groundwater from an aquifer in the surficial deposits usually has a chemical hardness of at least a few hundred milligrams per litre and a dissolved iron concentration such that the groundwater must be treated before being used for domestic needs. Within the County, casing diameter information is available for 165 of the 285 water wells completed in the surficial deposits; 41 of these have a casing diameter of more than 300 millimetres, and are assumed to be bored or dug water wells.

5.1.2 Bedrock Aquifers

The upper bedrock includes rocks that are less than 200 metres below the bedrock surface and above the Lea Park Formation. Some of this bedrock contains porous, permeable and saturated rocks that are permeable enough to transmit groundwater for a specific need. Water wells completed in bedrock aquifers usually do not require water well screens, although some of the sandstones are friable[8] and water well screens are a necessity. The groundwater from the bedrock aquifers is usually chemically soft.

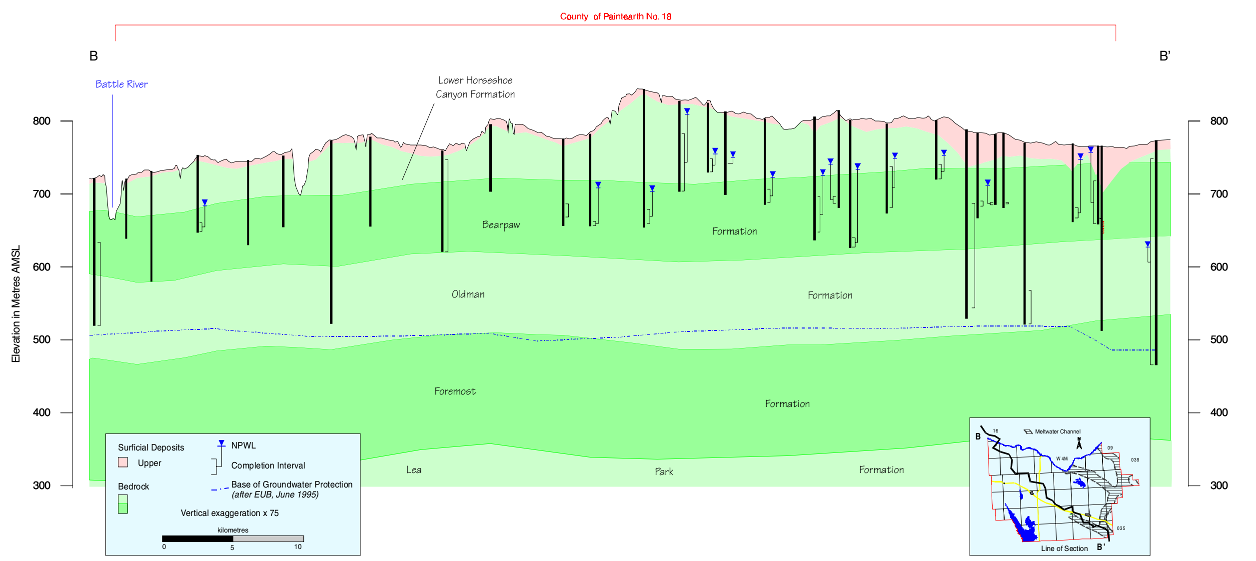

Figure 8. Cross-Section B - B'

The data for 845 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. Within the County, casing diameter information is available for 498 of the 845 water wells completed in the bedrock aquifers. Of these 498 water wells, 95% have surface casing diameters of less than 275 mm and these bedrock water wells have been mainly completed with either a slotted liner or as open hole. There were 53 bedrock water wells that were completed with a water well screen.

The upper bedrock includes the Middle and Lower Horseshoe Canyon formations, the Bearpaw Formation and the Oldman Formation (Figure 8). The Foremost Formation underlies the Oldman Formation; the Lea Park Formation underlies the Foremost Formation and is a regional aquitard[9].

8 See glossary
9 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[10] and lacustrine[11] deposits. The lacustrine deposits include clay, silt and fine-grained sand. The *upper surficial deposits* include the more traditional glacial deposits of till[12] and meltwater deposits. In the County, no lower surficial deposits have been defined to date and the upper surficial deposits include mainly till.

5.2.1 Geological Characteristics of Surficial Deposits

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

Over the majority of the County, the upper surficial deposits are less than ten metres thick. The exceptions are mainly in association with areas where linear bedrock lows are indicated, where the deposits can have a thickness of up to 30 metres. There are several connecting linear bedrock lows in the County as shown on the adjacent bedrock topography map. These lows trend mainly northwest to southeast in the County and are indicated as being of meltwater origin. One linear bedrock low trends northeast to southwest and occupies the present-day Ribstone Creek.

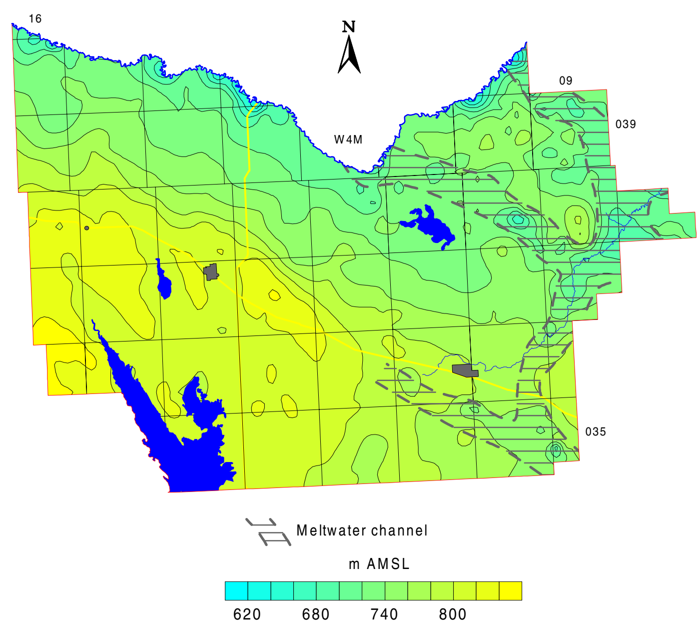

Figure 9. Bedrock Topography

Sand and gravel deposits can occur throughout the surficial deposits. The total thickness of sand and gravel deposits is generally less than five metres but can be more than 15 metres in the areas of the linear bedrock lows.

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10 See glossary
11 See glossary
12 See glossary

The combined thickness of all sand and gravel deposits has been determined as a function of the total thickness of the surficial deposits. Over approximately 30% of the County, the sand and gravel deposits are more than 50% of the total thickness of the surficial deposits. The areas where the sand and gravel percentages are more than 50% in the County occur mainly in the northwestern, northeastern and southern parts of the County. In the meltwater channels, the sand and gravel percentages are expected to be mostly more than 50% of the total thickness of the surficial deposits.

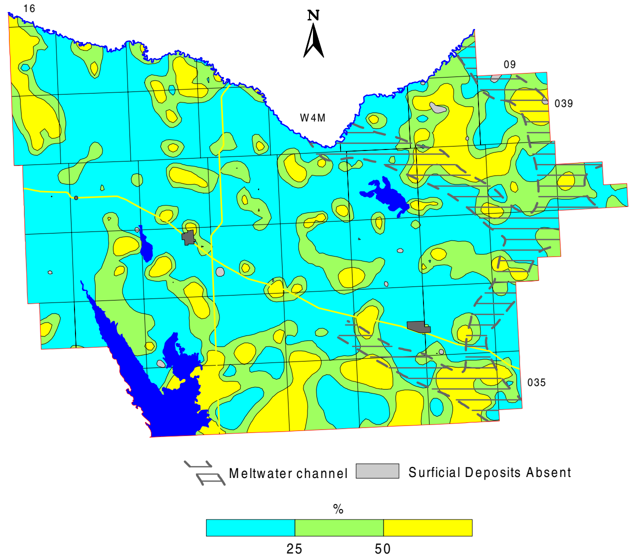

Figure 10. Amount of Sand and Gravel in Surficial Deposits

5.2.2 Water Wells Completed in Surficial Deposits

One source of groundwater in the County includes aquifers in the surficial deposits. Since the sand and gravel aquifer(s) are not everywhere, the actual aquifer that is developed at a given location is usually dictated by the aquifer that is present. From the present hydrogeological analysis, 402 water wells are completed in aquifers in the upper surficial deposits. This number of water wells is nearly 1.5 times the number determined to be completed in aquifers in the surficial deposits, based on lithologies given on the water well drilling reports. The larger number is obtained by comparing the elevation of the reported depth of a water well to the elevation of the bedrock surface at the same location. For example, if only the depth of a water well is known, the elevation of the completed depth can be calculated. If the elevation of the completed depth is above the expected elevation of the bedrock surface at the same location, then the water well is determined to be completed in an aquifer in the surficial deposits.

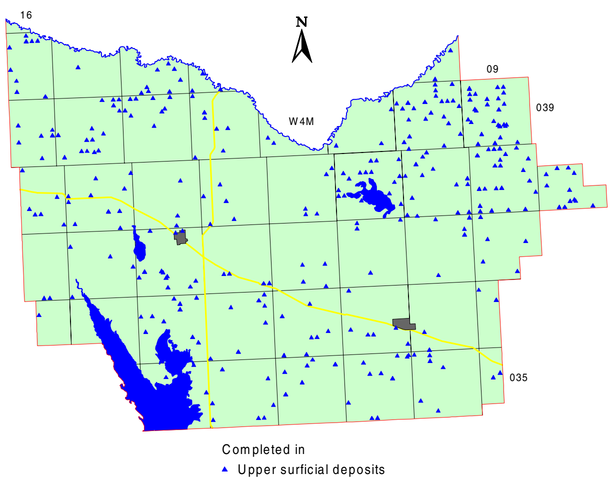

Figure 11. Water Wells Completed in Surficial Deposits

The water wells completed in the upper surficial deposits occur throughout the County, but are mainly concentrated in the northeastern part of the County, as shown in Figure 11.

5.2.2.1 Chemical Quality of Groundwater from Surficial Deposits

The groundwaters from the surficial deposits are mainly calcium-magnesium-bicarbonate or sodium-bicarbonate-type waters, with approximately 80% of the groundwaters having a TDS of less than 1,500 mg/L. The groundwaters with TDS of more than 1,500 mg/L occur mainly in the central and northwestern parts of the County. Groundwaters from the surficial deposits are expected to have dissolved iron concentrations of less than 1 mg/L.

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

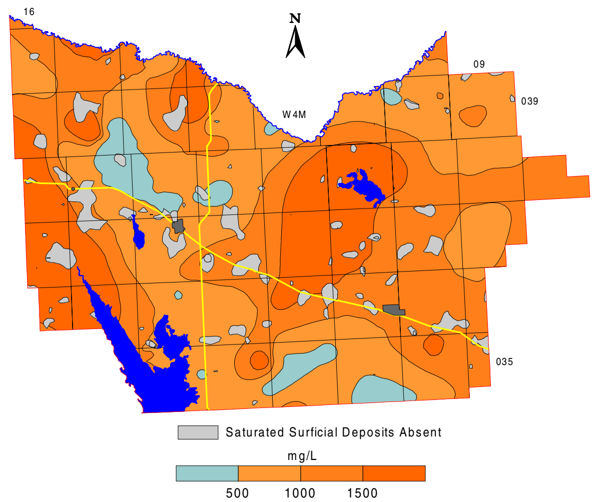

Figure 12. Total Dissolved Solids in Groundwater from Surficial Deposits

Constituent	Range for County in mg/L Minimum	Maximum	Average	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	372	4908	1193	500
Sodium	23	966	324	200
Sulfate	2	3200	382	500
Chloride	2	506	87	250
Fluoride	0.1	1.3	0.4	1.5

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives

GCDWQ - Guidelines for Canadian Drinking Water Quality, Sixth Edition
Minister of Supply and Services Canada, 1996

Table 4. Concentrations of Constituents in Groundwaters from Surficial Deposits

The minimum, maximum and average concentrations of TDS, sodium, sulfate, chloride and fluoride in the groundwaters from water wells completed in the surficial deposits in the County have been compared to the Guidelines for Canadian Drinking Water Quality (GCDWQ) in the adjacent table. Of the five constituents that have been compared to the GCDWQ, only the average values of TDS and sodium concentrations exceed the guidelines.

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 can directly overlie or be close to the bedrock surface. Saturated sand and gravel deposits are not continuous but are expected over approximately 30% of the County.

5.2.3.1 Aquifer Thickness

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

While the sand and gravel deposits in the upper surficial deposits are not continuous, the Upper Sand and Gravel Aquifer includes all of the aquifers present in the upper surficial deposits. The Upper Sand and Gravel Aquifer is more than ten metres thick in a few areas, but over the majority of the County, is less than five metres thick; over 70% of the County, the Aquifer is absent. Most of the greater thickness in the Upper Sand and Gravel Aquifer occurs in the areas of linear bedrock lows.

The permeability of the Upper Sand and Gravel Aquifer can be high. The high permeability combined with significant thickness leads to an extrapolation of water wells with high yields; however, because the sand and gravel deposits occur mainly as hydraulically discontinuous pockets, the apparent yields of the water wells are limited. The apparent yields for water wells completed in this Aquifer are expected to be mainly less than 50 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.

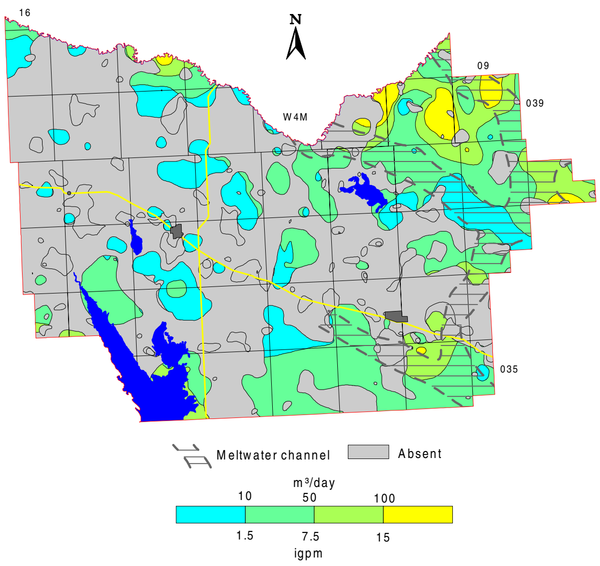

Figure 13. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

5.2.4 Lower Sand and Gravel Aquifer

In the County, no lower surficial deposits, and therefore no Lower Sand and Gravel Aquifer, have been defined to date.

5.3 Bedrock

5.3.1 Geological Characteristics

The upper bedrock in the County includes the Middle and Lower Horseshoe Canyon formations, the Bearpaw Formation, and the Oldman Formation of the Belly River Group. The Lea Park Formation underlies the Belly River Group. The adjacent bedrock geology map has been prepared from the interpretation of geophysical logs related to oil and gas activity.

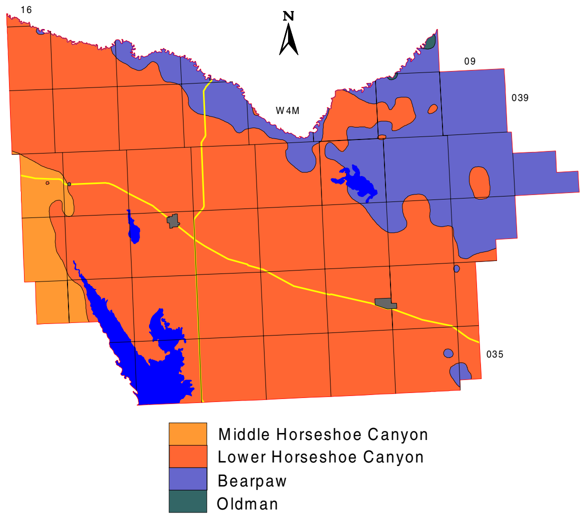

Figure 14. Bedrock Geology

The Horseshoe Canyon Formation is the lower part of the Edmonton Group and is the upper bedrock in the western two-thirds of the County. The Horseshoe Canyon Formation has a maximum thickness of 150 metres and has three separate designations: Upper, Middle and Lower. The Upper Horseshoe Canyon is absent within the County. The Middle Horseshoe Canyon subcrops in the extreme western part of the County and is up to 40 metres thick in this area. The Lower Horseshoe Canyon, which is up to 120 metres thick, subcrops in 70% of the County; there are also subcrops of the Lower Horseshoe Canyon Formation that occur as outliers within the area of the Bearpaw Formation.

The Horseshoe Canyon Formation consists of deltaic[13] and fluvial sandstone, siltstone and shale with interbedded coal seams, bentonite and thin nodular beds of limestone and ironstone. Because of the low-energy environment in which deposition occurred, the sandstones, when present, tend to be fine grained. The lower 60 to 70 metres and the upper 30 to 50 metres of the Horseshoe Canyon Formation can include coarse-grained sandstone deposits.

The Bearpaw Formation is the upper bedrock in the northeastern part of the County and is generally less than 100 metres thick in the County. The Bearpaw Formation consists of marine shale, siltstone and minor sandstone layers except in some areas where the thickness of the sandstone layers can be significant. The Bearpaw Formation "represents the final widespread marine unit in the Western Canada Foreland Basin" (Catuneanu et al, 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.

The Belly River Group in the County has a maximum thickness of 250 metres and includes the Oldman and Foremost formations. The Foremost Formation includes both a continental and a marine facies[14]. The Oldman Formation is present under the entire County, but subcrops only in a small area in township 040, range 10, W4M. The Oldman Formation has a maximum thickness of 130 metres within the County and is composed of sandstone, siltstone, shale and coal deposited in a continental environment. The Oldman Formation is composed of three parts: (a) the Comrey, (b) the Upper Siltstone and (c) 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.

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[13] See glossary
[14] See glossary

The Foremost Formation has a maximum thickness of 180 metres and is positioned between the overlying Oldman Formation and the underlying Lea Park Formation. The depositional environment for the Foremost Formation changed from continental in the west to marine in the east. In the marine section and close to the transition zone, individual members have been identified. The members include both sandstone and shale units. For the present project, the individual members are identified by the designation given to the sandstone members, with the underlying shale member being considered as the shale facies of the sandstone member. For example in this report, the Ribstone Creek Member includes the Ribstone Creek Member (a sandstone deposit) and the underlying shale deposit. In addition to having the Ribstone Creek Member include the underlying shale layers, the Member has been identified as a depositional interval that is present in both the continental and marine facies of the Foremost Formation. Therefore, within the continental facies of the Foremost Formation, a depositional interval has been identified that is given the same designation as the marine equivalent. Within the marine facies, the sandstone layers of individual members grade eastward into marine shale deposits.

The present breakdown of the Foremost Formation would not be possible without identifying a continuous top for the Lea Park Formation. The top of the Lea Park Formation represents a geologic time border between the marine environment of the Lea Park Formation and the mostly continental environment of the Foremost Formation. The top of the Lea Park Formation is the bottom of the higher resistivity layer that occurs within a few metres below a regionally identifiable bentonite marker, as shown in the adjacent e-log. This marker occurs approximately 100 metres above the Milk River shoulder. 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.

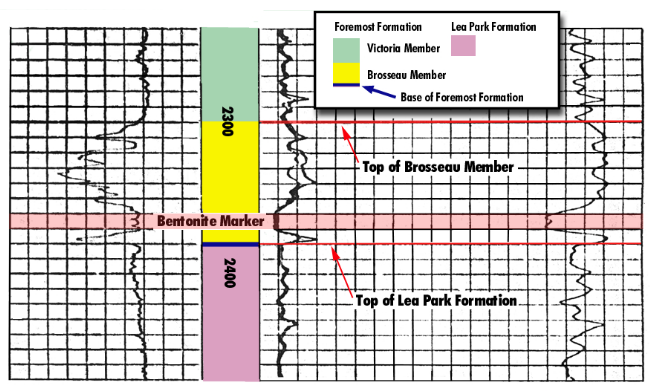

Figure 15. E-Log showing Base of Foremost Formation

The Milk River Formation underlies the Lea Park Formation and has a thickness of approximately 100 metres.

5.3.2 Aquifers

Of the 2,136 water wells in the database, 845 were defined as being completed in bedrock aquifers. This designation is based on the top of the completion interval being below the bedrock surface. However, the completion depth is available for the majority of water wells and assigning the water wells to specific geologic units is possible only if the completion interval is identified. 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. With this knowledge and the use of geological surfaces that were determined from the interpretation of geophysical logs, it has been possible to increase the aquifer of completion for 794 additional water wells with 191 water wells identified as being completed in more than one bedrock aquifer.

The bedrock water wells are mainly completed in the Lower Horseshoe Canyon and the Bearpaw aquifers, as shown in the adjacent table. Less than 10% of the bedrock water wells are likely to have multiple completions, of which 65% have the top of the first completion interval less than 100 metres below ground level.

Geological Unit	No. of Water Wells
Middle Horseshoe Canyon	32
Lower Horseshoe Canyon	940
Bearpaw	623
Oldman	41
Foremost	3
Other	191
Total	1,830

Table 5. Completion Aquifer

There are 579 records for bedrock water wells that have apparent yield values, 32% of all bedrock water wells. In the County, water well yields in the upper bedrock aquifer(s) are mainly less than 100 m³/day. The few areas of higher yields that are indicated on the adjacent figure are sporadic in the County. These higher yields may be a result of increased permeability that has resulted from the weathering process.

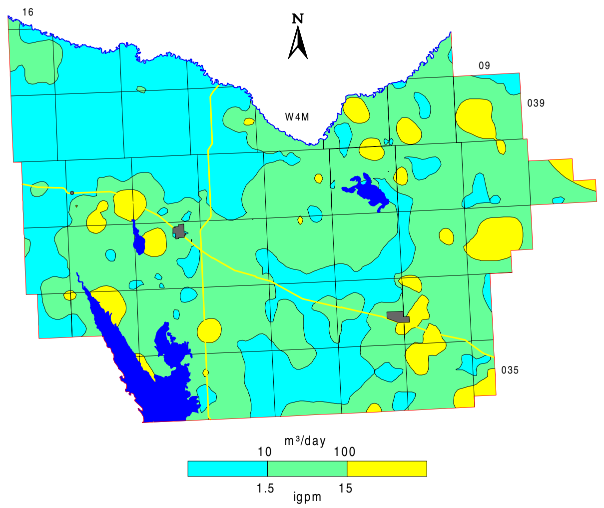

Figure 16. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

Of the 579 water well records with apparent yield values, 570 have been assigned to aquifers associated with specific geologic units. Fifty-one percent of the water wells completed in the bedrock aquifers have apparent yields that range from 10 to 100 m³/day, and 38% have apparent yields that are less than 10 m³/day, as shown in the adjacent table.

Aquifer	No. of Water Wells with Values for Apparent Yield	Number of Water Wells with Apparent Yields <10 m³/day	10 to 100 m³/day	>100 m³/day
Middle Horseshoe Canyon	3	1	1	1
Lower Horseshoe Canyon	267	121	127	19
Bearpaw	272	90	144	38
Oldman	27	5	19	3
Foremost	1	0	1	0
Totals	570	217	292	61

Table 6. 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. The TDS values of less than 1,000 mg/L are mainly in the south and northeastern parts of the County. In the northwestern part of the County, TDS values of greater than 1,700 mg/L tend to be associated with areas having apparent yields of less than 10 m³/day.

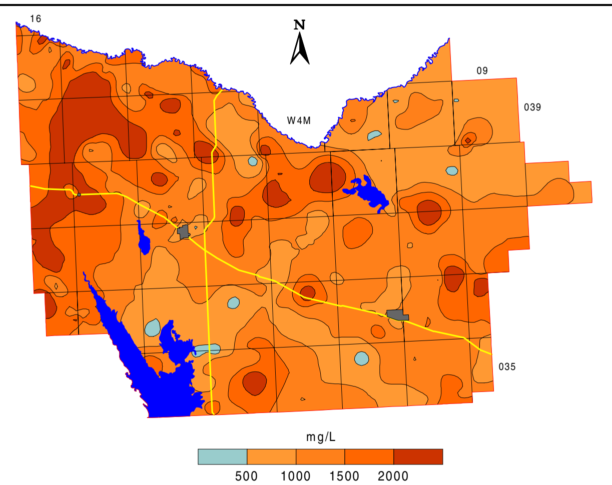

Figure 17. Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

The relationship between TDS and sulfate concentrations shows that when TDS values in the upper bedrock aquifer(s) exceed 1,200 mg/L, the sulfate concentrations exceed 400 mg/L. The chloride concentrations in the groundwaters from the upper bedrock aquifer(s) are less than 250 mg/L in more than 70% of the County.

In 90% of the County, the fluoride ion concentration in the groundwater from the upper bedrock aquifer(s) is less than 1.5 mg/L.

The Piper tri-linear diagrams [15] (see Appendix A) show that all chemical types of groundwater occur in the bedrock aquifers. However, the majority of the groundwaters are sodium-bicarbonate or sodium-sulfate types.

[15] See glossary

5.3.4 Middle Horseshoe Canyon Aquifer

The Middle Horseshoe Canyon Aquifer comprises the porous and permeable parts of the middle part of the Horseshoe Canyon Formation that underlies the extreme western part of the County, mainly in townships 036 to 038, ranges 15 and 16, W4M. The thickness of the Middle Horseshoe Canyon Formation is generally less than 30 metres; in most of the County, the Middle Horseshoe Canyon Formation has been eroded.

5.3.4.1 Depth to Top

The depth to the top of the middle part of the Horseshoe Canyon Formation is mainly less than ten metres below ground level and is a reflection of the thickness of the surficial deposits.

5.3.4.2 Apparent Yield

The apparent yields for individual water wells completed through the Middle Horseshoe Canyon Aquifer are mainly less than 50 m³/day. The adjacent map shows the expected variation in apparent yields for water wells completed in the Middle Horseshoe Canyon Aquifer.

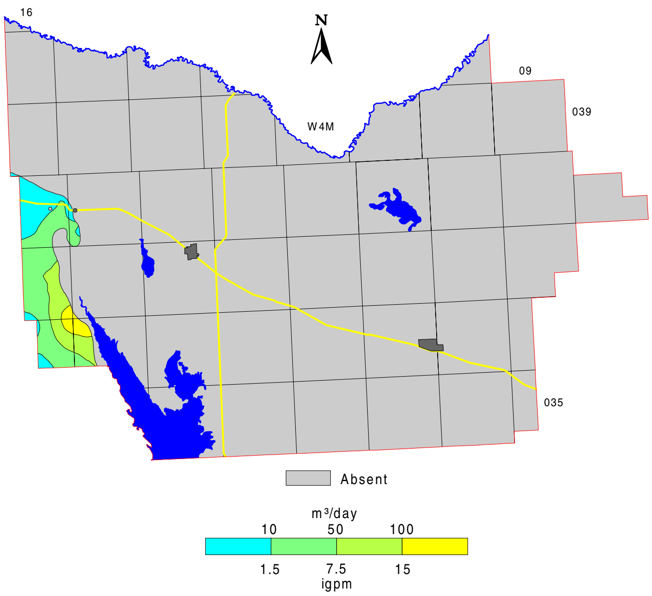

Figure 18. Apparent Yield for Water Wells Completed through Middle Horseshoe Canyon Aquifer

5.3.4.3 Quality

The groundwaters from the Middle Horseshoe Canyon Aquifer are mainly a sodium-bicarbonate type (see CD-ROM). The TDS concentrations for groundwaters from the Middle Horseshoe Canyon Aquifer range from less than 1,000 to more than 2,000 mg/L. The sulfate concentrations range from less than 100 to more than 500 mg/L. The chloride concentrations of the groundwaters from the Middle Horseshoe Canyon Aquifer can be expected to be more than 50 mg/L.

5.3.5 Lower Horseshoe Canyon Aquifer

The Lower Horseshoe Canyon Aquifer comprises the porous and permeable parts of the lower part of the Horseshoe Canyon Formation that underlies the western two-thirds of the County. The thickness of the Lower Horseshoe Canyon Formation is generally less than 100 metres; the lower part of the Horseshoe Canyon Formation has been eroded in the eastern third of the County. The lowest 70 metres of the Horseshoe Canyon Formation tend to contain more porous and permeable materials than the overlying 40 metres of the Horseshoe Canyon Formation.

5.3.5.1 Depth to Top

The depth to the top of the lower part of the Horseshoe Canyon Formation is mainly less than ten metres below ground level and is a reflection of the thickness of the surficial deposits. Close to the western edge of the County, the lower part of the Horseshoe Canyon Formation is more than 100 metres thick. In these areas, water well depths would need to be in the order of 130 metres to fully penetrate the lower part of the Formation, assuming a combined thickness of 30 metres for the surficial deposits and the middle part of the Horseshoe Canyon Formation.

5.3.5.2 Apparent Yield

The apparent yields for individual water wells completed through the Lower Horseshoe Canyon Aquifer are mainly less 50 m³/day. The areas where water wells with higher yields are expected are mainly in the southwestern and southeastern parts of the County. The southwestern part includes townships 035 to 038, ranges 13 to 15, W4M and the southeastern part includes township 035, range 11 and township 036, range 10, W4M.

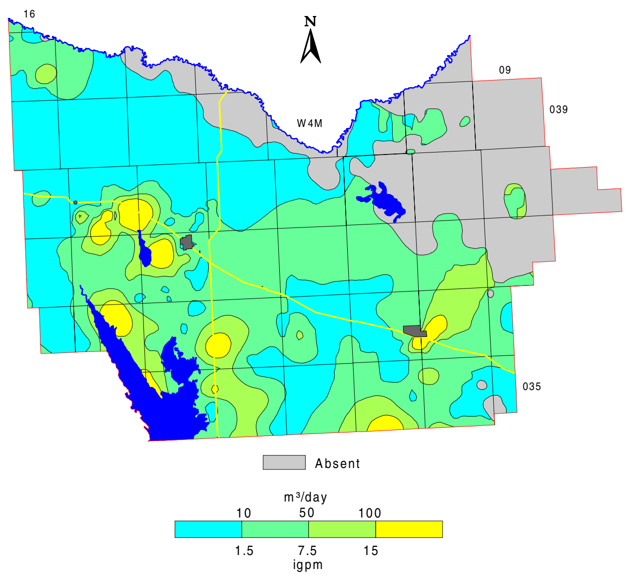

Figure 19. Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer

An extended aquifer test was conducted with a water supply well used by the Village of Halkirk in township 038, range 15, W4M. The water supply well is completed in the Lower Horseshoe Canyon Aquifer and was interpreted by Tokarsky to have a 20-year safe yield of 16 m³/day (Geoscience, 1976). The Village of Halkirk is licensed to divert 10.1 m³/day from a water supply well completed in the Lower Horseshoe Canyon Aquifer.

5.3.5.3 Quality

The groundwaters from the Lower Horseshoe Canyon Aquifer are mainly sodium-bicarbonate or sodium-sulfate types (see CD-ROM). The TDS concentrations for groundwaters from the Lower Horseshoe Canyon Aquifer range from less than 500 to more than 2,000 mg/L. The lower values of TDS occur mainly in townships 035 and 036, W4M. When TDS values in the groundwaters from the Lower Horseshoe Canyon Aquifer exceed 1,200 mg/L, the sulfate concentrations exceed 400 mg/L. The chloride concentrations of the groundwaters from the Lower Horseshoe Canyon Aquifer can be expected to be mainly less than 250 mg/L.

5.3.6 Bearpaw Aquifer

The Bearpaw Aquifer comprises the porous and permeable parts of the Bearpaw Formation and subcrops in the northeastern part of the County. The Bearpaw Formation is generally less than 100 metres thick.

5.3.6.1 Depth to Top

The depth to the top of the Bearpaw Formation is mainly less than 20 metres below ground level where the Formation subcrops. The largest area where the top of the Bearpaw is more than 100 metres below ground level is in the western part of the County. In this area, the Bearpaw Formation underlies the lower and middle parts of the Horseshoe Canyon Formation and the depth to the top of the Bearpaw Formation can exceed 140 metres.

5.3.6.2 Apparent Yield

The apparent yields for water wells completed through the Bearpaw Aquifer range from less than ten to more than 100 m³/day, with 70% of the values being less than 50 m³/day. The lower yield values presented in the western part of the County could be a result of the gridding procedure used to process a limited number of data points. The areas where water wells with higher yields are expected are mainly in the eastern half of the County.

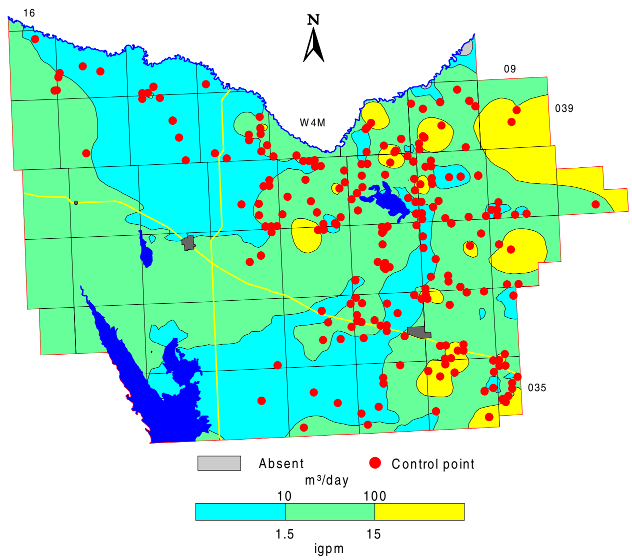

Figure 20. Apparent Yield for Water Wells Completed through Bearpaw Aquifer

An example of a high yielding water well in the eastern part of the County is a water supply well drilled for the Town of Coronation in SE 13-036-11 W4M and having a long-term yield of 600 m³/day (Lakeman and Tokarsky, 1977). Additional examples of high yielding water wells in the eastern part of the County were two former Chevron Standard water source wells in 09-11-035-10 W4M and 13-01-035-10 W4M. These two water wells are indicated as having long-term yields of 360 m³/day each (Hydrogeological Consultants Ltd. (HCL), 1971).

Two water test holes completed in the Bearpaw Aquifer for Luscar Limited in the northwestern part of the County in 16-01-040-16 W4M have long-term yields of no more than 25 m³/day each. This lower yield is thought to be a result of the low-permeability fine-grained sandstone in which the water test holes are completed (HCL, 1980).

5.3.6.3 Quality

The groundwaters from the Bearpaw Aquifer are mainly sodium-bicarbonate or sodium-sulfate types, although sodium-chloride type groundwater occurs in the northwestern part of the County (see CD-ROM). The TDS concentrations of the groundwaters range from less than 500 to more than 2,000 mg/L. The higher values of TDS trend from the northwest corner of the County southeast to township 036, range 09, W4M. The sulfate concentrations are mainly less than 500 mg/L. Chloride concentrations in the groundwaters from the Bearpaw Aquifer are mainly less than 100 mg/L where the Bearpaw Formation subcrops. The chloride concentrations in the groundwaters from the Bearpaw Aquifer are expected to be more than 250 mg/L in the western part of the County.

5.3.7 Oldman Aquifer

The Oldman Aquifer comprises the porous and permeable parts of the Oldman Formation. The Oldman Formation is present under the entire County, but subcrops only in a small area of township 040, range 10, W4M. The thickness of the Oldman Formation is mainly between 100 and 120 metres, but can be up to 130 metres in parts of township 035 and 036, W4M.

5.3.7.1 Depth to Top

The depth to the top of the Oldman Formation is mainly less than 20 metres in the eastern part of the County where the Formation subcrops. In the western part of the County where the Oldman is below the Bearpaw and the Horseshoe Canyon formations, the depth to the top of the Oldman Formation can be more than 180 metres. In the western part of the County, the Base of Groundwater Protection coincides with the base of the Oldman Formation. A map showing the depth to the Base of Groundwater Protection is given on page 6 of this report, in Appendix A, and on the CD-ROM.

5.3.7.2 Apparent Yield

The apparent yields for individual water wells completed through the Oldman Aquifer are mainly less than 50 m³/day. However, the large expanse of expected low yields may be a reflection of the limited amount of data rather than the hydraulic properties of the Aquifer. The adjacent map indicates that water wells with apparent yields of more than 100 m³/day are expected toward the eastern side of the County. There are little or no data for the Aquifer in the western parts of the County. In these areas, the Oldman Aquifer would be at a depth of more than 180 metres.

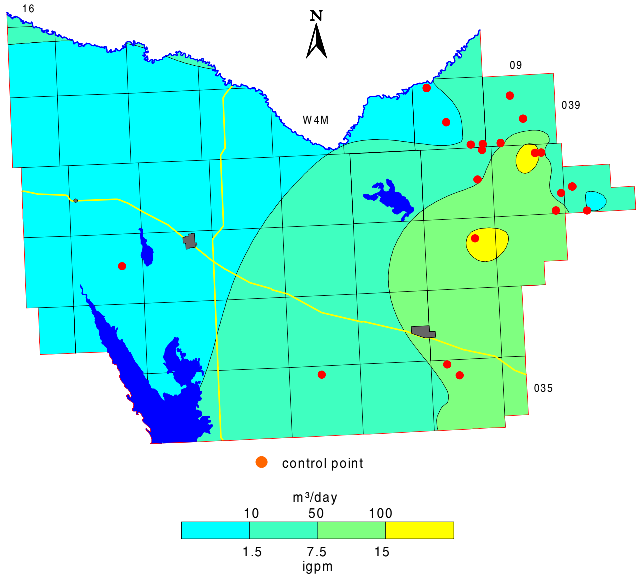

Figure 21. Apparent Yield for Water Wells Completed through Oldman Aquifer

5.3.7.3 Quality

Groundwaters from the Oldman Aquifer are mainly sodium-bicarbonate-type waters (see CD-ROM). TDS concentrations are expected to be in the order of less than 1,000 to more than 1,500 mg/L, although there is a paucity of data west of range 10, W4M. However, since the Base of Groundwater Protection coincides with the base of the Oldman Formation in the western part of the County, the TDS west of range 10 would still be expected to be below 4,000 mg/L.

Chloride concentrations in the groundwaters from the Oldman Aquifer are less than 10 mg/L where the Formation subcrops. The indications are that in the central and western parts of the County, the chloride concentrations are expected to be over 250 mg/L.

5.3.8 Foremost Aquifer

The Foremost Aquifer comprises the porous and permeable parts of the Foremost Formation and underlies the Oldman Formation. The thickness of the Foremost Aquifer generally ranges from 140 to 180 metres in the County. There are three records in the database for water wells completed in the Foremost Aquifer in the County; however, no chemistry and limited apparent yield data were available from the database for this Aquifer in the County.

5.3.8.1 Depth to Top

The Foremost Formation is present under the entire County. The depth to the top of the Formation is variable, ranging from less than 100 metres near the Battle River in the northeastern part of the County, to more than 360 metres in the western part of the County. In most of the area, the Base of Groundwater Protection coincides with the top of the Foremost Formation.

5.3.8.2 Apparent Yield

With only one apparent yield control point in the County from the groundwater database, the summary results of DSTs from the EUB database were used. The DST summaries from temporary completions in the Foremost Aquifer were used to determine apparent yield values available from the Aquifer.

The results of 60 DST summaries were used to calculate apparent long-term yields at locations where no water well information is available. The apparent long-term yield values vary from less than one to more than 40 m³/day. The apparent yields for individual water wells completed in the Foremost Aquifer are mainly less than 10 m³/day, based on data from the EUB database. The adjacent map indicates that apparent yields of more than 30 m³/day are expected in the northeastern part of the County.

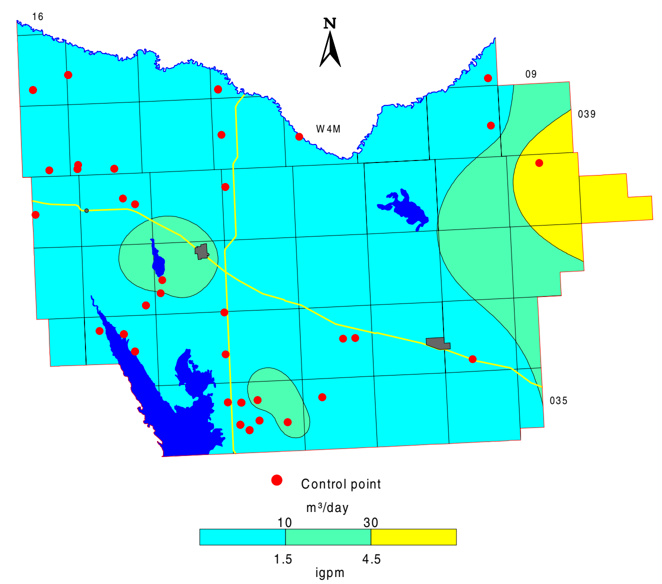

Figure 22. Apparent Yield for Water Wells Completed through Foremost Aquifer

5.3.8.3 Quality

There are no chemistry data for groundwaters from the Foremost Aquifer in the County of Paintearth; however, data from the adjacent municipality, Flagstaff County, indicate that the groundwaters from the Foremost Formation are mainly sodium-bicarbonate or sodium-sulfate-type waters. In Flagstaff County, TDS concentrations in the groundwaters from the Foremost Aquifer are expected to be in the order of 500 to 2,000 mg/L. Although no chemistry data are available for the County of Paintearth, chemistry maps for the County have been prepared based on the data from adjacent municipalities. Chemical data from the Energy Resources Conservation Board (ERCB) microfiche indicate that the TDS concentrations of groundwaters from the Foremost Formation, at depths below 220 metres, will be greater than 5,000 mg/L.

6 Groundwater Budget

6.1 Hydrograph

There are two locations in the County where water levels are being measured and recorded with time. These sites are observation water wells that are part of the AEP regional groundwater-monitoring network. Observation Water Well (Obs WW) No. 130 is in 09-18-035-09 W4M and Obs WW No. 231 is in 04-31-035-10 W4M; both are in the vicinity of the Town of Coronation. The hydrograph for AEP Obs WW No. 130 is shown on the adjacent graph and in Appendix A; the hydrograph for AEP Obs WW No. 231 is also shown in Appendix A, but is of limited use.

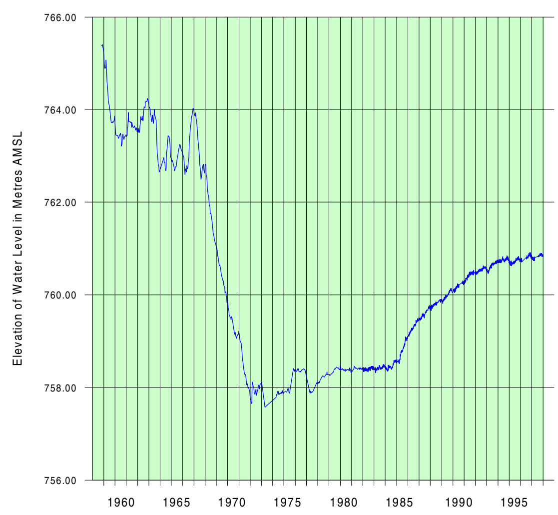

Figure 23. Hydrograph - AEP Observation Water Well No. 130

AEP Obs WW No. 130 is completed at a depth of 62.0 metres in the Bearpaw Aquifer. The water level in the AEP Obs WW declined 1.5 metres from 1958 to 1967 and declined an additional four metres between 1968 and 1971. There are eight water source wells within a four-kilometre radius of AEP Obs WW No. 130 that are completed in the Bearpaw Aquifer.

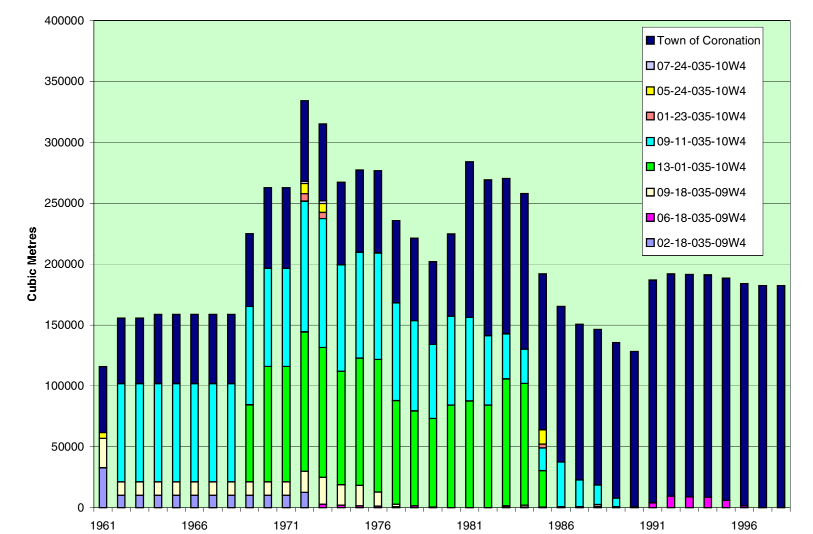

Figure 24. Annual Groundwater Production - WSWs

Groundwater production is available from these eight water source wells from the EUB database. Groundwater production has been recorded since 1961, with the data estimated until 1968; after 1968, the groundwater production was measured. The adjacent graph shows that the maximum production from the eight water source wells occurred in 1972 when the maximum groundwater diversion was over 250,000 cubic metres. The adjacent graph also shows the groundwater use by the Town of Coronation from the Bearpaw Aquifer. When the Town's groundwater use is added to the production from the water source wells, the maximum diversion in 1972 is close to 350,000 cubic metres. In recent years, the production from the water source wells has decreased and use by the Town has increased. In 1998, the Town used just under 200,000 cubic metres and there is no reported use by the water source wells.

In order to determine if these water source wells have had an impact on the Bearpaw Aquifer in which AEP Obs WW No. 130 is completed, a mathematical model was used to calculate water levels at the location corresponding to the Obs WW.

The model aquifer has an effective transmissivity of 30 m²/day and a corresponding storativity of 0.0004. The model assumes a homogeneous, isotropic aquifer of infinite areal extent and does not account for aquifer recharge. Two simulations were completed. The first is based on the annual groundwater production from the eight water source wells, without the Town of Coronation production. The second simulation includes the combined production from the water source wells and the Town of Coronation water supply wells. The simulations are used to calculate the water level at the site of AEP Obs WW No. 130. The results of the two simulations are shown on the adjacent graph.

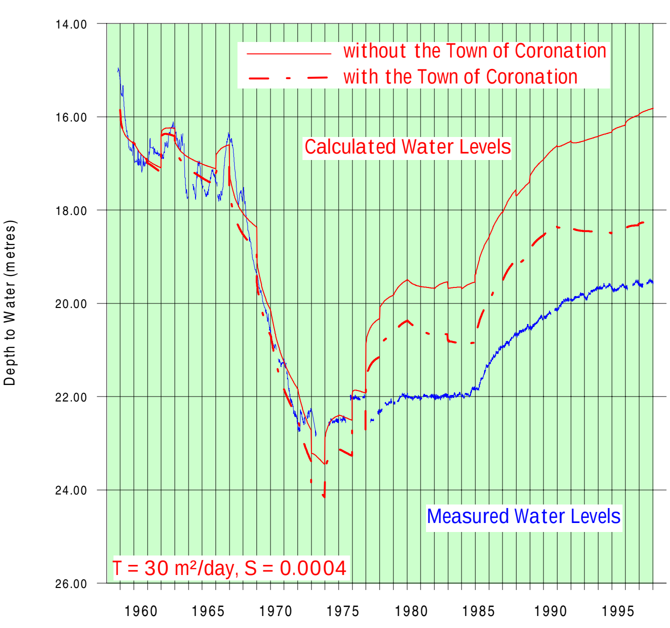

Figure 25. AEP Observation Water Well No. 130 - Water-Level Simulations

There is a reasonable match between the three water-level-data sets from 1959 to 1972. For the simulation that includes only the production from the water source wells, there is a reasonable match between the measured and calculated from 1972 to 1976 but from 1976 to 1998, the calculated water level is up to four metres higher than the measured water level. In the simulation that includes the Town of Coronation's production, the calculated water level is lower than the measured water level from 1972 to 1976 and higher than the measured from 1976 to 1998. However, in the 1976 to 1998 data set, the calculated water level from the simulation that includes the Town's production is closer to the measured water level than the simulation that does not include the production.

The present simulations do not provide a definitive answer. However, they do show that production from the Town of Coronation water supply wells could have an impact on the water level in the Bearpaw Aquifer at the site of AEP Obs WW. No. 130, 15 kilometres from the Town.

An attempt was made to determine if there has been any other change in water levels in the Bearpaw Aquifer within the County. Since there are only two observation water well sites, the attempt included documenting the difference in water levels when new water well(s) were drilled at sites of an existing water well(s). There are 258 sites where there is more than one water well, each with a water level recorded at the time the water well was drilled. There are 71 sites when the water wells at the given site have depths that differ by less than five metres and the dates between the two water levels are more than 200 days. The water-level changes at these sites vary between a rise of 33.5 metres and a decline of 68.9 metres. An analysis of 67 water-level changes between a rise of nine metres and a decline of 40 metres shows that 30% of the water levels rose and 70% declined; the average decline was ten metres. The main area of water-level decline is in the vicinity of the Town of Coronation and ten kilometres southeast of the Town. In the remainder of the County where the Bearpaw Aquifer is used as a source of potable water, the water-level change with time shows there are very few areas with a water-level rise.

6.2 Groundwater Flow

A direct measurement of groundwater recharge or discharge is not possible from the data that are available for the County. One indirect method of measuring recharge is to determine the quantity of groundwater flowing laterally through each individual aquifer. This method assumes that there is sufficient recharge to the aquifer to maintain the flow through the aquifer and the discharge is equal to the recharge. However, even the data that can be used to calculate the quantity of flow through an aquifer must be averaged and estimated. To determine the flow requires a value for the average transmissivity of the aquifer, an average hydraulic gradient and an estimate for the width of the aquifer. For the present program, the flow has been estimated for those parts of the various aquifers within the County.

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

Aquifer Designation	Transmissivity (m^2/day)	Gradient (m/m)	Width (km)	Main Direction of Flow	Quantity (m^3/day)	Authorized Diversion (m^3/day)
Surficial Deposits (northwestern part)	9	0.008	30	Northeast	2,160	**61**
Middle Horseshoe Canyon	5	0.002	5	North	50	**0**
Lower Horseshoe Canyon	5	0.004	70	Northeast	1,000	**869**
Bearpaw	3	0.004	40	Northeast	480	**683**
Oldman	2	0.0001	48	Northwest	10	**433**

The data provided in the above table indicate there is more groundwater flowing through the individual bedrock aquifers than has been authorized to be diverted from each aquifer, except for the Bearpaw and Oldman aquifers. The calculations of flow through individual aquifers as presented in the above table are very approximate and are intended as a guide for future investigations.

6.2.1 Quantity of Groundwater

An estimate of the volume of groundwater stored in the sand and gravel aquifers in the surficial deposits is 0.1 to 0.7 cubic kilometres. This volume is based on an areal extent of 800 square kilometres and a saturated sand and gravel thickness of three 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 from water levels associated with water wells completed in aquifers in the surficial deposits. These water levels were used for the calculation of the saturated thickness of surficial deposits. In areas where the elevation of the water-level surface is below the bedrock surface, the surficial deposits are not saturated. The water-level map for the surficial deposits shows a general flow direction toward the Battle River, with the lowest water-level elevations occurring in township 040, range 10, W4M.

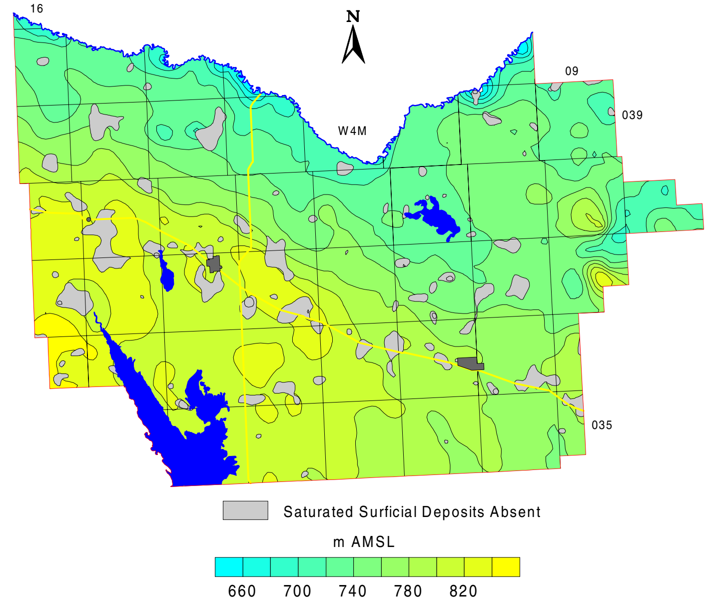

Figure 26. Non-Pumping Water-Level Surface in Surficial Deposits

6.2.2 Recharge/Discharge

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

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.

6.2.2.1 Surficial Deposits/Bedrock Aquifers

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

The adjacent map shows that, in more than 65% of the County, there is a downward hydraulic gradient from the surficial deposits toward the upper bedrock aquifer(s). Areas where there is an upward hydraulic gradient from the bedrock to the surficial deposits are mainly in the vicinity of the meltwater channels. The remaining parts of the County are areas where there is a transition condition.

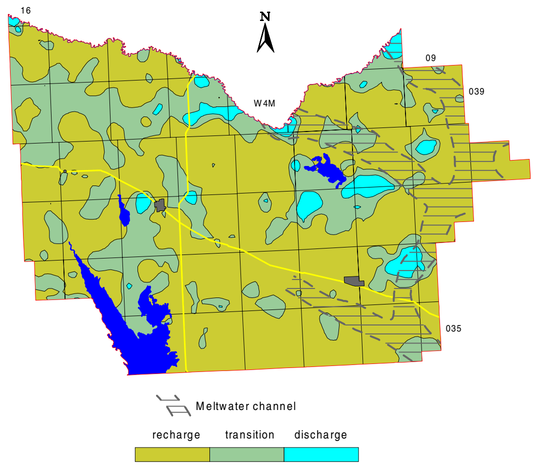

Figure 27. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)

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

6.2.2.2 Bedrock Aquifers

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

The hydraulic relationship between the surficial deposits and the Lower Horseshoe Canyon Aquifer indicates that in more than 50% of the County where the Lower Horseshoe Canyon Aquifer is present, there is a downward hydraulic gradient. Discharge areas for the Lower Horseshoe Canyon Aquifer are associated with the northeast edge of the Aquifer. The hydraulic relationship between the surficial deposits and the remainder of the bedrock aquifers indicates there is mainly a downward hydraulic gradient.

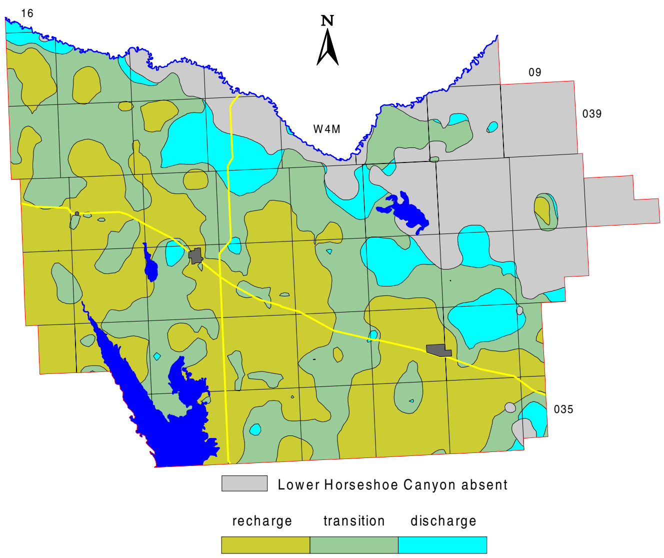

Figure 28. Recharge/Discharge Areas between Surficial Deposits and Lower Horseshoe Canyon Aquifer

7 Potential for Groundwater Contamination

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

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

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

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

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

To identify the areas where sand and gravel can be expected within one metre of the ground surface, all groundwater database records with lithologies were reviewed. From a total of 1,180 records in the area of the County with lithological descriptions, 135 have the tops of a sand and gravel deposit present within one metre of ground level. In the remaining 1,045 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 Groundwater 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 - Top Within One Metre Of Ground Surface	Groundwater Contamination Risk
Low	No	Low
Moderate	No	Moderate
High	No	High
Low	Yes	High
Moderate	Yes	High
High	Yes	Very High

Table 7. Risk of Groundwater Contamination Criteria

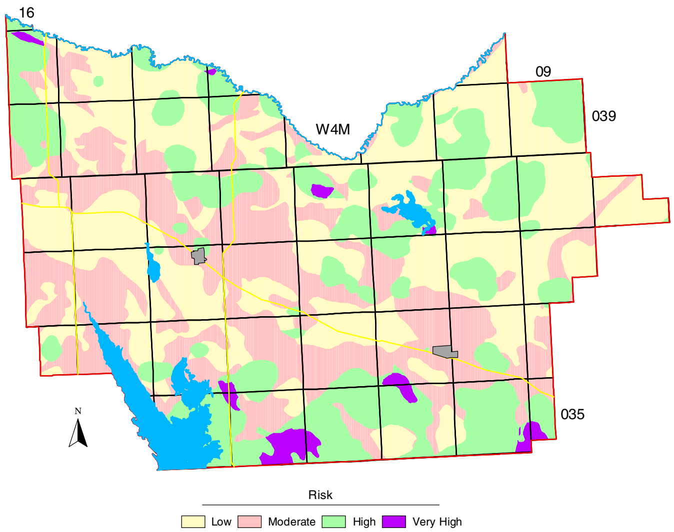

Figure 29. Risk of Groundwater Contamination

The Risk of Groundwater Contamination map shows that, in more than 25% of the County, there is a high or very high risk for the groundwater to be contaminated. These areas would be considered the least desirable ones for a development that has a product or by-product that could cause groundwater contamination. However, because the map has been prepared as part of a regional study, the designations are a guide only; detailed hydrogeological studies must be completed at any proposed development site to ensure the groundwater is protected from possible contamination. At all locations, good environmental practices should be exercised in order to ensure that contaminants will 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 first step would be to field-verify the 100 existing water wells listed in Appendix E. These water well records indicate that a complete water well drilling report is available along with at least a partial chemical analysis. The level of verification would have to include identifying the water well in the field, obtaining meaningful horizontal coordinates for the water well and the verification of certain parameters such as water level and completed depth. Even though the water wells for which the County has responsibility do not satisfy the above criteria, it is recommended that they be field-verified, water levels be measured, a water sample collected for analysis and a short aquifer test be conducted. An attempt to update the quality of the entire database is not recommended.

Two water wells that did not make the list in Appendix E due to lack of some data are the former Chevron Standard Ltd. water source wells completed in the Bearpaw Aquifer in 13-01-035-10 W4M and 09-11-035-10 W4M. From 1962 to 1989, these two water wells each produced up to 300 m³/day. Since 1990, they have been inactive according to the EUB database and the current status of these two water source wells is unknown. In the event of a groundwater shortage, it is recommended that the County look into the possibility of reestablishing the water wells as a water source that could be used to fill tankers for rural activities.

While there are a few areas where water-level data are available, on the overall, there are an insufficient number of water levels to set up a groundwater budget. One method to obtain additional water-level data is to solicit the assistance of the water well owners who are stakeholders in the groundwater resource. In the M.D. of Rocky View, water well owners are being provided with a tax credit if they accurately measure the water level in their water well once per week for a year. A pilot project indicated that approximately five years of records are required to obtain a reasonable data set. The cost of a five-year project involving 50 water wells would be less than the cost of one drilling program that may provide two or three observation water wells. Another municipality, Flagstaff County, is currently in the process of setting up a regional groundwater-monitoring program.

A second approach to obtain water-level data would be to conduct a field survey to identify water wells not in use that could be used as part of an observation water well network. The water levels in the water wells could be measured regularly by County personnel and/or local residents.

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 (see pages C-2 to C-4):

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.

A list of 100 water wells that could be considered for the above program is given in Appendix E.

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. One area in the northeastern part of the County where this condition may exist is where the upper bedrock is a sandstone layer within the Bearpaw Formation. In this area, the friable sandstone bedrock is being reported and interpreted as a sand layer within the unconsolidated sediments. One method of obtaining uniformity would be to have the water well drilling reports submitted to the AEP Resource Data Division in an electronic form. The money presently being spent by AEP and PFRA to transpose the paper form to the electronic form should be used to allow for a technical review of the data and follow-up discussions with the drillers.

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

Groundwater is a renewable resource and it must be managed.

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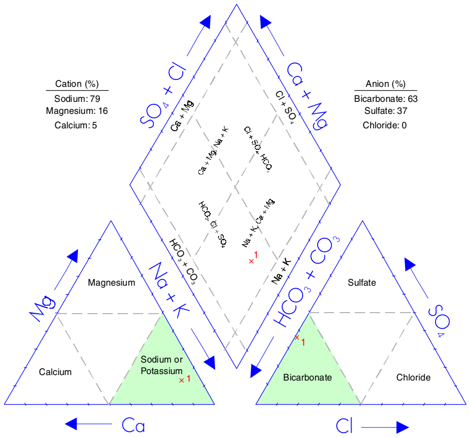
10 Glossary

AEP	Alberta Environmental Protection
AMSL	above mean sea level
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 too or from an adjacent aquifer
Available Drawdown	in a confined aquifer, the distance between the non-pumping water level and the top of the aquifer
	in an unconfined aquifer (water table aquifer), two thirds of the saturated thickness of the aquifer
Deltaic	a depositional environment in standing water near the mouth of a river
DEM	Digital Elevation Model
DST	drill stem test
EUB	Alberta Energy and Utilities Board
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
GCDWQ	Guidelines for Canadian Drinking Water Quality
Hydraulic Conductivity	the rate of flow of water through a unit cross-section under a unit hydraulic gradient; units are length/time
km	kilometre
Kriging	a geo-statistical method for gridding irregularly-spaced data (Cressie, 1990)
Lacustrine	fine-grained sedimentary deposits associated with a lake environment and not including shore-line deposits
Lsd	Legal Subdivision
m	metres
mm	millimetres
m^2/day	metres squared per day
m^3	cubic metres
m^3/day	cubic metres per day
mg/L	milligrams per litre
NPWL	non-pumping water level

Obs WW	Observation Water Well
PFRA	Prairie Farm Rehabilitation Administration

Piper tri-linear diagram — a method that permits the major cation and anion compositions of single or multiple samples to be represented on a single graph. This presentation allows group-ings or trends in the data to be identified. From the Piper tri-linear diagram, it can be seen that the groundwater from this sample water well is a sodium-bicarbonate-type. The chemical type has been determined by graphically calculating the dominant cation and anion. For a more detailed explanation, please refer to Freeze and Cherry, 1979



Piper Tri-Linear Diagram

Surficial Deposits	includes all sediments above the bedrock
TDS	Total Dissolved Solids
Till	a sediment deposited directly by a glacier that is unsorted and consisting of any grain size ranging from clay to boulders
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

WSW	Water Source Well or Water Supply Well
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

11 Conversions

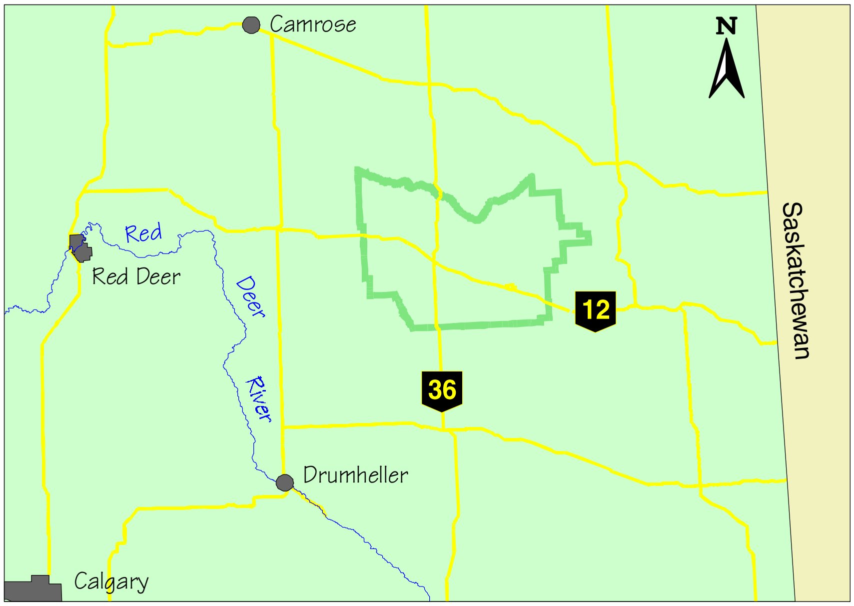
Mulitiply	by	To Obtain
Length/Area		
feet	0.304 785	metres
metres	3.281 000	feet
hectares	2.471 054	acres
centimetre	0.032 808	feet
centimetre	0.393 701	inches
acres	0.404 686	hectares
inchs	25.400 000	millimetres
miles	1.609 344	kilometres
kilometer	0.621 370	miles (statute)
square feet (ft^2)	0.092 903	square metres (m^2)
square metres (m^2)	10.763 910	square feet (ft^2)
square metres (m^2)	0.000 001	square kilometres (km^2)
Concentration		
grains/gallon (UK)	14.270 050	parts per million (ppm)
ppm	0.998 859	mg/L
mg/L	1.001 142	ppm
Volume (capacity)		
acre feet	1233.481 838	cubic metres
cubic feet	0.028 317	cubic metres
cubic metres	35.314 667	cubic feet
cubic metres	219.969 248	gallons (UK)
cubic metres	264.172 050	gallons (US liquid)
cubic metres	1000.000 000	litres
gallons (UK)	0.004 546	cubic metres
imperial gallons	4.546 000	litres
Rate		
litres per minute (lpm)	0.219 974	UK gallons per minute (igpm)
litres per minute	1.440 000	cubic metres/day (m^3/day)
igpm	6.546 300	cubic metres/day (m^3/day)
cubic metres/day	0.152 759	igpm

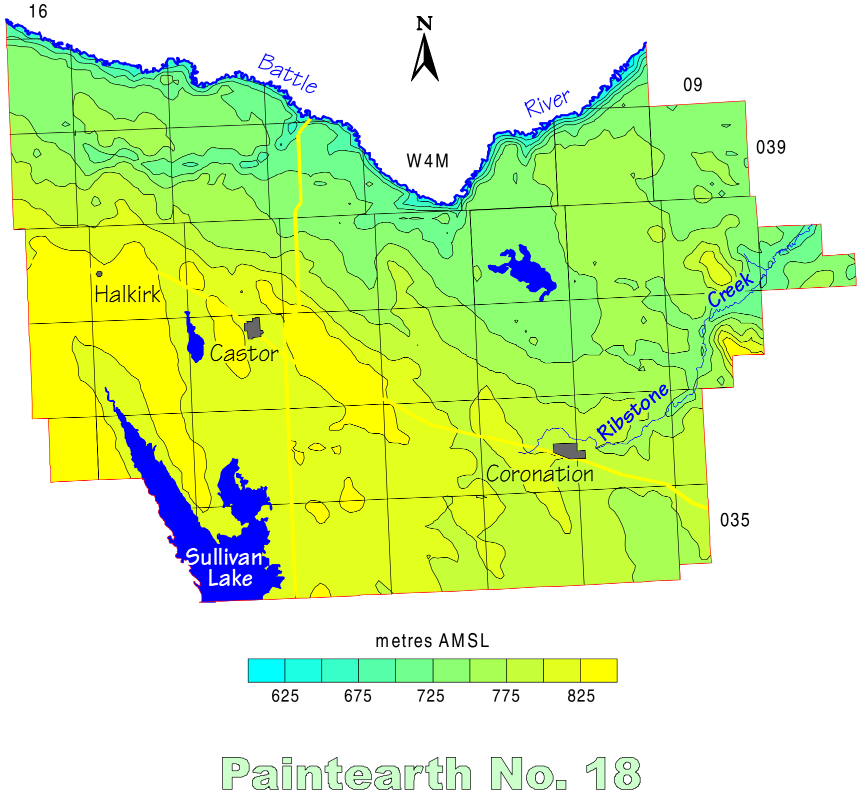
COUNTY OF PAINTEARTH NO. 18

Appendix A

HYDROGEOLOGICAL MAPS AND FIGURES

Index Map





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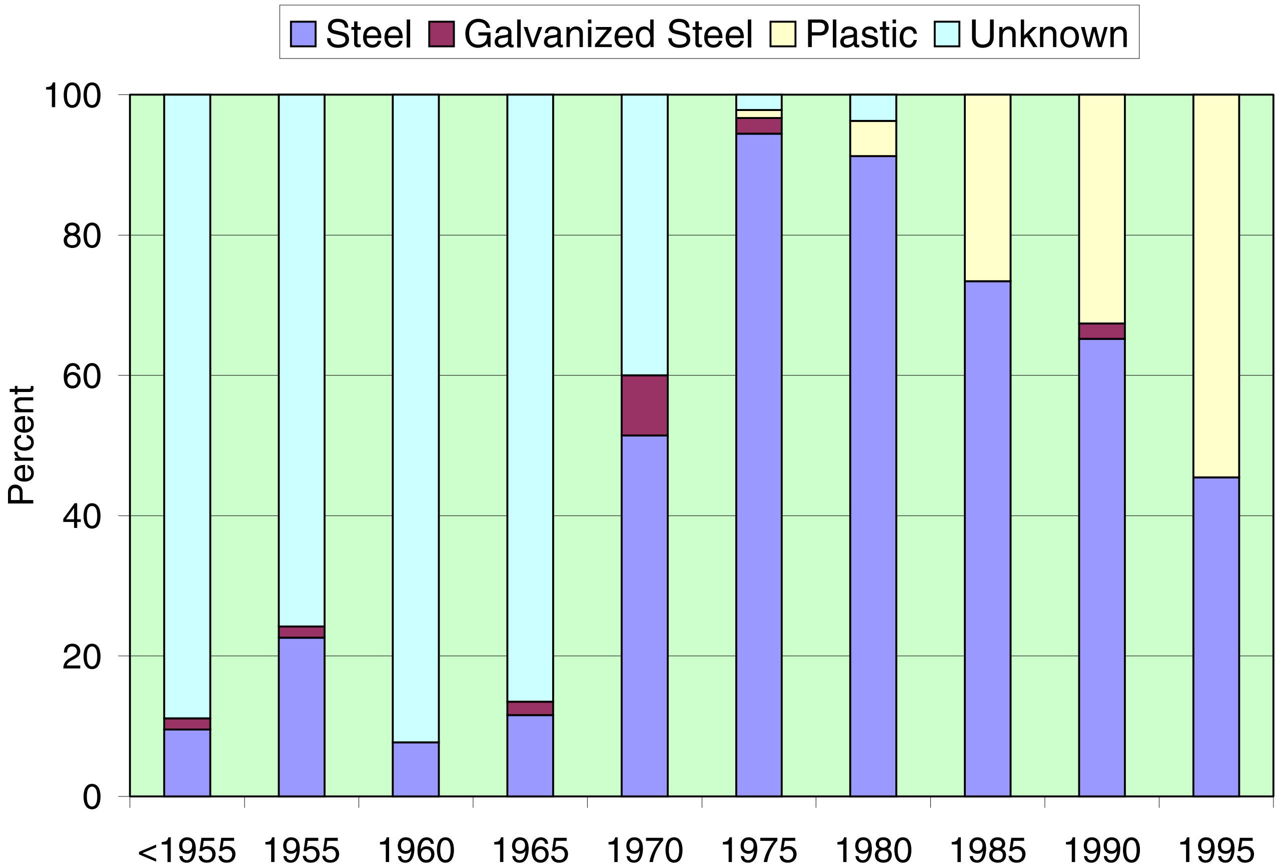
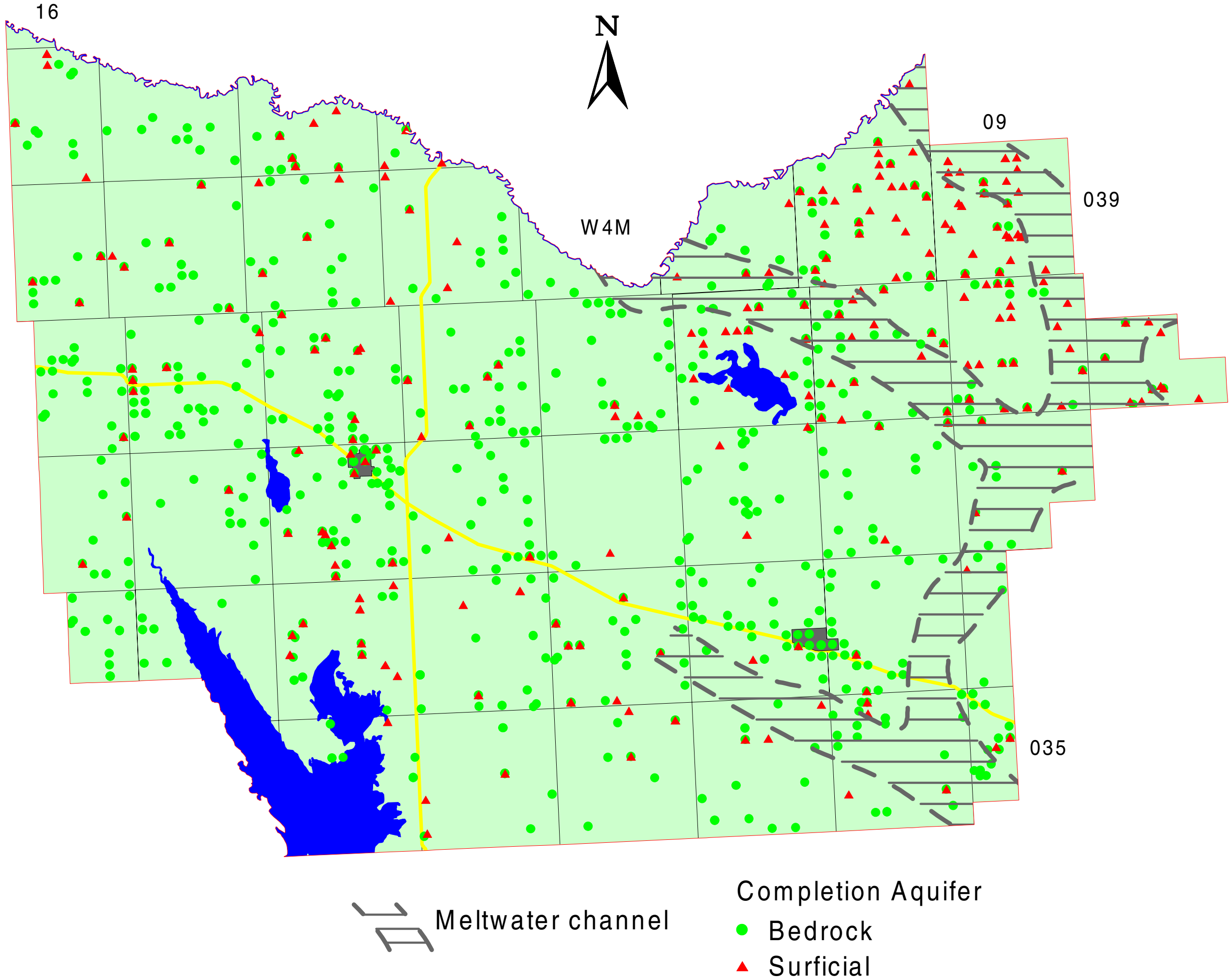
Surface Casing Types used in Drilled Water Wells

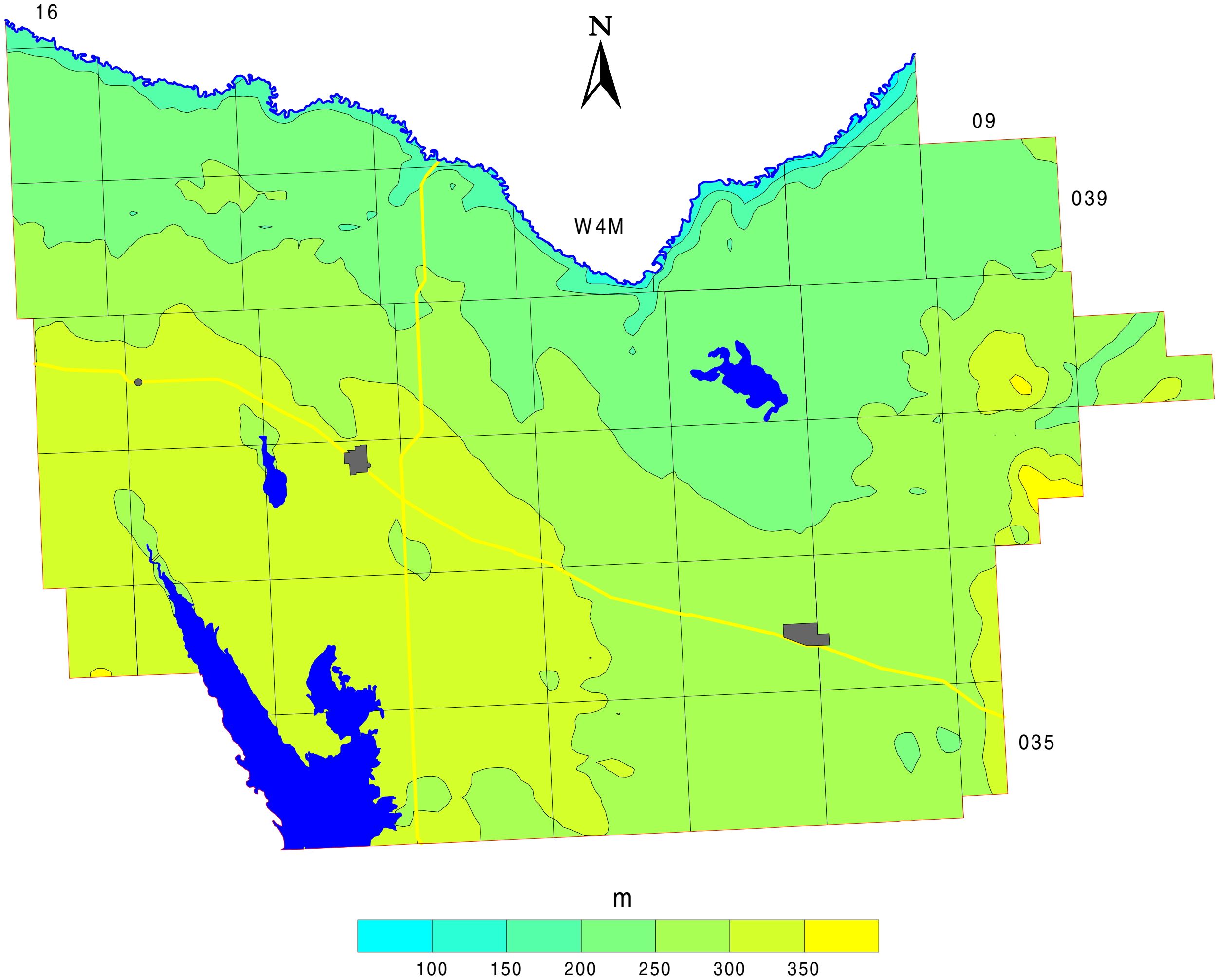


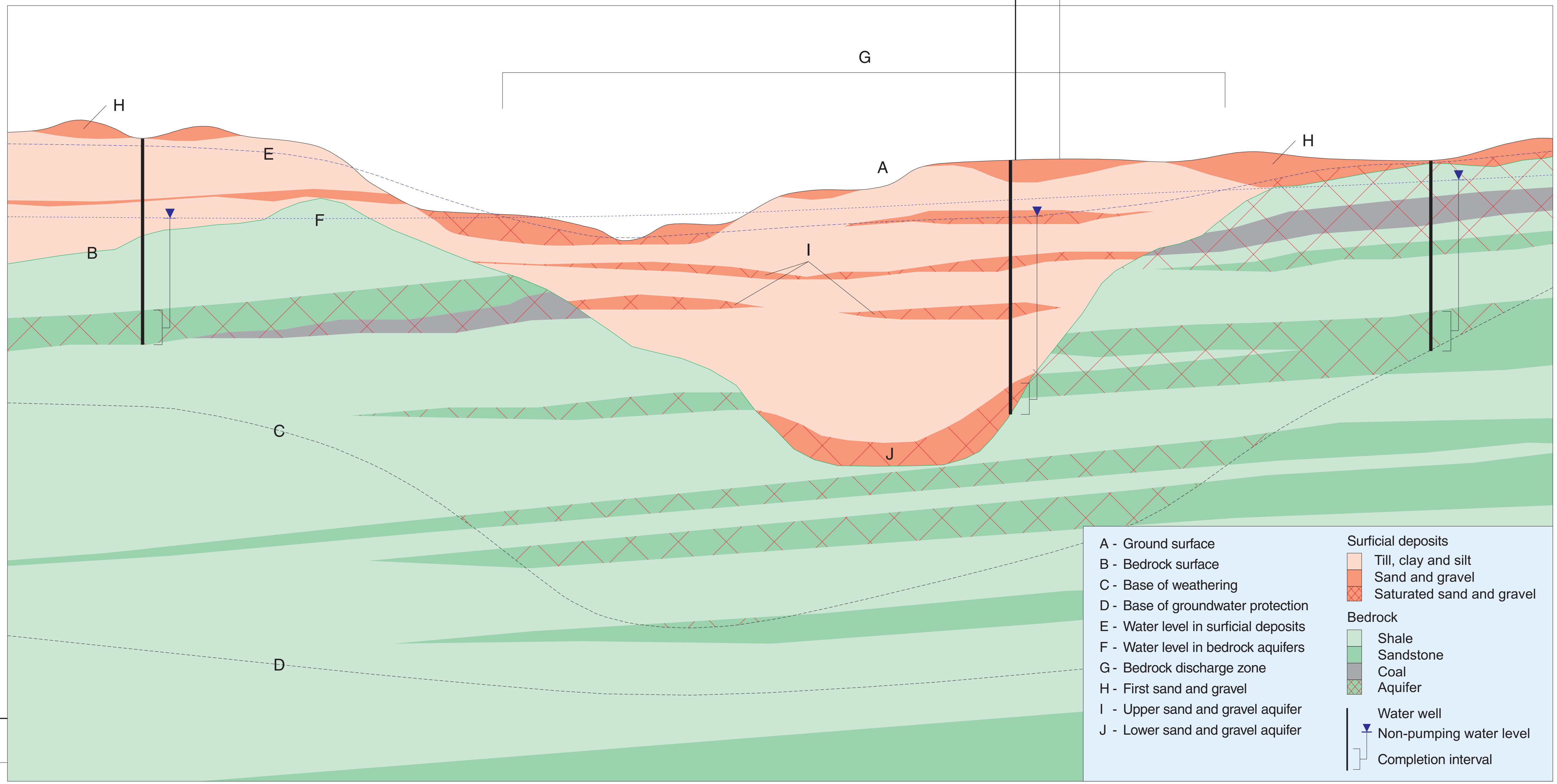
Location of Water Wells



Depth to Base of Groundwater Protection

(after EUB, 1995)

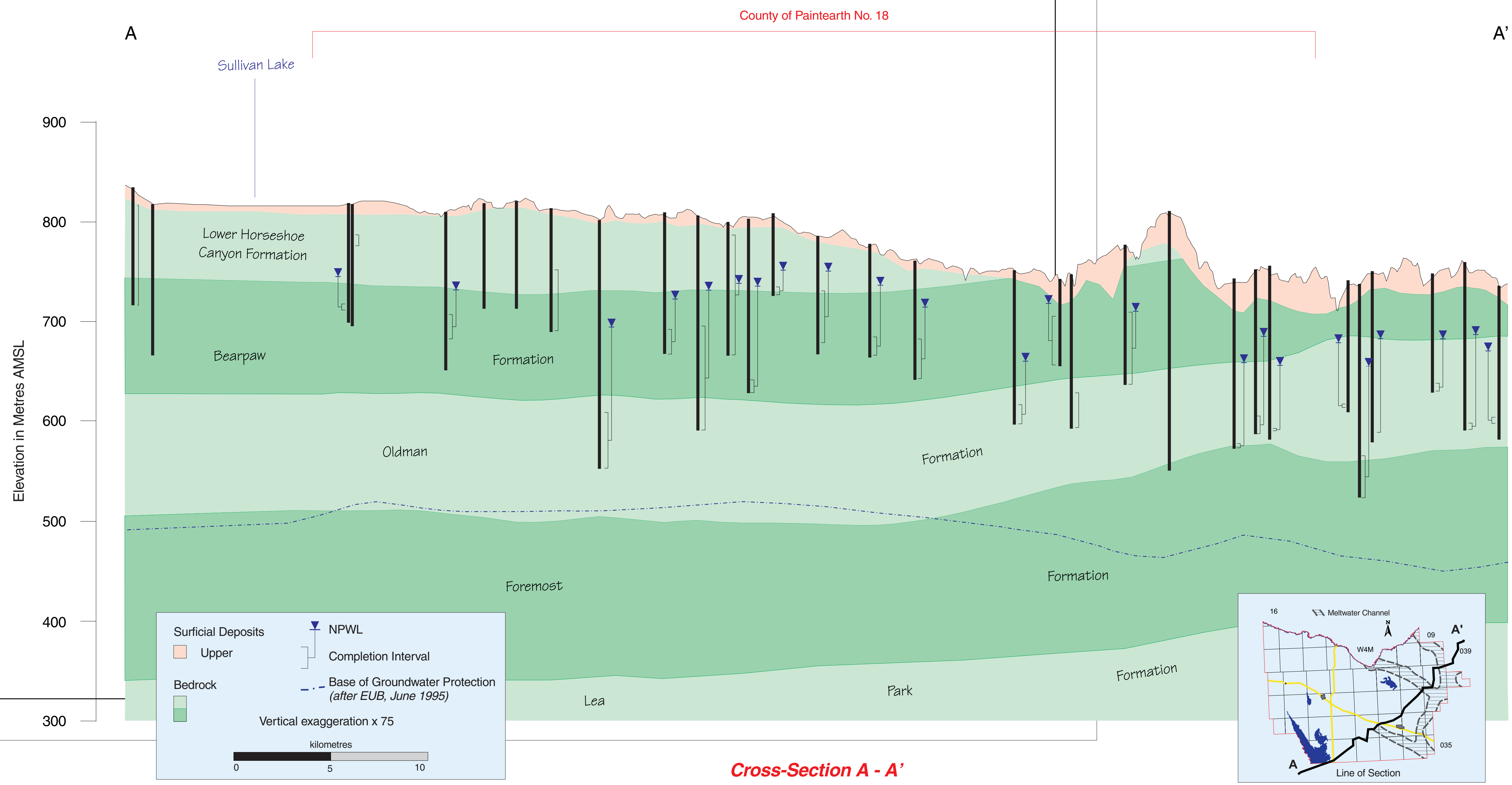




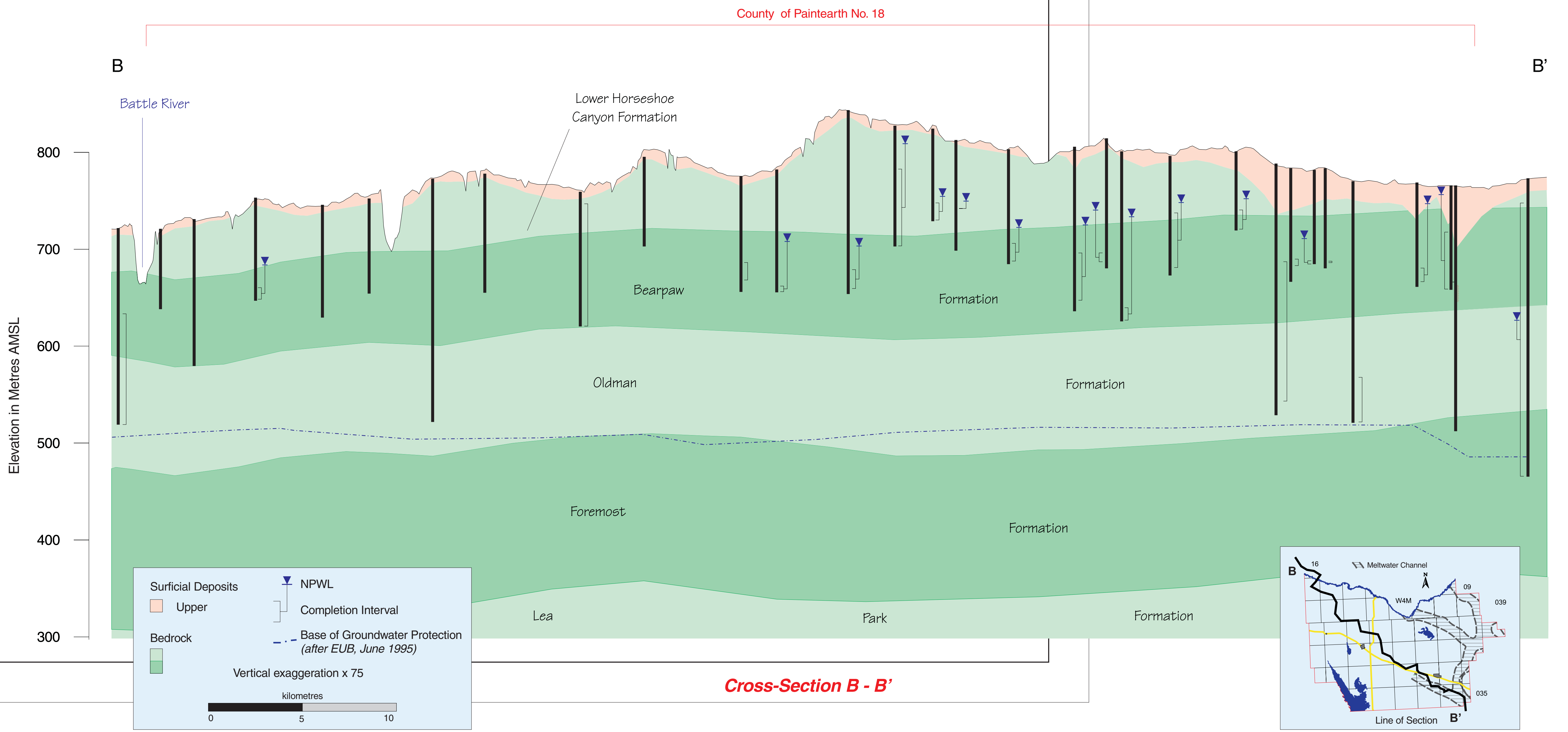
Generalized Cross-Section
(for terminology only)

		Group and Formation			Member		Zone	
Lithology	Lithologic Description	Thickness (m)	Group	Designation	Thickness (m)	Designation	Thickness (m)	Designation
	sand, gravel, till, clay, silt	<50		Surficial Deposits	<50	Upper	<15	First Sand and Gravel
	shale, sandstone, siltstone, coal, bentonite, limestone, ironstone	300-380	Edmonton Group	Horseshoe Canyon Formation	~100	Upper		
					~100	Middle		
					~170	Lower		
	shale, sandstone, siltstone	60-120		Bearpaw Formation				
	sandstone, siltstone, shale, coal	40-130	Belly River Group	Oldman Formation		Dinosaur Member	<0-25	Lethbridge Coal Zone
						Upper Siltstone Member		
						Comrey Member		
	sandstone, shale, coal	<200		Foremost Formation	<70	Birch Lake Member		Taber Coal Zone
					<60	Ribstone Creek Member		
					<70	Victoria Member		
					<30	Brosseau Member		McKay Coal Zone
	shale, siltstone	30-60		Lea Park Formation				
	sandstone, siltstone, shale, coal	90-120		Milk River Formation				

Geologic Column

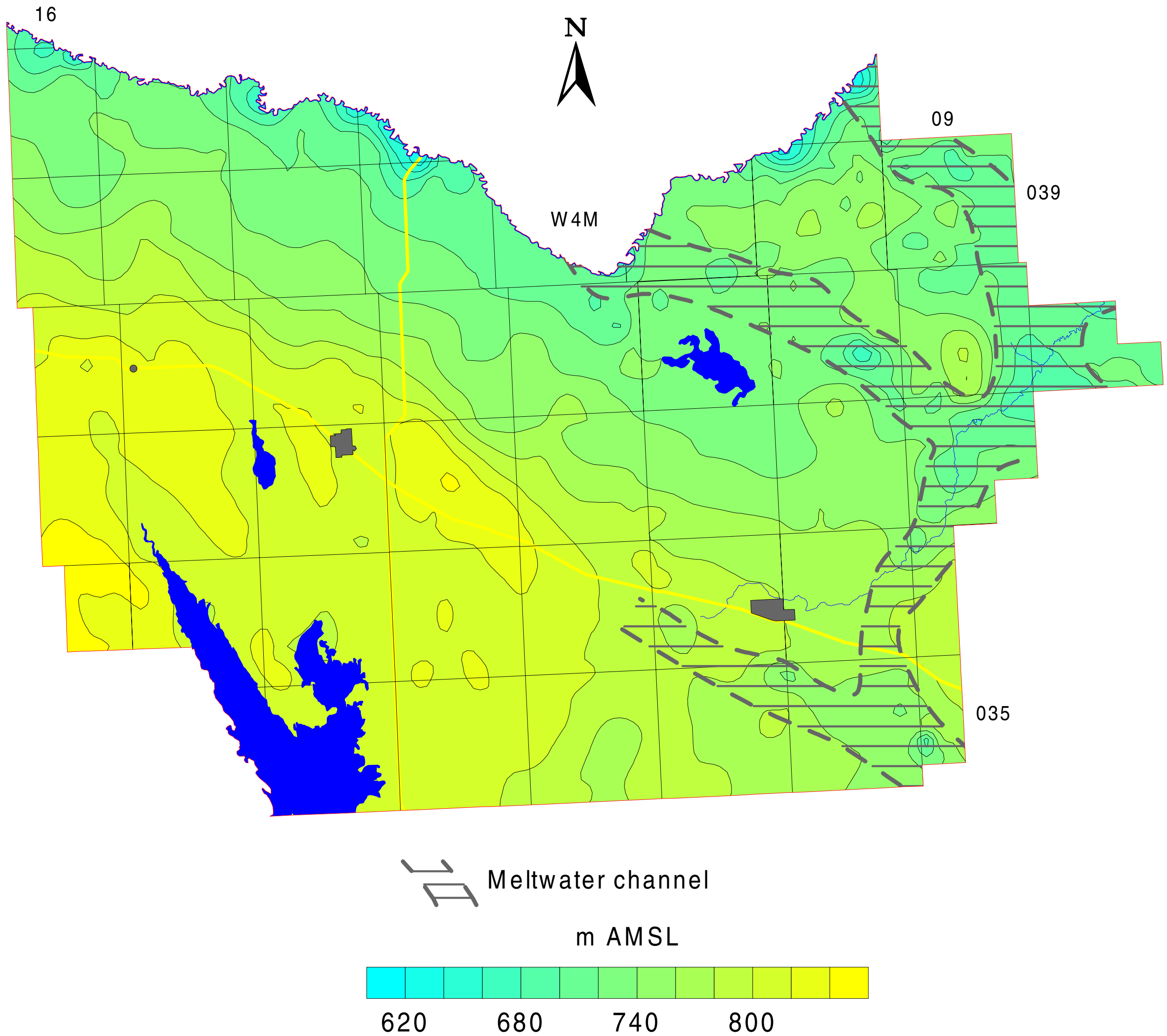


Cross-Section A - A'

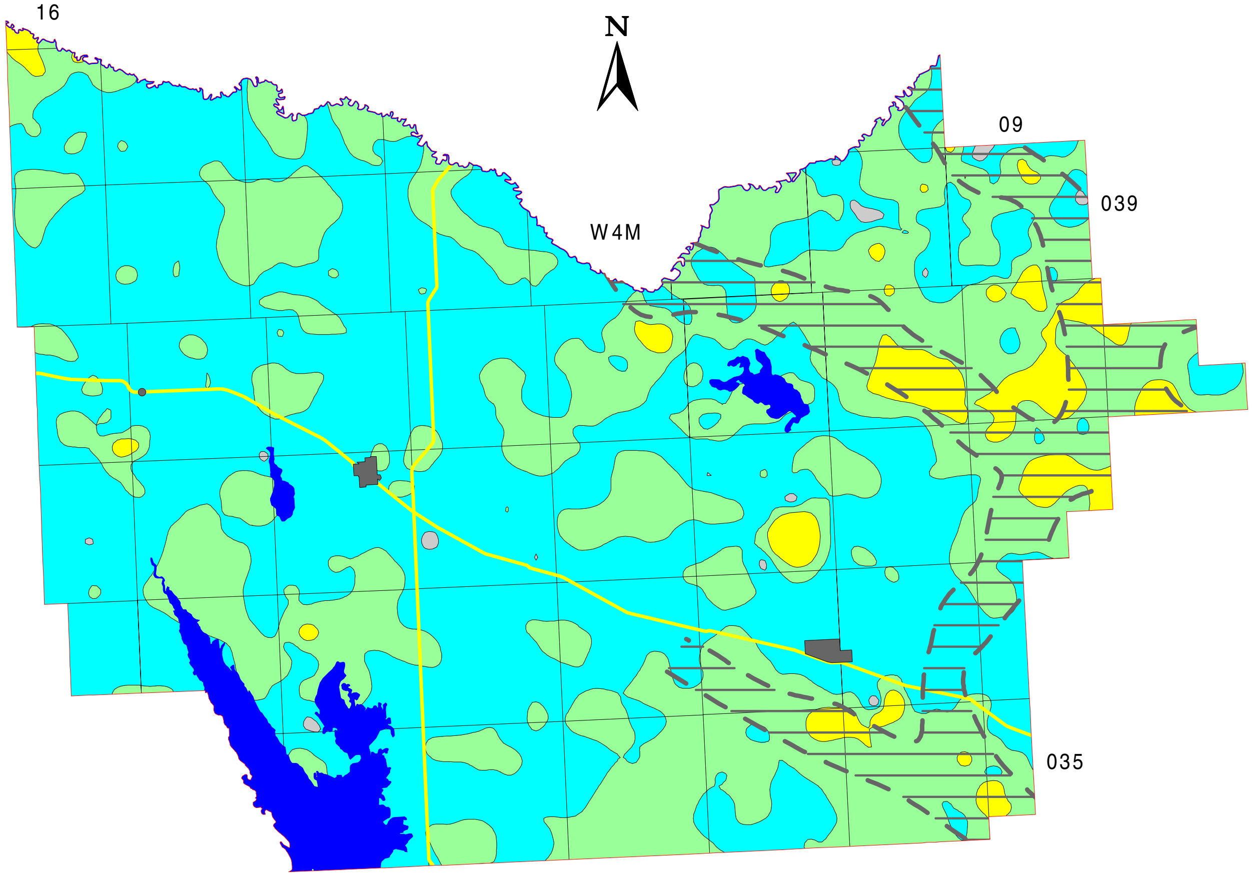


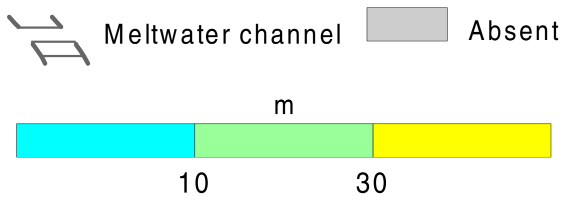
Cross-Section B - B'

Bedrock Topography



Thickness of Surficial Deposits





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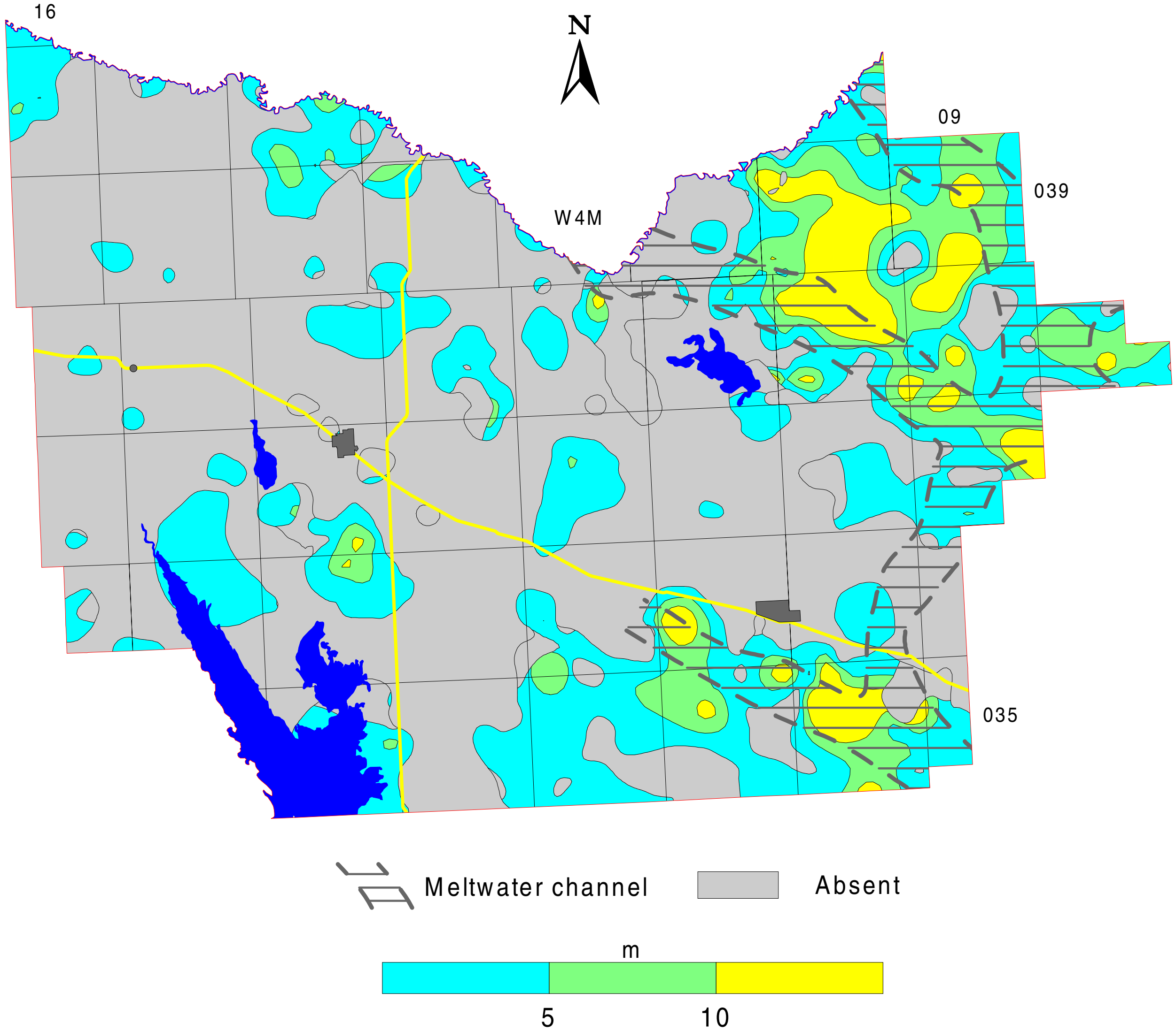
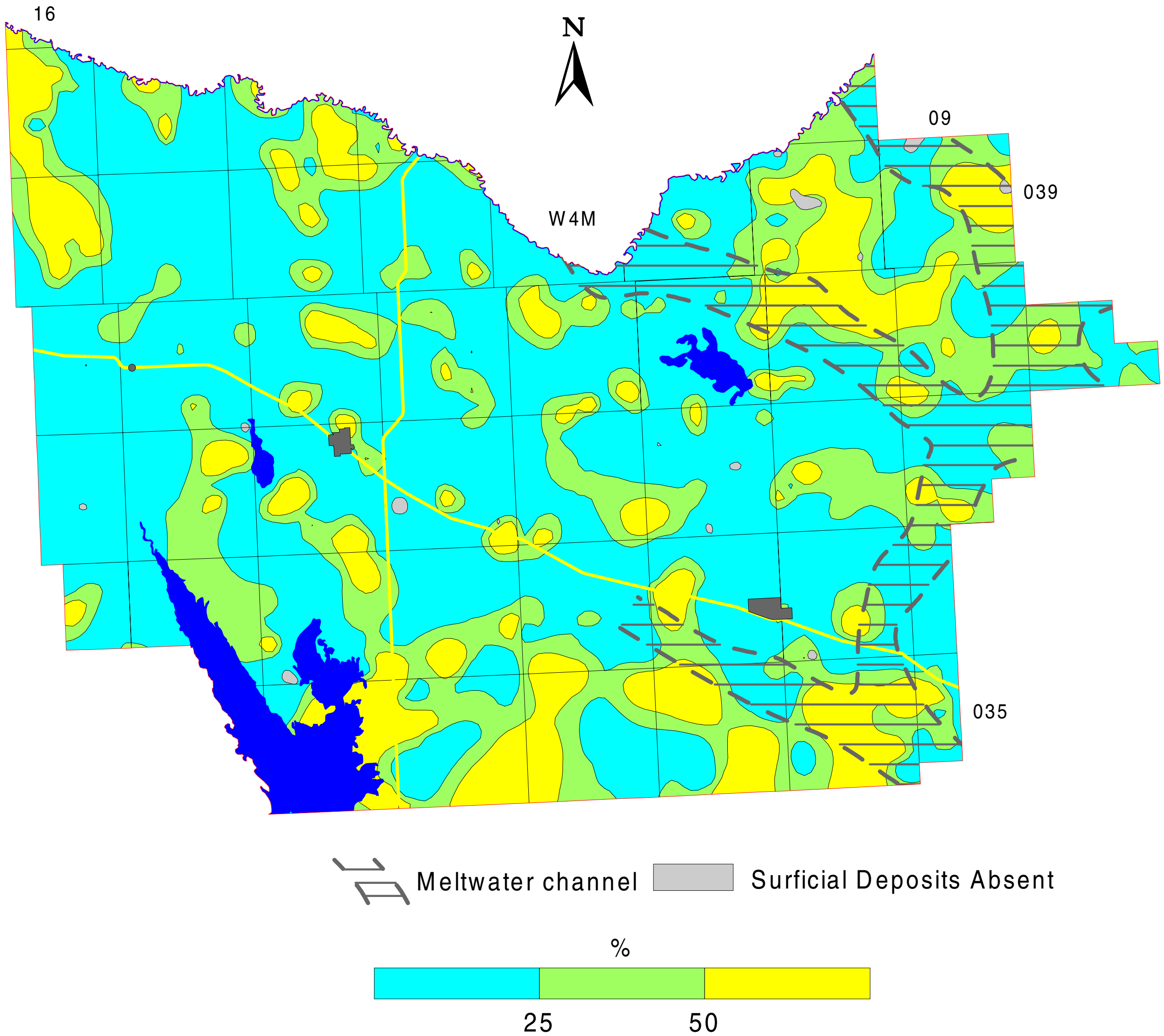
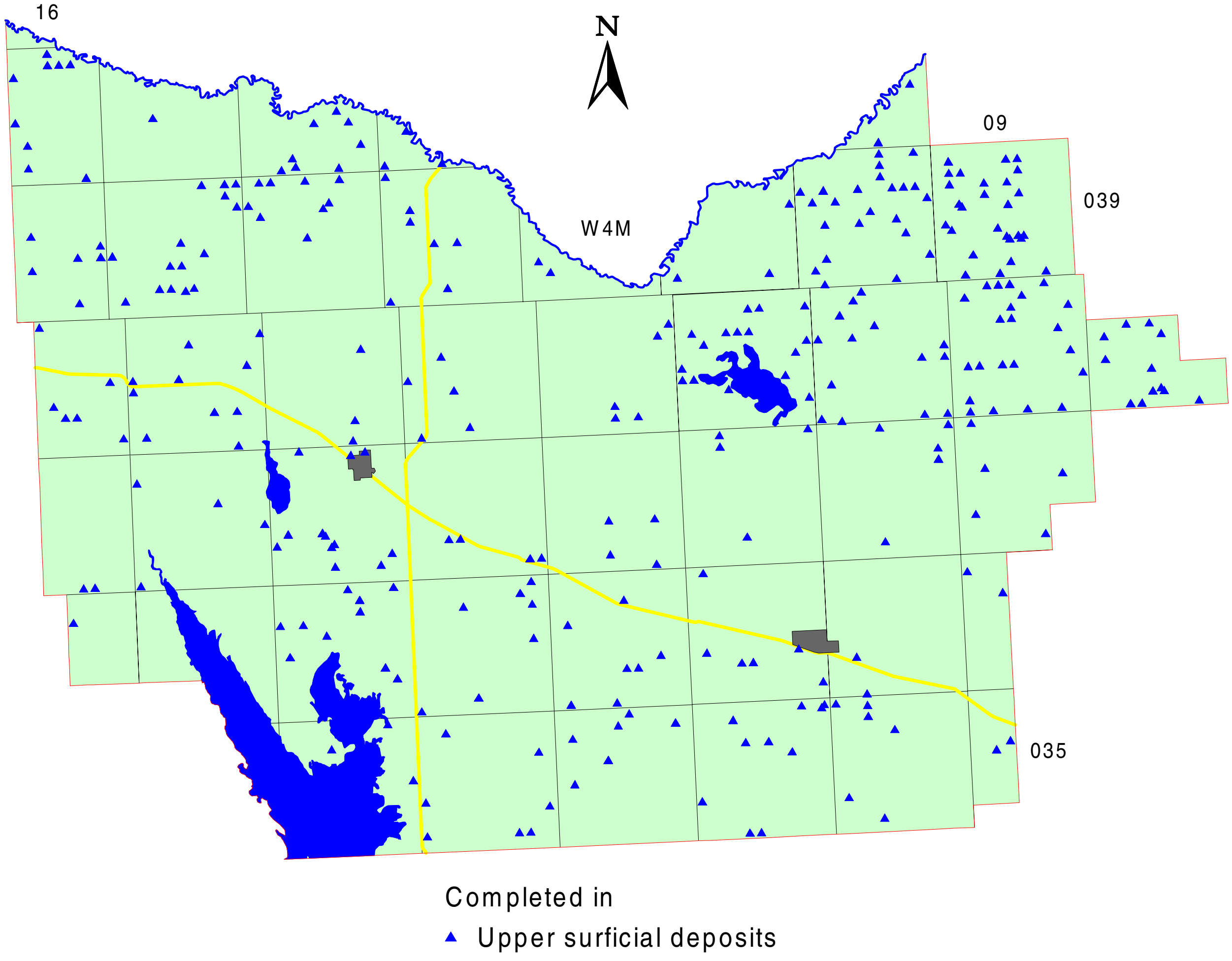
Thickness of Sand and Gravel Aquifer



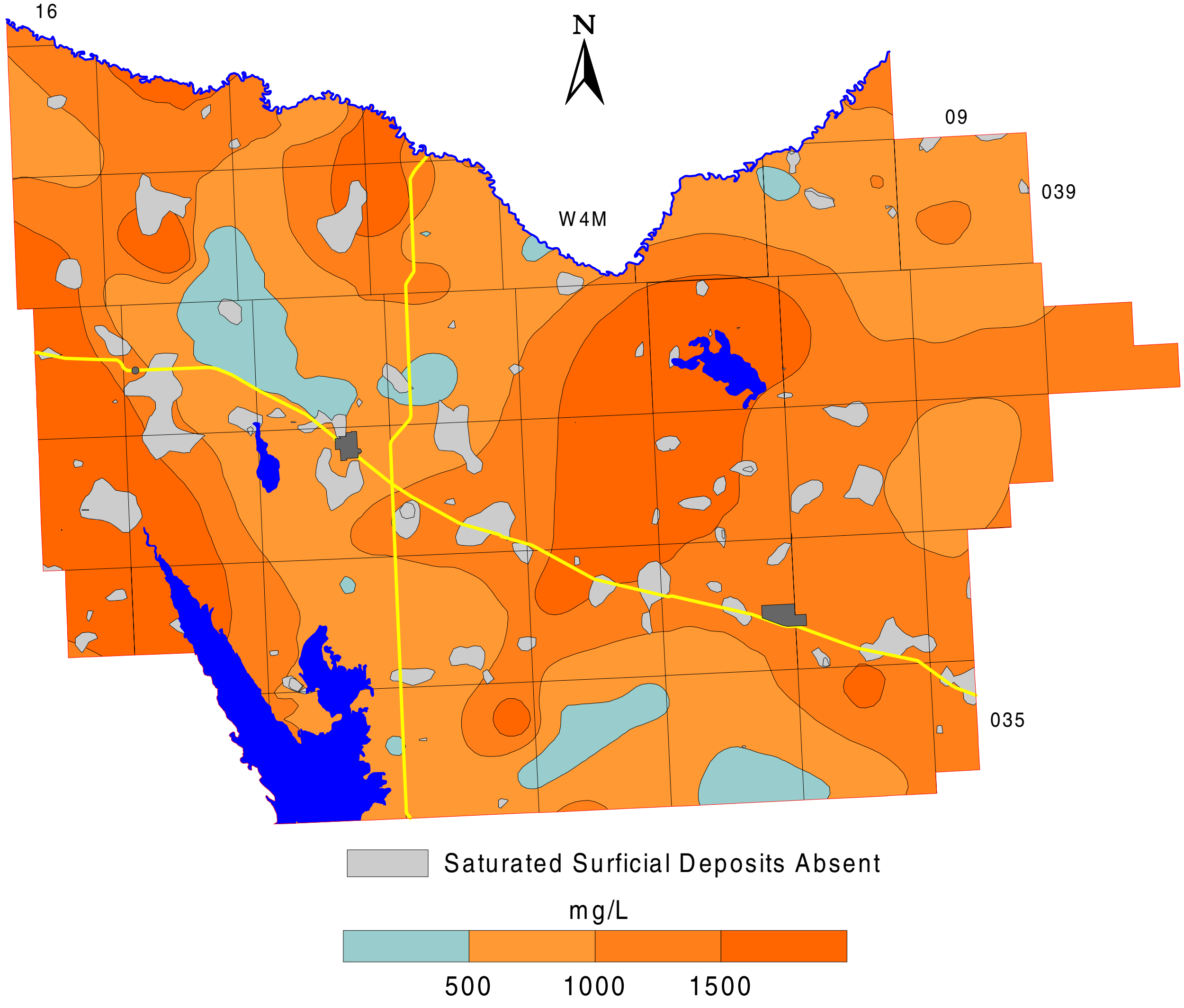
Amount of Sand and Gravel in Surficial Deposits



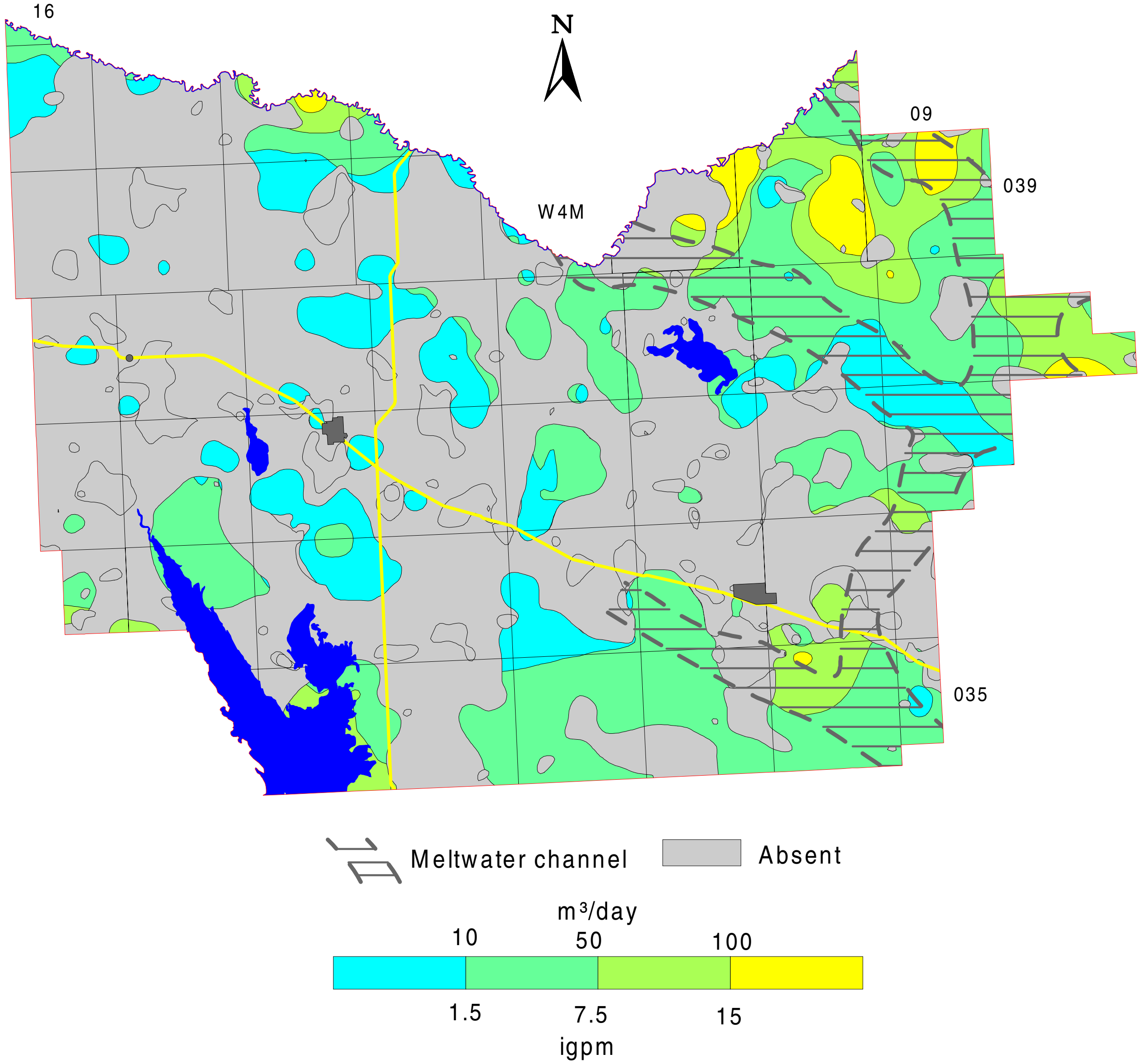
Water Wells Completed in Surficial Deposits



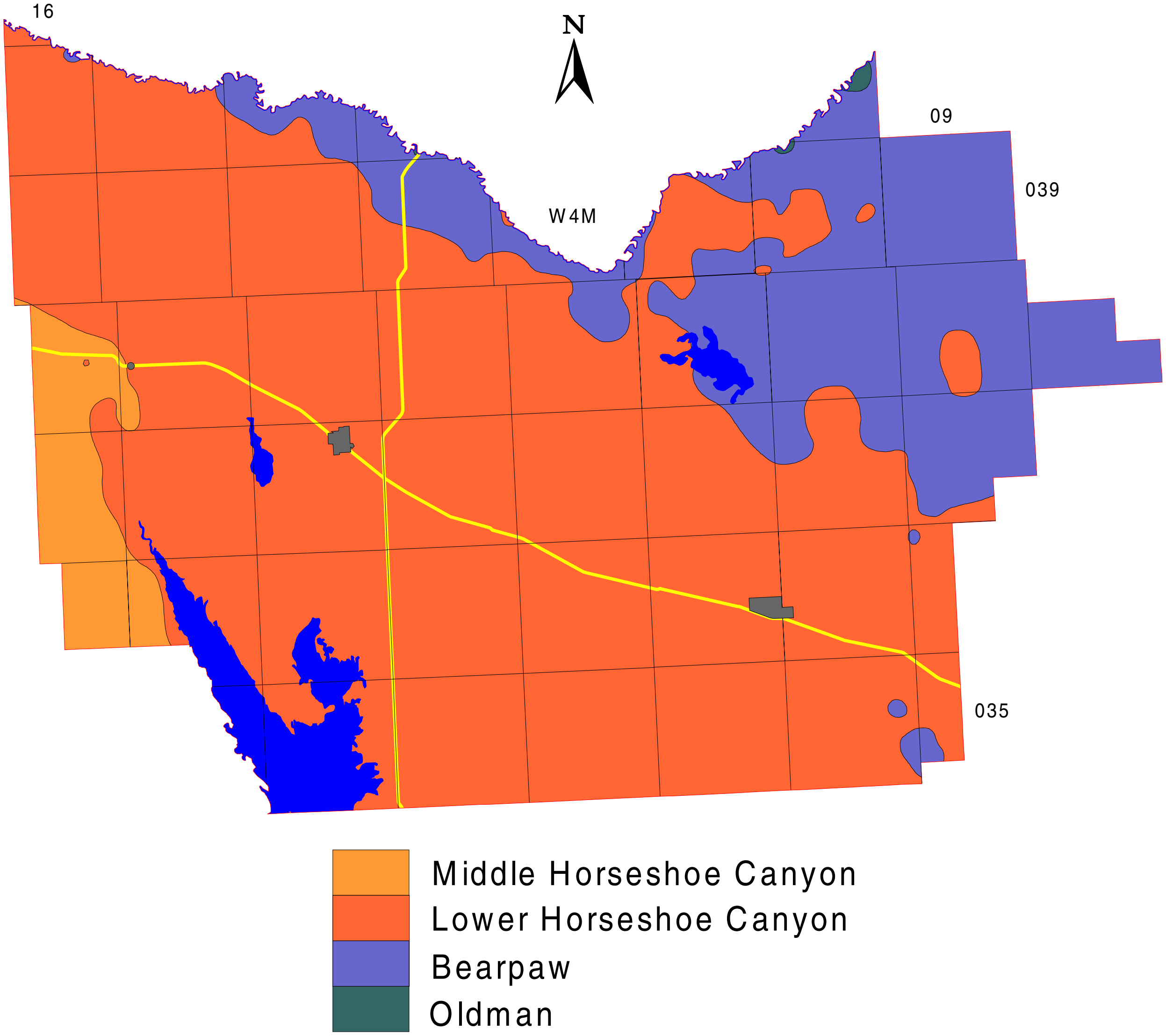
Total Dissolved Solids in Groundwater from Surficial Deposits



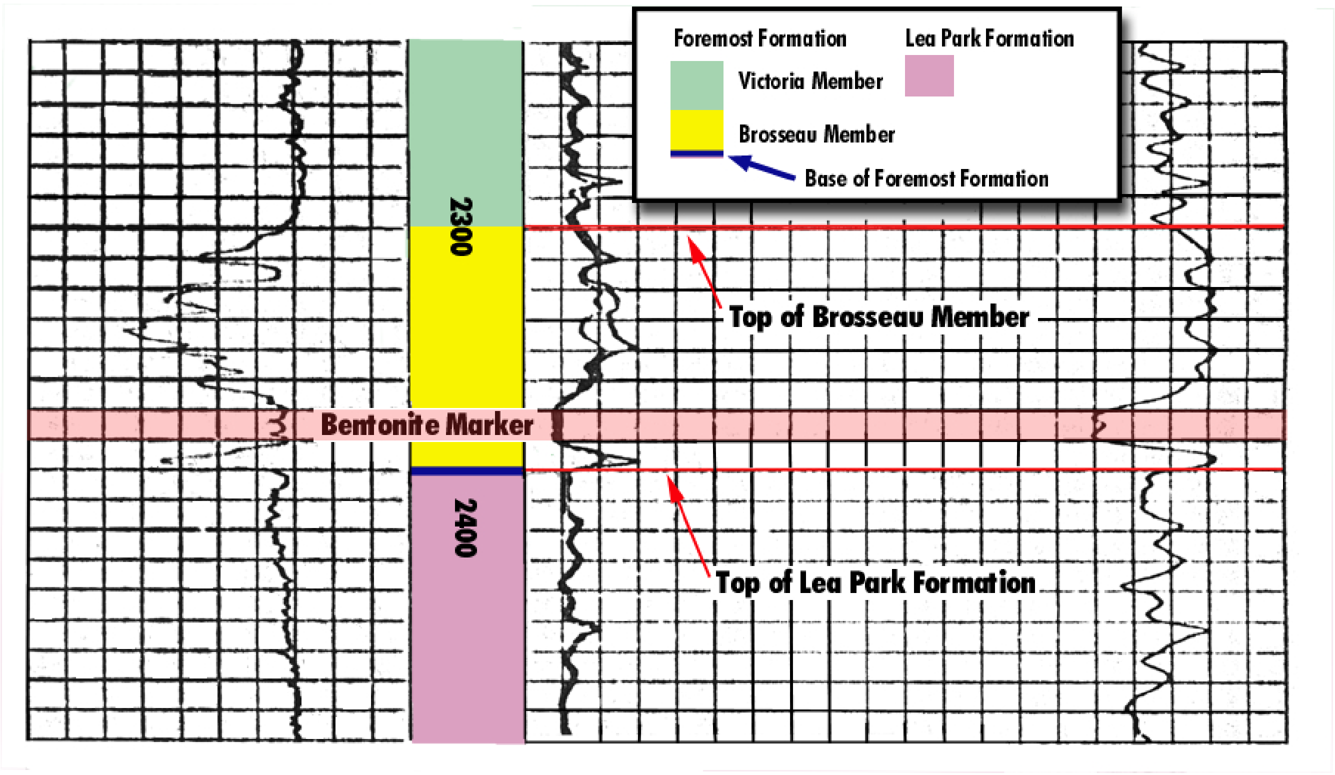
Apparent Yield for Water Wells Completed through Sand and Gravel Aquifer



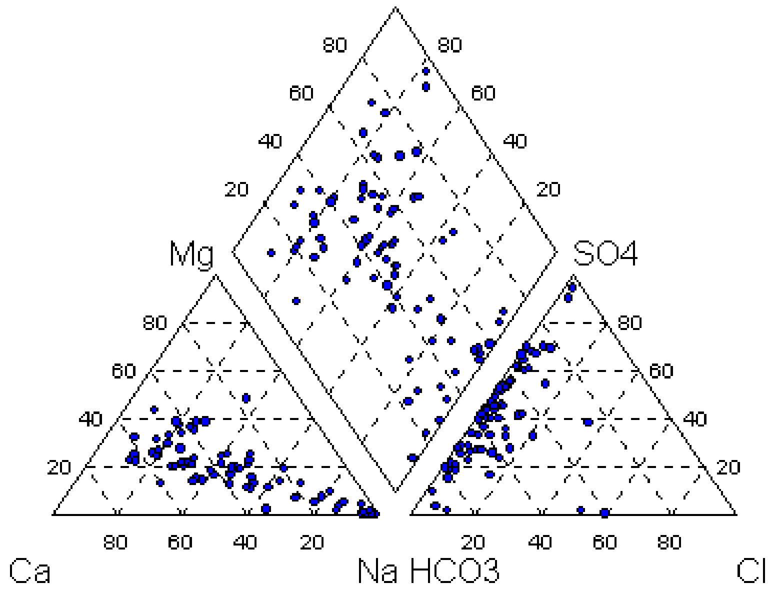
Bedrock Geology



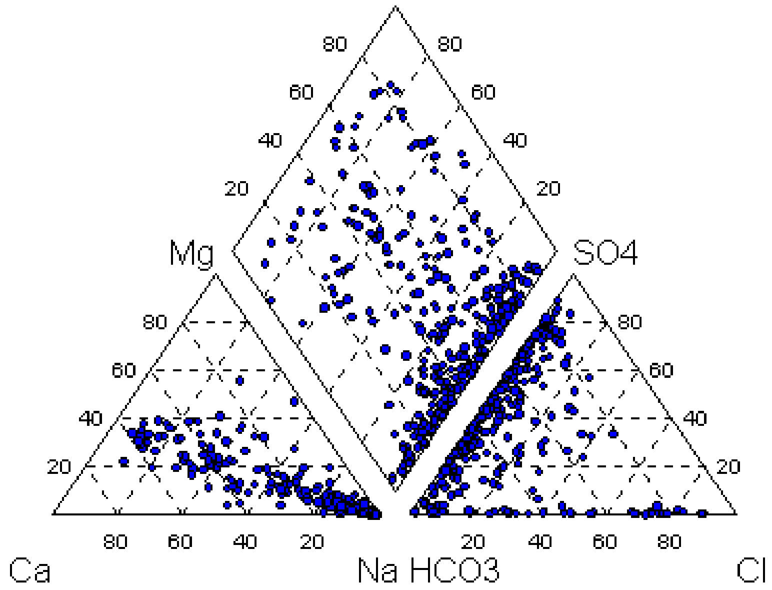
E-Log showing Base of Foremost Formation



Piper Diagrams

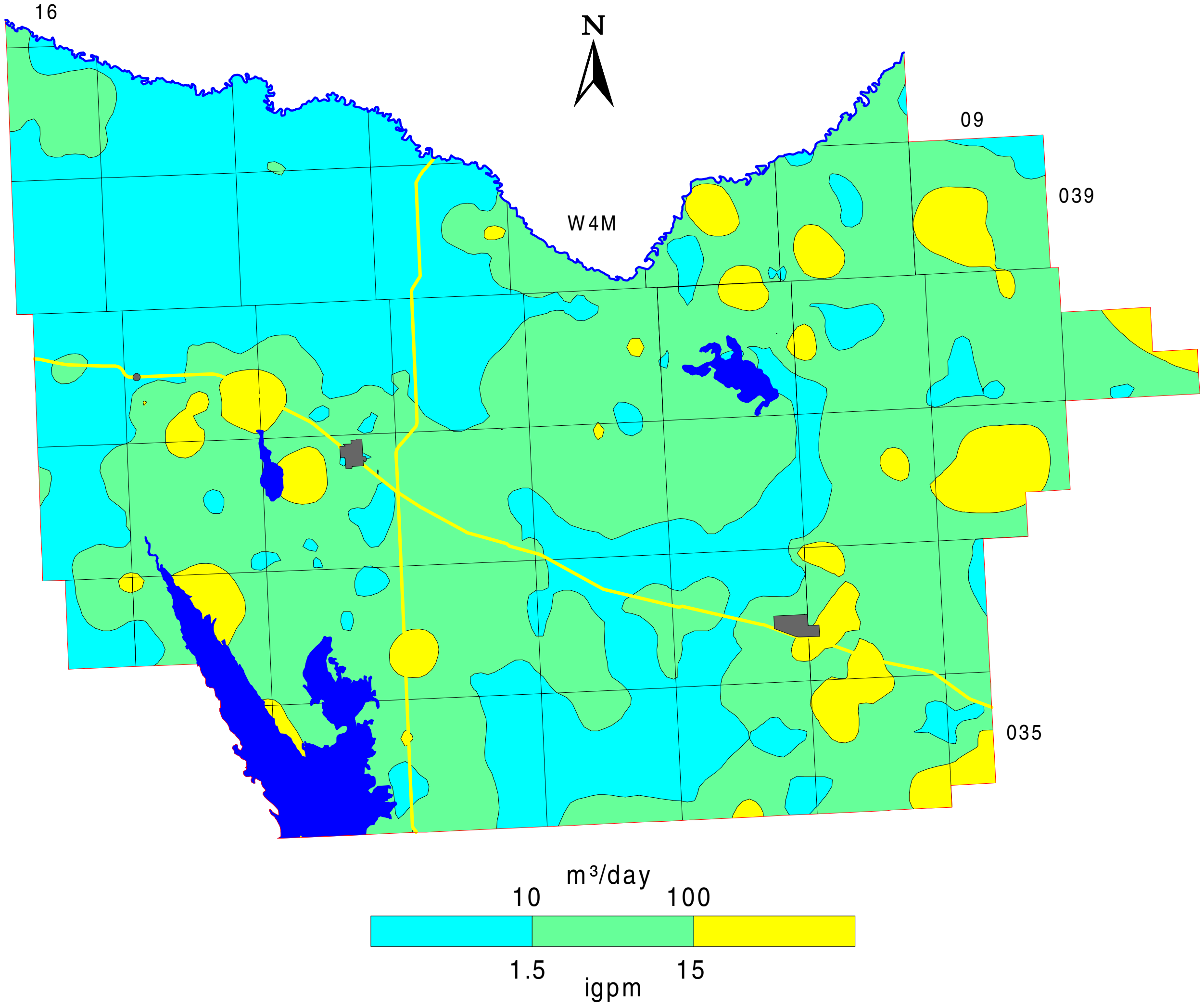


Surficial Deposits

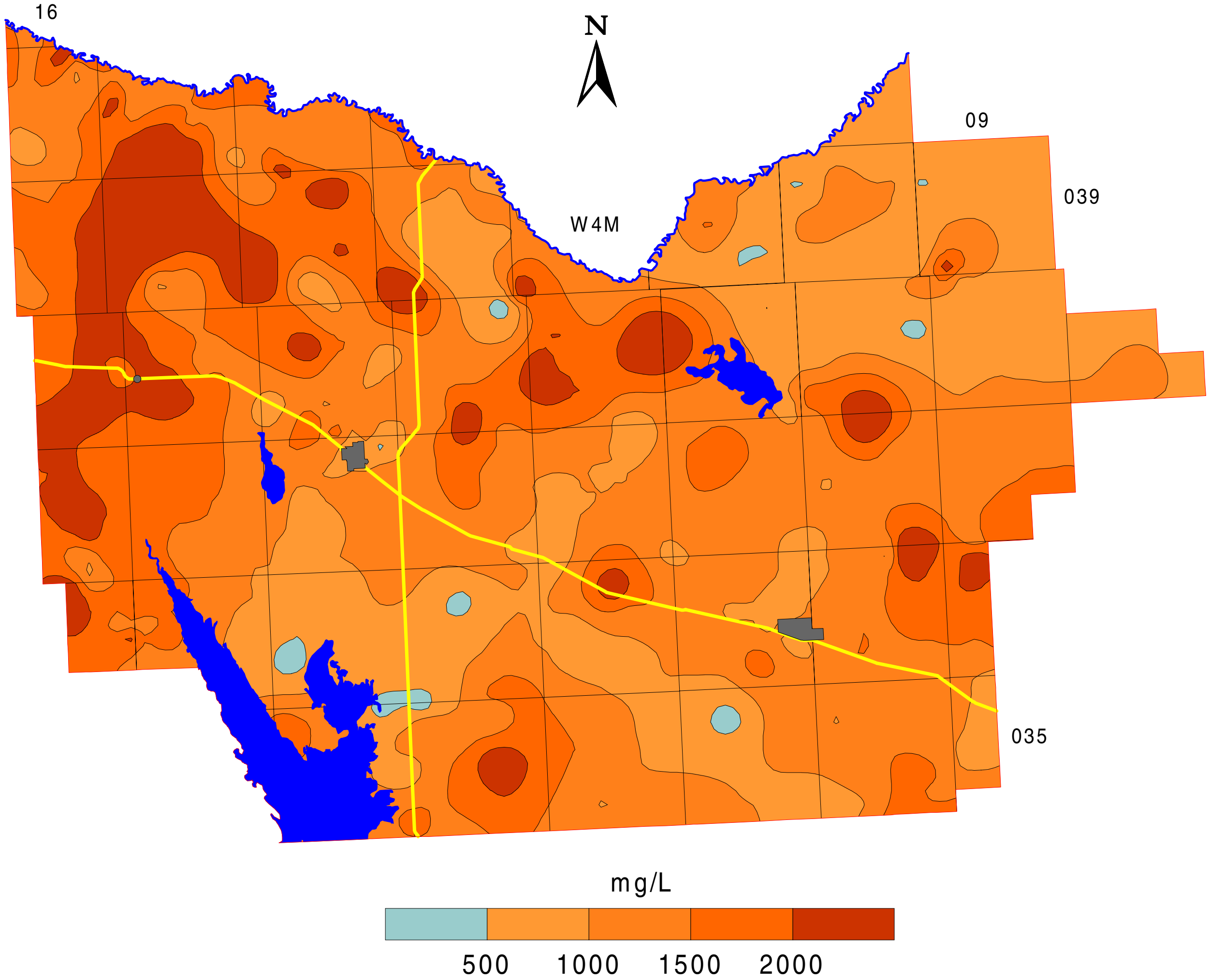


Bedrock Aquifers

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



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



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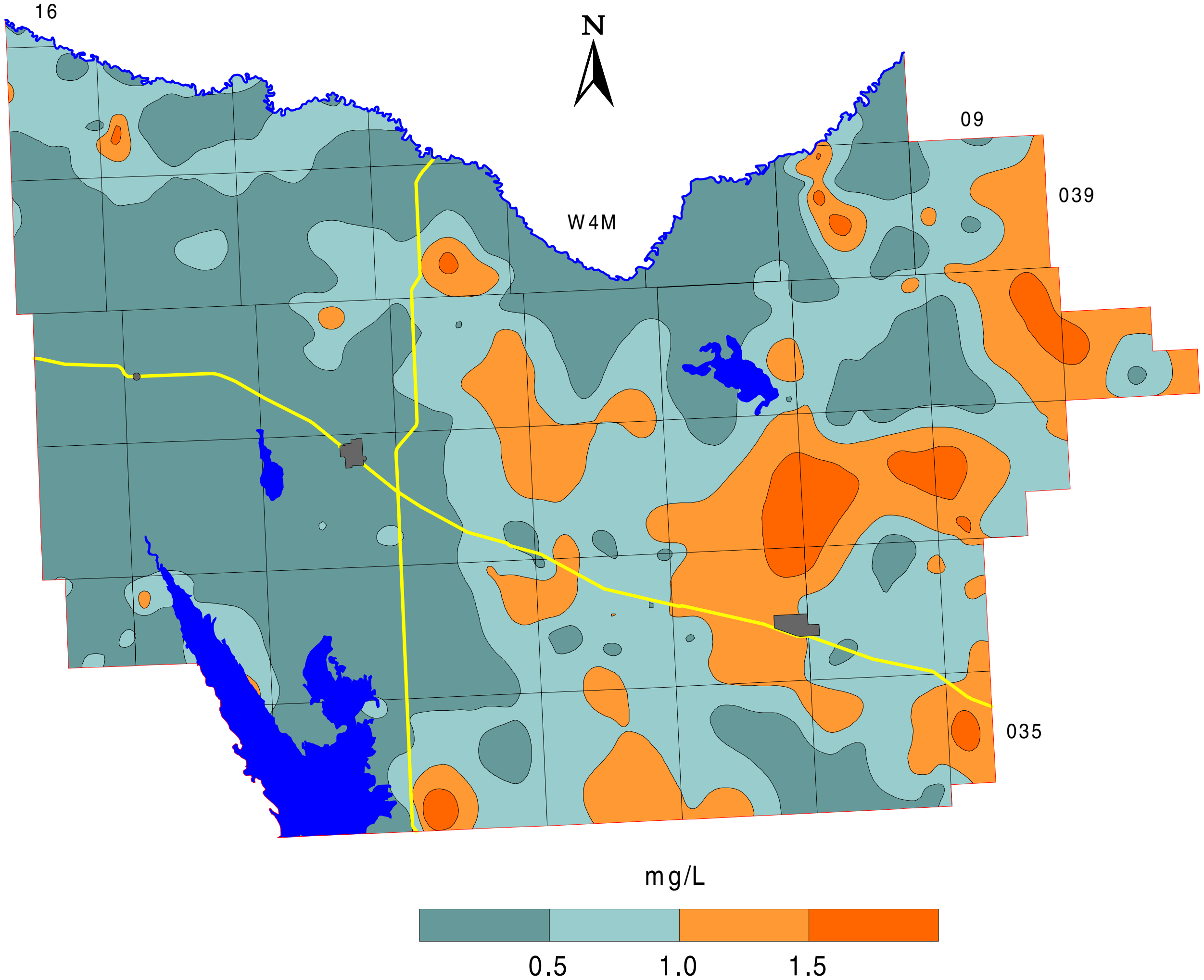
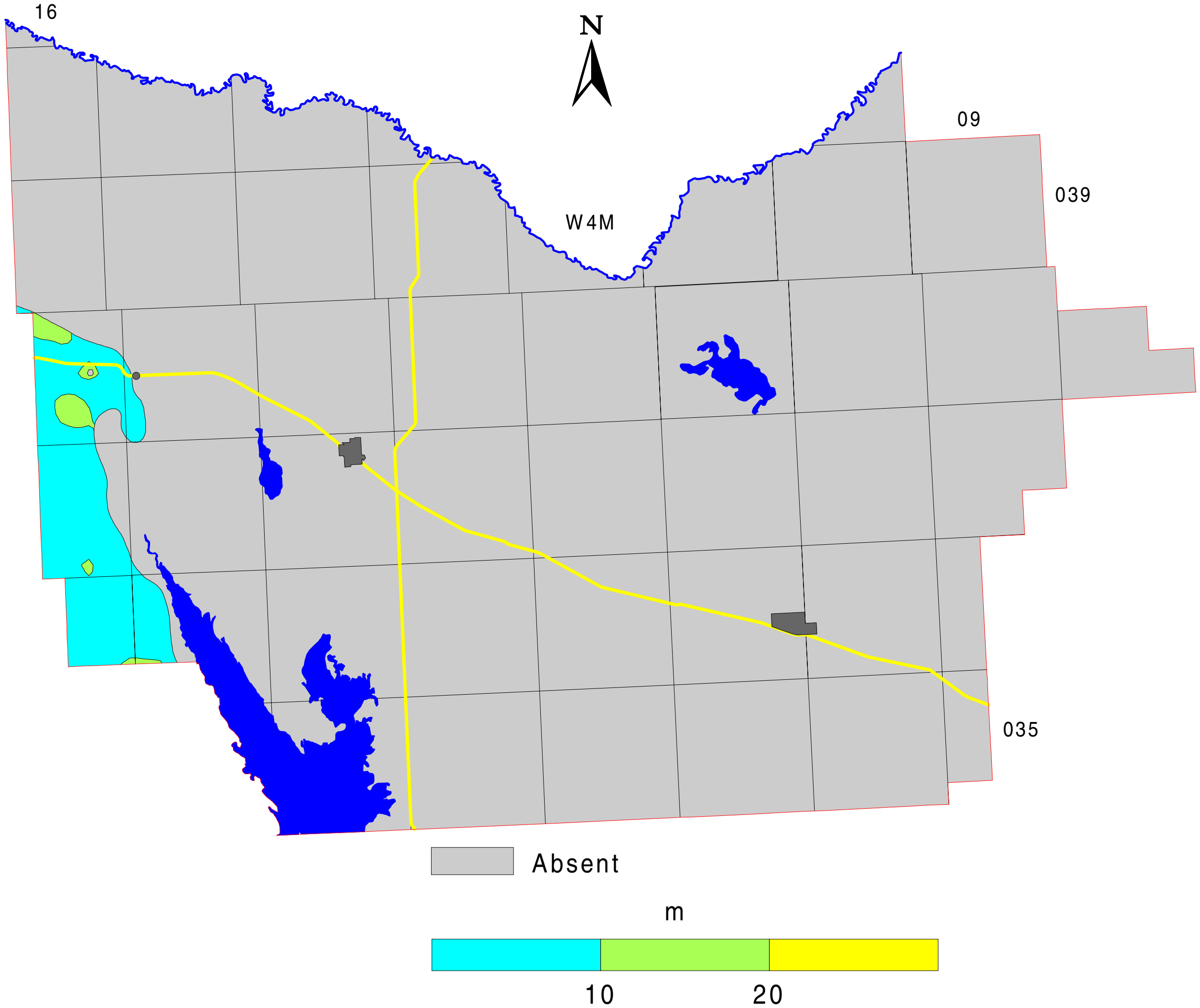
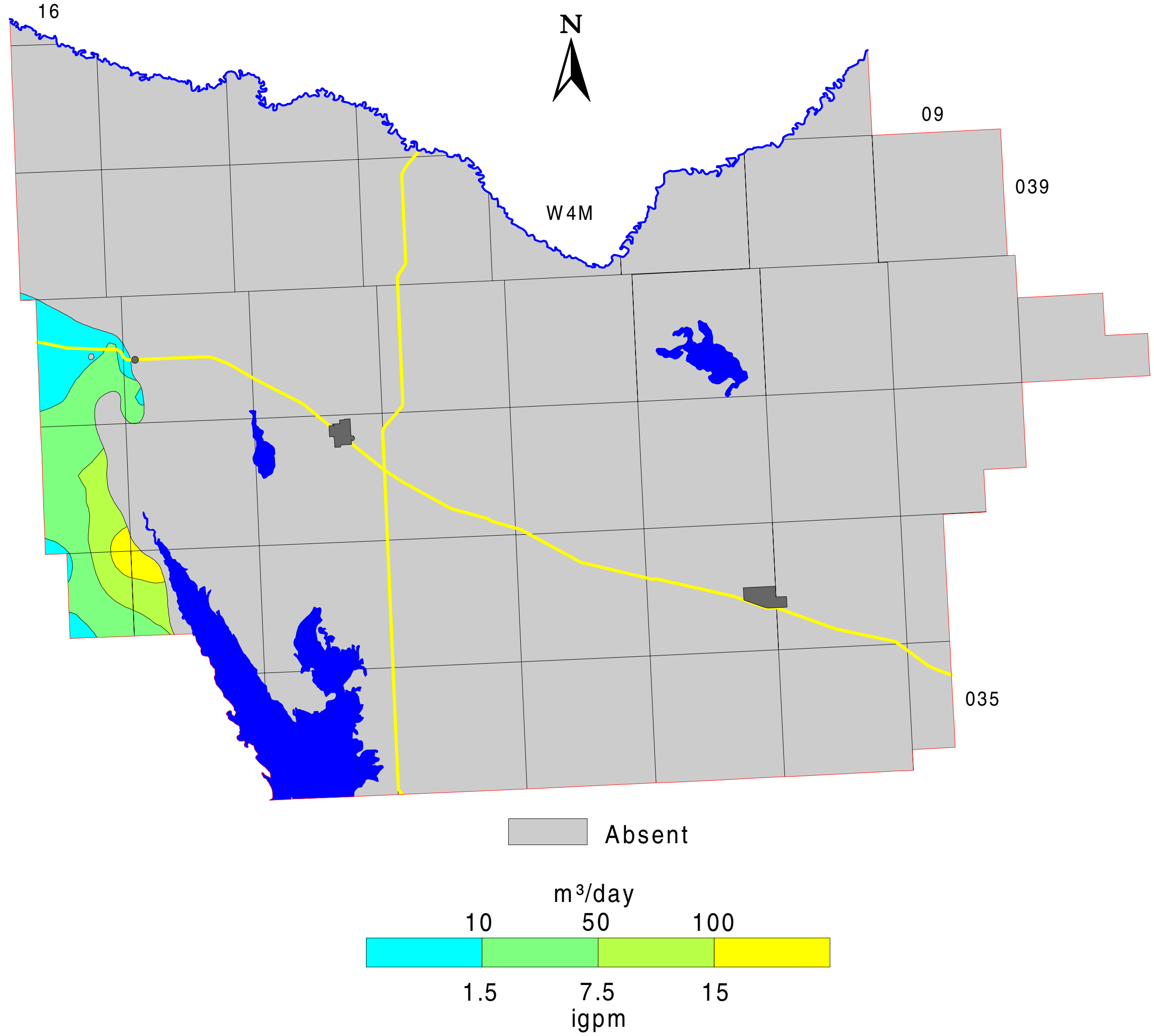
Fluoride in Groundwater from Upper Bedrock Aquifer(s)



Depth to Top of Middle Horseshoe Canyon Formation



Apparent Yield for Water Wells Completed through Middle Horseshoe Canyon Aquifer



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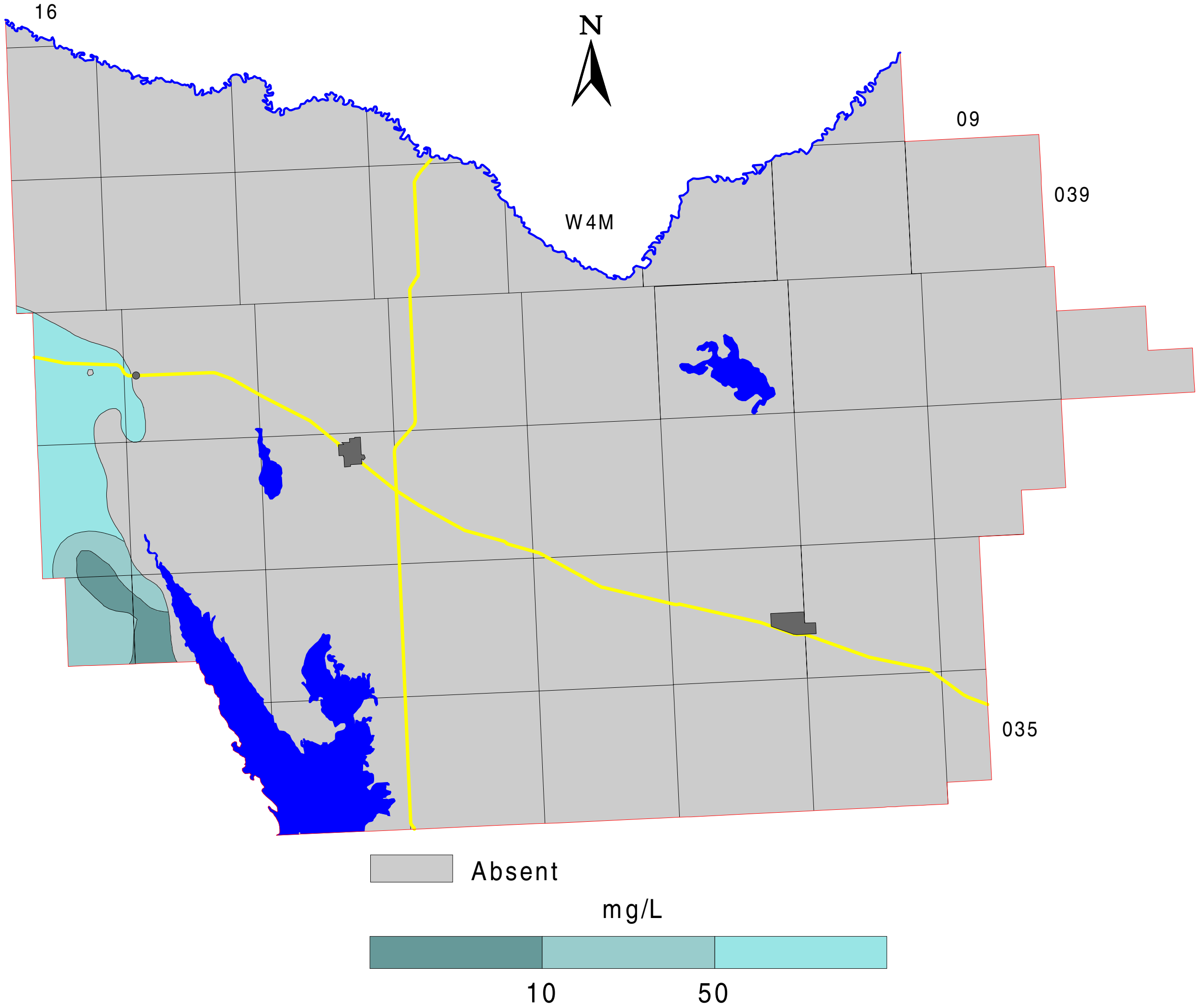
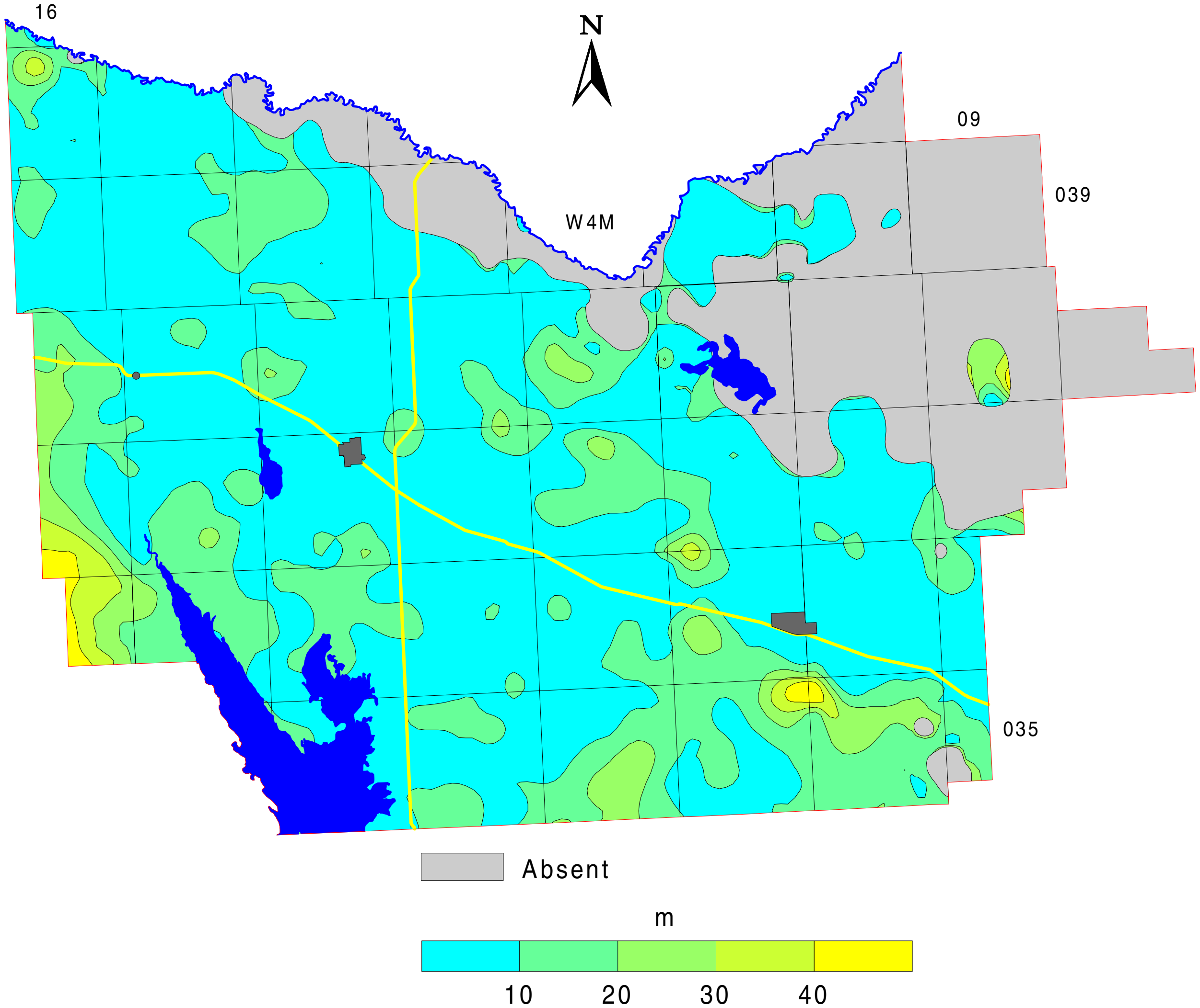
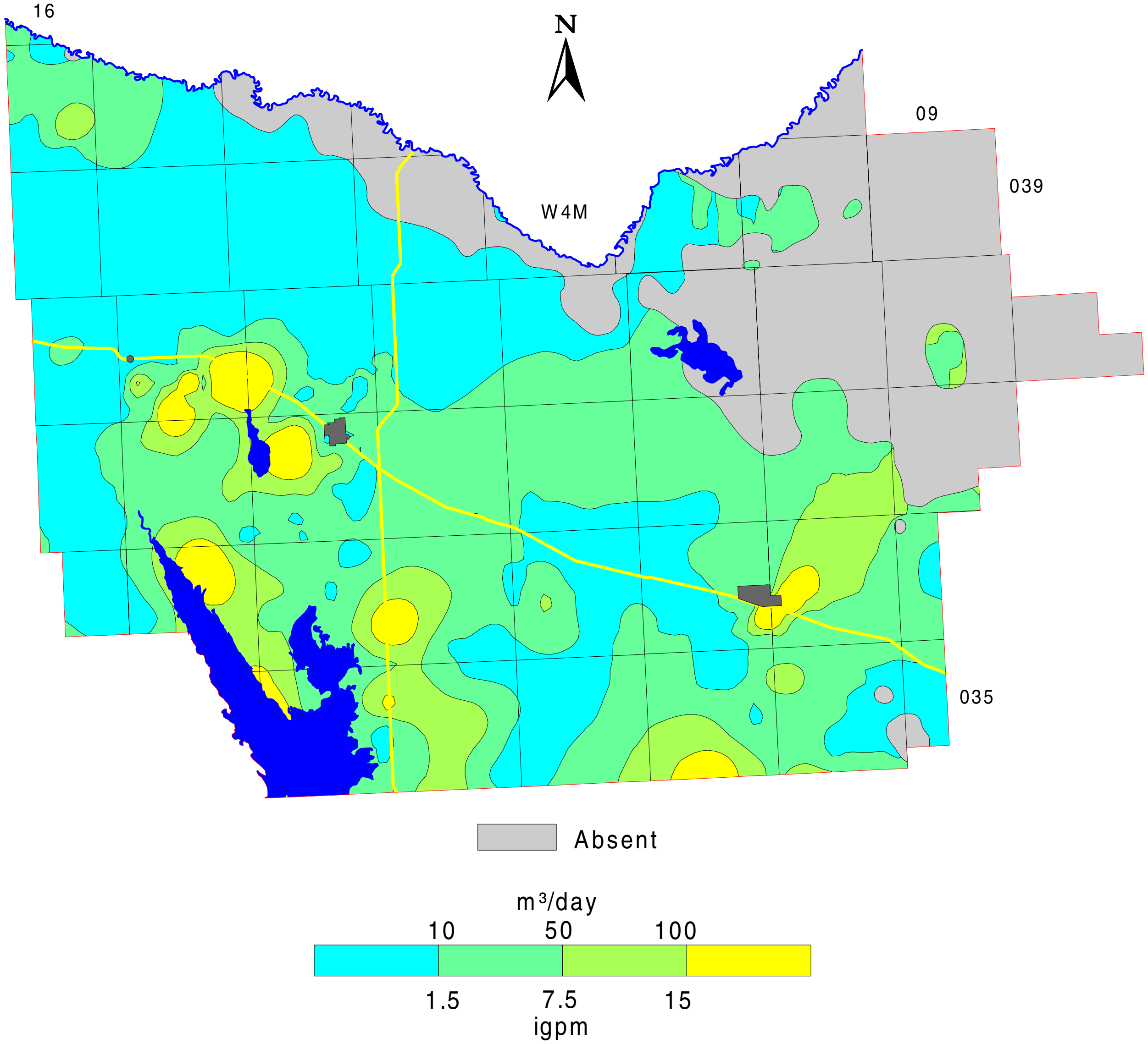
Chloride in Groundwater from Middle Horseshoe Canyon Aquifer



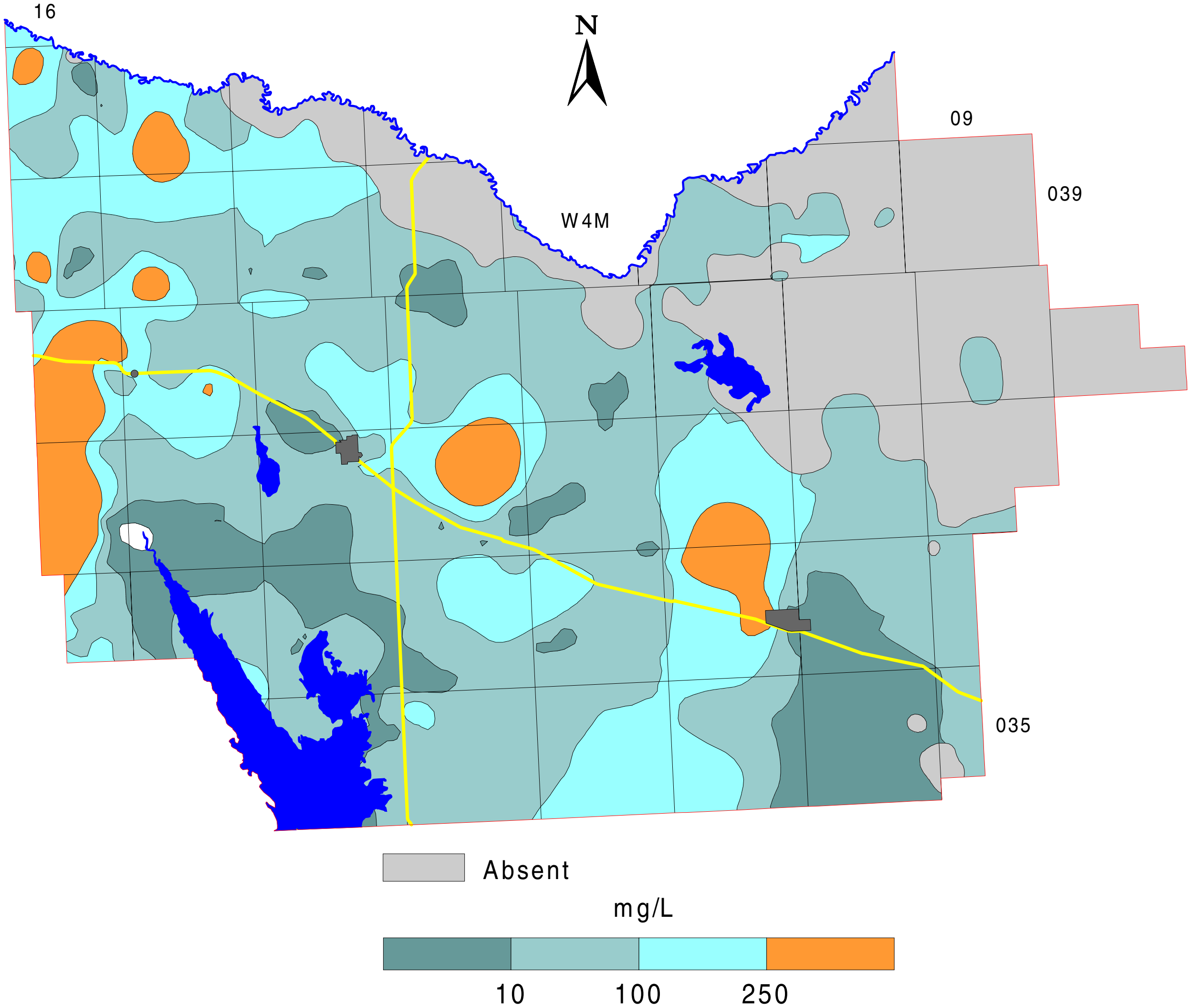
Depth to Top of Lower Horseshoe Canyon Formation



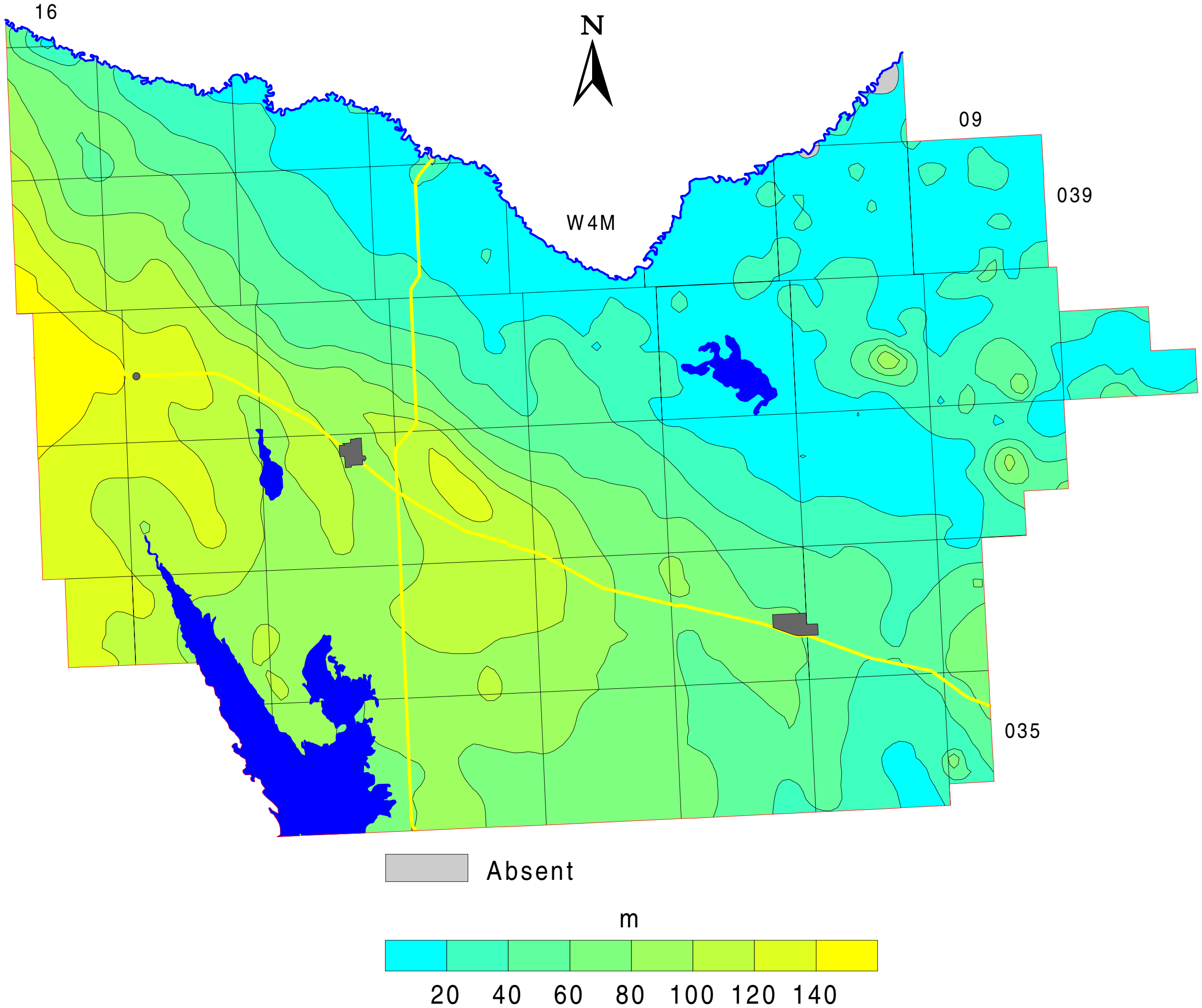
Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer



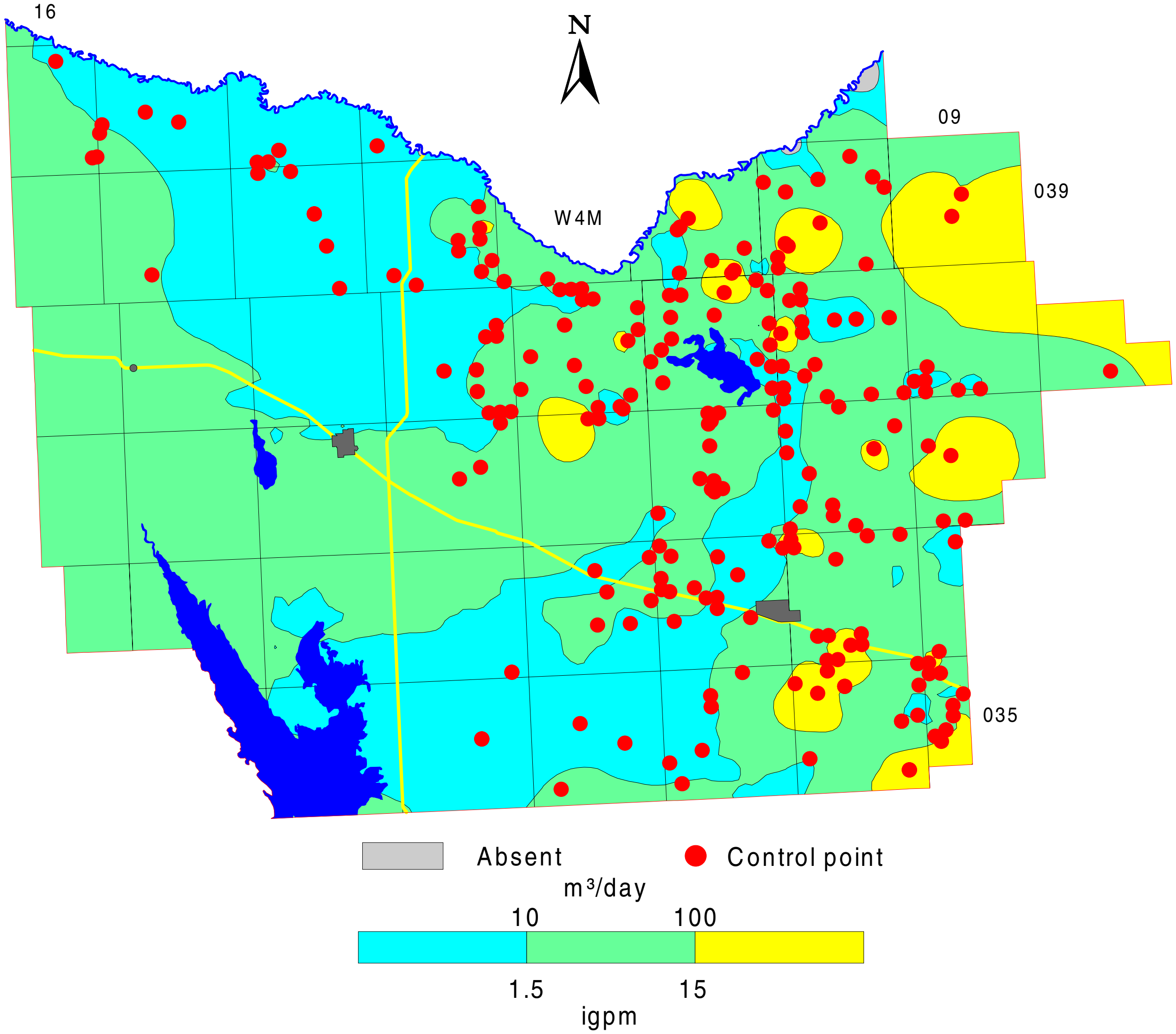
Chloride in Groundwater from Lower Horseshoe Canyon Aquifer



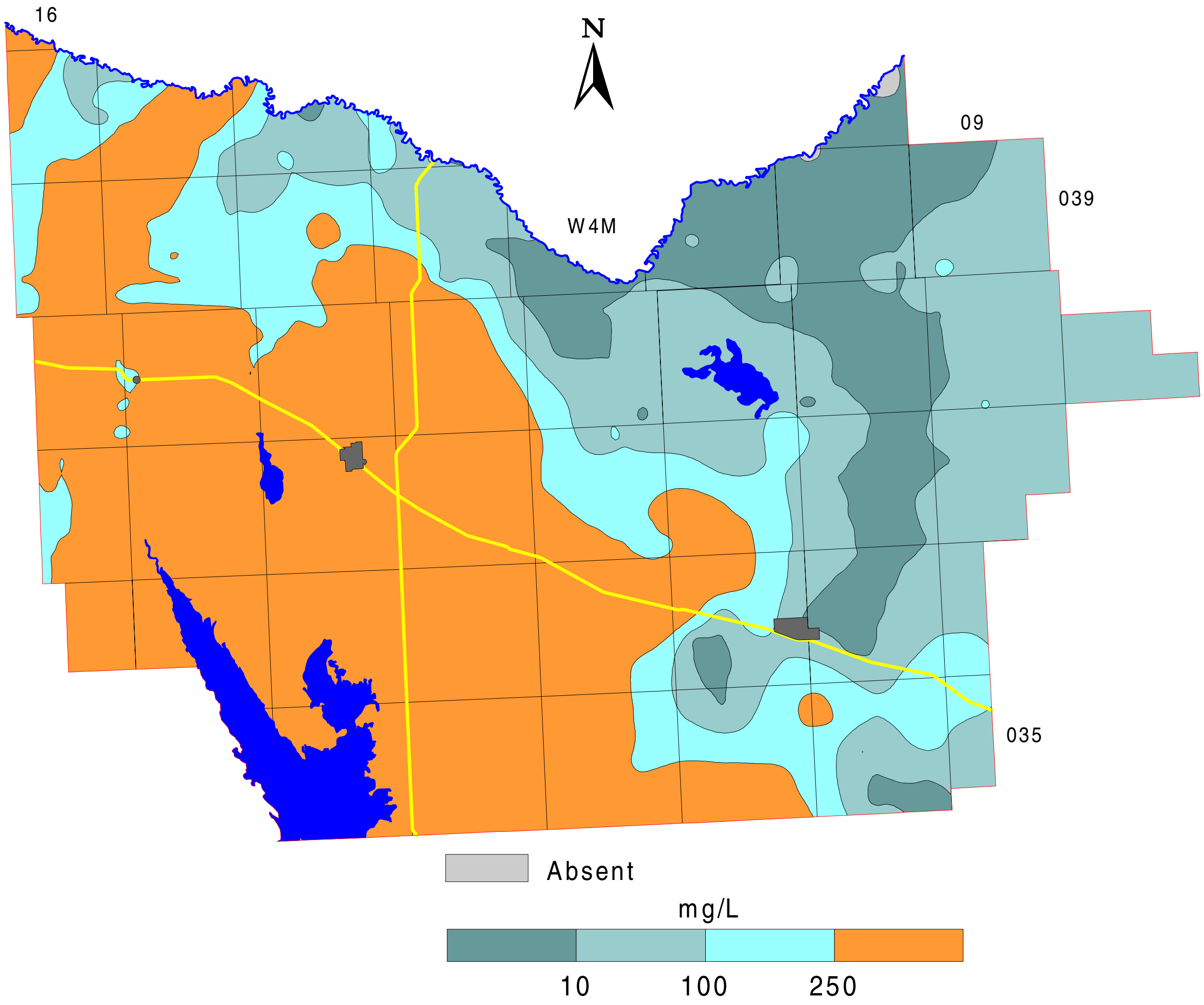
Depth to Top of Bearpaw Formation



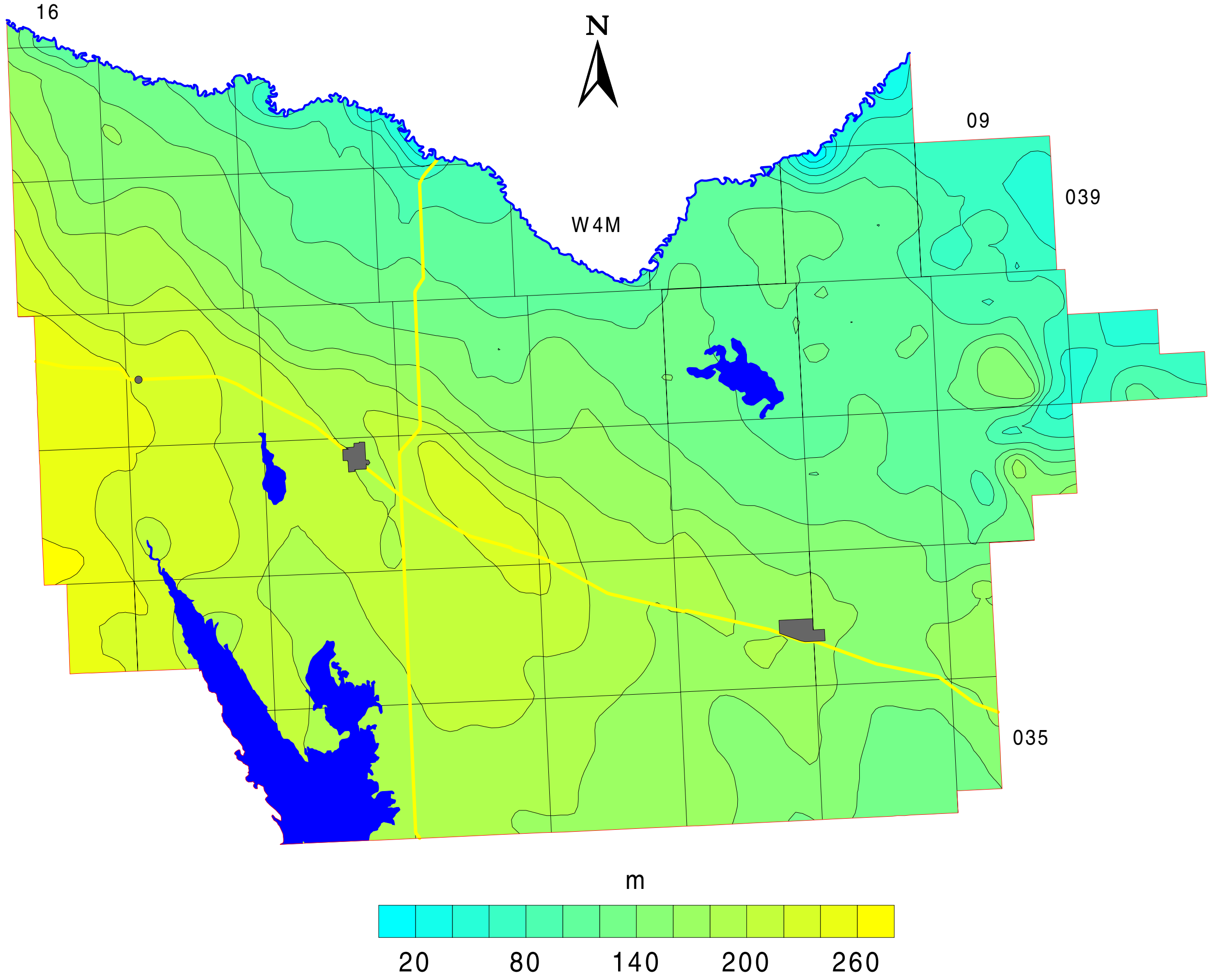
Apparent Yield for Water Wells Completed through Bearpaw Aquifer



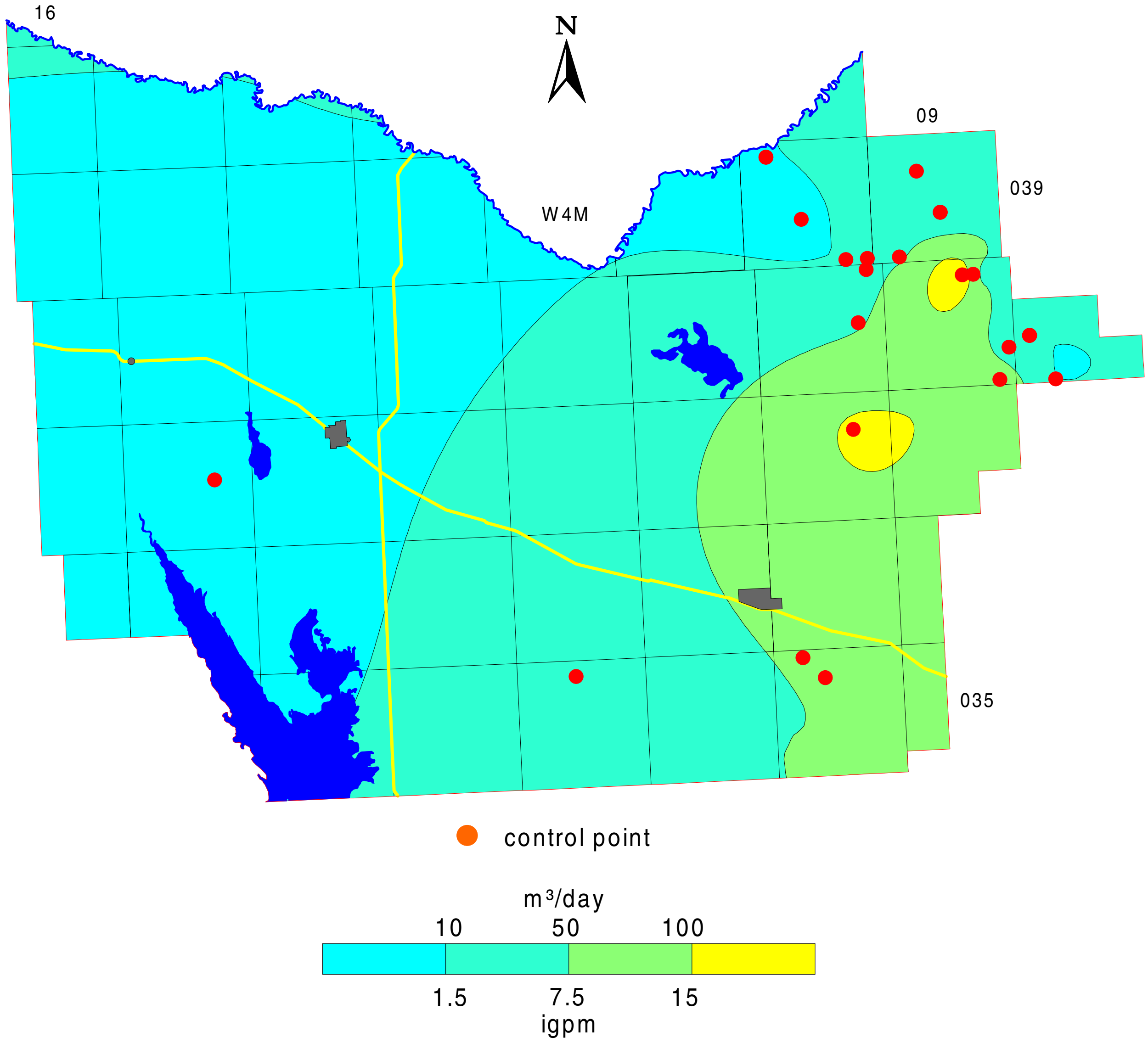
Chloride in Groundwater from Bearpaw Aquifer



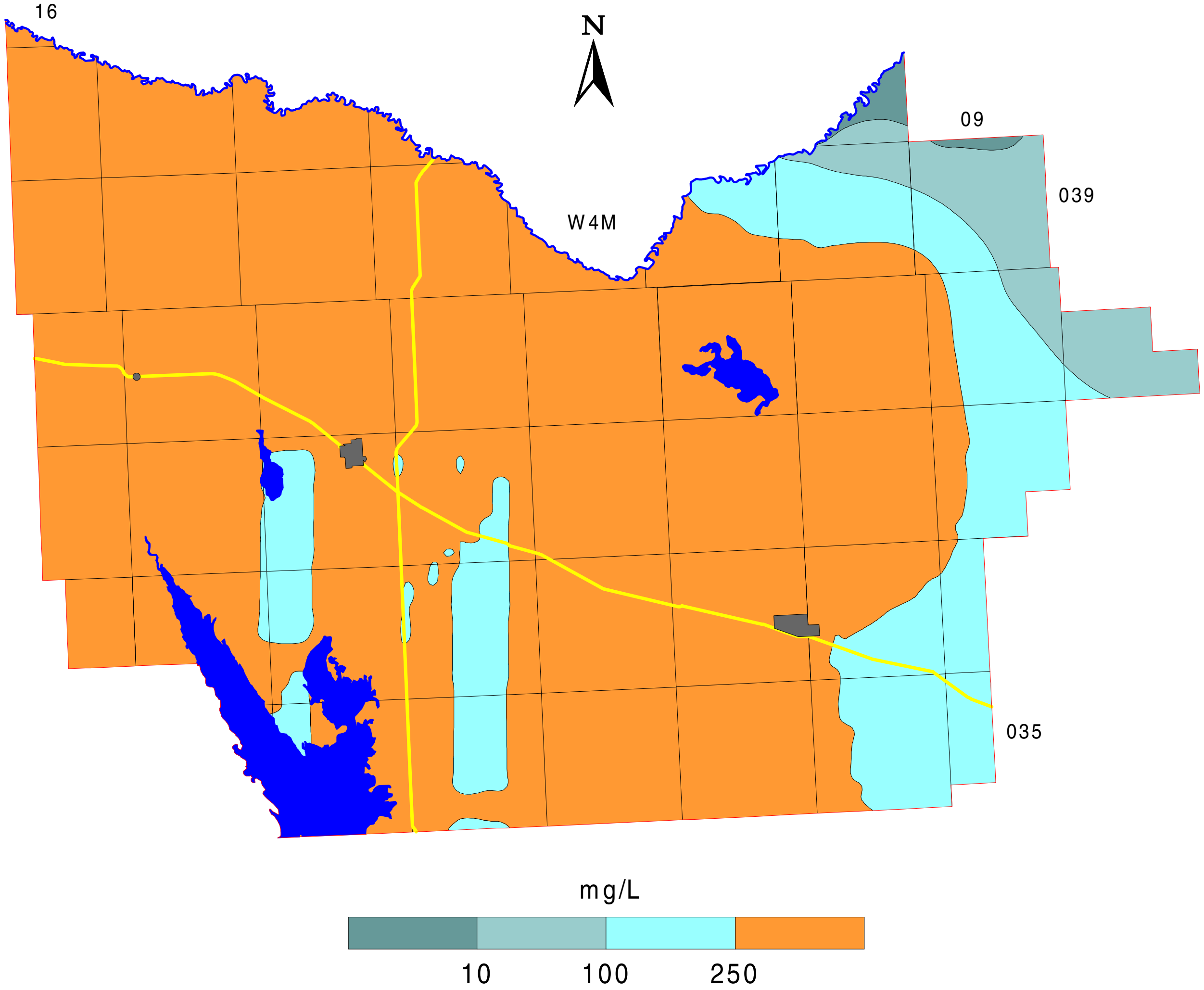
Depth to Top of Oldman Formation



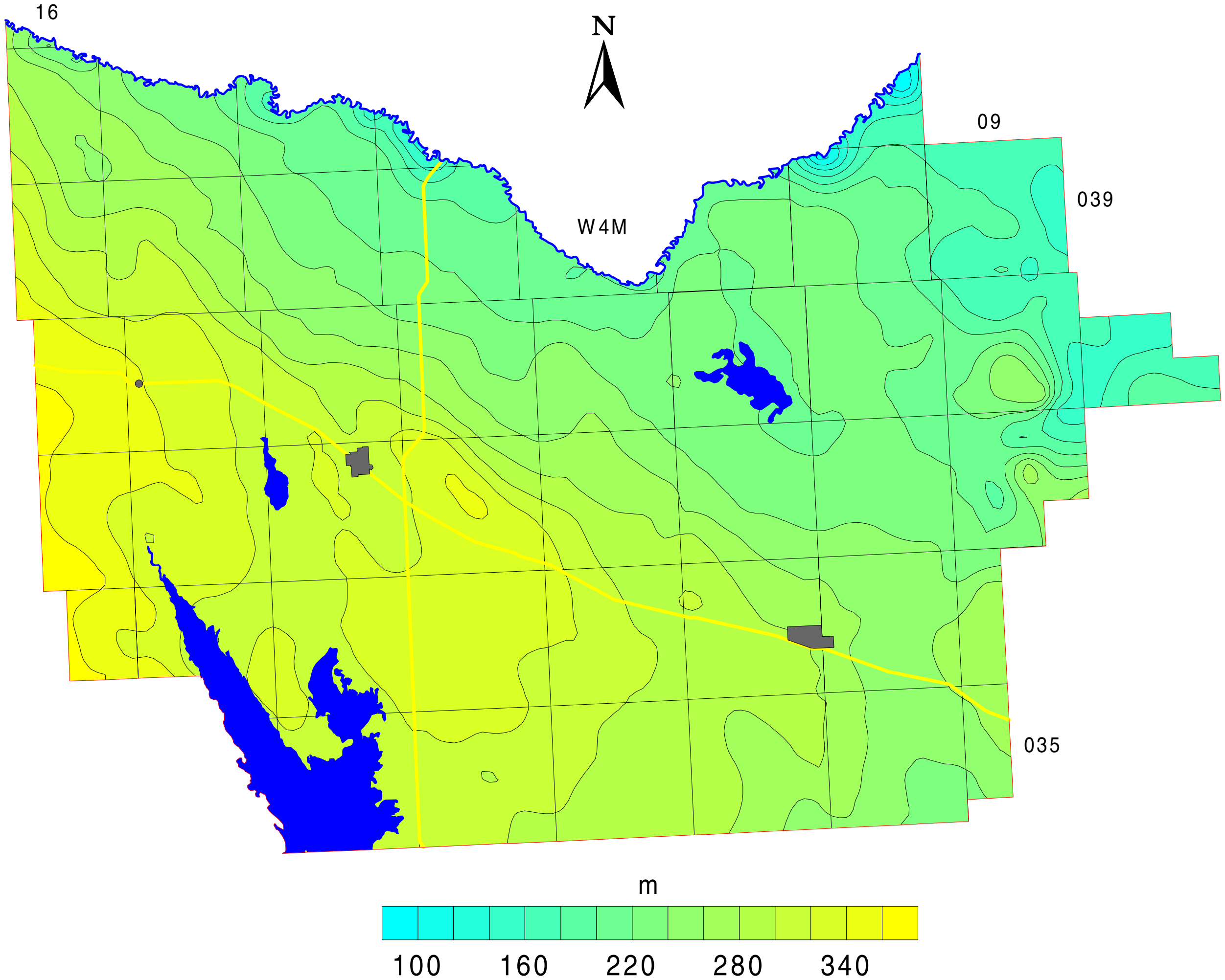
Apparent Yield for Water Wells Completed through Oldman Aquifer



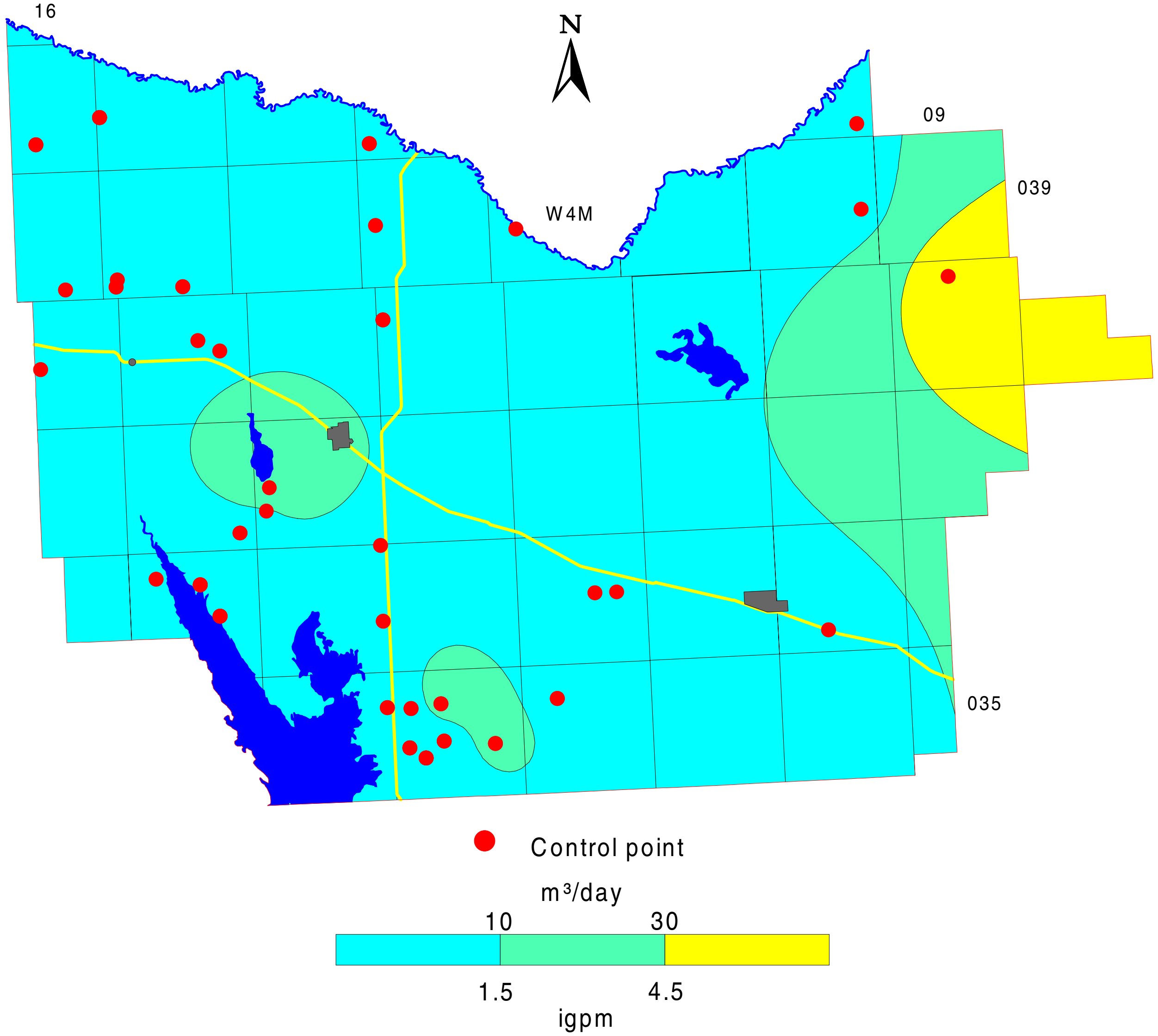
Chloride in Groundwater from Oldman Aquifer



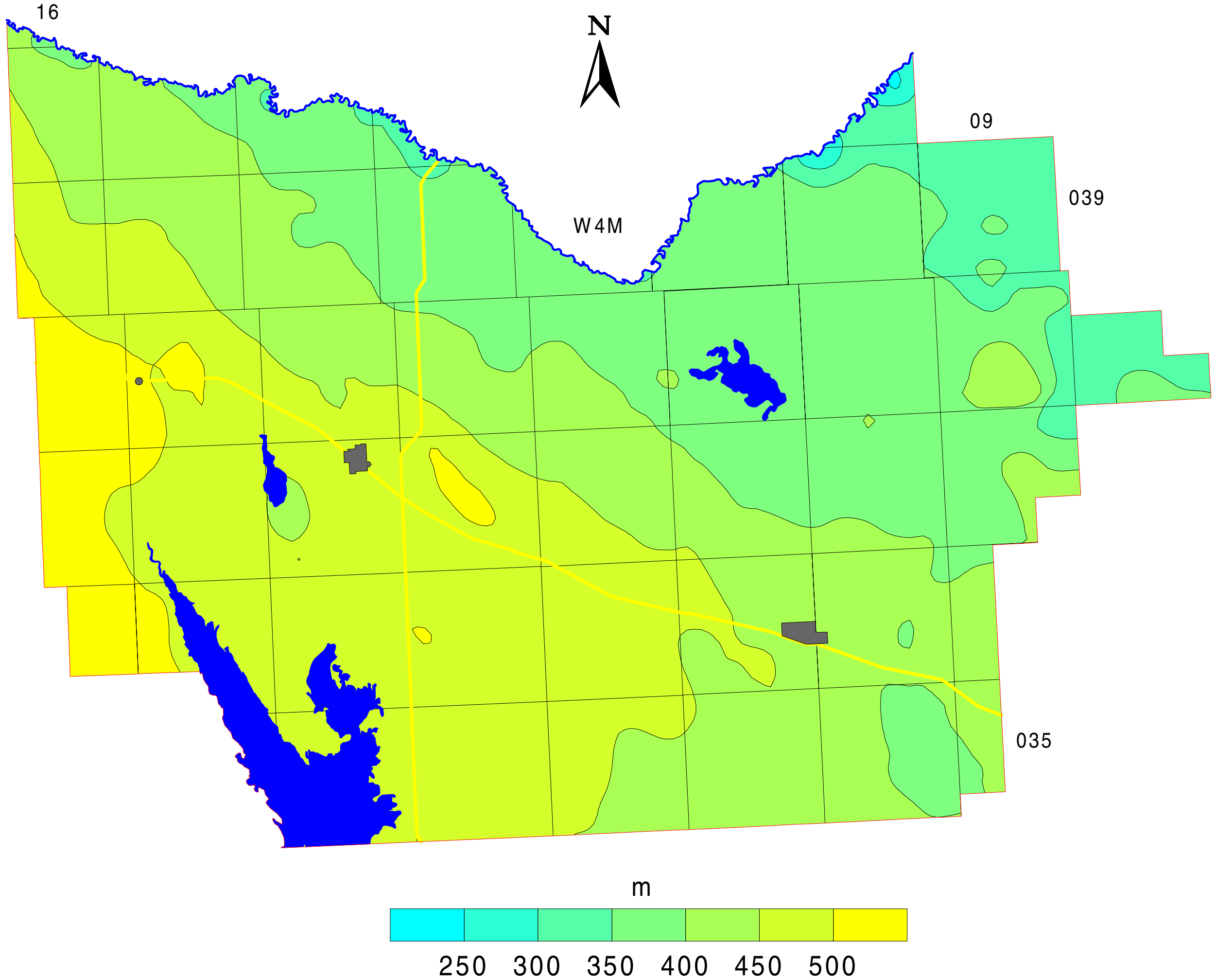
Depth to Top of Foremost Formation



Apparent Yield for Water Wells Completed through Foremost Aquifer



Depth to Top of Lea Park Formation



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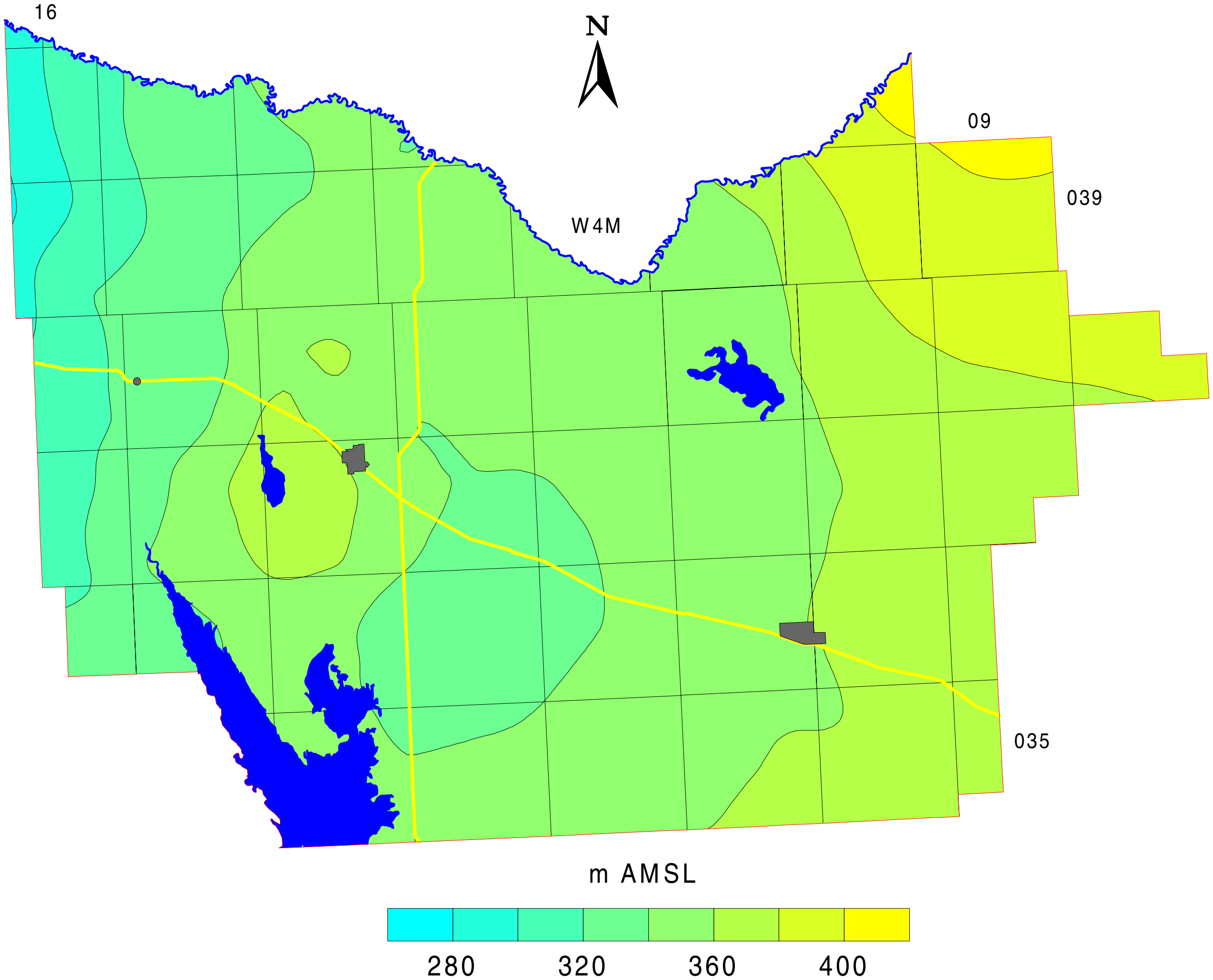
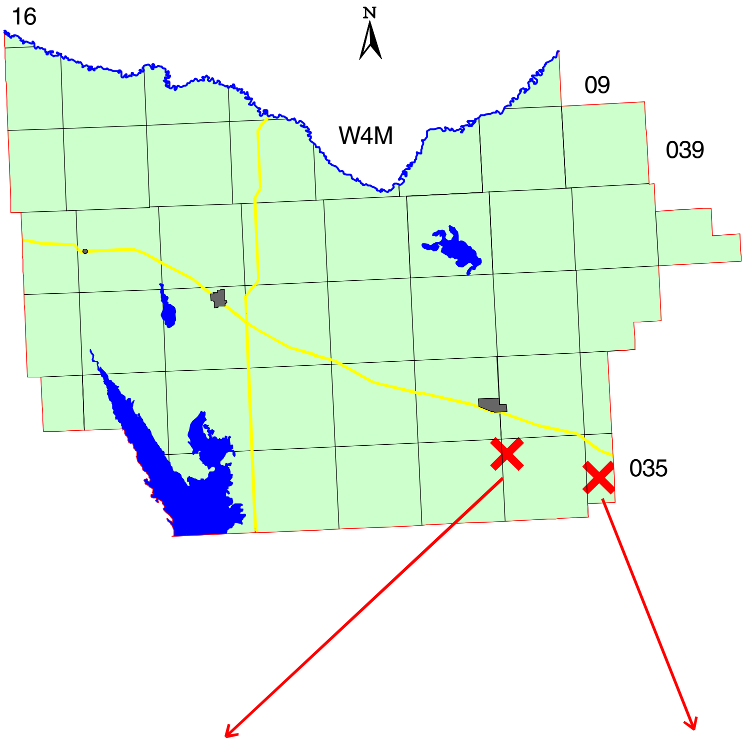
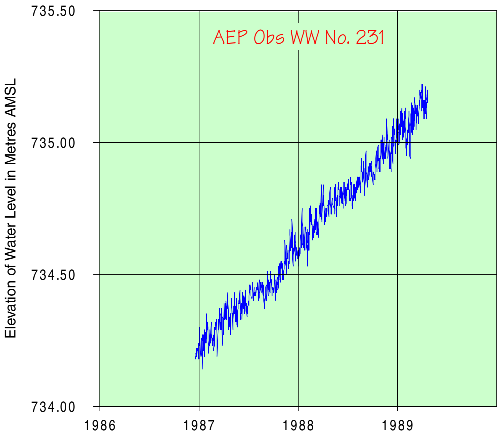
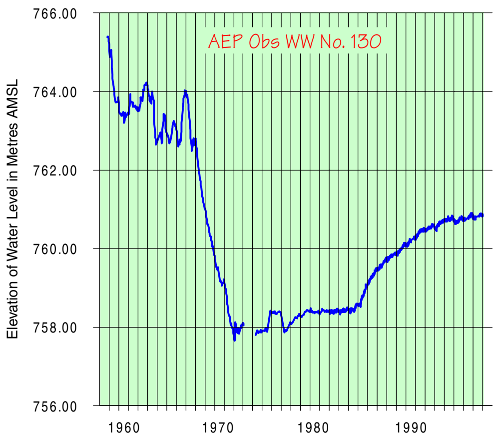
Structure-Contour Map - Top of Lea Park Formation



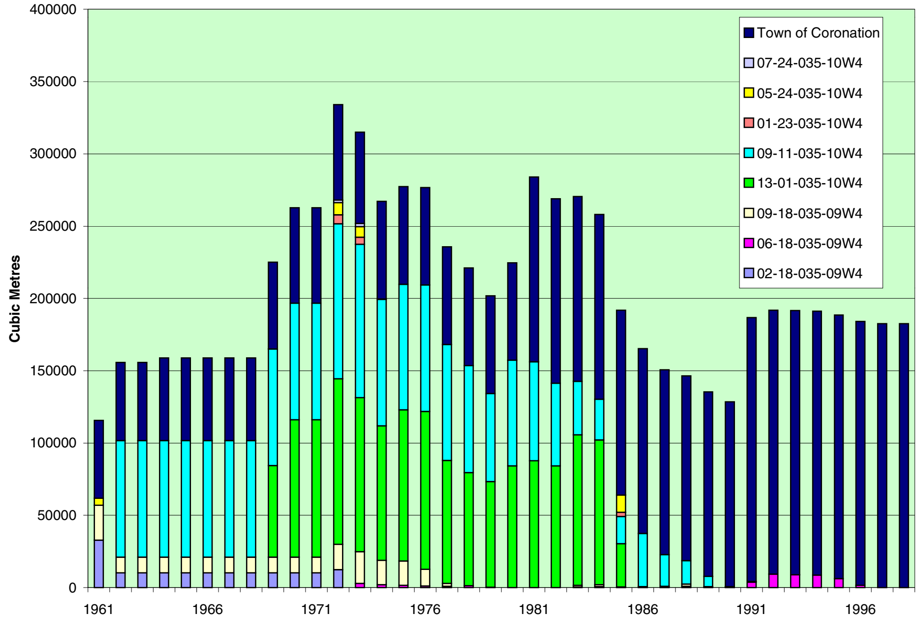
Hydrographs - AEP Observation Water Wells

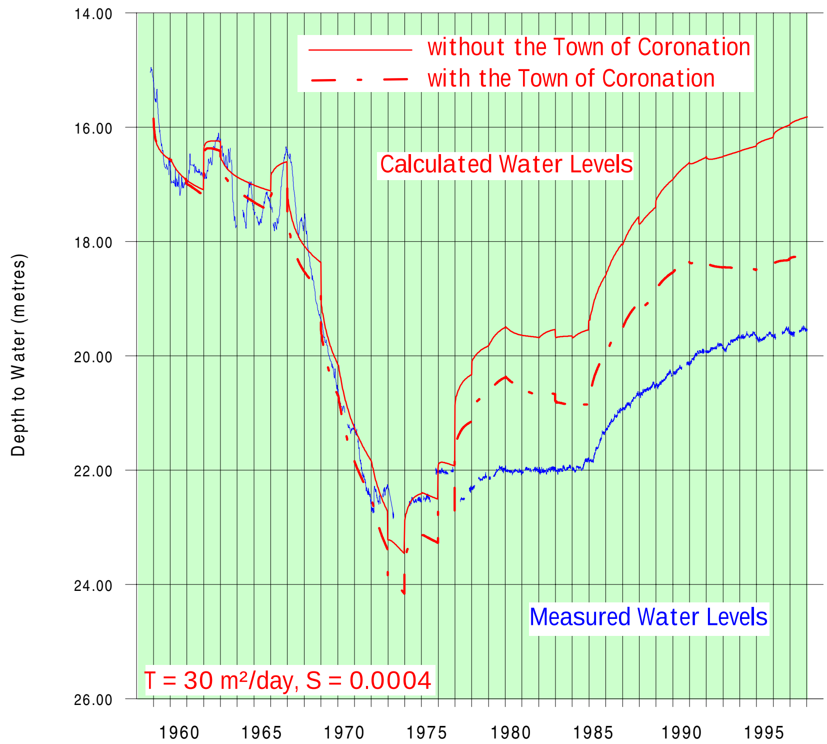




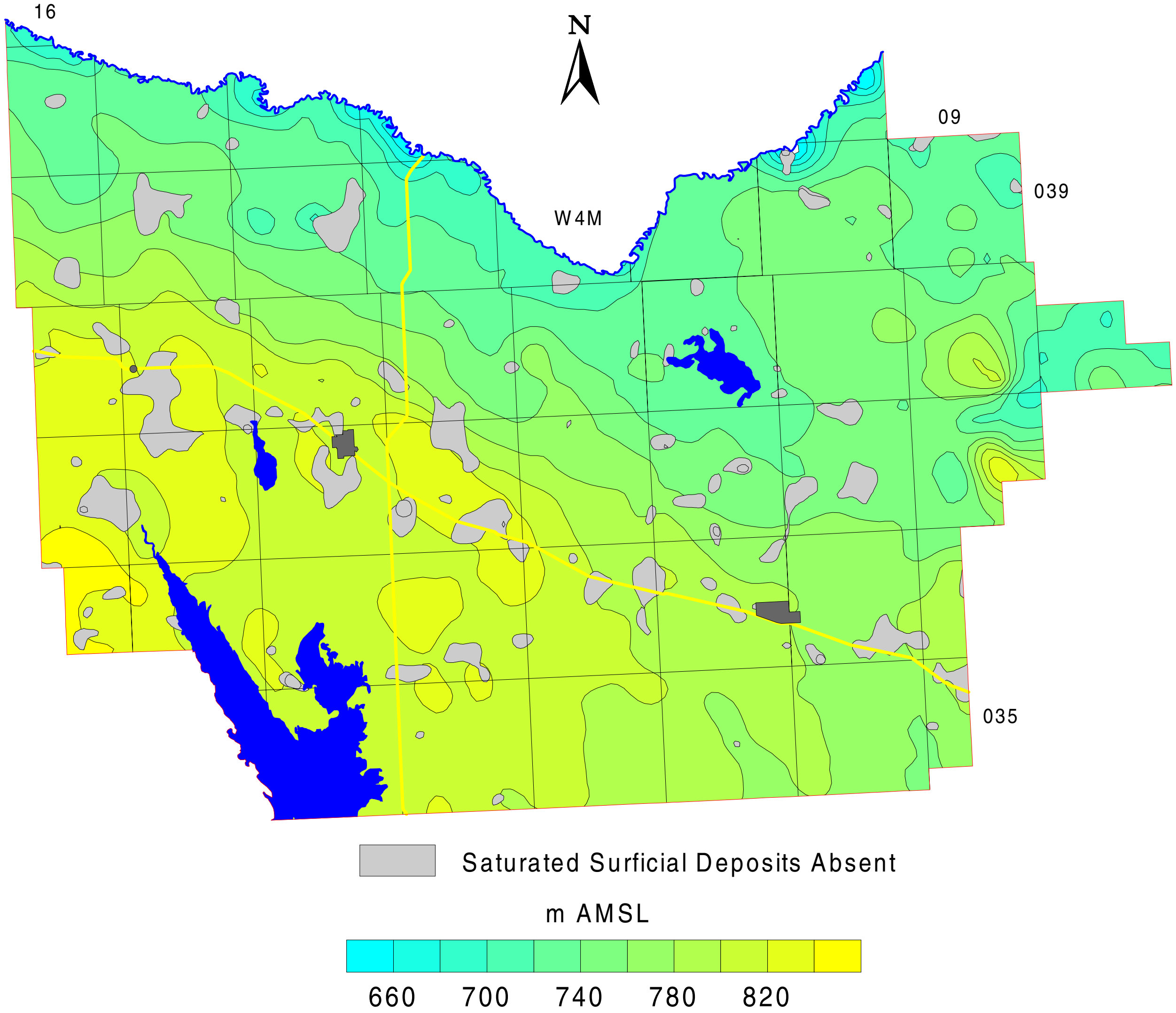


Water-Level Comparison - Based on Water Source Wells Completed in Bearpaw Aquifer

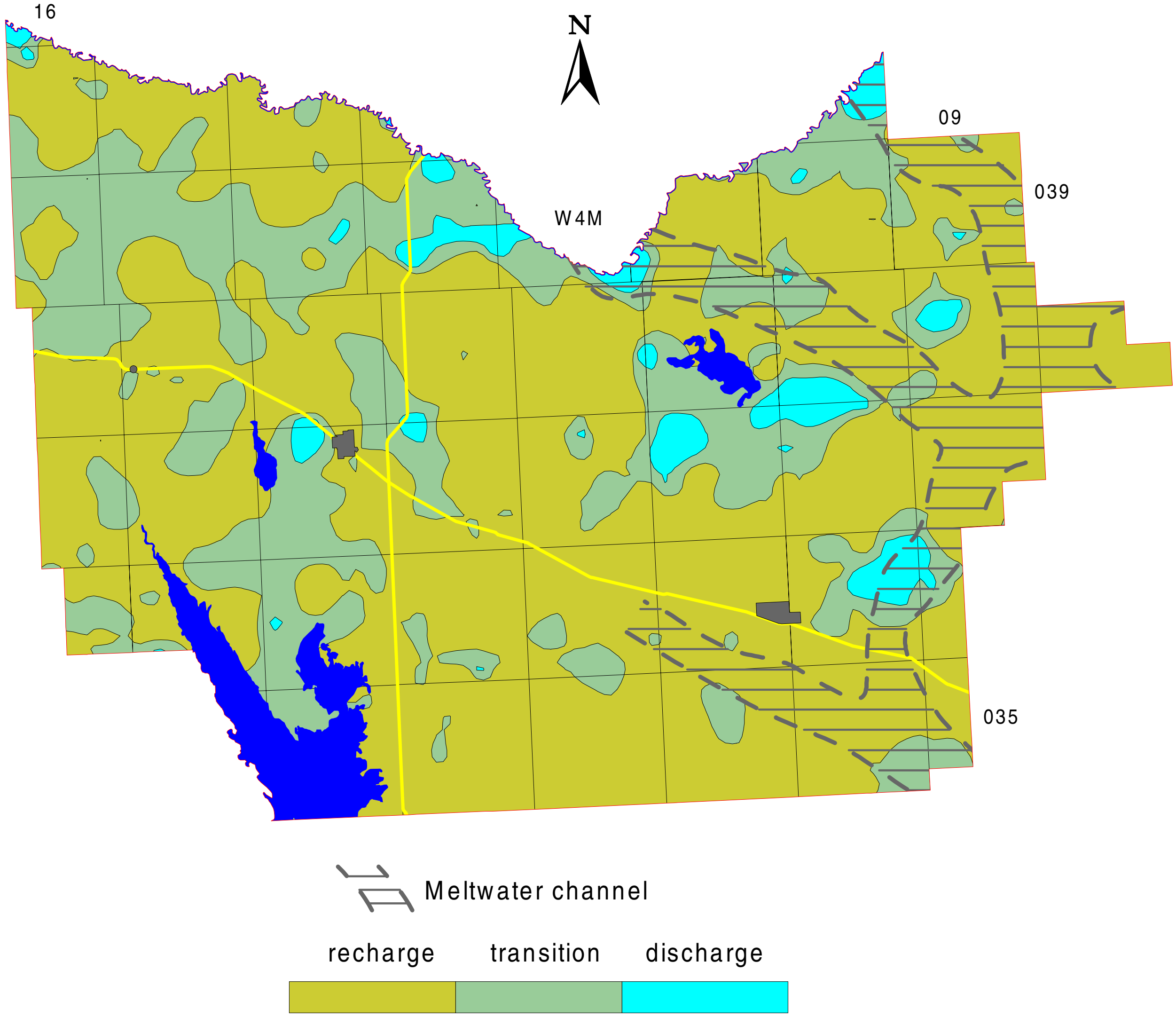




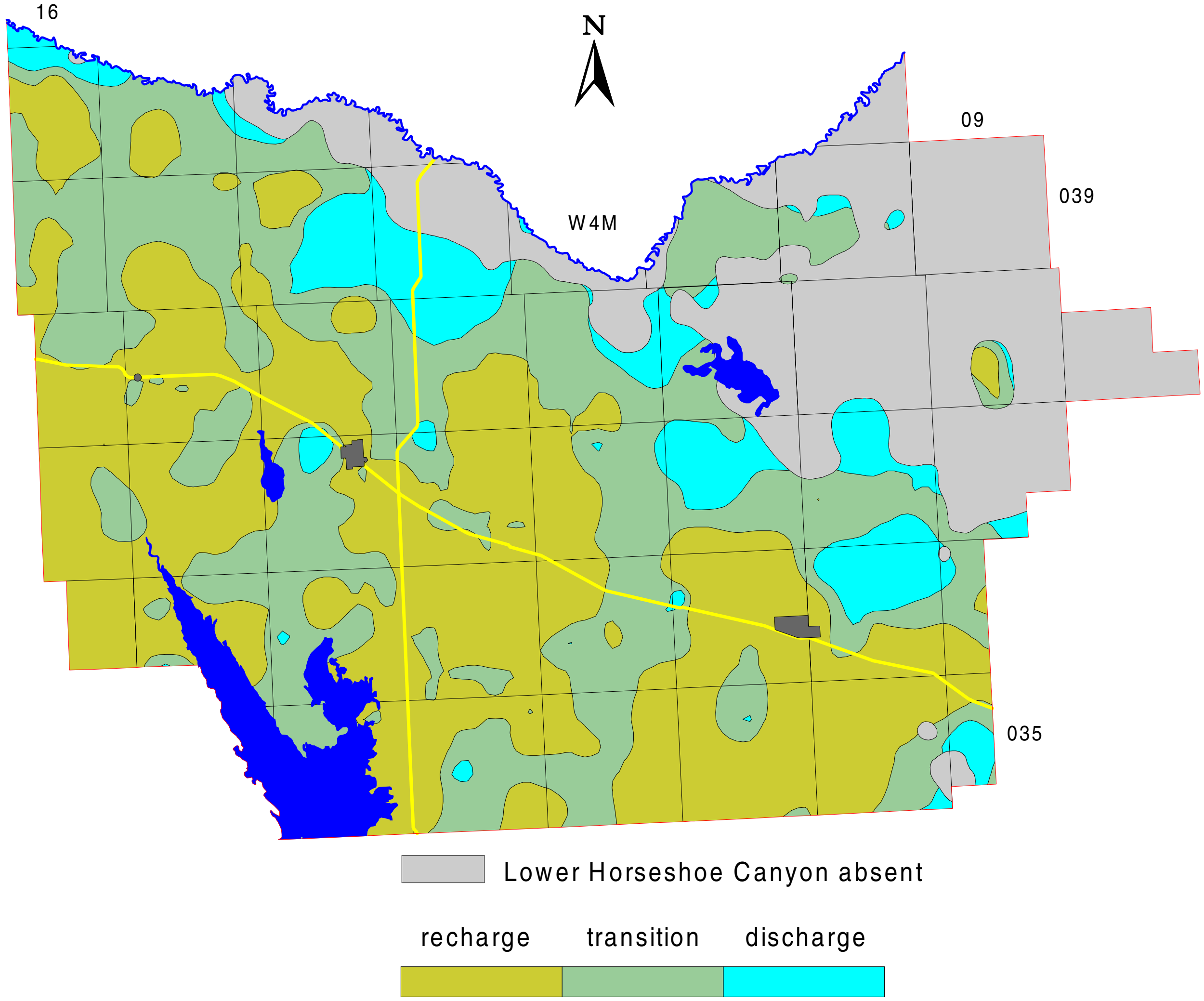
Non-Pumping Water-Level Surface in Surficial Deposits



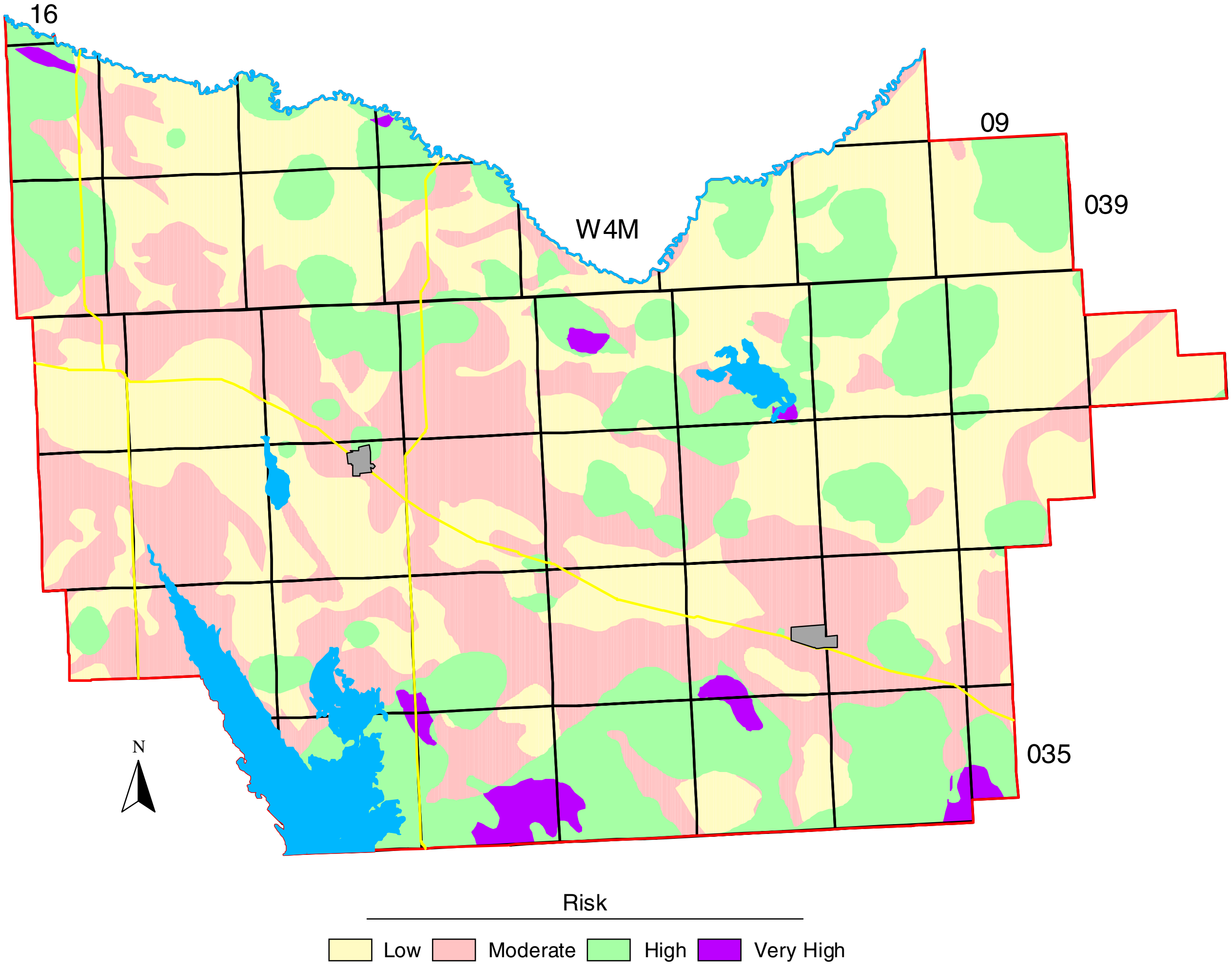
Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)



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



Risk of Groundwater Contamination



COUNTY OF PAINTEARTH NO. 18

Appendix B

MAPS AND FIGURES ON CD-ROM

A) Database
B) ArcView Files
C) Query
D) Maps and Figures
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Index Map
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Cross-Section B - B'
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Bedrock Geology
E-Log showing Base of Foremost Formation
Hydrographs - AEP Observation Water Wells
Water-Level Comparison - Based on Water Source Wells Completed in Bearpaw Aquifer
Risk of Groundwater Contamination
Relative Permeability
Water Wells Recommended for Field Verification

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Non-Pumping Water-Level Surface in Surficial Deposits
Total Dissolved Solids in Groundwater from Surficial Deposits
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Chloride in Groundwater from Surficial Deposits
Fluoride in Groundwater from Surficial Deposits
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Thickness of Sand and Gravel Aquifer
Water Wells Completed in Surficial Deposits

b) Upper Sand and Gravel

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

c) First Sand and Gravel

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

3) 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)
Sulfate in Groundwater from Upper Bedrock Aquifer(s)
Chloride in Groundwater from Upper Bedrock Aquifer(s)
Fluoride in Groundwater from Upper Bedrock Aquifer(s)
Total Hardness of Groundwater from Upper Bedrock Aquifer(s)
Piper Diagram - Bedrock Aquifers
Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)
Non-Pumping Water-Level Surface in Upper Bedrock Aquifer(s)

b) Middle Horseshoe Canyon Formation

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

c) Lower Horseshoe Canyon Formation

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

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

e) Oldman Formation

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

f) Foremost Formation

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

g) Lea Park Formation

Depth to Top of Lea Park Formation
Structure-Contour Map - Top of Lea Park Formation

COUNTY OF PAINTEARTH NO. 18
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

EXTRACT FROM THE ALBERTA GAZETTE

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Alberta Regulation 123/93

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

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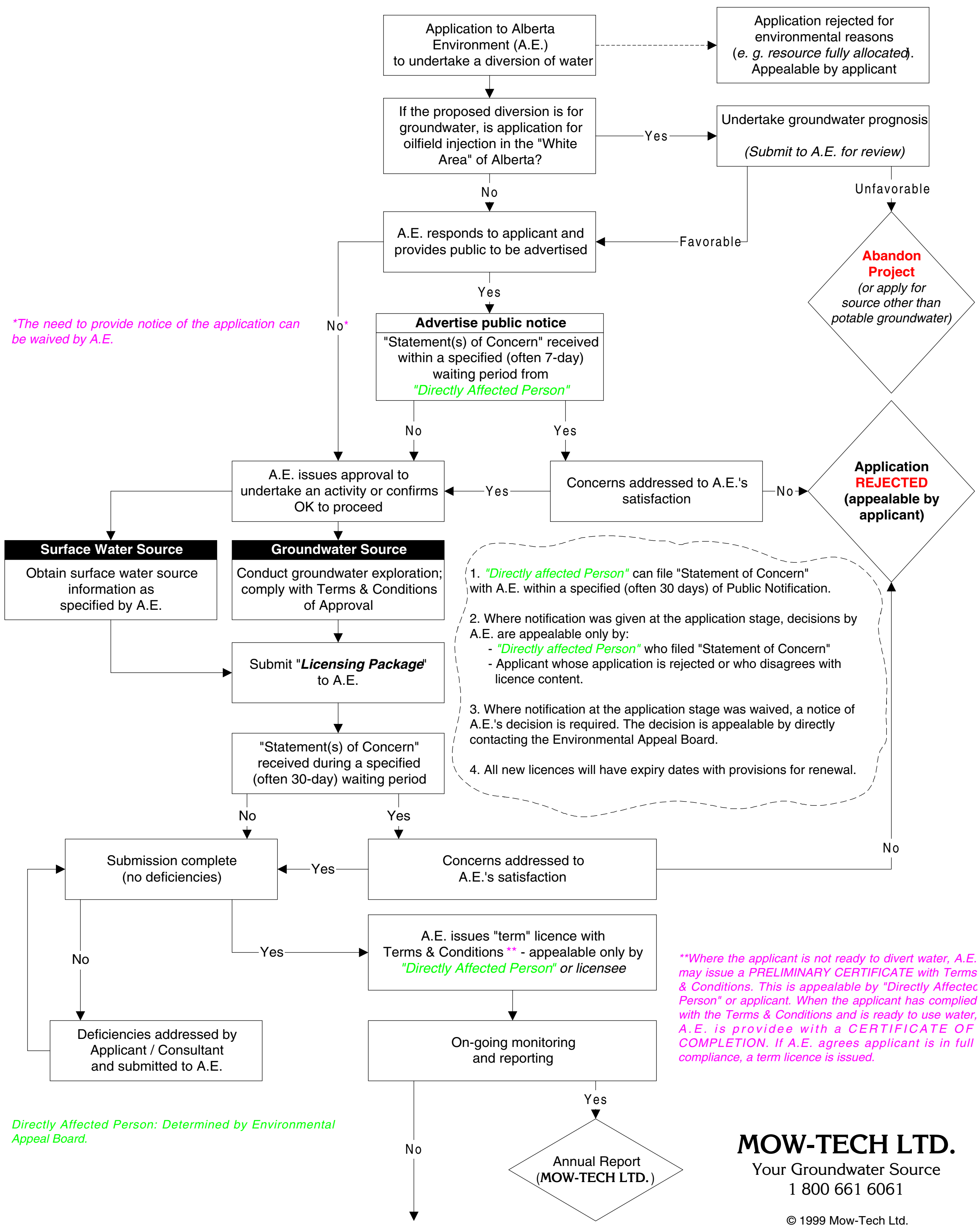
Water Act – Flow Chart



*This flow chart was developed by Mow-Tech Ltd. and is provided as a guide **only** to Alberta's new **Water Act**. Mow-Tech Ltd. accepts no responsibility for the information provided.*

Additional Information

VIDEOS

Will the Well Go Dry Tomorrow? (Mow-Tech Ltd.: 1-800 GEO WELL)
Water Wells that Last (PFRA – Edmonton Office: 780-495-3307)
Ground Water and the Rural Community (Ontario Ground Water Association)

BOOKLET

Water Wells that Last (PFRA – Edmonton Office: 780-495-3307)

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Edmonton: 780-427-3932

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PRAIRIE FARM REHABILITATION ADMINISTRATION

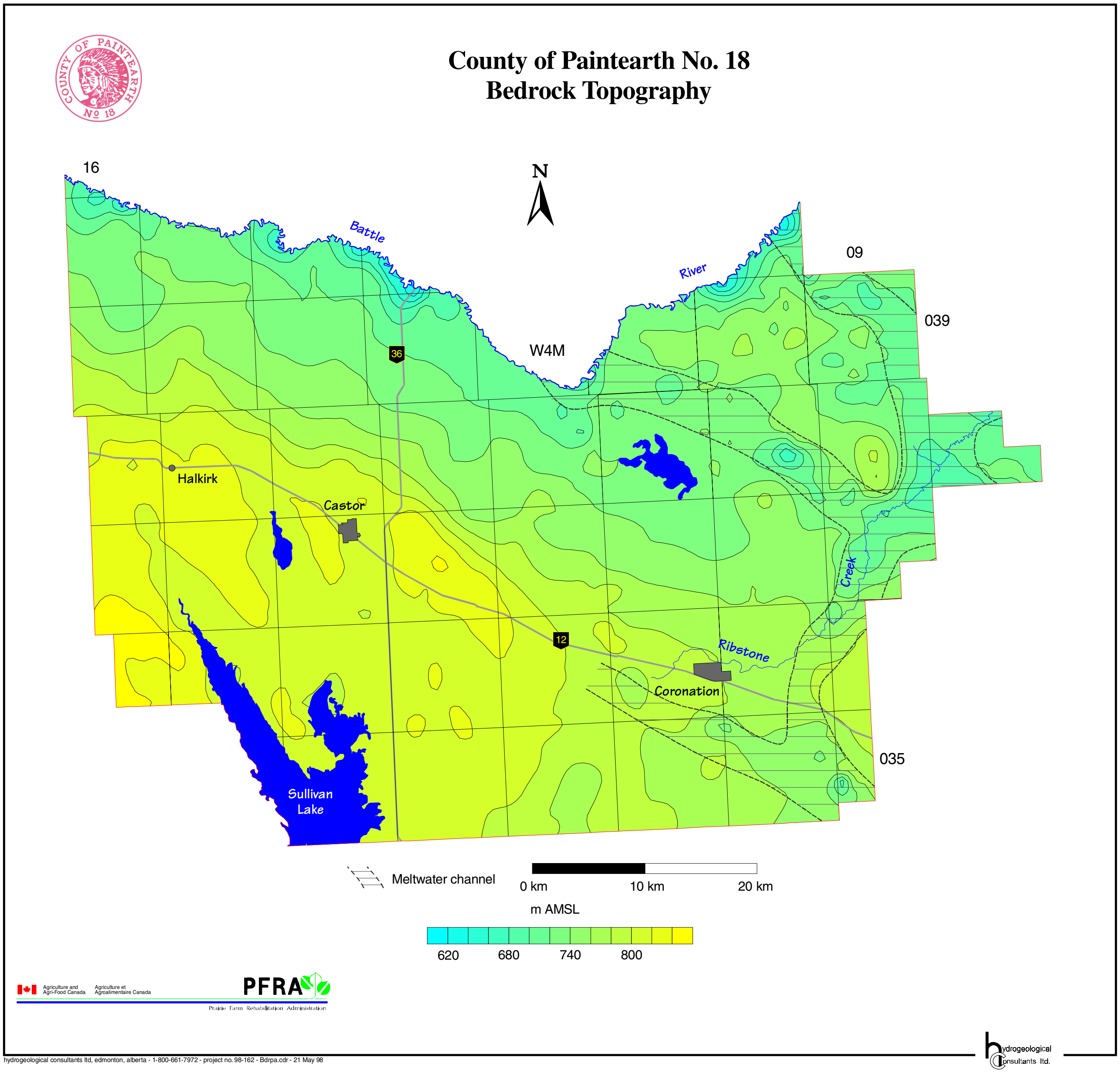
Dave Seitz (Hanna: 403-854-4448)

LOCAL HEALTH DEPARTMENTS

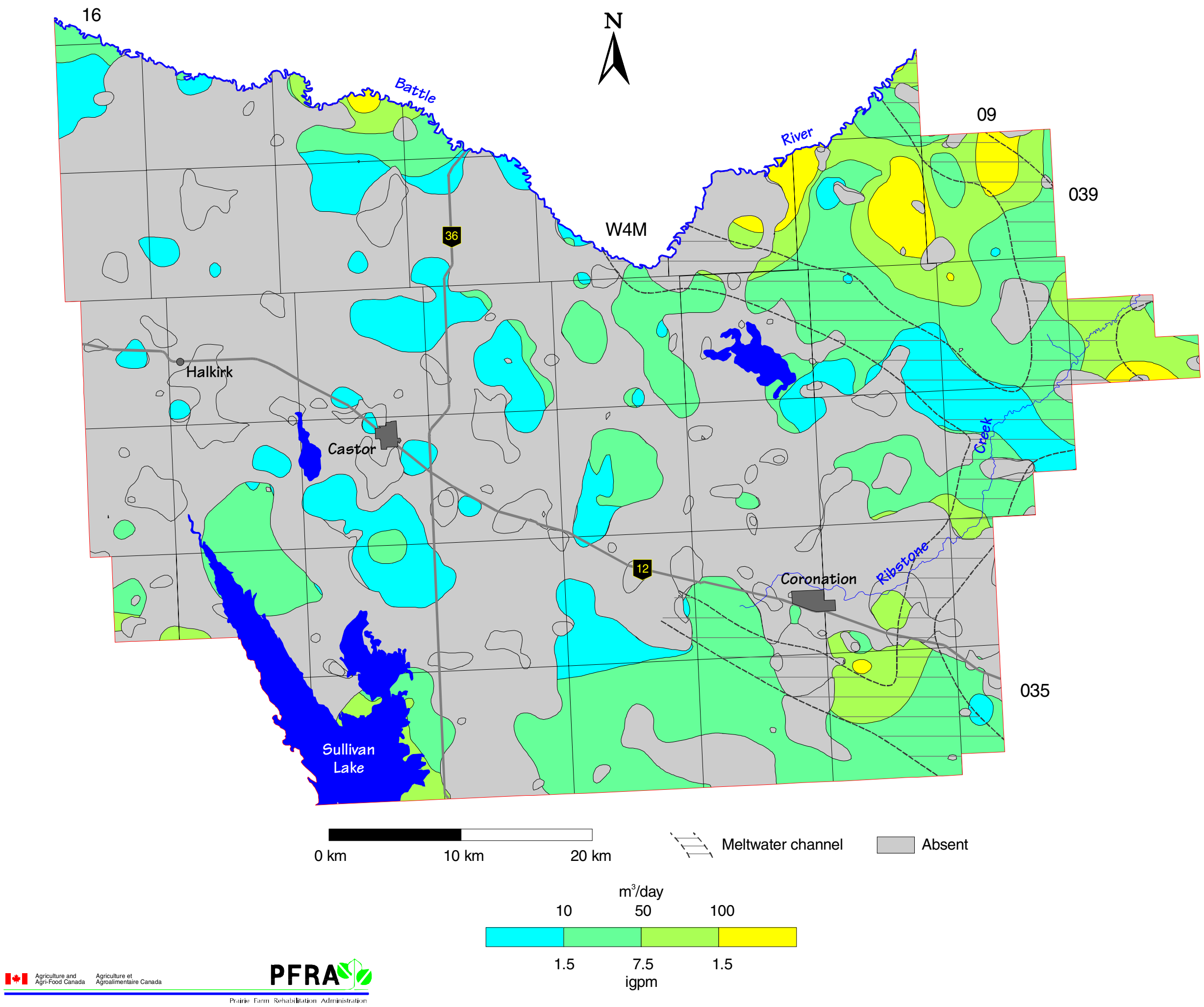
COUNTY OF PAINTEARTH NO. 18

Appendix D

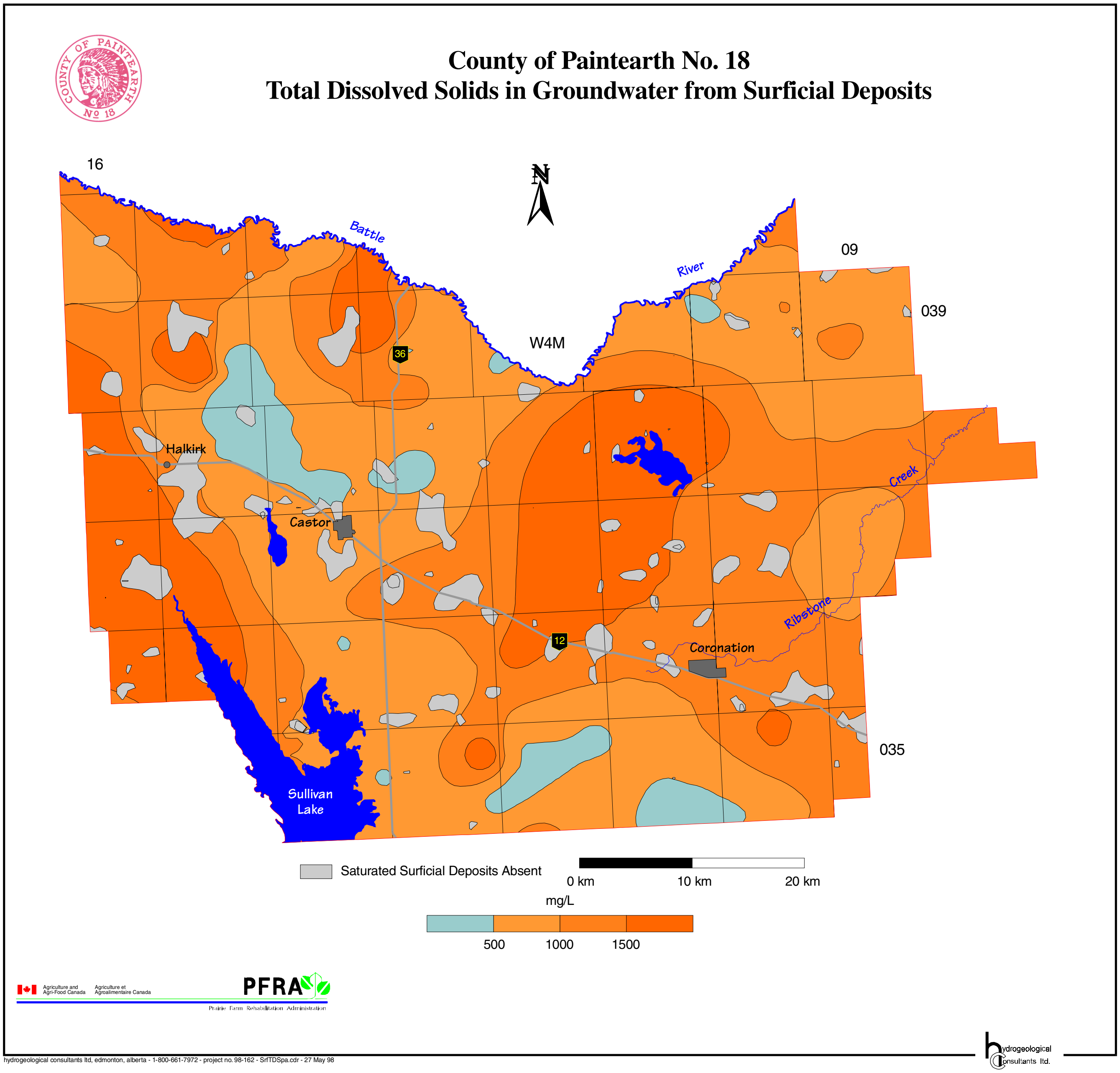
MAPS AND FIGURES INCLUDED AS LARGE PLOTS


County of Paintearth No. 18
Bedrock Topography
16
N
09
039
W4M
035
Battle
River
Halkirk
Castor
Creek
Ribstone
Coronation
Sullivan Lake
Meltwater channel
0 km
10 km
20 km
m AMSL
620
680
740
800
PFRA
hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 98-162 - Bdrpa.cdr - 21 May 98

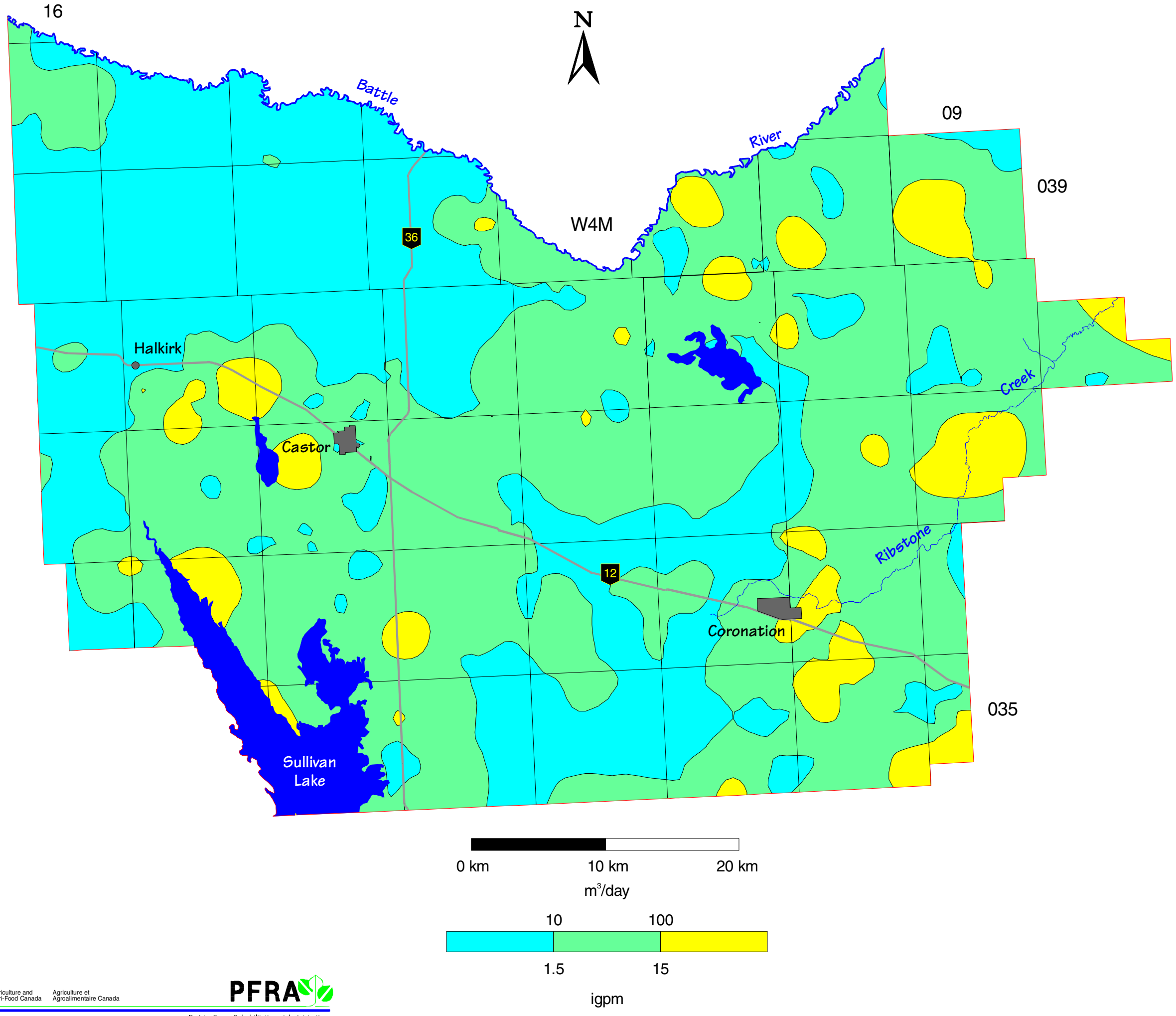
County of Paintearth No. 18
Apparent Yield for Water Wells Completed through Sand and Gravel Aquifer



County of Paintearth No. 18
Total Dissolved Solids in Groundwater from Surficial Deposits



County of Paintearth No. 18
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



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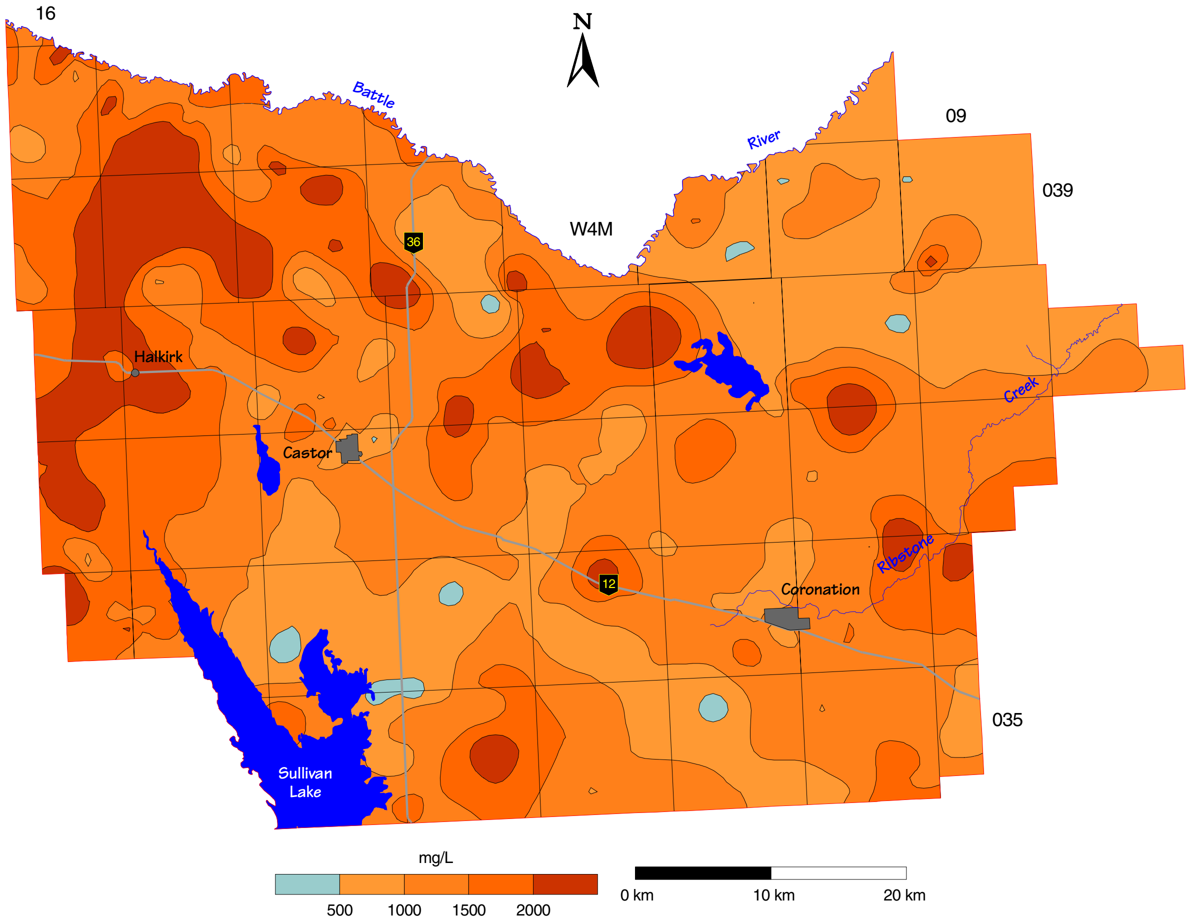
County of Paintearth No. 18
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



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

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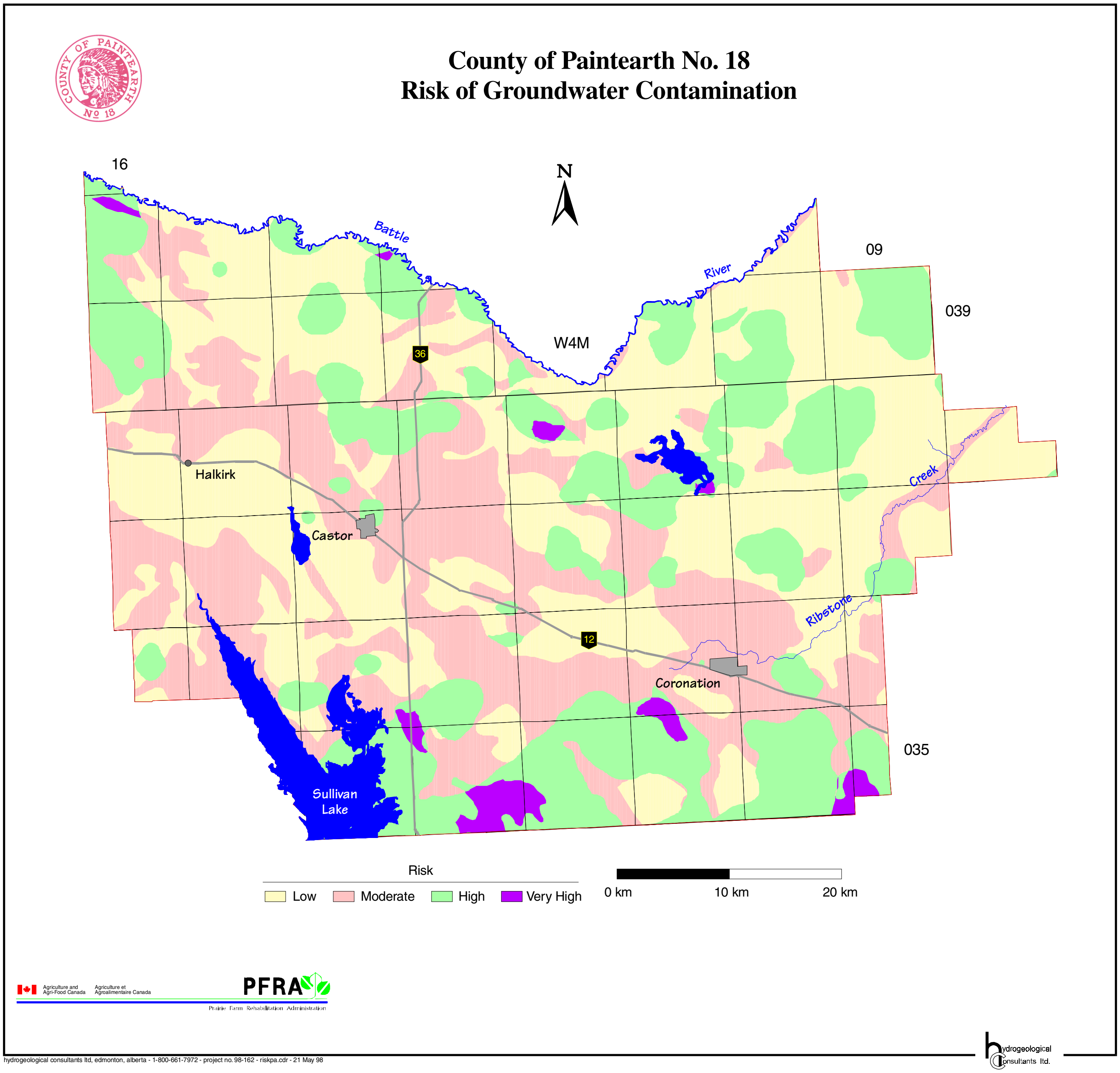
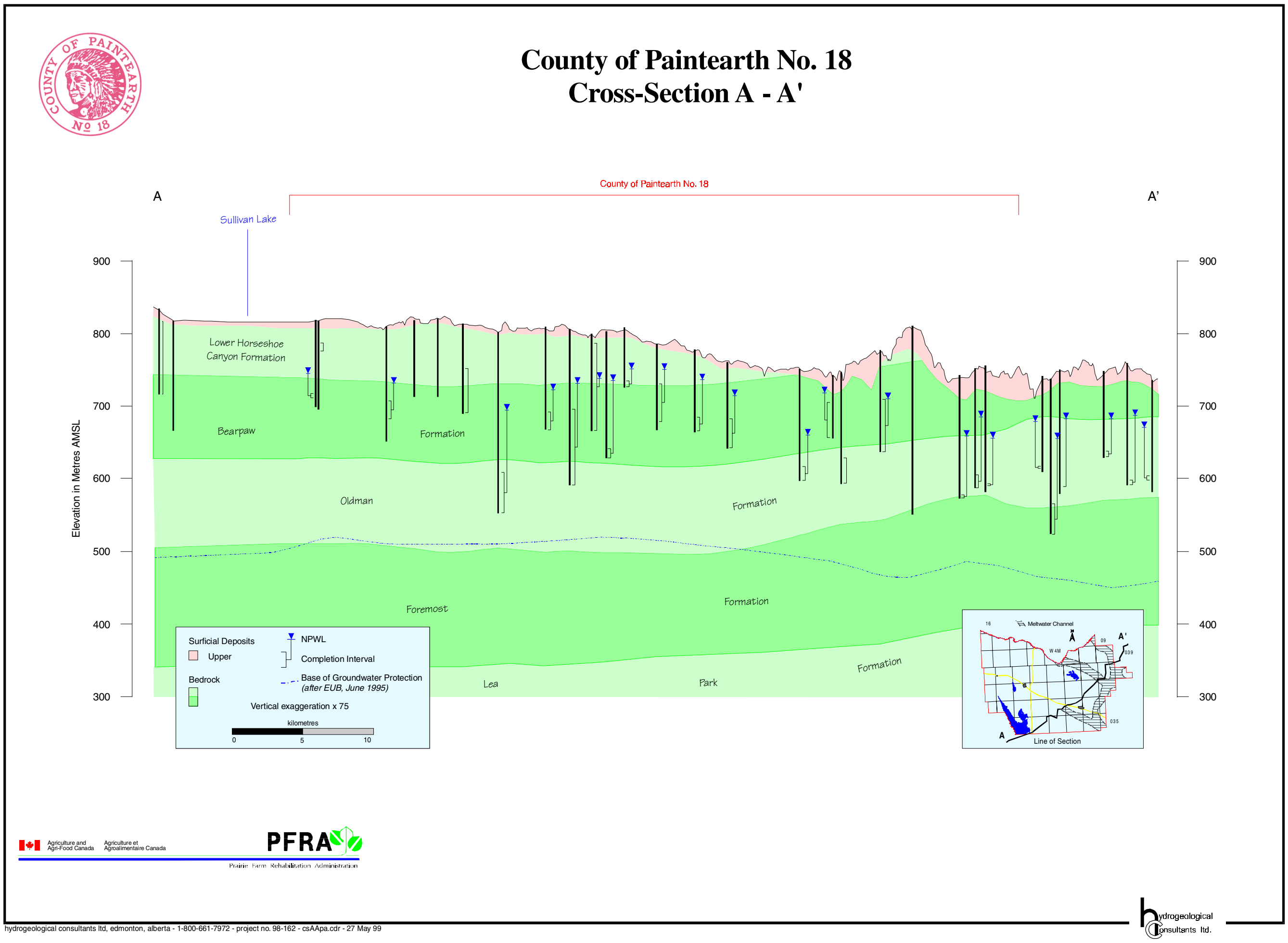
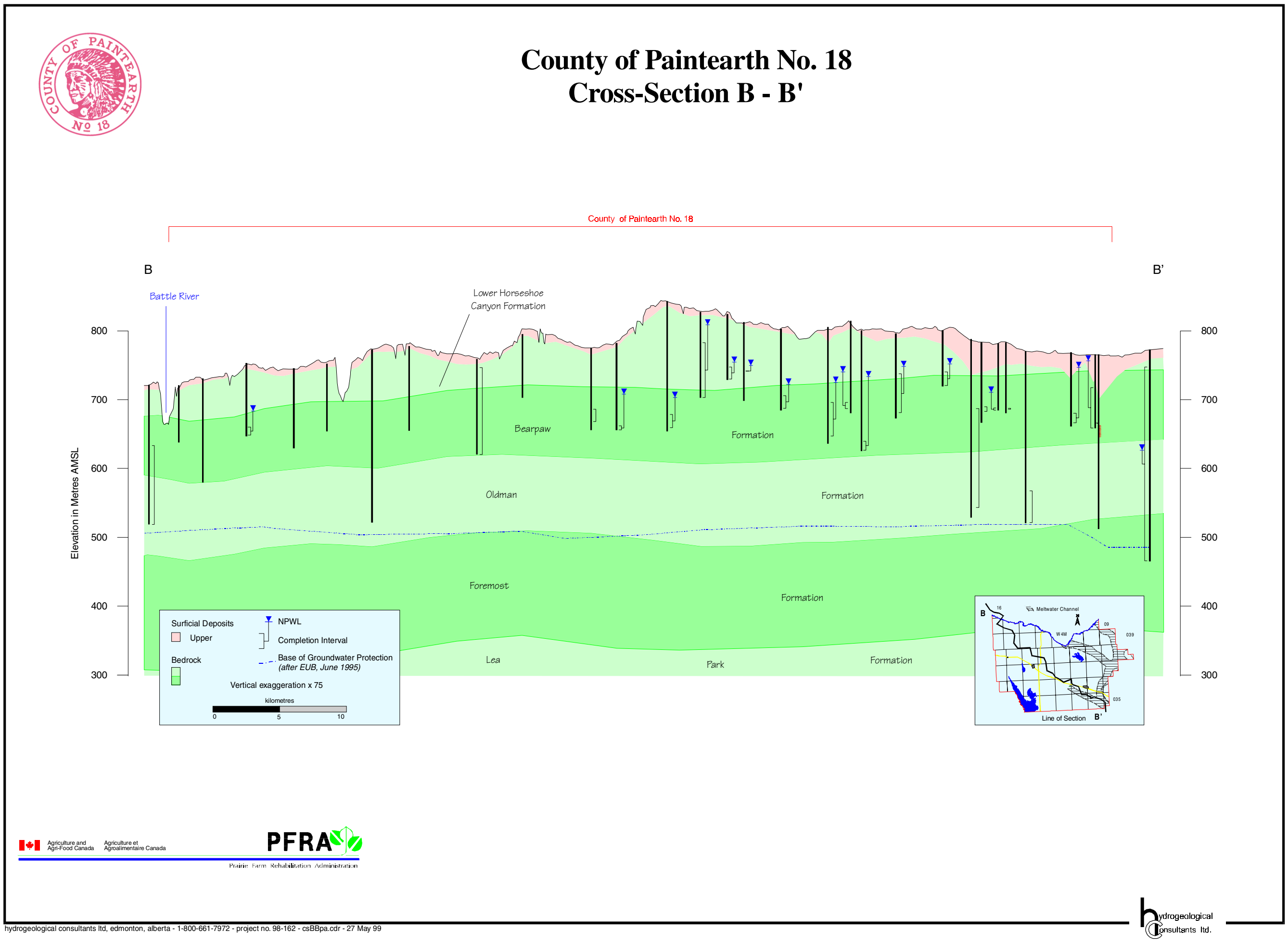
hydrogeological consultants ltd.


County of Paintearth No. 18
Risk of Groundwater Contamination
16
N
Battle
River
09
039
W4M
36
Halkirk
Castor
Creek
Ribstone
12
Coronation
035
Sullivan Lake
Risk
Low
Moderate
High
Very High
0 km
10 km
20 km
PFRA
hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 98-162 - riskpa.cdr - 21 May 98


County of Paintearth No. 18
Cross-Section A - A'
A
A'
County of Paintearth No. 18
Sullivan Lake
Elevation in Metres AMSL
900
800
700
600
500
400
300
Lower Horseshoe Canyon Formation
Bearpaw Formation
Oldman Formation
Foremost Formation
Lea Park Formation
Surficial Deposits
Upper
Bedrock
NPWL
Completion Interval
Base of Groundwater Protection (after EUB, June 1995)
Vertical exaggeration x 75
kilometres
0
5
10
Meltwater Channel
Line of Section
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
PFRA
Prairie Farm Rehabilitation Administration
hydrogeological consultants ltd.
hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 98-162 - csAApa.cdr - 27 May 99


County of Paintearth No. 18
Cross-Section B - B'
County of Paintearth No. 18
B
B'
Battle River
Lower Horseshoe Canyon Formation
Elevation in Metres AMSL
800
700
600
500
400
300
Bearpaw
Formation
Oldman
Formation
Foremost
Formation
Lea
Park
Formation
Surficial Deposits
Upper
Bedrock
NPWL
Completion Interval
Base of Groundwater Protection
(after EUB, June 1995)
Vertical exaggeration x 75
kilometres
0
5
10
Meltwater Channel
Line of Section
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
PFRA
Prairie Farm Rehabilitation Administration
hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 98-162 - csBBpa.cdr - 27 May 99

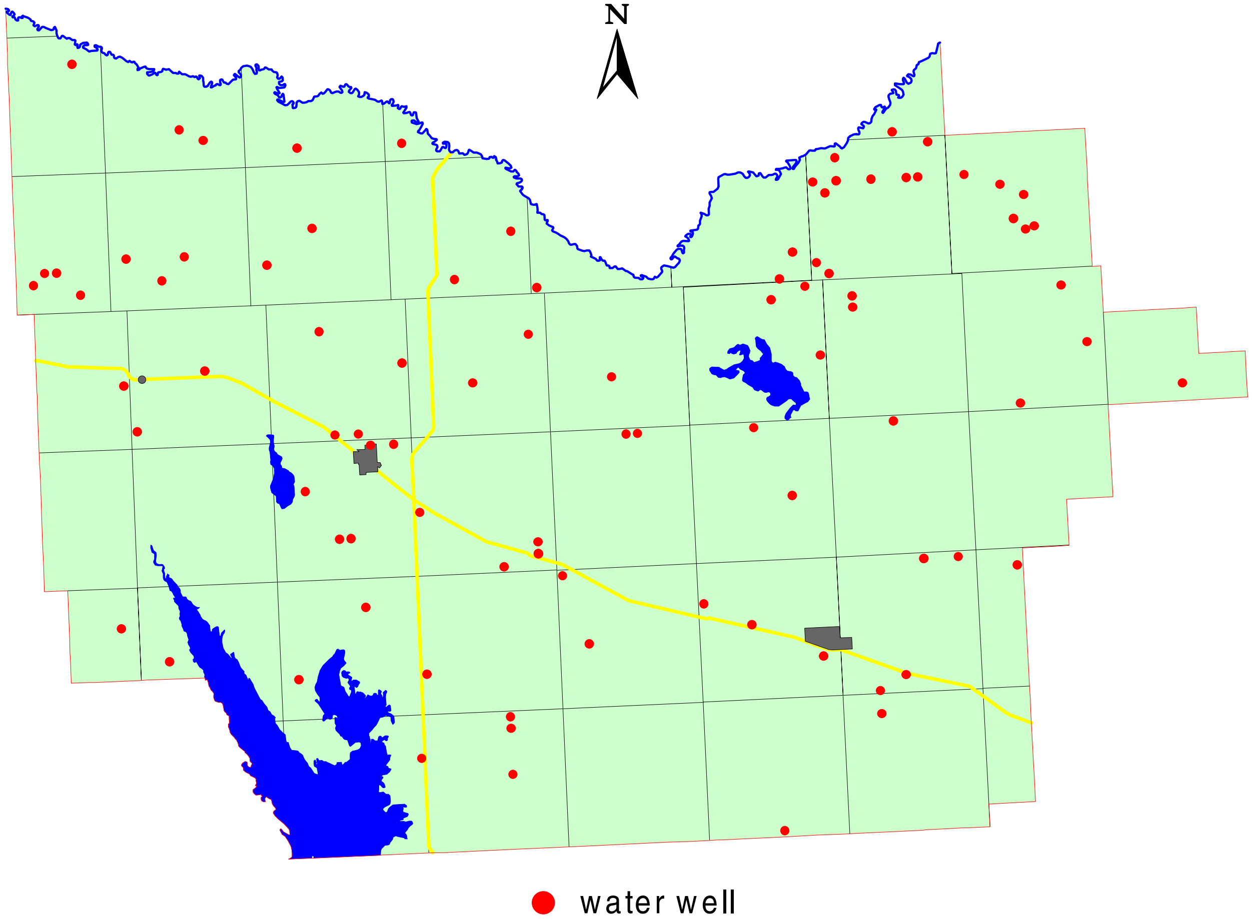
COUNTY OF PAINTEARTH NO. 18

Appendix E

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Water Wells Recommended for Field Verification

(details on following page)



WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Owner	Location	Water Well Contractor	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet
Zerbin, Don	01-25-035-14 W4M	Kern Water Well Ltd.	April-83	21.3	70.0	6.1	20.0
Circle Square Ranch	SW 09-039-15 W4M	Lousana Water Wells Ltd.	June-78	109.7	360.0	66.3	217.5
Lindmark, Bill	NE 13-038-11 W4M	Mjolsness, J.	August-84	68.3	224.0	10.7	35.0
Mosbacher, Robert #2A	02-05-036-10 W4M	<unknown contractor>	September-67	98.8	324.0	42.1	138.0
Bye, S.	SE 32-036-09 W4M	Barnard W T	April-61	57.9	190.0	15.2	50.0
Mosbacher	02-32-035-10 W4M	<unknown contractor>	November-67	193.5	635.0	61.6	202.0
Macgougan, Lee	SW 03-035-11 W4M	Mjolsness, J.	June-72	38.1	125.0	17.1	56.0
Jewett, E & D	NE 04-036-10 W4M	Mjolsness, J.	April-79	56.7	186.0	24.4	80.0
Perry, T.	NE 34-036-10 W4M	Barnard W T	July-77	38.7	127.0	14.0	46.0
Perry, Ted	NE 34-036-10 W4M	Mjolsness, J.	July-79	75.0	246.0	39.6	130.0
Perry, James	NW 36-036-10 W4M	Barnard W T	October-75	36.6	120.0	16.8	55.0
Stephenson, Henry	NW 12-036-11 W4M	Mjolsness, J.	September-74	56.7	186.0	38.1	125.0
Hampton, Jack	SW 21-036-11 W4M	Mjolsness, J.	November-80	81.1	266.0	51.8	170.0
Worth, Keith	SW 30-036-11 W4M	Mjolsness, J.	September-73	132.6	435.0	73.2	240.0
Bunbury, Barney	NW 17-036-12 W4M	Mjolsness, J.	June-81	25.6	84.0	6.1	20.0
Slemp, Raymond Bax	NW 31-036-12 W4M	Mjolsness, J.	October-74	100.6	330.0	80.8	265.0
Kneller, Herbert	NW 07-036-13 W4M	Schmidt Drilling Ltd.	March-73	22.9	75.0	7.0	23.0
Schwenk, Herman	NE 33-037-10 W4M	Mjolsness & Mckenzie	November-76	32.9	108.0	20.7	68.0
Zimmer, Harry	NE 07-036-14 W4M	Lousana Water Wells Ltd.	August-75	18.3	60.0	7.6	25.0
Pals, F.M.	NE 27-036-14 W4M	WM Well Service	August-79	13.1	43.0	6.1	20.0
Waltham, John	NW 14-037-11 W4M	Mjolsness & Mckenzie	October-75	19.5	64.0	4.6	15.0
Holdsworth, Larry	NW 17-036-15 W4M	Schmidt Drilling Ltd.	June-73	36.6	120.0	23.2	76.0
Collier Enterprizes	NE 33-037-11 W4M	Mjolsness & Mckenzie	January-65	39.6	130.0	6.1	20.0
Shilling, Fred	SW 25-036-16 W4M	Baird Jc Junior	October-69	15.2	50.0	7.3	24.0
Shilling, Fred	SW 25-036-16 W4M	Baird Jc Junior	October-69	18.3	60.0	6.7	22.0
Hoffart, L.	NW 34-037-12 W4M	Mjolsness, J.	June-77	62.8	206.0	13.7	45.0
Perreault, Bob	NE 34-037-12 W4M	Mjolsness, J.	August-80	93.3	306.0	57.9	190.0
Mills, C.	NW 01-037-13 W4M	Mjolsness & Mckenzie	June-58	44.2	145.0	17.1	56.0
Harder, D.	NW 01-037-13 W4M	Mjolsness, J.	July-78	105.5	346.0	79.2	260.0
Sidiac, Peter	NW 01-037-13 W4M	Mjolsness, J.	July-78	19.2	63.0	11.0	36.0
Mckenzie, Ada	NW 01-037-13 W4M	Mjolsness, J.	August-86	104.9	344.0	77.7	255.0
Hanson, Olaf	SE 03-037-13 W4M	Losness Drilling (1975) Ltd.	June-78	43.0	141.0	12.8	42.0
Wetter, G.	SW 12-037-13 W4M	Mjolsness & Mckenzie	December-62	34.1	112.0	4.6	15.0
Schulmiester, L.	NW 18-037-13 W4M	Mjolsness, J.	July-74	38.1	125.0	15.2	50.0
Adair, Don	SE 34-038-11 W4M	Mjolsness, J.	September-75	32.0	105.0	3.7	12.0
Butterfield, Dale	NW 36-038-11 W4M	Losness Drilling (1975) Ltd.	June-72	61.3	201.0	6.4	21.0
Smith, Marcus	NW 03-038-08 W4M	Larson's Waterwell Servicing Ltd.	June-84	67.1	220.0	30.2	99.0
Gamroth, Lewis A.	SE 16-038-12 W4M	Erickson Drilling	September-76	54.3	178.0	37.8	124.0
Robinson, Glen	SW 04-038-09 W4M	Schaffer, Robert.	August-60	15.2	50.0	10.4	34.0
Golby, Clarence	NW 13-038-09 W4M	Losness Drilling (1975) Ltd.	October-79	18.6	61.0	10.4	34.0
Duguid, Jim	SE 16-038-13 W4M	Mjolsness & Mckenzie	February-68	112.8	370.0	64.0	210.0
Gilbertson, R.D.	SW 35-038-09 W4M	McAllister Holdings Ltd.	November-84	174.0	571.0	100.0	328.0
Shipton, Will	SW 25-038-13 W4M	Hi-Rate Drilling 1985 Ltd.	September-81	42.7	140.0	30.8	101.0
Roland, Joe	SE 03-038-14 W4M	WM Well Service	October-74	12.2	40.0	7.3	24.0
Stearns, James	SE 04-038-14 W4M	Mjolsness & Mckenzie	August-76	25.6	84.0	10.7	35.0
Stienwand, Norman	SE 24-038-14 W4M	Mjolsness, J.	August-85	37.8	124.0	5.5	18.0
Downey, Cliff	NE 09-037-14 W4M	Mjolsness, J.	May-78	44.5	146.0	12.2	40.0
Wiart, Paul	NW 10-037-14 W4M	Mjolsness, J.	July-72	32.0	105.0	11.9	39.0
Wiart, Paul	NW 10-037-14 W4M	Hi-Rate Drilling 1985 Ltd.		22.9	75.0	11.3	37.0
Taylor, M. And J.	NW 29-038-10 W4M	Mjolsness, J.	July-78	50.6	166.0	4.3	14.0
Nichols, George H.	NW 28-038-14 W4M	Mjolsness, J.	February-74	44.5	146.0	8.5	28.0

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Owner	Location	Water Well Contractor	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet
Taylor, Jim	SW 32-038-10 W4M	Jack Pine Drilling	September-70	41.2	135.0	7.6	25.0
Jaboeuf, F.	14-20-037-14 W4M	Mjolsness & Mckenzie	June-60	32.0	105.0	5.5	18.0
Knispel, Erwin	NW 06-038-15 W4M	WM Well Service	April-75	36.6	120.0	21.3	70.0
Nichols, R.G.	NW 35-037-14 W4M	WM Well Service	July-78	16.8	55.0	6.1	20.0
Rendall, Bob	SW 22-038-15 W4M	Losness Drilling (1975) Ltd.	May-84	70.7	232.0	36.0	118.0
Wimmer Bros.	NW 36-037-14 W4M	Mjolsness, J.	May-74	12.8	42.0	6.4	21.0
Schaedel, Balthasar	NE 13-038-16 W4M	Erickson Drilling	July-75	48.8	160.0	25.9	85.0
Spady, Willie	SW 06-039-12 W4M	Erickson Drilling	April-76	29.9	98.0	14.3	47.0
Weber, Dennis	NE 04-039-13 W4M	Greene Farms Drilling Ltd.	October-85	54.9	180.0	26.2	86.0
Clarke, Dave	NW 13-039-13 W4M	Forrester Water Well Drilling (1981) Ltd.	September-73	29.0	95.0	4.6	15.0
Howe, Darrel	NE 07-039-14 W4M	AMA Drilling Co. Ltd.	July-86	9.8	32.0	0.3	1.0
Kaminski, Art & Harold	SE 21-039-14 W4M	Erickson Drilling	June-75	23.2	76.0	7.6	25.0
Hronek, Allan	SW 15-039-15 W4M	Mjolsness, J.	May-77	25.6	84.0	9.1	30.0
Doan, Merle	SE 18-039-15 W4M	WM Well Service	July-75	14.0	46.0	4.3	14.0
Scott, Ken	NW 10-039-09 W4M	Losness Drilling (1975) Ltd.	December-74	24.4	80.0	14.3	47.0
Johnson, Kent	NE 02-039-16 W4M	AMA Drilling Co. Ltd.	July-86	23.5	77.0	12.2	40.0
Elliott, Delbert J.	15-10-039-09 W4M	Bakken, S.	June-64	19.2	63.0	7.9	26.0
Mcdavid, A.G.	SE 09-039-16 W4M	WM Well Service	July-75	20.7	68.0	9.1	30.0
Elliott, Les	SE 16-039-09 W4M	WM Well Service	June-76	24.4	80.0	6.1	20.0
Elliott, Leslie	SE 16-039-09 W4M	McAllister Waterwells Ltd.	August-84	67.1	220.0	5.2	17.0
Green, W.	NW 10-039-16 W4M	Kern Water Well Ltd.	March-82	41.2	135.0	25.0	82.0
Green, William	NE 10-039-16 W4M	Lousana Water Wells Ltd.	August-73	15.2	50.0	8.5	28.0
Stephenson, Bruce	NW 21-039-09 W4M	McAllister Drilling Ltd.	May-76	37.2	122.0	14.3	47.0
Scott, H.A.	SW 22-039-09 W4M	Schaffer, Jack.	June-61	129.2	424.0	79.2	260.0
Saunders, Ronald	SE 30-039-09 W4M	Losness Drilling (1975) Ltd.	July-75	27.1	89.0	12.5	41.0
Dome Petroleum	02-02-039-11 W4M	Hi-Rate Drilling 1985 Ltd.	July-81	49.4	162.0	8.5	28.0
Cameron, Duncan	SE 06-039-10 W4M	Mjolsness, J.	August-85	37.8	124.0	6.1	20.0
Paintearth County	NW 06-039-10 W4M	Mjolsness, J.	August-75	62.8	206.0	5.5	18.0
Bargholz, J.S. (Bud)	SW 12-039-11 W4M	Mjolsness, J.	May-77	49.4	162.0	13.7	45.0
Bargholz, Bud	SW 12-039-11 W4M	Schaffer, Jack.	June-62	16.8	55.0	9.1	30.0
Bedson, Jim	NE 19-039-10 W4M	Losness Drilling (1975) Ltd.	July-79	21.3	70.0	16.0	52.5
Hudson, Lee	SE 26-039-10 W4M	Larson's Waterwell Servicing Ltd.	April-83	28.7	94.0	11.9	39.0
Hudson, Ron	SW 26-039-10 W4M	Losness Drilling (1975) Ltd.	November-79	16.5	54.0	5.2	17.0
Fairfield Baptist Church	SE 28-039-10 W4M	Losness Drilling (1975) Ltd.	June-72	39.0	128.0	18.3	60.0
Thomson, Gary	SE 28-039-10 W4M	Losness Drilling (1975) Ltd.	October-81	23.8	78.0	18.6	61.0
Richardson, Donald	SW 29-039-10 W4M	Gunderson Cornell	October-68	24.4	80.0	18.3	60.0
D.M. Richardson Farms Ltd.	SW 29-039-10 W4M	Losness Drilling (1975) Ltd.	August-79	23.5	77.0	18.3	60.0
Adair, Bruce	SW 30-039-10 W4M	Losness Drilling (1975) Ltd.	July-79	24.4	80.0	17.8	58.5
Richardson, Clayton	SW 32-039-10 W4M	Losness Drilling (1975) Ltd.	June-72	70.7	232.0	18.3	60.0
Hudson, Melvin	NW 36-039-10 W4M	Losness Drilling (1975) Ltd.	August-86	27.4	90.0	7.9	26.0
Wiart, Armond	NE 06-040-13 W4M	AMA Drilling Co. Ltd.	February-85	15.2	50.0	3.7	12.0
Brown, Albert	NW 04-040-14 W4M	Mjolsness, J.	August-77	62.8	206.0	48.8	160.0
Hepp, Clarence	NW 10-040-15 W4M	Shumansky Waterwell Services Ltd.	March-88	25.9	85.0	13.4	44.0
Matier, Doug	SW 11-040-15 W4M	Gordon's Drilling Ltd.	August-84	23.2	76.0	12.2	40.0
Blackmoor, Charlie	NE 26-040-16 W4M	WM Well Service	September-76	17.7	58.0	12.2	40.0
Hudson, James	SE 03-040-10 W4M	McAllister Drilling Ltd.	November-76	28.0	92.0	16.2	53.0
Castor Colony	SE 34-035-13 W4M	Losness Drilling (1975) Ltd.	June-80	27.4	90.0	15.2	50.0
Suncrest Colony	SE 22-035-13 W4M	Losness Drilling (1975) Ltd.	April-83	15.2	50.0	5.8	19.0
Solorenko, Roy	NE 34-035-13 W4M	Gunderson Cornell	July-54	33.5	110.0	25.9	85.0