County of Beaver No. 9

Part of the North Saskatchewan River Basin
Parts of Tp 046 to 052, R 10 to 21, W4M
Revised Regional Groundwater Assessment

Prepared for

COUNTY OF BEAVER
No. 9

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
hydrogeological consultants ltd.
1-800-661-7972
Our File No.: **98-111**

December, 99
(Revised December 1999)

PERMIT TO PRACTICE
HYDROGEOLOGICAL CONSULTANTS LTD.
Signature ______________________
Date ______________________
PERMIT NUMBER: P 385
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

hydrogeological consultants ltd.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

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 Beaver No. 9 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 Beaver No. 9, (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. 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 - Training Session

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

1.3 Purpose

This project is a regional groundwater assessment of the County of Beaver No. 9. The regional groundwater assessment provides the information to assist in the management of the groundwater resource within the County. Groundwater resource management involves determining the suitability of various areas in the County for particular activities. These activities can vary from the development of groundwater for agricultural or industrial purposes, to the siting of waste storage. **Proper management ensures protection and utilization of the groundwater resource for the maximum benefit of the people of the County.**

The regional groundwater assessment includes:

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

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

---

[1] See glossary
[2] See glossary

2 INTRODUCTION

2.1 Setting

The County of Beaver No. 9 is situated in east-central Alberta. This area is part of the Alberta Plains region. The County exists within the North Saskatchewan River Basin. The County boundaries follow township or section lines. The area includes parts of the area bounded by township 52, range 21, W4M in the northwest and township 046, range 10, W4M in the southeast.

Regionally, the topographic surface varies between 630 and 810 metres above mean sea level (AMSL), with the lowest elevation occurring in the northern part of the County as shown in Figure 1.

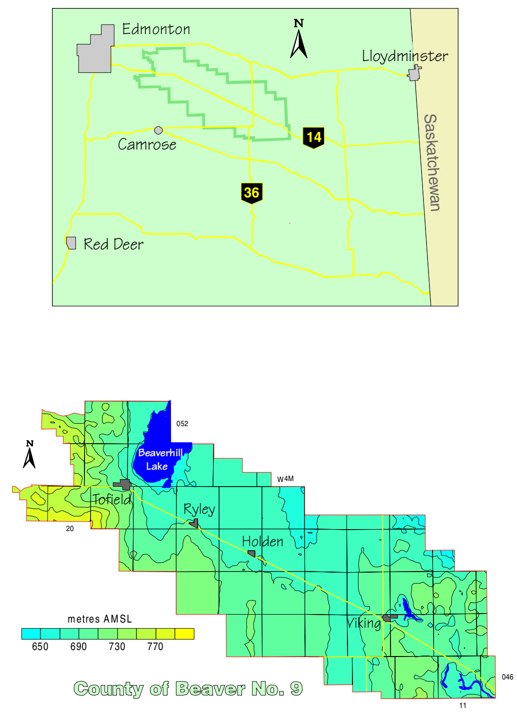


Figure 1. Index Map

2.2 Climate

The County of Beaver 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 420 millimetres (mm), based on data from 1958 to 1993. The annual temperature averaged 2.3 °C, with the mean monthly temperature reaching a high of 16.9 °C in July, and dropping to a low of -15.1 °C in January. The calculated annual potential evapotranspiration is 524 millimetres.

2.3 Background Information

There are currently records for 3,970 water wells in the groundwater database for the County. Of the 3,970 water wells, 3,656 are for domestic/stock purposes. The remaining 314 water wells were completed for a variety of uses, including municipal, investigation, observation and industrial purposes. Based on a rural population of 5,659, there are 2.6 domestic/stock water wells per family of four. The domestic or stock water wells vary in depth from 2.7 metres to 246.8 metres below ground level. Lithologic details are available for 1,618 water wells.

Data for casing diameters are provided on 1,754 records, with 1,580 having a diameter of less than 275 mm and 174 having a diameter of more than 450 mm. The casing diameters of greater than 450 mm are mainly bored water wells and those with a surface casing of less than 275 mm are drilled water wells.

Steel, plastic and galvanized steel represent 99% of the materials that have been used for surface casing in drilled water wells over the last 40 years in water wells completed in the County. From before 1955 to the mid-1960s, the type of surface casing used was unknown in a significant number of the drilled water wells. Steel casing was in use in the 1950s and is still used in 24% of the new water wells being drilled in the County. Galvanized steel surface casing was used in 29% of the new water wells in the mid-1950s. By the mid-1970s, galvanized steel casing was being used in 35% of the new water wells, more than at any other time. The last reported use of galvanized steel was in October 1990. Plastic casing was used for the first time in June 1978. The percentage of water wells with plastic casing has increased and in the mid-1990s, plastic casing was used in 76% of the water wells drilled in the County.

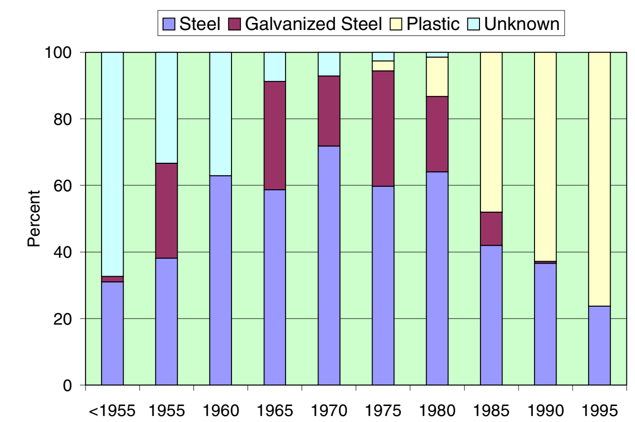


Figure 2. Surface Casing Types Used in Drilled Water Wells

There are 1,757 water well records with sufficient information to identify the aquifer in which the water wells are completed. The water wells that were not drilled deep enough to encounter the bedrock surface plus water wells that have the bottom of their completion interval above the bedrock surface are water wells completed in surficial aquifers. The number of water wells completed in aquifers in the surficial deposits is 555. The adjacent map shows that these water wells occur over most of the County.

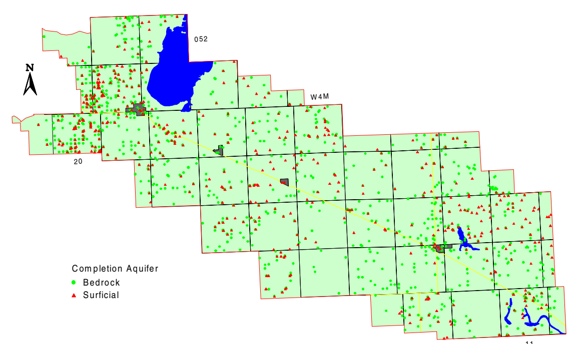


Figure 3. Location of Water Wells

The remaining 1,202 water wells have the top of their completion interval deeper than the depth to the bedrock surface. From Figure 3, it can be seen that the water wells completed in bedrock aquifers also occur over most of the County.

Water wells not used for domestic needs must be licensed. At the end of 1996, 74 groundwater diversions were licensed in the County. The total maximum authorized diversion from these 74 water wells is 512.5 cubic metres per day (m³/day); more than 80% of the authorized groundwater diversion is allotted for agricultural use. The largest licensed groundwater diversion within the County, of 22 m³/day, is for the Joseph T. Petras water supply well in 04-34-046-13 W4M.

The adjacent table shows a breakdown of the 74 licensed groundwater diversions by the aquifer in which the water well is completed. The highest diversions are for licensed water wells completed in the *continental* Foremost Aquifer, of which the majority of the groundwater is used for agricultural purposes. The highest use of groundwater in the County is also for agricultural purposes.

	Licensed Groundwater Users (m³/day)				
Aquifer	Agricultural	Domestic	Municipal	Industrial	Total
Upper Sand and Gravel	31.4	0.0	0.0	33.8	65.2
Lower Horseshoe Canyon	34.0	0.0	0.0	0.0	34.0
Bearpaw	67.7	0.0	0.0	0.0	67.7
Oldman	94.9	0.0	13.6	0.0	108.5
continental Foremost	183.0	6.8	27.0	6.8	223.6
marine Foremost	13.5	0.0	0.0	0.0	13.5
Total	424.5	6.8	40.6	40.6	512.5

Table 1. Licensed Groundwater Diversions

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

Groundwaters from the surficial deposits can be expected to be chemically hard with a high dissolved iron content. The total dissolved solids (TDS) concentrations in the groundwaters from the upper bedrock in the County are generally less than 1,500 milligrams per litre (mg/L). Groundwaters from the bedrock aquifers frequently are chemically soft with generally low concentrations of dissolved iron. The chemically soft groundwater is high in sodium concentration. Approximately 5% of the chemical analyses indicate a fluoride concentration above 1.5 mg/L.

Alberta Environmental Protection (AEP) defines the Base of Groundwater Protection as the elevation below which the groundwater is expected to have more than 4,000 mg/L of total dissolved solids. By using the ground elevation, the bedrock surface and the Base of Groundwater Protection, a depth to the Base of Groundwater Protection can be determined. This depth, for the most part, would be the maximum drilling depth for a water supply well. Over approximately 70% of the County, the depth to the Base of Groundwater Protection is more than 150 metres. The area where the depth to the Base of Groundwater Protection is less than 150 metres is east of range 17 and west of range 13, W4M as shown on the map above.

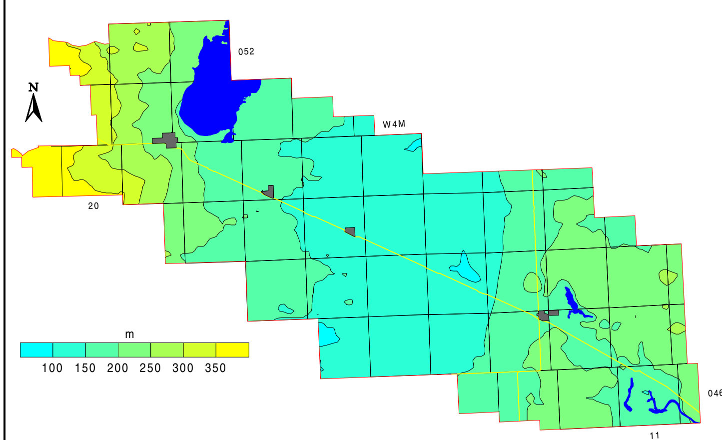


Figure 4. Depth to Base of Groundwater Protection (after EUB, June 1995)

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

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

3 TERMS

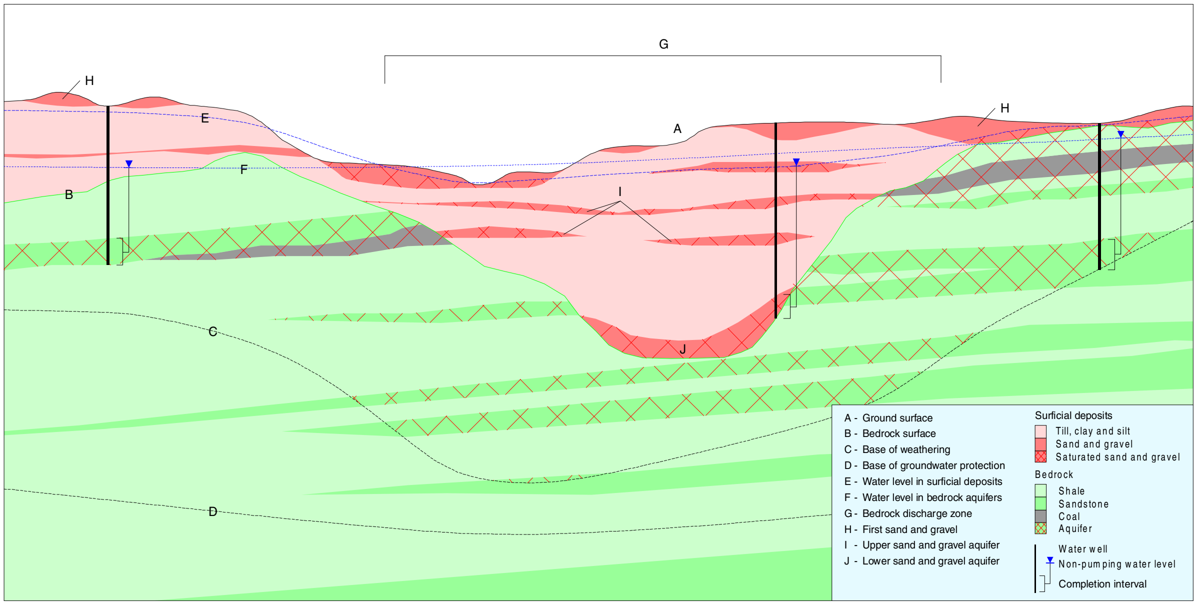


Figure 5. Generalized Cross-Section (for terminology only)

Lithology	Lithologic Description	Group and Formation: Thickness (m)	Group and Formation: Designation	Member: Thickness (m)	Member: Designation	Zone: Thickness (m)	Zone: Designation
	sand, gravel, till, clay, silt	<70	Surficial Deposits	<70	Upper	<15	First Sand and Gravel
	shale, sandstone, coal, bentonite, limestone, ironstone	300-380	Edmonton Group: Horseshoe Canyon Formation	~100	Upper		
				~100	Middle		
				<10	Drumheller Member		
				~170	Lower		
	shale, sandstone, siltstone	60-120	Bearpaw Formation				
	sandstone, siltstone, shale, coal	40-80	Belly River Group: Oldman Formation	<30	Dinosaur Member	<25	Lethbridge Coal Zone
				<20	Upper Siltstone Member		
				8-20	Comrey Member		
	shale, sandstone, coal	10-220	Belly River Group: *continental* Foremost Formation			<20	Taber Coal Zone
						<20	McKay Coal Zone
	sandstone, shale	<200	Belly River Group: *marine* Foremost Formation (Basal Belly River Sandstone)	<30	Birch Lake Member		
				<30	Ribstone Creek Member		
				<30	Victoria Member		
				<30	Brosseau Member		
	shale, siltstone	100-200	Lea Park Formation	50-100	Upper		
				50-100	Lower		

***Figure 6.* Geologic Column**

4 METHODOLOGY

4.1 Data Collection and Synthesis

The AEP groundwater database is the main source of groundwater data. The present revision includes 1,454 records added to the database by AEP in February 1999. The database includes the following:

1) water well drilling reports;
2) aquifer test results from some water wells;
3) location of some springs;
4) water well locations determined during water well surveys;
5) chemical analyses for some groundwaters;
6) location of flowing shot holes;
7) location of structure test holes; and
8) a variety of data related to the groundwater resource.

The main disadvantage to the database is the absence of quality control. Very little can be done to overcome this lack of quality control in the data collection, other than to assess the usefulness of control points relative to other data during the interpretation. Another disadvantage to the database is the lack of adequate spatial information.

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

The present project uses the 10TM coordinate system. This means that a record for the SE ¼ of section 36, township 050, range 19, W4M would have a horizontal coordinate with an Easting of 156,936 metres and a Northing of 5,911,867 metres, the centre of the quarter section. Once the horizontal coordinates are determined, a ground elevation is obtained from the 1:20,000 Digital Elevation Model (DEM) from the Resource Data Division of AEP.

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

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

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

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

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

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

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

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

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

4.2 Spatial Distribution of Aquifers

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

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

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

After obtaining values for the elevation of the top and bottom of individual geological units at specific locations, the spatial distribution of the individual surfaces can be determined. Digitally, establishment of

---

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

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.

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 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.

[6] See glossary

4.4 Maps and Cross-Sections

Once grids for geological surfaces have been prepared, various grids need to be combined to establish the extent and thickness of individual geological units. For example, the relationship between an upper bedrock unit and the bedrock surface must be determined. This process provides both the 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:

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

[7] See glossary

5 AQUIFERS

5.1 Background

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

5.1.1 Surficial Aquifers

Surficial deposits in the County are mainly less than 40 metres thick, except in areas of linear bedrock lows where the thickness of the surficial deposits can exceed 60 metres. The Buried Vegreville and Vermilion valleys are two of the main linear bedrock lows that pass through the County of Beaver and into the County of Minburn. The Buried Vegreville Valley is present in the northwestern part of the County of Beaver and trends generally from southwest to northeast. The Buried Vermilion Valley is present in the northeastern part of the County and also trends generally from southwest to northeast. Cross-section A-A' below crosses the Buried Vegreville Valley, and shows the thickness of the surficial deposits varies from less than 20 to more than 60 metres.

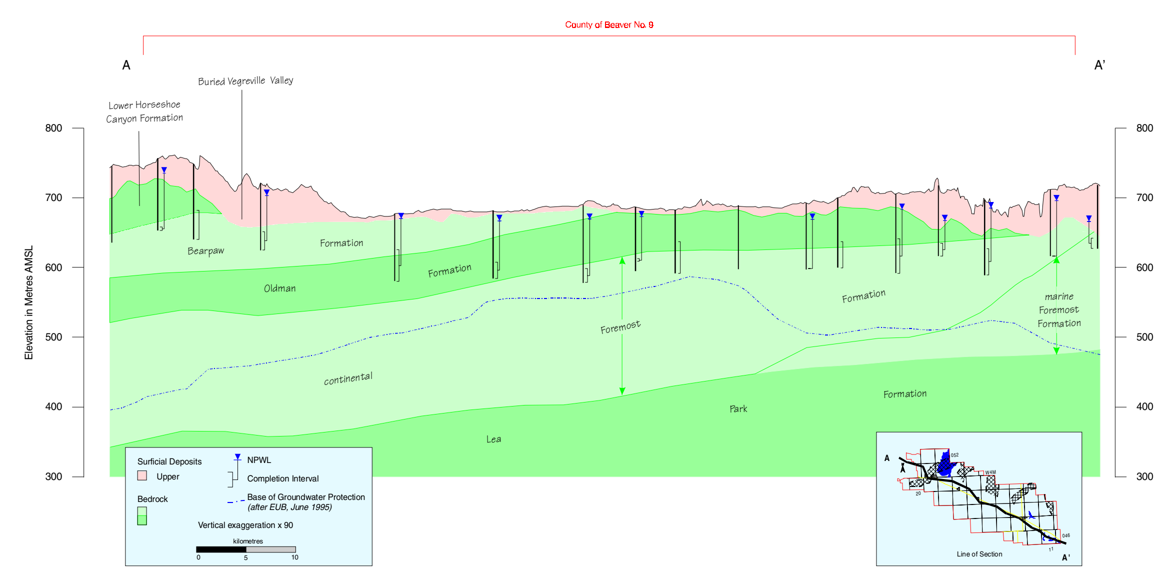


Figure 7. Cross-Section A - A'

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

For a water well with a small-diameter casing to be effective in surficial deposits and to provide sand-free groundwater, the water well must be completed with a water well screen. Some of the water wells completed in the surficial deposits are completed in low-permeability aquifers and have a large-diameter casing. The large-diameter water wells may have been hand dug or bored and because they are completed in very low permeability aquifers, most of these water wells would not benefit from water well screens. The groundwater from an aquifer in the surficial deposits usually has a chemical hardness of at least a few hundred mg/L and a dissolved iron concentration such that the groundwater is usually treated before being used for domestic needs. Within the County, 13% of the water wells completed in the surficial deposits have a casing diameter of greater than 450 millimetres or no reported diameter for the surface casing, and are assumed to be dug or bored water wells.

5.1.2 Bedrock Aquifers

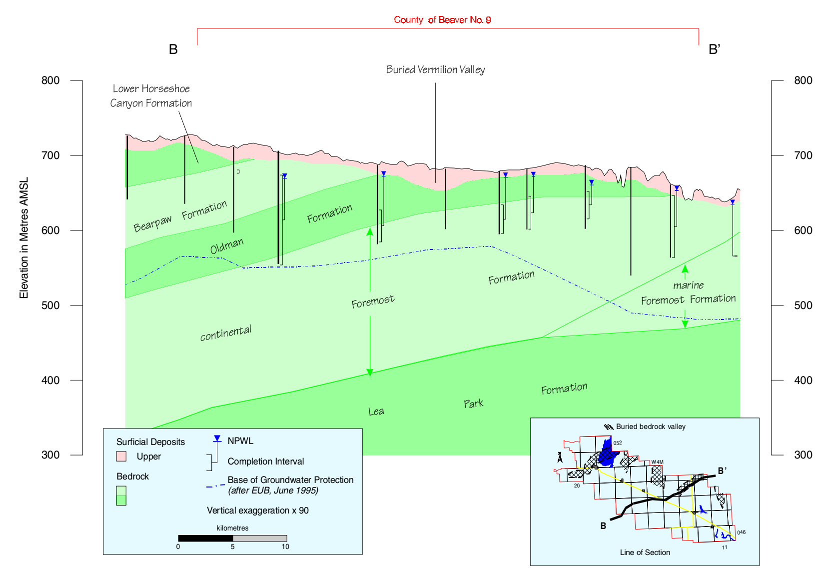


Figure 8. Cross-Section B - B'

The upper bedrock includes rocks that are less than 200 metres below the bedrock surface. Some of this bedrock contains porous, permeable and saturated rocks that are permeable enough to transmit groundwater for a specific need. Water wells completed in bedrock aquifers usually do not require water well screens, though some of the sandstones are friable[8] and water well screens are a necessity. The groundwater from the bedrock aquifers is usually chemically soft. The data for 1,202 water wells show that the top of the water well completion interval is below the bedrock surface, indicating that the water wells are completed in at least one bedrock aquifer. Of these 1,202 water wells, more than 95% have surface casing diameters of less than 275 mm and 20% of these bedrock water wells have been completed with water well screens. Of the drilled water wells completed in bedrock aquifers without water well screens, 55% have completion intervals of 20 metres or less.

The upper bedrock includes parts of the Lower Horseshoe Canyon and Bearpaw formations and the Belly River Group, as shown on cross-section B-B' above. The Belly River Group, which includes the Oldman and the *continental* and *marine* facies[9] of the Foremost formations, has a maximum thickness of 250 metres in the County. Near the base of the Foremost Formation is a sandstone unit that is referred to as the Basal Belly River Sandstone Zone. This unit extends eastward and becomes the Brosseau Member of the *marine* Foremost Formation.

The Lea Park Formation underlies the Belly River Group. In the County, the Lea Park Formation is a regional aquitard[10].

8 See glossary
9 See glossary
10 See glossary

5.2 Aquifers in Surficial Deposits

The surficial deposits are the sediments above the bedrock surface. This includes pre-glacial materials, which were deposited before glaciation, and materials deposited directly or indirectly by glaciation. The lower surficial deposits include pre-glacial fluvial[11] and lacustrine[12] deposits. The lacustrine deposits include clay, silt and fine-grained sand. The upper surficial deposits include the more traditional glacial deposits of till[13] and meltwater deposits. Because only minor quantities of pre-glacial materials are present in the County, there will be no direct review of the Lower Sand and Gravel Aquifer in this report and there are no maps for this Aquifer provided on the CD-ROM.

5.2.1 Geological Characteristics of Surficial Deposits

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

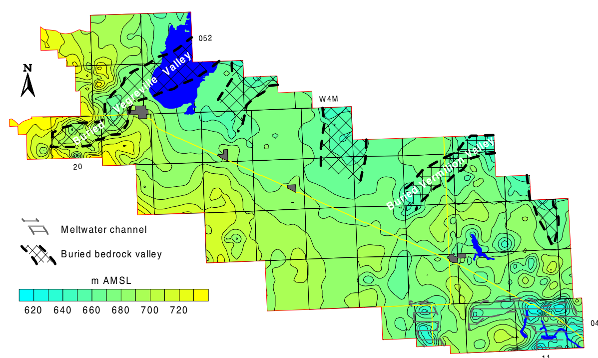


Figure 9. Bedrock Topography

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

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

---

11 See glossary
12 See glossary
13 See glossary

There are other linear bedrock lows shown on the bedrock topography map. These lows are present in parts of township 046, ranges 10 to 14, W4M and are indicated as being of meltwater origin. However, because sediments associated with the lower surficial deposits are indicated as being present in these linear bedrock lows, it is possible that the bedrock lows were originally tributaries to the Buried Wainwright Valley drainage systems present in the M.D. of Wainwright to the east of the County of Beaver.

The lower surficial deposits are composed mainly of fluvial and lacustrine deposits. Lower surficial deposits occur over less than 5% of the County, in association with linear bedrock lows. The total thickness of the lower surficial deposits is mainly less than five metres, but can be up to 20 metres in the areas of linear bedrock lows. The lowest part of the lower surficial deposits includes pre-glacial sand and gravel deposits. These deposits would generally be expected to directly overlie the bedrock surface in the Buried Vegreville and Vermilion valleys. The lowest sand and gravel deposits are of fluvial origin, are usually less than two metres thick and may be discontinuous.

The upper surficial deposits are either directly or indirectly a result of glacial activity. The deposits include till plus sand and gravel deposits of meltwater origin. The thickness of the upper surficial deposits is mainly less than 40 metres. The greatest thickness of upper surficial deposits occurs mainly in association with the Buried Vermilion Valley and meltwater channels.

Sand and gravel deposits can occur throughout the entire unconsolidated section. The total thickness of sand and gravel deposits is generally less than 10 metres but can be more than 15 metres in the areas of the buried bedrock lows and meltwater channels.

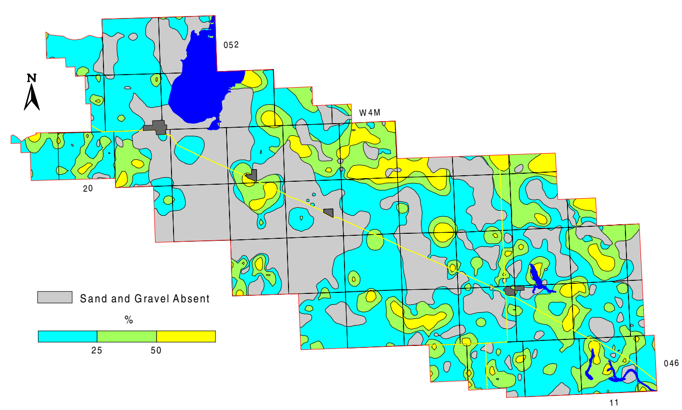


Figure 10. Amount of Sand and Gravel in Surficial Deposits

The combined thickness of all sand and gravel deposits has been determined as a function of the total thickness of the surficial deposits. Over approximately 10% of the County, the sand and gravel deposits are more than 50% of the total thickness of the surficial deposits. The main areas where the sand and gravel percentages are higher are areas where linear bedrock lows are present. The other areas where sand and gravel deposits constitute more than 50% of the surficial deposits can be areas of meltwater channels or areas where linear bedrock lows exist but have not been identified due to a shortage of accurate bedrock control points.

5.2.2 Sand and Gravel Aquifer(s)

One source of groundwater in the County includes aquifers in the surficial deposits. Since the sand and gravel aquifer(s) are not everywhere, the actual aquifer that is developed at a given location is usually dictated by the aquifer that is present. From the present hydrogeological analysis, 1,049 water wells are completed in aquifers in the upper surficial deposits and 49 water wells are completed in aquifers in the lower surficial deposits. This number of water wells is nearly twice the number of water wells determined to be completed in aquifers in the surficial deposits, based on lithologies given on the water well drilling reports. The 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.

The 1,049 water wells completed in the upper surficial deposits are located throughout the County, except in most of ranges 13 and 14, W4M, as shown in the adjacent map. The 49 water wells completed in the lower surficial deposits are mainly associated with the buried bedrock lows or meltwater channels in the eastern half of the County.

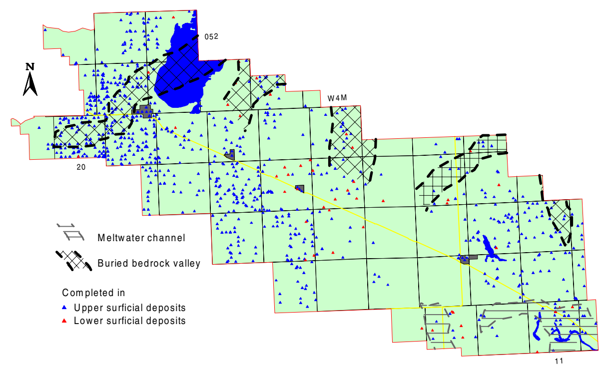


Figure 11. Water Wells Completed in Surficial Deposits

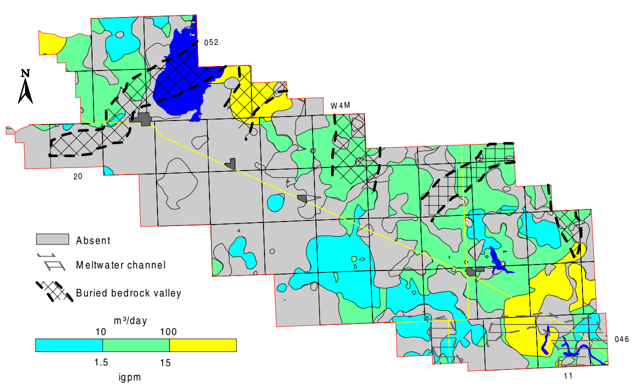


Figure 12. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)

The adjacent map shows expected water well yields in the County, based on sand and gravel aquifer(s) that have been developed by existing water wells. These data show that water wells with yields of more than 100 m³/day from sand and gravel aquifer(s) can be expected in less than 5% of the County. The most notable areas where yields of more than 100 m³/day are expected are mainly in association with linear bedrock lows. Over the majority of the County, water wells completed in the sand and gravel aquifer(s) are expected to have apparent yields of less than 100 m³/day.

5.2.2.1 Chemical Quality of Groundwater from Surficial Deposits

The chemical analysis results of groundwaters from the surficial deposits have not been differentiated based on aquifers in the upper or lower surficial deposits. The main reason for not separating the chemical analysis results into the different aquifers is the lack of data that can be attributed to the Lower Sand and Gravel Aquifer. This is in part related to the number of control points from this Aquifer, which is in part related to the limited areal extent of the lower surficial deposits.

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

The groundwaters from the surficial deposits are mainly calcium-magnesium-bicarbonate or sodium-sulfate-type waters, with 70% of the groundwaters having a TDS of less than 1,500 mg/L. Groundwaters from the surficial deposits are expected to have dissolved iron concentrations of greater than 1 mg/L.

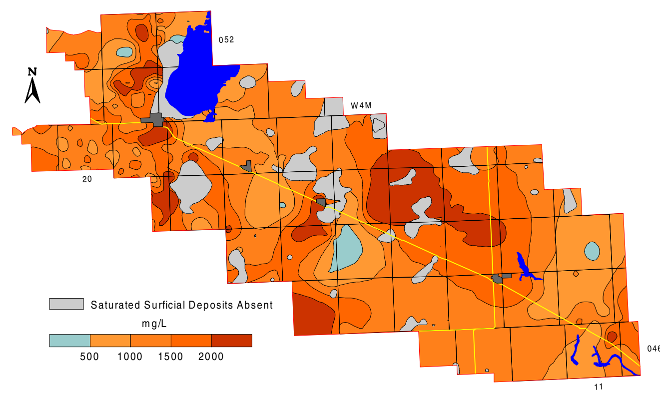


Figure 13. Total Dissolved Solids in Groundwater from Surficial Deposits

Although the majority of the groundwaters are calcium-magnesium-bicarbonate-type waters, there are groundwaters from the surficial deposits with sodium as the main cation; there are also groundwaters with significant concentrations of the sulfate ion. The groundwaters with elevated levels of sulfate generally occur in areas where there are elevated levels of total dissolved solids. 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 250 mg/L.

5.3 Bedrock

5.3.1 Geological Characteristics

The upper bedrock in the County includes the Lower Horseshoe Canyon Formation, the Bearpaw Formation and the Belly River Group. The Lea Park underlies the Belly River Group.

The Lower Horseshoe Canyon Formation is the lower part of the Edmonton Group and is the upper bedrock in the western part of the County. The Lower Horseshoe Canyon Formation has a maximum thickness of 170 metres. The Upper and the Middle Horseshoe Canyon formations are absent within the County.

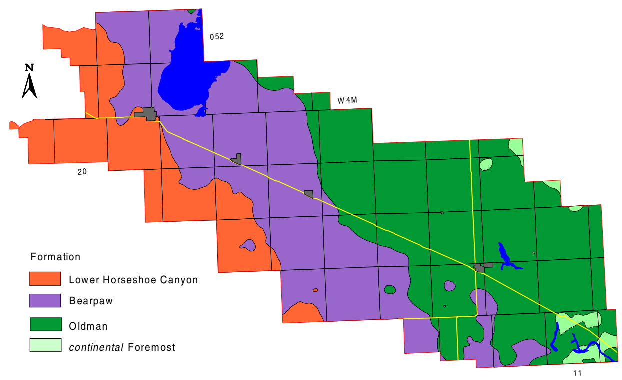


Figure 14. Bedrock Geology

The Lower Horseshoe Canyon Formation consists of deltaic[14] and fluvial sandstone, siltstone and shale layers 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 finer grained. The lower 60 to 70 metres of the Lower Horseshoe Canyon can include coarser grained sandstone deposits. The Lower Horseshoe Canyon Formation is underlain by the Bearpaw Formation.

The Bearpaw Formation is the upper bedrock in the west-central part of the County and has been eroded in the northeastern half of the County. There are also subcrops of the Bearpaw Formation that occur as outliers within the area of the Oldman Formation. The Bearpaw Formation is generally less than 100 metres thick in the County. "The Bearpaw Formation consists of marine shale, siltstone and minor sandstone, and represents the final widespread marine unit in the Western Canada Foreland Basin" (Catuneanu 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 Formation, and both the *continental* and *marine* facies of the Foremost Formation. There are zones of higher permeability that occur in the *marine* facies of the Belly River Group. These porous and permeable zones are present in the eastern one quarter of the County but there are very few areas where they are within 100 metres of the ground surface. Where the porous and permeable zones are present, the fluids in the aquifers may be hydrocarbons or groundwater. However, the groundwater could be expected to have total dissolved solids concentrations of 5,000 mg/L.

The Oldman Formation is the upper bedrock in the majority of the eastern half of the County. The Oldman Formation has a maximum thickness of 75 metres within the County and is composed of sandstone, siltstone, shale and coal deposited in a continental environment. The Oldman Formation is

[14] See glossary

composed of three parts: (a) the Comrey Member, which is the lowermost part of the Oldman Formation, (b) the Upper Siltstone Member, which is mainly composed of sandstone and siltstone layers and overlies the Comrey Member; and (c) the Dinosaur Member, which is mainly composed of shale and coal layers. The uppermost part of the Dinosaur Member is the Lethbridge Coal Zone.

The *continental* Foremost Formation underlies the Oldman Formation and subcrops under the surficial deposits in parts of the northeastern and southeastern edges of the County. The *continental* Foremost Formation, a backshore deposit, consists mainly of shale deposits with minor amounts of sandstone present, usually as linear narrow channel deposits. Coal zones occur within the *continental* Foremost Formation, with the main ones referred to as the McKay and the Taber Coal zones. There are also minor amounts of ironstone, a chemical deposit, in the *continental* Foremost Formation. Where the *continental* Foremost Formation is close to the bedrock surface, it can be fractured or weathered and can have significant local permeability.

The *marine* Foremost Formation, which includes up to five sandstone members and has a maximum thickness of 50 metres within the County, underlies the *continental* Foremost Formation. The upper part of the *marine* Foremost Formation is present in the eastern part of the County. In parts of eastern Alberta, the *marine* Foremost Formation can be separated into individual sandstone and shale members. However, toward the western extent of the *marine* Foremost Formation, the sandstones making up the *marine* Foremost Formation cannot always be separated into individual members. This situation occurs because the sandstone members of the *marine* Foremost Formation can thicken and the intervening shale layers thin toward the western extent of the *marine* facies. The westward extent of the *marine* Foremost Formation coincides with the position where the Basal Belly River Sandstone Zone of the *continental* Foremost Formation can be distinguished. In the County of Beaver, the *marine* Foremost Formation is present under the *continental* Foremost Formation in the northeastern part of the County but does not subcrop in the County.

The Lea Park Formation is mostly composed of shale, with only minor amounts of bentonitic sandstone present in some areas. Regionally, the Lea Park Formation is an aquitard.

5.3.2 Aquifers

Bedrock Aquifer	No. of Water Wells
Lower Horseshoe Canyon	358
Bearpaw	607
Oldman	1078
continental Foremost	261
marine Foremost	9
Total	2313

Table 2. Completion Aquifer

Of the 3,970 water wells in the database, 1,202 were defined as being completed in bedrock aquifers. This designation is based on the top of the completion interval being below the bedrock surface. For the remaining 2,768 water wells, a completion depth is available for the majority. In order to make use of additional information within the groundwater database, it was statistically determined that water wells typically have completion intervals equivalent to one quarter of their completed depth. This relationship was used to increase the number of water wells identified as completed in bedrock aquifers to 2,795 from 1,202. With the use of geological surfaces that were determined from the interpretation of geophysical logs, it has been possible to assign the water wells completed in bedrock aquifers to specific aquifers based on their completion intervals. Of the 2,795 bedrock water wells, 2,313 could be assigned a specific aquifer. The majority of the bedrock water wells are completed in the Oldman Aquifer as shown in the table above.

There are 539 records for bedrock water wells that have apparent yield values. In the County, 58% of the yields for water well completed in upper bedrock aquifer(s) are between 1 and 10 m³/day and 33% have yields of between 10 and 100 m³/day. The areas where higher yields are expected are mainly in the western part of the County. In this area, the Lower Horseshoe Canyon Formation is present. The areas where water wells with lower yields are expected are mainly in the eastern two-thirds of the County. Where the Bearpaw and Oldman formations are the upper bedrock, the water well yields are mainly less than 10 m³/day. Within the areas where lower yield water wells are present, there are small areas where higher yields also occur. This is because most water wells within these small areas would be completed in the *continental* Foremost Formation.

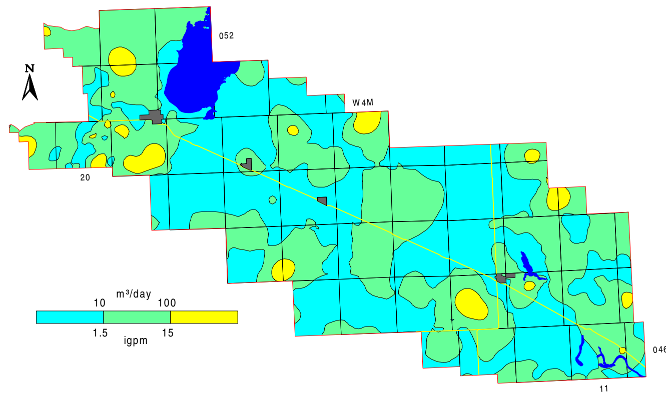


Figure 15. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

Aquifer	No. of Water Wells with Apparent Yields	Number of Water Wells with Apparent Yields: <10 m³/day	10 to 100 m³/day	>100 m³/day
Lower Horseshoe Canyon	104	45	37	22
Bearpaw	84	59	16	9
Oldman	203	130	66	7
continental Foremost	100	50	43	7
marine Foremost	10	1	5	4
Totals	501	285	167	49

Table 3. Apparent Yields of Bedrock Aquifers

There are 501 apparent yield values that can be assigned to a specific bedrock aquifer. The majority of the water wells completed in the bedrock aquifers have apparent yields that are less than 10 m³/day, as shown in the adjacent table.

5.3.3 Chemical Quality of Groundwater

The TDS concentrations in the groundwaters from the upper bedrock aquifer(s) range from less than 500 to more than 2,000 mg/L. In approximately 50% of the area, TDS values are more than 1,500 mg/L, with only a few areas having TDS concentrations of less than 1,000 mg/L. The lower values are expected mainly in the western and eastern parts of the County.

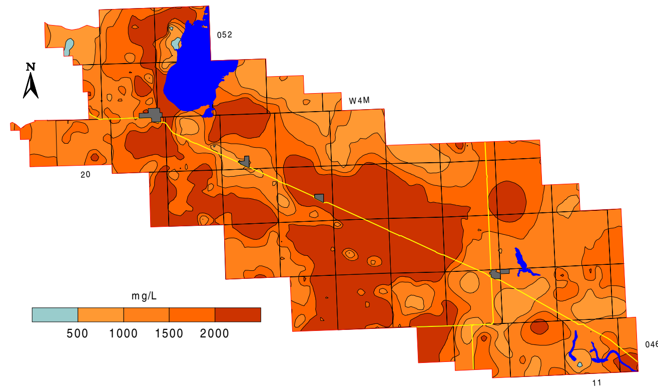


Figure 16. Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

The relationship between TDS and sulfate concentrations shows that when TDS values in the upper bedrock aquifer(s) exceed 1,200 mg/L, the sulfate concentrations exceed 400 mg/L. The chloride concentrations in the groundwaters from the upper bedrock aquifer(s) exceed 250 mg/L in 50% of the County, most noticeably in the south-central parts.

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

The Piper tri-linear diagrams[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 Lower Horseshoe Canyon Aquifer

The Lower Horseshoe Canyon Aquifer comprises the porous and permeable parts of the Lower Horseshoe Canyon Formation that underlies the western part of the County. The thickness of the Lower Horseshoe Canyon Formation is generally less than 80 metres; in the eastern two-thirds of the County, the Lower Horseshoe Canyon Formation has been eroded. The lowest 70 metres of the Horseshoe Canyon Formation tend to contain more porous and permeable materials.

5.3.4.1 Depth to Top

The depth to the top of the Lower Horseshoe Canyon Formation is mainly less than 40 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 Horseshoe Canyon Formation is more than 75 metres thick. In these areas, water well depths would need to be in the order of 100 metres to fully penetrate the lower part of the Formation, assuming a thickness of 20 metres for the surficial deposits.

5.3.4.2 Apparent Yield

The apparent yields for individual water wells completed through the Lower Horseshoe Canyon Aquifer are mainly in the range of 10 to 100 m³/day. The areas where water wells with higher yields are expected are mainly in township 050, range 19, W4M. There is no apparent relationship between expected water well yield and thickness of the Aquifer.

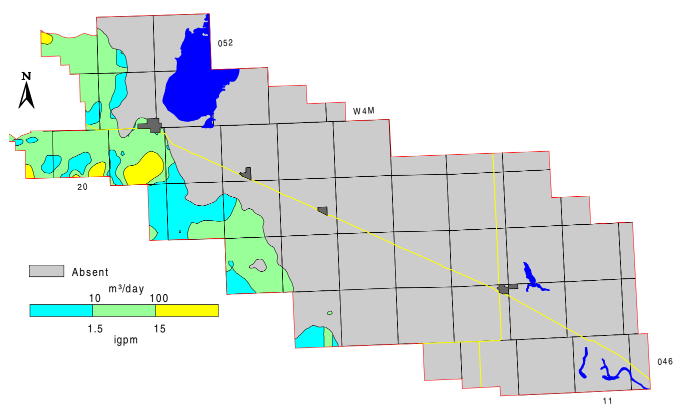


Figure 17. Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer

5.3.4.3 Quality

The groundwaters from the Lower Horseshoe Canyon Aquifer are mainly sodium-bicarbonate, sodium-sulfate or sodium-chloride types (see CD-ROM). The TDS concentrations for groundwaters from the Lower Horseshoe Canyon Aquifer range from less than 1,000 to more than 2,000 mg/L. The higher values of TDS occur mainly in townships 049 and 050, ranges 18 and 19, W4M. When TDS values in the groundwaters from the Lower Horseshoe Canyon Aquifer exceed 1,300 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 less than 100 mg/L. In a few areas, in the western part of the County, the chloride concentrations exceed 250 mg/L.

5.3.5 Bearpaw Aquifer

The Bearpaw Aquifer comprises the porous and permeable parts of the Bearpaw Formation and subcrops in the west-central part of the County. The Bearpaw Formation is generally less than 80 metres thick and is present only in the western half of the County; in the remainder of the County, the Bearpaw Formation has been eroded.

5.3.5.1 Depth to Top

The depth to the top of the Bearpaw Formation is mainly less than 100 metres below ground level. 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 Horseshoe Canyon Formation and the depth to the top of the Bearpaw Formation can exceed 140 metres.

5.3.5.2 Apparent Yield

The apparent yields for water wells completed through the Bearpaw Aquifer are mainly less than 10 m³/day. Higher yields occur mainly in ranges 16, 19 and 20, W4M. These higher yields may be related to inaccurate classification due to poor stratigraphic control.

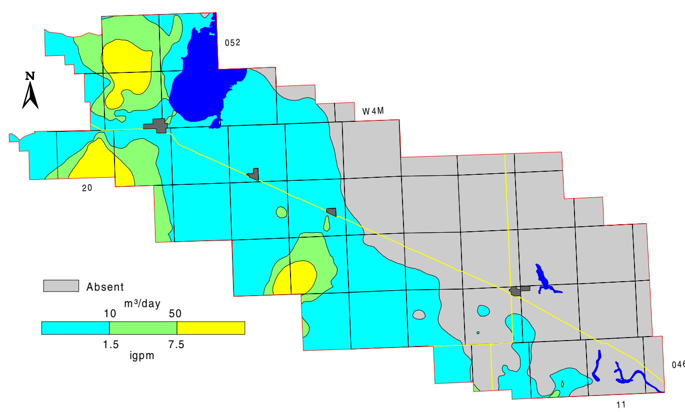


Figure 18. Apparent Yield for Water Wells Completed through Bearpaw Aquifer

5.3.5.3 Quality

The groundwaters from the Bearpaw Aquifer are mainly sodium-bicarbonate, sodium-sulfate or sodium-chloride types (see CD-ROM). The TDS concentrations are expected to be mainly less than 2,000 mg/L. The higher values occur mainly in the southern and southwestern parts of the County. The sulfate concentrations are mainly less than 500 mg/L. Chloride concentrations in the groundwaters from the Bearpaw Aquifer are mainly less than 250 mg/L, although there are areas where the chloride concentrations exceed 250 mg/L. The main areas where the chloride concentrations in the groundwaters from the Bearpaw Aquifer are expected to be more than 250 mg/L are in townships 049 and 050, ranges 18 and 19, W4M.

5.3.6 Oldman Aquifer

The Oldman Aquifer comprises the porous and permeable parts of the Oldman Formation. The Oldman Formation is present under most of the County, being absent only in small areas in the northeastern and southeastern parts of the County. The thickness of the Oldman Formation is in the order of 60 metres in the western half of the County. In the eastern half of the County, the Oldman Formation subcrops below the surficial deposits and the thickness decreases to zero in areas where the underlying *continental* Foremost Formation subcrops.

5.3.6.1 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 it subcrops. In the western part of the County where the Oldman is below the Bearpaw and the Lower Horseshoe Canyon formations, the depth to the top of the Oldman Formation can be more than 240 metres.

5.3.6.2 Apparent Yield

The apparent yields for individual water wells completed through the Oldman Aquifer are expected to be mainly less than 10 m³/day. The higher water well yields expected in the western part of the County, as shown on the adjacent map, reflect the gridding of a limited amount of data in that part of the County. The limited amount of data is a result of the depth of burial of the Oldman Formation, which is at a depth of more than 100 metres south and west of Beaverhill Lake.

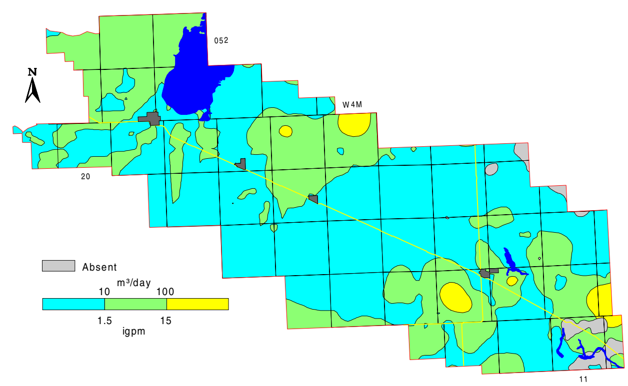


Figure 19. Apparent Yield for Water Wells Completed through Oldman Aquifer

The patchy areas of higher yields in township 050, ranges 15 and 16, W4M and township 047, ranges 10, 12 and 13, W4M may be a result of inadequate stratigraphic control.

5.3.6.3 Quality

Groundwaters from the Oldman Aquifer are mainly sodium-bicarbonate, sodium-sulfate or sodium-chloride-type waters. TDS concentrations are expected to be in the order of 500 to 3,000 mg/L, although there is a paucity of data west of range 15 and south of Highway 14. When TDS values exceed 1,200 mg/L, the sulfate concentrations exceed 400 mg/L.

Chloride concentrations in the groundwaters from the Oldman Aquifer are mainly less than 250 mg/L in ranges 10 to 12, W4M, where the Formation subcrops. The indications are that west of range 12, W4M, the chloride concentrations are expected to be over 250 mg/L.

5.3.7 *continental* Foremost Aquifer

The *continental* Foremost Aquifer comprises the porous and permeable parts of the *continental* Foremost Formation and subcrops in a few small areas in the northeastern and southeastern parts of the County. The thickness of the *continental* Foremost Aquifer can be more than 160 metres in the western half of the County. The *continental* Foremost Formation consists mainly of shale deposits with minor amounts of coal and sandstone present. The sandstone deposits usually occur as narrow linear channel deposits.

5.3.7.1 Depth to Top

The *continental* Foremost Formation is present under the entire County. The depth to the top of the Formation is variable, ranging from less than 20 metres where it subcrops in the eastern part of the County, to more than 280 metres in the western part of the County. In most of the area, the Base of Groundwater Protection occurs within the *continental* Foremost Formation.

5.3.7.2 Apparent Yield

The apparent yields for individual water wells completed in the *continental* Foremost Aquifer are mainly less than 10 m³/day, based on data from the groundwater database. The adjacent map indicates that apparent yields of more than 100 m³/day are expected where the Aquifer subcrops and this could be a result of increased permeability due to weathering processes. There are little or no data from the groundwater database for the Aquifer west of range 14, W4M, and the map indicates that expected water well yields are mainly less than 10 m³/day. The low yields presented in the majority of the County could be a result of the gridding procedure used to process a very limited number of data points.

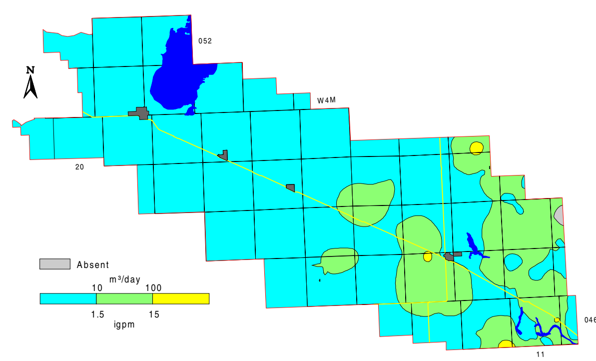


Figure 20. Apparent Yield for Water Wells Completed through continental Foremost Aquifer

5.3.7.3 Quality

Groundwaters from the *continental* Foremost Aquifer are mainly sodium-bicarbonate, sodium-sulfate or sodium-chloride-type waters. TDS concentrations in the groundwaters from the *continental* Foremost Aquifer are expected to be in the order of 1,000 to 3,000 mg/L.

In the eastern part of the County, when TDS values of the groundwaters from the *continental* Foremost Aquifer exceed 1,200 mg/L, the sulfate concentrations exceed 400 mg/L. Also, the chloride concentrations in these groundwaters are mainly less than 100 mg/L where the Formation subcrops.

5.3.7.4 C1

A detailed review of 174 resistivity logs available in a 12-township area (Figure 21) for the *continental* Foremost Formation was used to delineate two sandstone channels. Outside the 12-township area, the two sandstone channels have been identified using one resisitivity log per township. The lower channel was designated as C1 and the upper as C2. The sandstone thickness in C1 is more than 30 metres in township 050, range 16, W4M. The depth to the top of C1, where present, is mainly between 200 and 300 metres below ground level and is below the Base of Groundwater Protection west of range 12, W4M in the County. The sandstone thickness in C2 is mainly less than five metres.

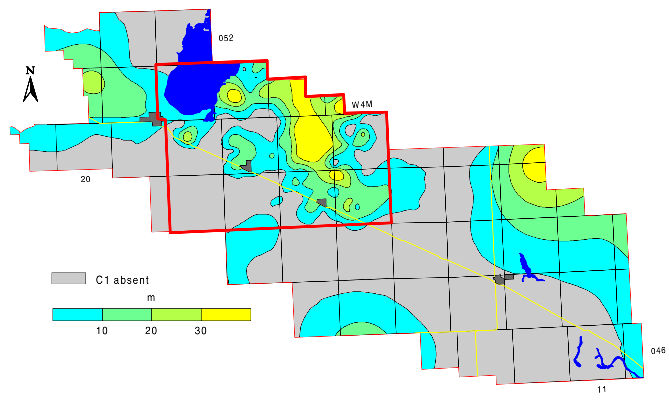


Figure 21. Thickness of C1

The summary results of drill stem tests are available from the EUB database. The DST summaries often provide a description of fluid obtained during the DST. Therefore, the DST summaries can be used to determine an apparent yield and the quality of fluid available from the Aquifer. The indications are that the TDS will be in the order of 5,000 mg/L.

The DST results associated with the C1 deposits indicate water well yields of in the order of 10 m³/day could be expected.

5.3.8 *marine* Foremost Aquifer

The *marine* Foremost Aquifer comprises the porous and permeable parts of the *marine* Foremost Formation. The Aquifer is present only in the eastern third of the County and underlies the *continental* Foremost Formation. The thickness of the *marine* Foremost Formation is generally less than 20 metres at its western extent but can be more than 180 metres in the northeastern part of the County.

5.3.8.1 Depth to Top

The depth to the top of the *marine* Foremost Formation is variable, ranging from less than 50 metres in the northeastern part of the County, to more than 250 metres at its western extent.

5.3.8.2 Apparent Yield

Although there are only four water well records in the County with apparent yields for individual water wells completed through the *marine* Foremost Aquifer, data available from the adjacent regions indicate apparent yields of less than 100 m³/day can be expected.

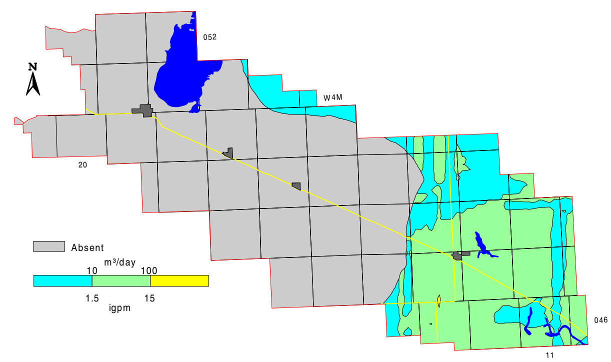


Figure 22. Apparent Yield for Water Wells Completed through marine Foremost Aquifer

5.3.8.3 Quality

There are insufficient data in the County to determine the chemical type of groundwaters from the *marine* Foremost Aquifer.

The TDS concentrations in the groundwaters from the *marine* Foremost Aquifer are expected to be mainly less than 1,500 mg/L. The sulfate concentrations are mainly less than 500 mg/L. Chloride concentrations in the groundwaters from the *marine* Foremost Aquifer are mainly less than 100 mg/L.

5.3.9 Basal Belly River Sandstone Aquifer

The Basal Belly River Sandstone Aquifer comprises the porous and permeable parts of the Basal Belly River Sandstone Zone that underlies the *continental* Foremost Formation, west of the edge of the *marine* Foremost Formation. The depth to the top of the Basal Belly River Sandstone Zone is mainly greater than 200 metres throughout the County. The shallower locations are in the northeastern part of the County. There are no records in the database for water wells completed in the Basal Belly River Sandstone Aquifer in the County.

With no data available from the groundwater database, the summary results of drill stem tests (DSTs) available from the EUB database were used. The DST summaries often provide a description of fluid obtained during the DST. Therefore, the DST summaries can be used to determine an apparent yield and the quality of fluid available from the Aquifer.

The fluids from 110 DSTs have been grouped as water, gas and water, and oil. The distribution of the various fluids is shown on the adjacent map.

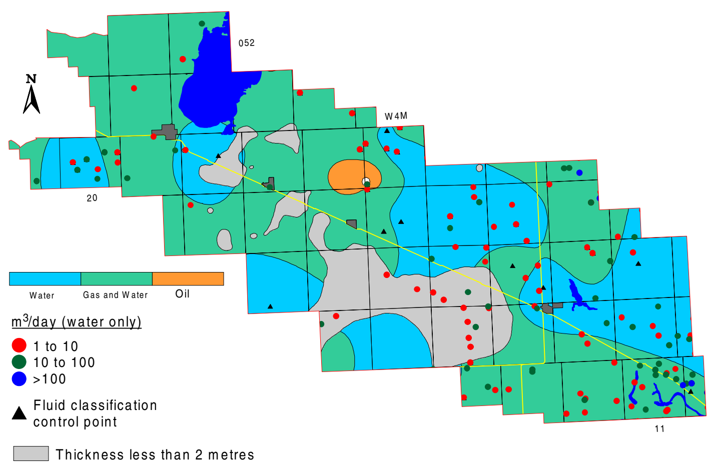


Figure 23. Type of Fluid Encountered in Basal Belly River Sandstone

Of the 110 DSTs, 69 have sufficient information to allow for the calculation of an apparent long-term yield. The projected long-term yield values vary from less than 5 m³/day to a maximum of 16.6 m³/day, with the mean being 8.7 m³/day and the median 7.7 m³/day.

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

5.3.10 Lea Park Aquitard

The Lea Park Formation is composed mainly of shale and has a very low permeability. In some of the area, the top of the Lea Park coincides with the Base of Groundwater Protection. In most areas, the Base of Groundwater Protection extends into the *continental* Foremost Formation. A map showing the depth to the Base of Groundwater Protection is given on page 5 of this report, in Appendix A, and on the CD-ROM.

6 GROUNDWATER BUDGET

6.1 Hydrographs

There are three locations in the County where water levels are being measured and recorded with time. These sites are observation water wells (Obs WWs) that are part of the AEP regional groundwater-monitoring network. Two Obs WWs are in 08-11-051-20 W4M in the vicinity of Cooking Lake, west of the Town of Tofield and one Obs WW is in NE 23-048-13 W4M, north of the Town of Viking. Hydrographs for the three Obs WWs are shown on the adjacent figure.

AEP Obs WW No. 157 in 08-11-051-20 W4M is completed at a depth of 34 metres below ground level in the Upper Sand and Gravel Aquifer. AEP Obs WW No. 158 in 08-11-051-20 W4M is completed at a depth of 61 metres below ground level in the Lower Horseshoe Canyon Aquifer. From 1980 to 1986, there is a water-level decline of more than one metre in AEP Obs WW No. 157. In AEP Obs WW No. 158, there is a water-level decline of more than 1.5 metres, but the decline is from 1981 to 1988. Following the water-level declines in both AEP Obs WWs, the water levels rose in the order of the same magnitude. There are no known licensed water well users in the immediate area of the Obs WWs. The closest licensed groundwater user is 5,000 metres from the Obs WWs and the licensed water well is completed in the Bearpaw Aquifer. The reason for the decline and subsequent rise in the water levels is not apparent. However, the decline does coincide with the drought of the early 1980s in Alberta. It is possible that the water-level decline is regional and is in response to the lack of groundwater recharge associated with the drought.

The third AEP Obs WW in NE 23-052-15 W4M, Obs WW No. 298, is completed at a depth of 103.6 metres below ground level in the *continental* Foremost Aquifer. This hydrograph shows annual cycles of water-level rise and decline; however, the water-level rise begins in winter and the decline begins in spring. Overall annual fluctuations are approximately 10 centimetres.

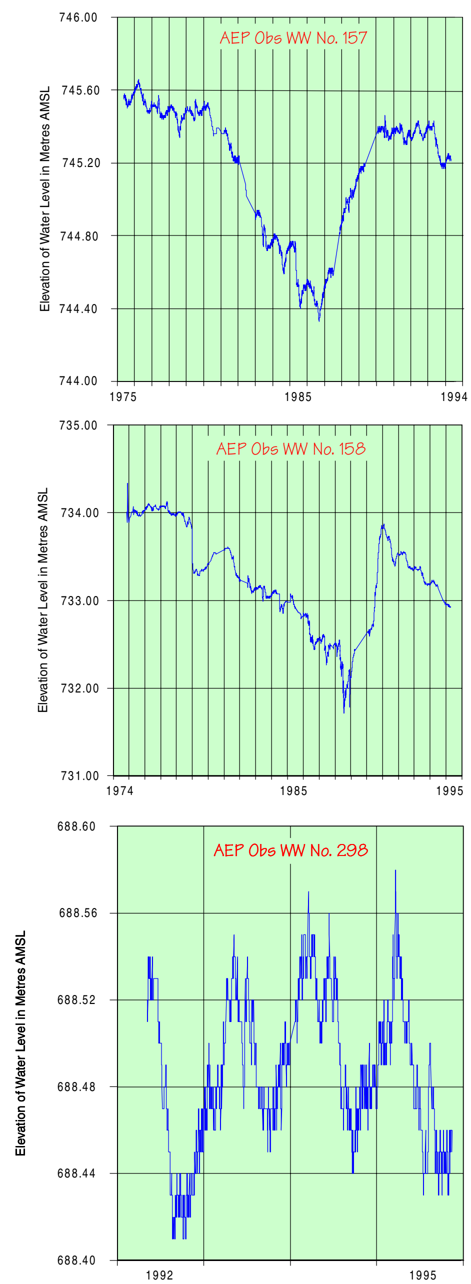


Figure 24. Hydrographs - AEP Observation Water Wells

6.2 Groundwater Flow

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

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

Aquifer Designation	Transmissivity (m^2/day)	Gradient (m/m)	Width (km)	Main Direction of Flow	Quantity (m^3/day)	Authorized Diversion (m^3/day)
Upper Sand and Gravel						65.2
Lower Horseshoe Canyon	2.6	0.003	40	Northeast	312	34.0
Bearpaw	1.0	0.003	70	Northeast	200	67.7
Oldman	2.6	0.002	90	North	468	108.5
continental Foremost	1.0	0.002	100	North	200	223.6
marine Foremost	3.1	0.001	40	Northwest	124	13.5

The above table indicates that there is more groundwater flowing through the aquifers than has been authorized to be diverted from the individual aquifers, with the exception of the *continental* Foremost Aquifer. In the case of the Upper Sand and Gravel Aquifer, no value has been calculated for the flow through the Aquifer because of the difficulty in obtaining a reasonable value for hydraulic gradient in the Upper Sand and Gravel Aquifer. However, because of the very approximate nature of the calculation of the quantity of groundwater flowing through the individual aquifers, more detailed work is required to establish the flow through the aquifers.

6.3 Quantity of Groundwater

An estimate of the volume of groundwater stored in the sand and gravel aquifers in the surficial deposits is 0.2 to 1.5 cubic kilometres. This volume is based on an areal extent of 3,500 square kilometres and a saturated sand and gravel thickness of 1.5 metres. The variation in the total volume is based on the value of porosity that is used for the sand and gravel. One estimate of porosity is 5%, which gives the low value of the total volume. The high estimate is based on a porosity of 30% (Ozoray, Dubord and Cowen, 1990).

The adjacent water-level map has been prepared by considering water wells completed in surficial deposits, except in the vicinity of the Buried Vegreville and Vermilion valleys. In these two valleys, only the water levels from water wells completed in the deeper sand and gravel deposits have been included. These water levels were used for the calculation of saturated surficial deposits and for the calculation of recharge/discharge areas.

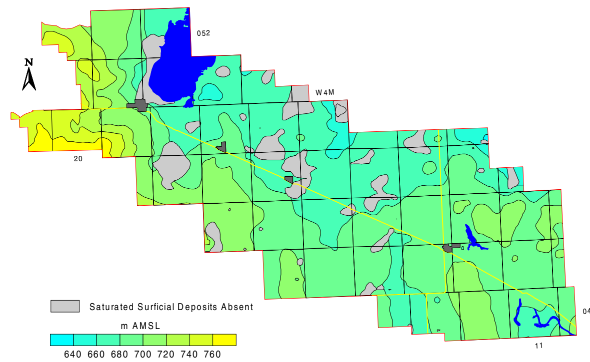


Figure 25. Non-Pumping Water-Level Surface in Surficial Deposits

6.4 Recharge/Discharge

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

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

6.4.1.1 Surficial Deposits/Upper Bedrock Aquifer(s)

The hydraulic gradient between the surficial deposits and the upper bedrock aquifer(s) has been determined. The determination is made 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 that are less than 15 metres deep. The recharge classification includes 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 classification includes areas 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 one of transition.

The adjacent map shows that, in more than 60% of the County, there is a downward hydraulic gradient from the surficial deposits toward the upper bedrock aquifer(s). The areas where there is an upward hydraulic gradient from the bedrock to the surficial deposits are mainly in the vicinity of linear bedrock lows. The remaining parts of the County are areas where there is a transition condition.

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

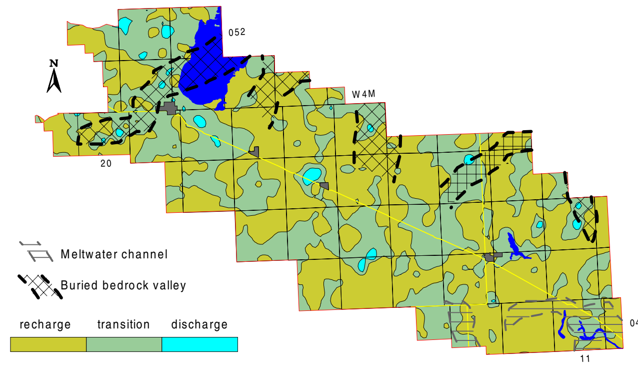


Figure 26. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)

6.4.1.2 Bedrock Aquifers

Recharge to the bedrock aquifers within the County takes place from the overlying surficial deposits and from flow in the aquifers 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 Bearpaw Aquifer indicates that in more than 40% of the County where the Bearpaw Aquifer is present, there is a downward hydraulic gradient. Discharge areas for the Bearpaw Aquifer are either in or adjacent to the bedrock lows. The hydraulic relationship between the surficial deposits and the remainder of the bedrock aquifers present in the County indicates there is mainly a downward hydraulic gradient.

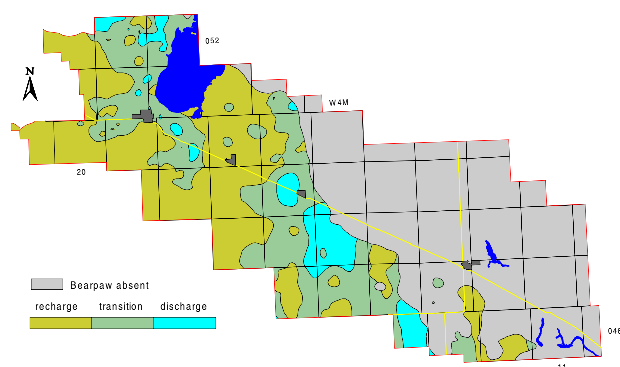


Figure 27. Recharge/Discharge Areas between Surficial Deposits and Bearpaw Aquifer

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 1,851 records in the area of the County with lithological descriptions, 189 have sand and gravel within one metre of ground level. In the remaining 1,662 records, the first sand and gravel is deeper or not present. This information was gridded to prepare a distribution of where the first sand and gravel deposit could be expected within one metre of ground level.

7.1.1 Risk of Contamination Map

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

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

Table 4. Risk of Groundwater Contamination Criteria

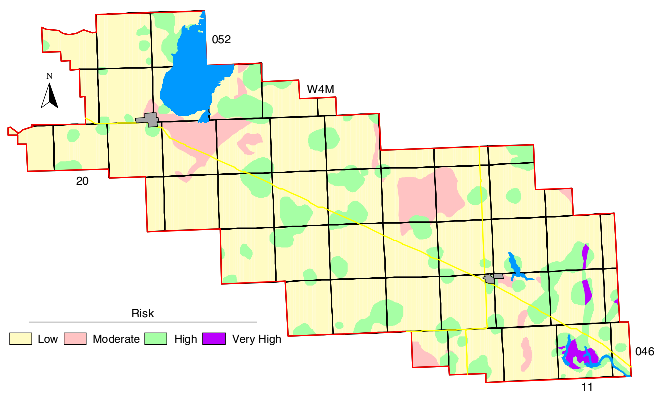


Figure 28. Risk of Groundwater Contamination

The Risk of Groundwater Contamination map shows that, in 15% of the County, there is a high or very high risk of the groundwater being contaminated. These areas would be considered the least desirable ones for a development that has a product or by-product that could cause groundwater contamination. However, because the map has been prepared as part of a regional study, the designations are a guide only; detailed hydrogeological studies must be completed at any proposed development site to ensure the groundwater is protected from possible contamination. At all locations, good environmental practices should be exercised in order to ensure that groundwater contamination would not affect groundwater quality.

8 RECOMMENDATIONS

The present study has been based on information available from the AEP 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 147 existing water wells listed in Appendix E. These water well records indicate that a complete water well drilling report is available along with at least a partial chemical analysis. The level of verification would have to include identifying the water well in the field, obtaining meaningful horizontal coordinates for the water well and the verification of certain parameters such as water level and completed depth. An attempt to update the quality of the entire database is not recommended.

The results of the present study indicate that the only readily identifiable aquifers in the surficial deposits are the sand and gravel deposits associated with the linear bedrock low present in the western part of the County. The present analysis has shown that the groundwater flow in the *continental* Foremost Aquifer may not be sufficient to sustain the authorized diversion by AEP. However, because this analysis is based on a regional study, the results should be considered no more than an indication.

In the bedrock, there are indications that a useable aquifer may be present in parts of the *continental* Foremost Formation. As part of the present study, 174 e-logs were reviewed in detail to identify the extent of two sandstone channels in the *continental* Foremost Formation. DST results from the EUB database were used to establish possible yields for water wells completed in one sandstone channel designated as C1. The EUB chemical database was used to obtain an indication of the quality of the groundwater that could be expected from the sandstone channels. Even though the groundwater from these channel sandstone aquifers would need to be treated before being used, it is recommended that a test drilling program be undertaken to obtain a better understanding of the potential of these types of deposits. Three recommended locations for the drilling of water test holes are as follows:

08-050-17 W4M: maximum depth 350 metres
02-050-16 W4M: maximum depth 250 metres
20-050-16 W4M: maximum depth 300 metres

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

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

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

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

A list of 147 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. The water well drilling reports should be submitted to the AEP Resource Data Division in an electronic form. The money presently being spent by AEP and Prairie Farm Rehabilitation Administration (PFRA) to transpose the paper form to the electronic form should be used to allow for a technical review of the data and follow-up discussions with the drillers.

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

Groundwater is a renewable resource and it must be managed.

9 REFERENCES

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

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

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

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

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

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

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

Stein, R. 1982. Hydrogeology of the Edmonton Area (Southeast Segment), Alberta. Alberta Research Council. Report 79-6.

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

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

10 GLOSSARY

Aquifer	a formation, group of formations, or part of a formation that contains saturated permeable rocks capable of transmitting groundwater to water wells or springs in economical quantities.
Aquitard	a confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer.
Available Drawdown	in a confined aquifer, the distance between the non-pumping water level and the top of the aquifer. in an unconfined aquifer (water table aquifer), two thirds of the saturated thickness of the aquifer.
Deltaic	a depositional environment in standing water near the mouth of a river.
Facies	the aspect or character of the sediment within beds of one and the same age (Pettijohn, 1957).
Fluvial	produced by the action of a stream or river.
Friable	poorly cemented.
Hydraulic Conductivity	the rate of flow of water through a unit cross-section under a unit hydraulic gradient; units are length/time.
Kriging	a geo-statistical method for gridding irregularly-spaced data.
Lacustrine	fine-grained sedimentary deposits associated with a lake environment and not including shore-line deposits.
Piper tri-linear diagram	a method that permits the major cation and anion compositions of single or multiple samples to be represented on a single graph. This presentation allows groupings or trends in the data to be identified.
Surficial Deposits	includes all sediments above the bedrock.
Till	a sediment deposited directly by a glacier that is unsorted and consisting of any grain size ranging from clay to boulders.
Transmissivity	the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient: a measure of the ease with which groundwater can move through the aquifer. Apparent Transmissivity: the value determined from a summary of aquifer test data, usually involving only two water-level readings. Effective Transmissivity: the value determined from late pumping and/or late recovery water-level data from an aquifer test. Aquifer Transmissivity: the value determined by multiplying the hydraulic conductivity of an aquifer by the thickness of the aquifer.

Yield — a regional analysis term referring to the rate a properly completed water well could be pumped, if fully penetrating the aquifer.

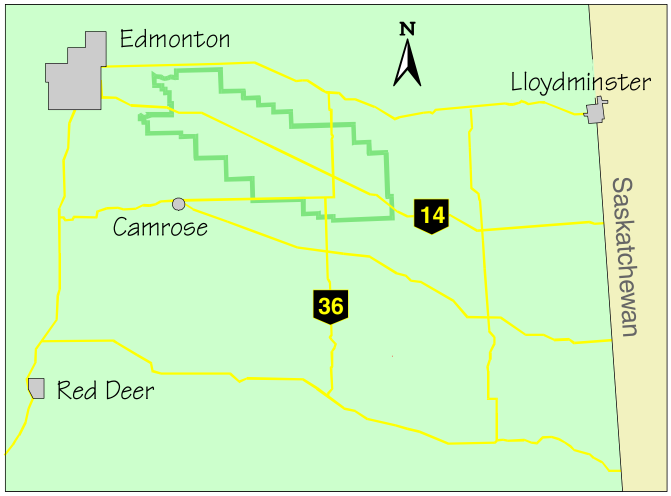
Apparent Yield: based mainly on apparent transmissivity.

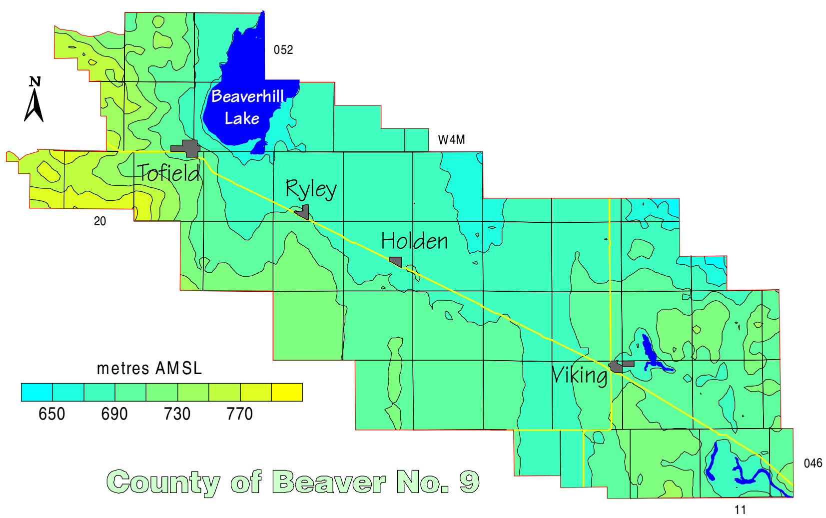
Long-Term Yield: based on effective transmissivity.

COUNTY OF BEAVER NO. 9
Appendix A

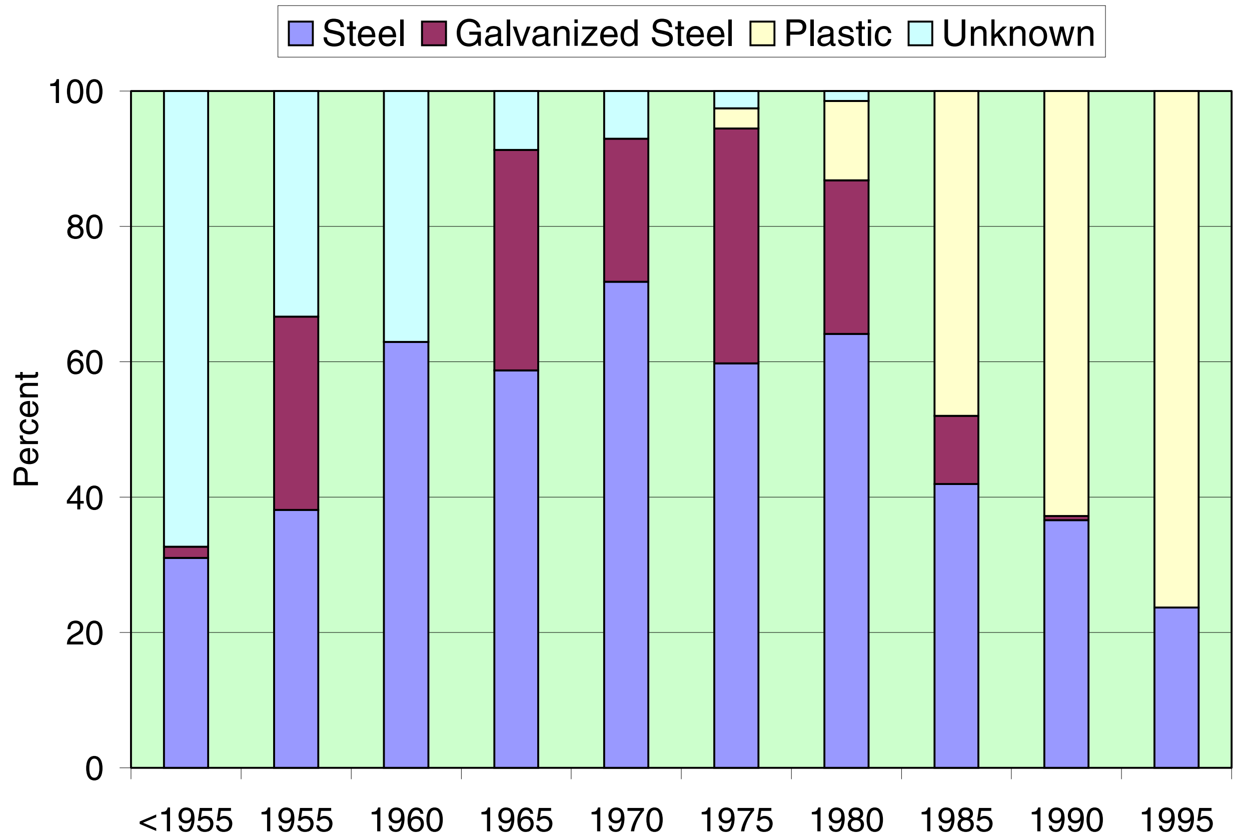
HYDROGEOLOGICAL MAPS AND FIGURES

Index Map

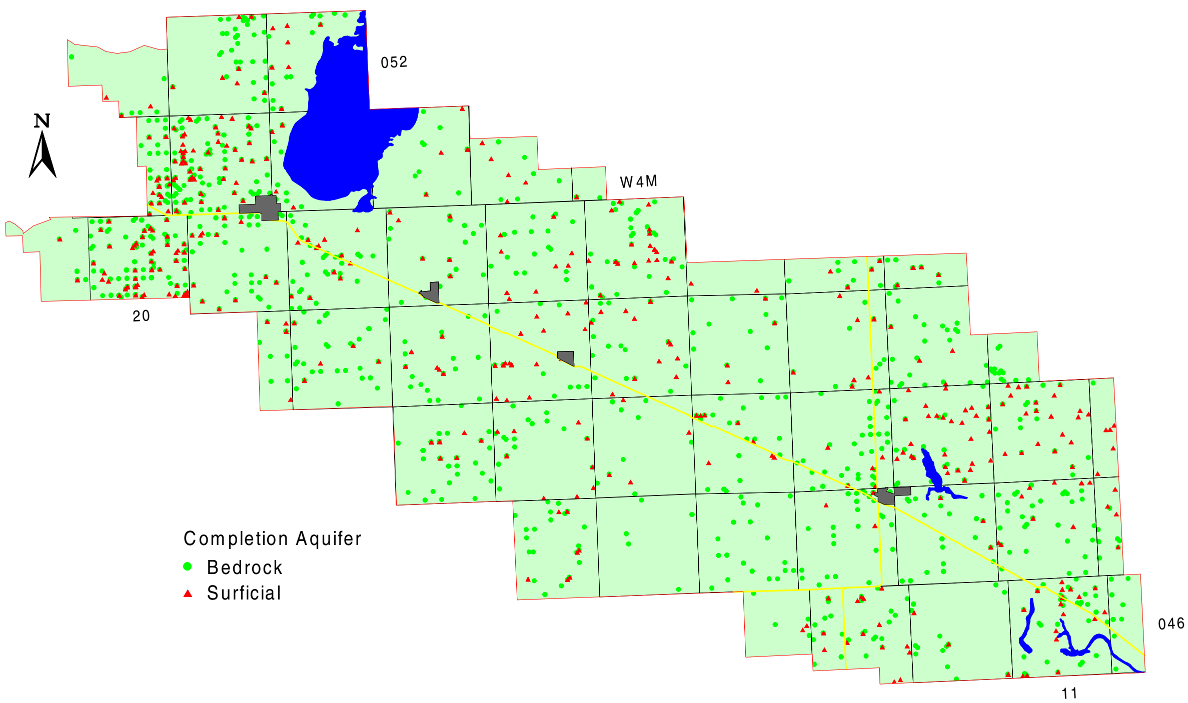

Edmonton
N
Lloydminster
Saskatchewan
14
Camrose
36
Red Deer


052
N
Beaverhill
Lake
W4M
Tofield
Ryley
20
Holden
metres AMSL
650
690
730
770
Viking
046
County of Beaver No. 9
11

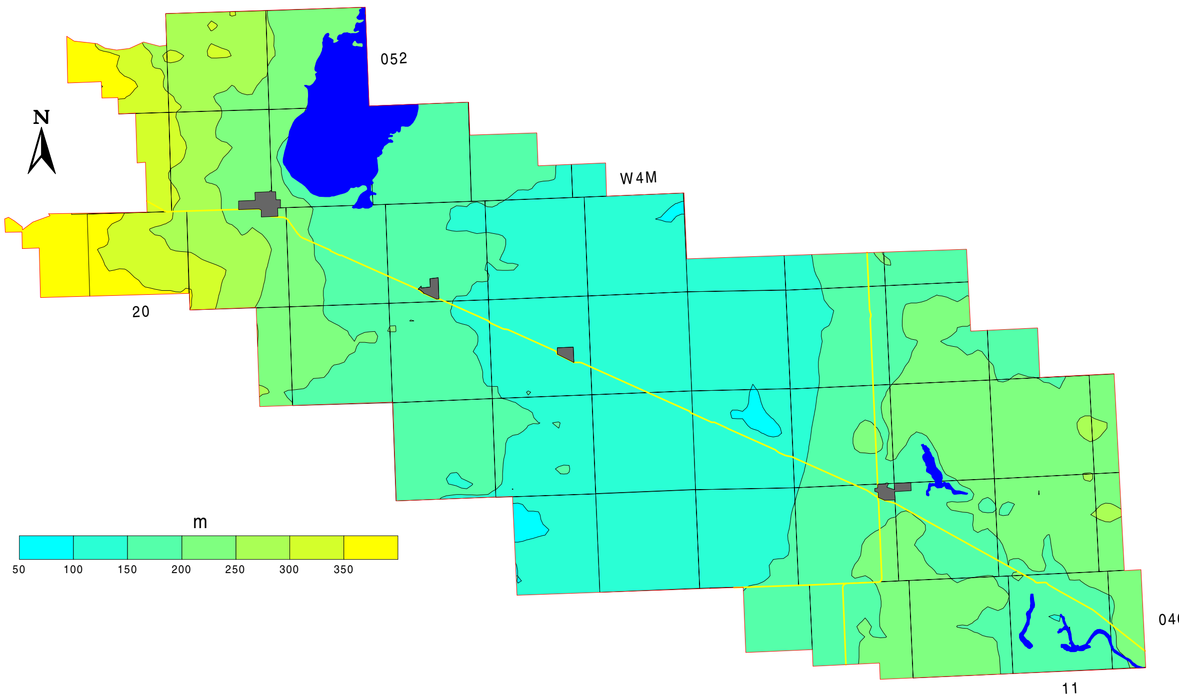
Surface Casing Types used in Drilled Water Wells

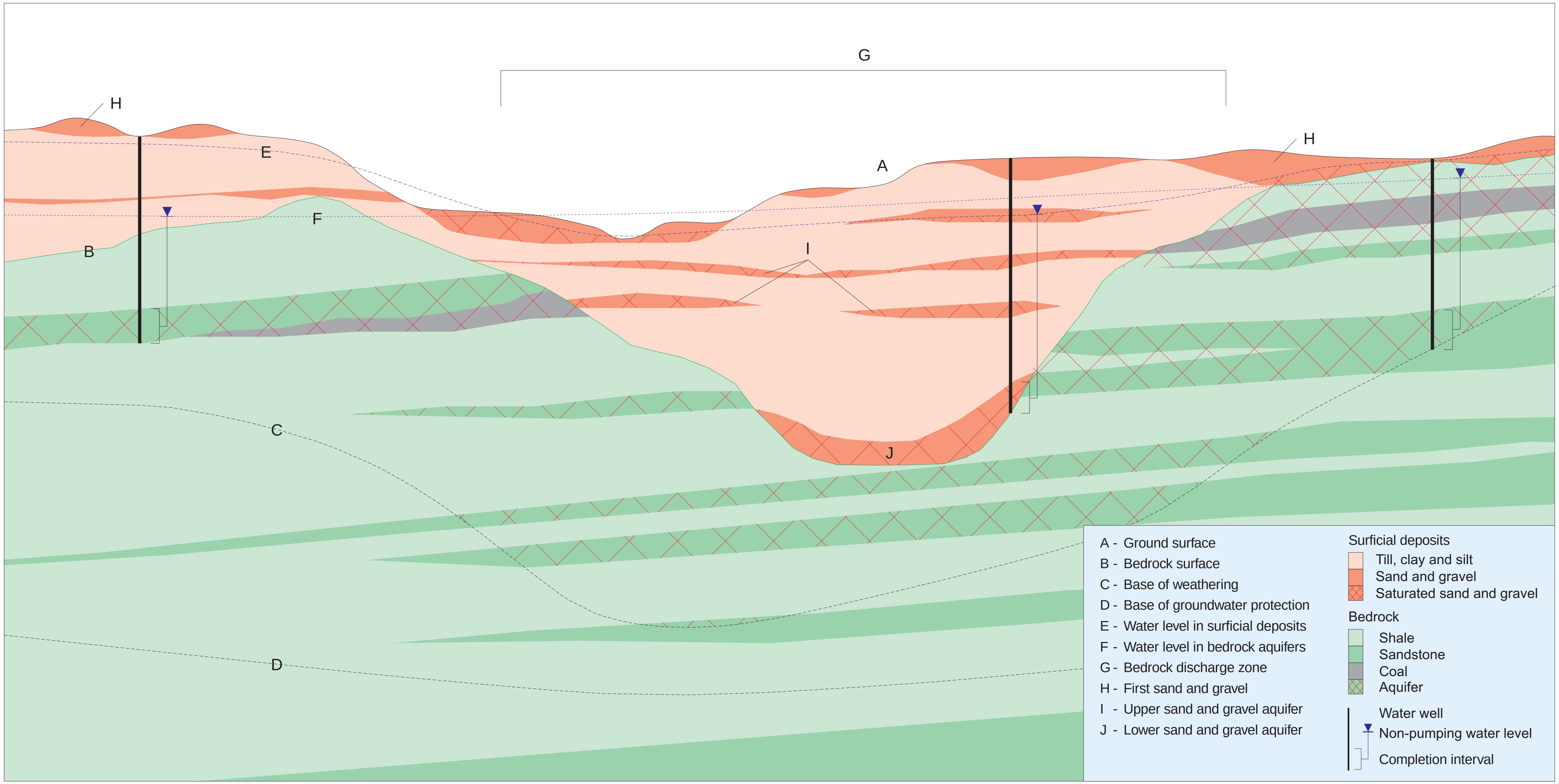


Location of Water Wells



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

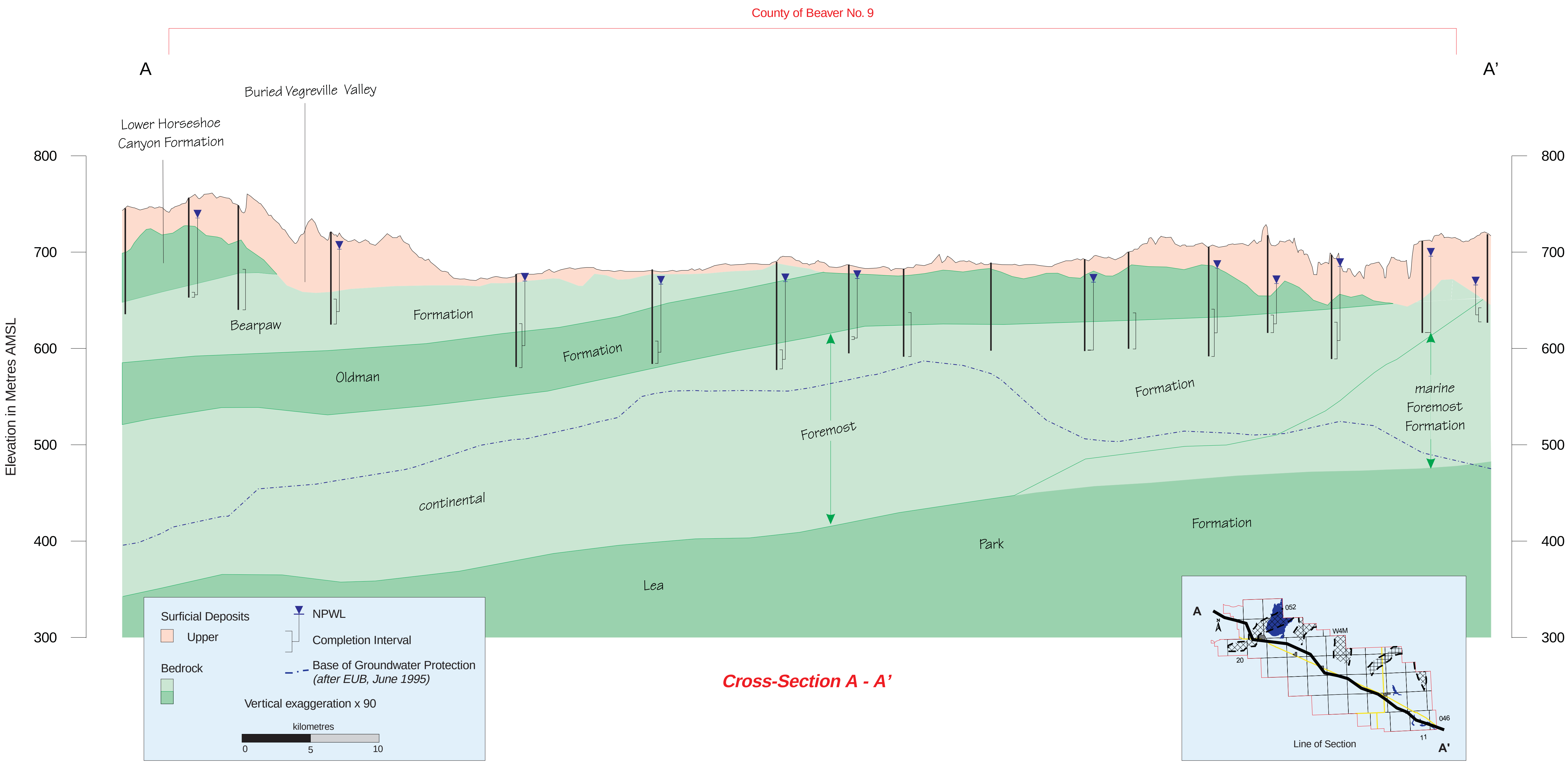




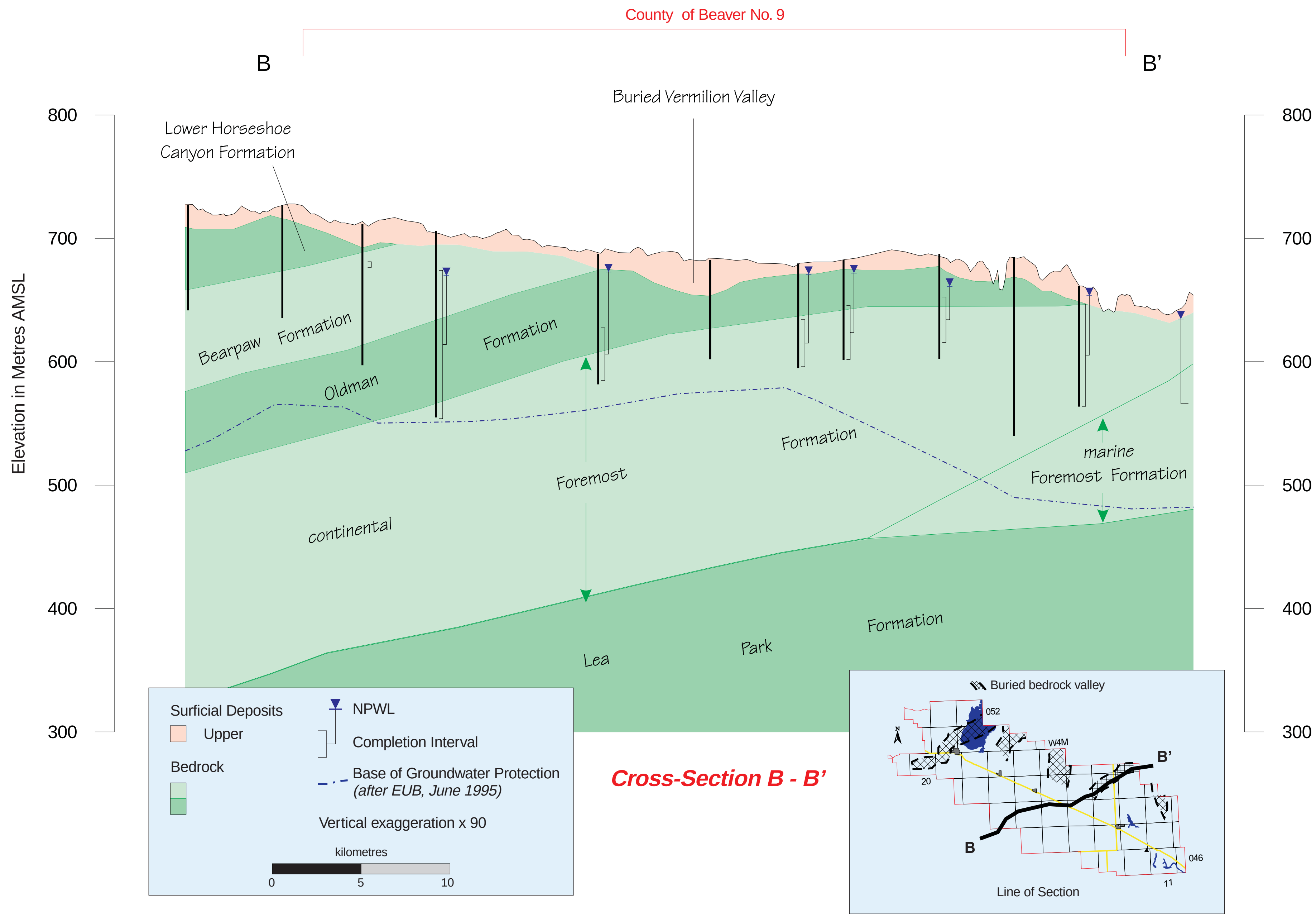
Generalized Cross-Section
(for terminology only)

		Group and Formation			Member		Zone	
Lithology	**Lithologic Description**	**Thickness (m)**	**Group**	**Designation**	**Thickness (m)**	**Designation**	**Thickness (m)**	**Designation**
	sand, gravel, till, clay, silt	<70		Surficial Deposits	<70	Upper	<15	First Sand and Gravel
	shale, sandstone, coal, bentonite, limestone, ironstone	300-380	Edmonton Group	Horseshoe Canyon Formation	~100	Upper		
					~100	Middle		
					<10	Drumheller Member		
					~170	Lower		
	shale, sandstone, siltstone	60-120		Bearpaw Formation				
	sandstone, siltstone, shale, coal	40-80	Belly River Group	Oldman Formation	<30	Dinosaur Member	<25	Lethbridge Coal Zone
					<20	Upper Siltstone Member		
					8-20	Comrey Member		
	shale, sandstone, coal	10-220		*continental* Foremost Formation			<20	Taber Coal Zone
							<20	McKay Coal Zone
	sandstone, shale	<200		*marine* Foremost Formation (Basal Belly River Sandstone)	<30	Birch Lake Member		
					<30	Ribstone Creek Member		
					<30	Victoria Member		
					<30	Brosseau Member		
	shale, siltstone	100-200		Lea Park Formation	50-100	Upper		
					50-100	Lower		

Geologic Column

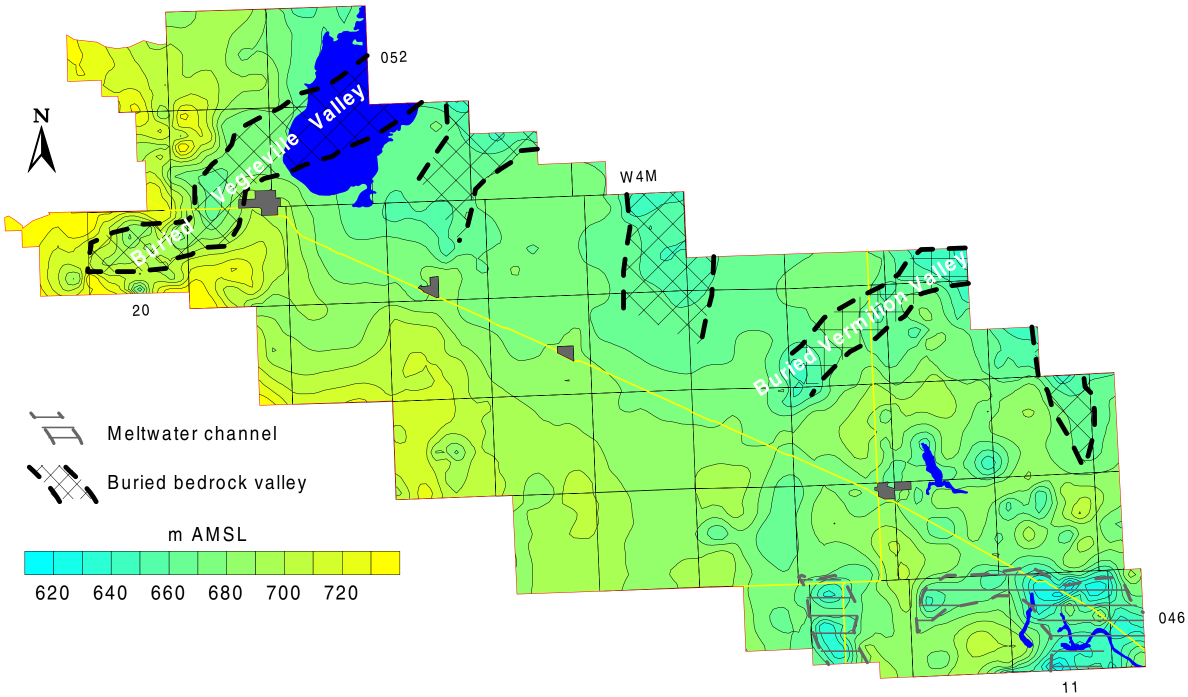


Cross-Section A - A'

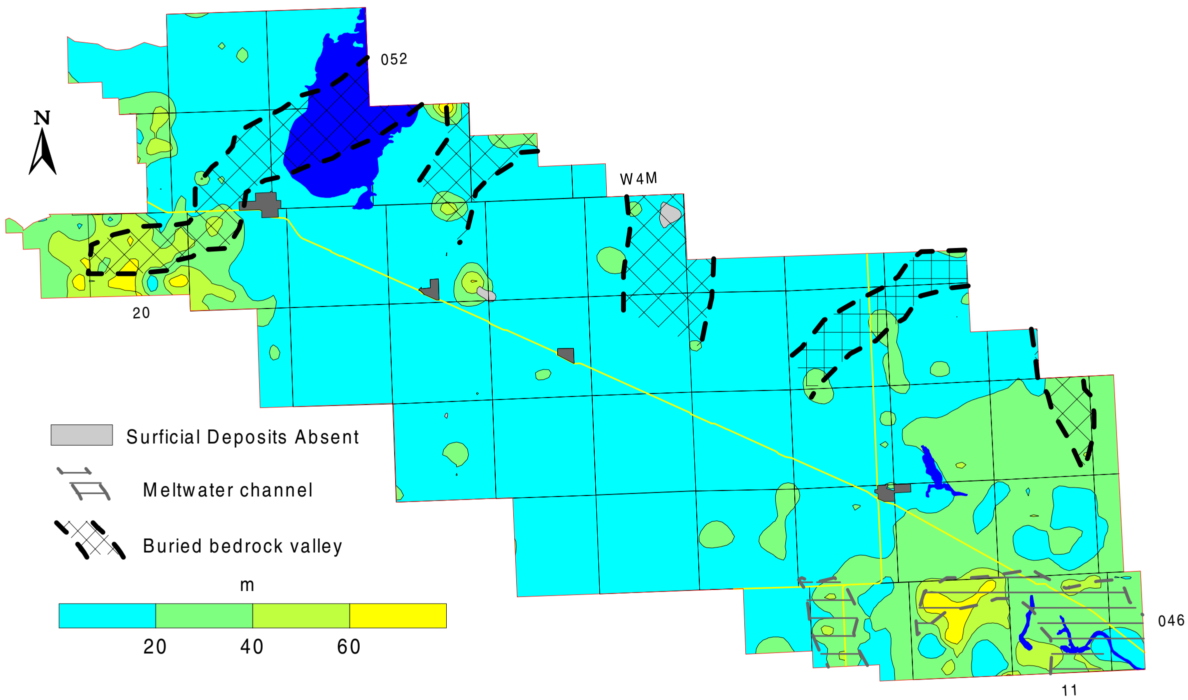


Cross-Section B - B'

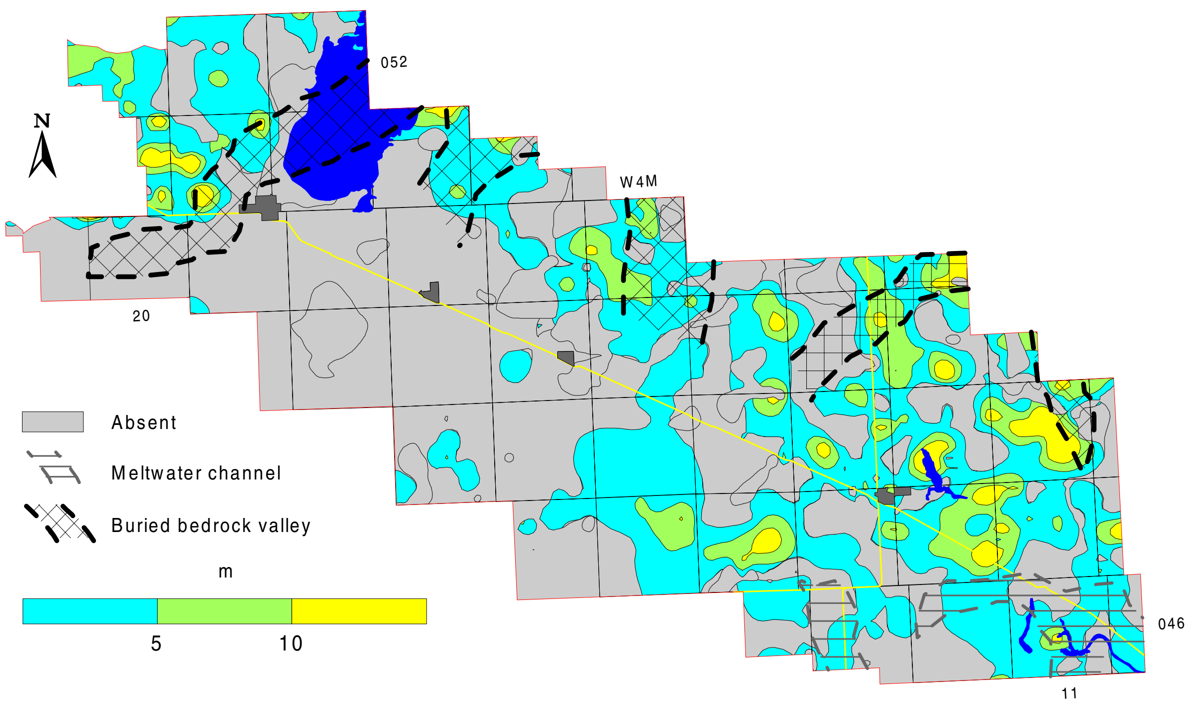
Bedrock Topography



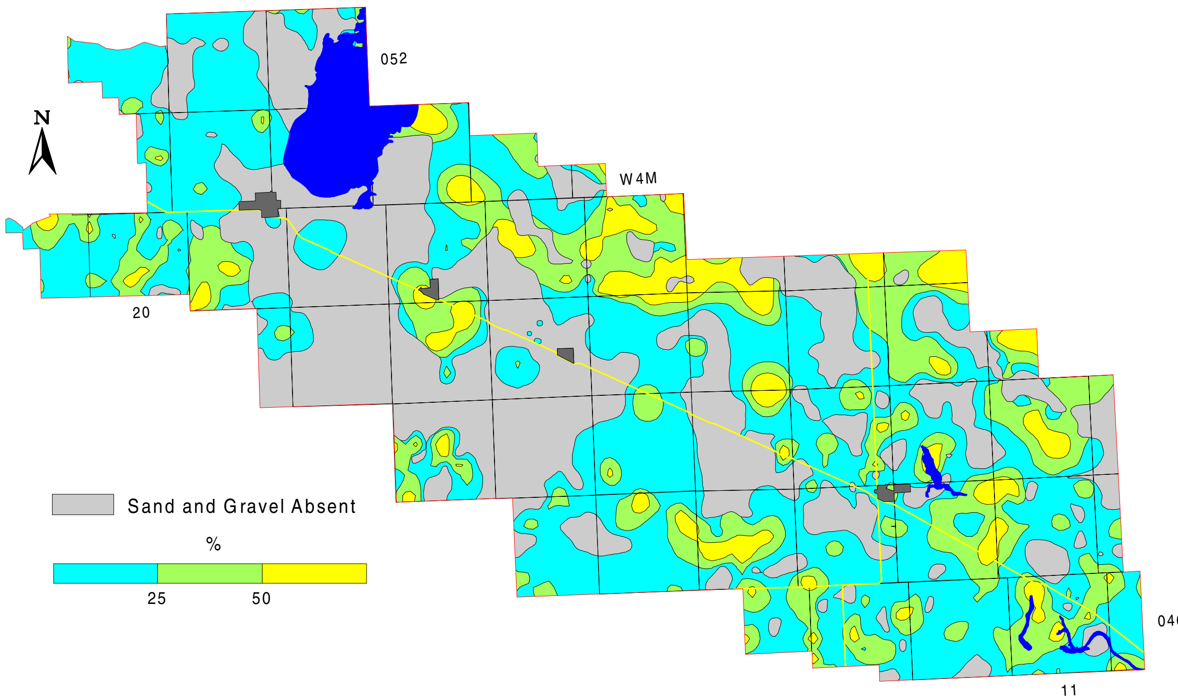
Thickness of Surficial Deposits



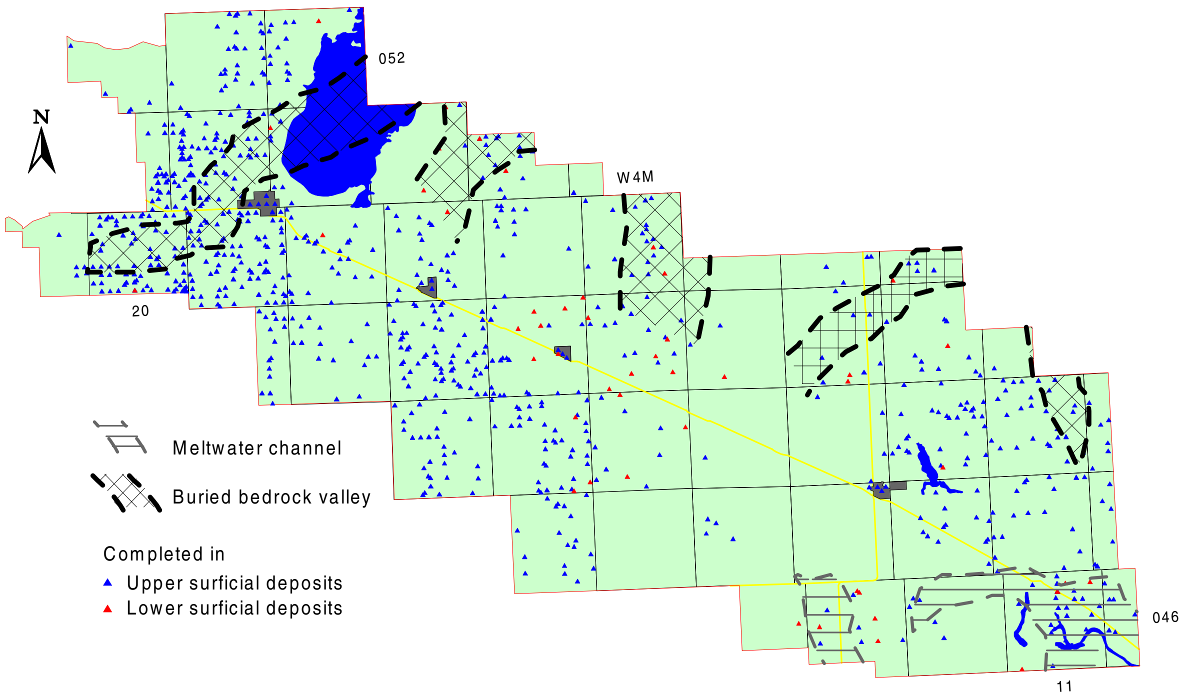
Thickness of Sand and Gravel Aquifer(s)



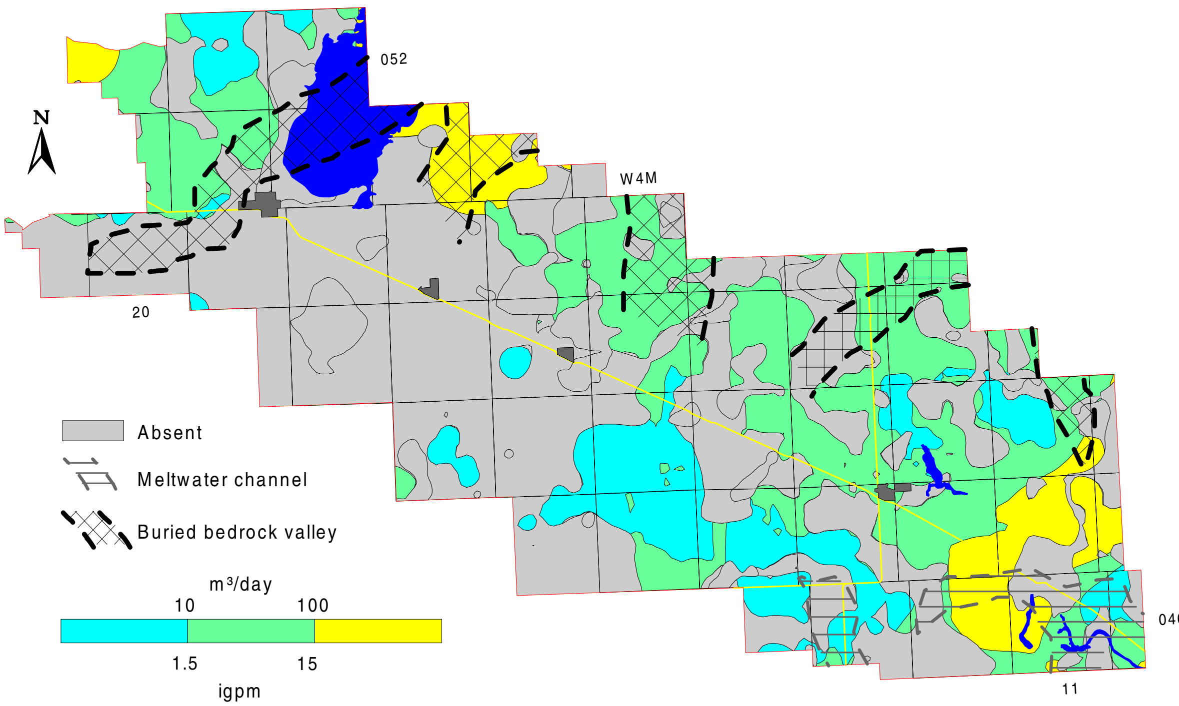
Amount of Sand and Gravel in Surficial Deposits



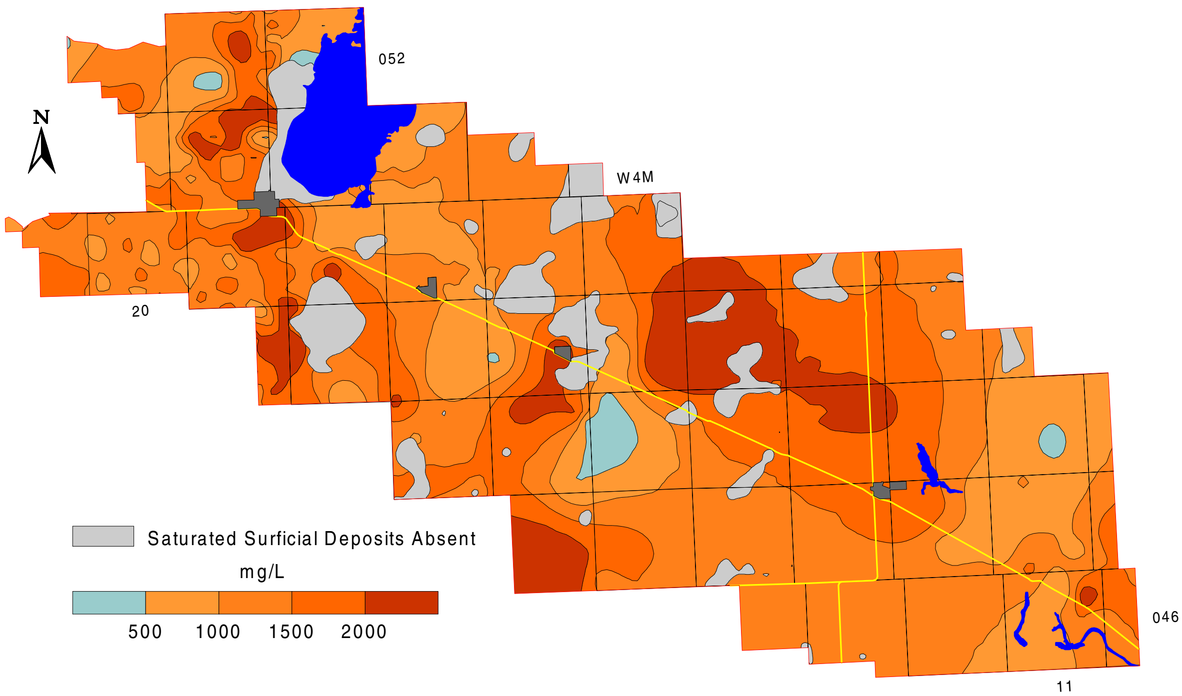
Water Wells Completed in Surficial Deposits



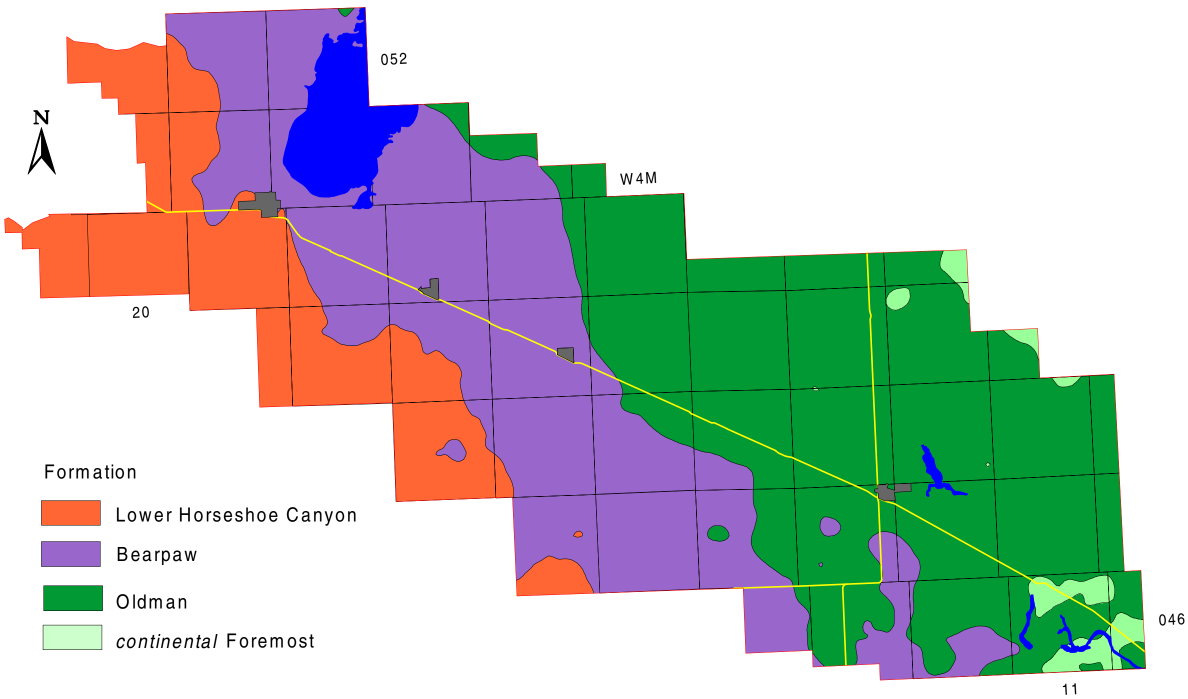
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)



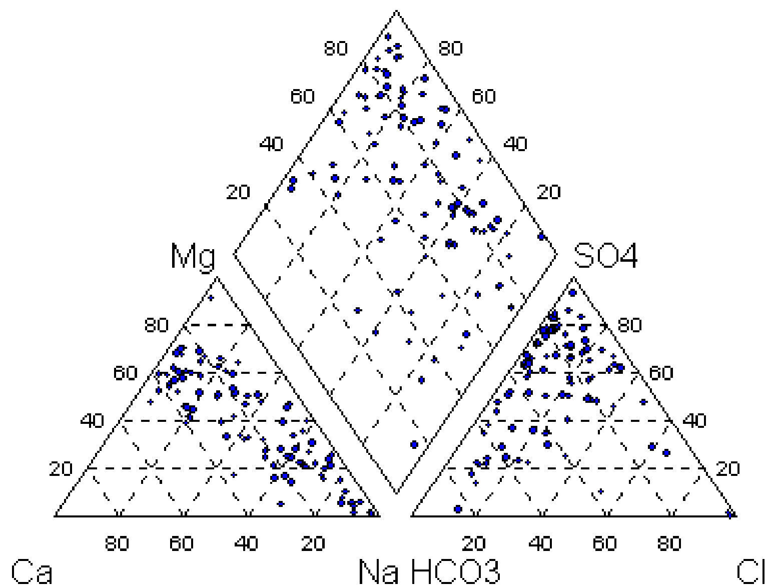
Total Dissolved Solids in Groundwater from Surficial Deposits



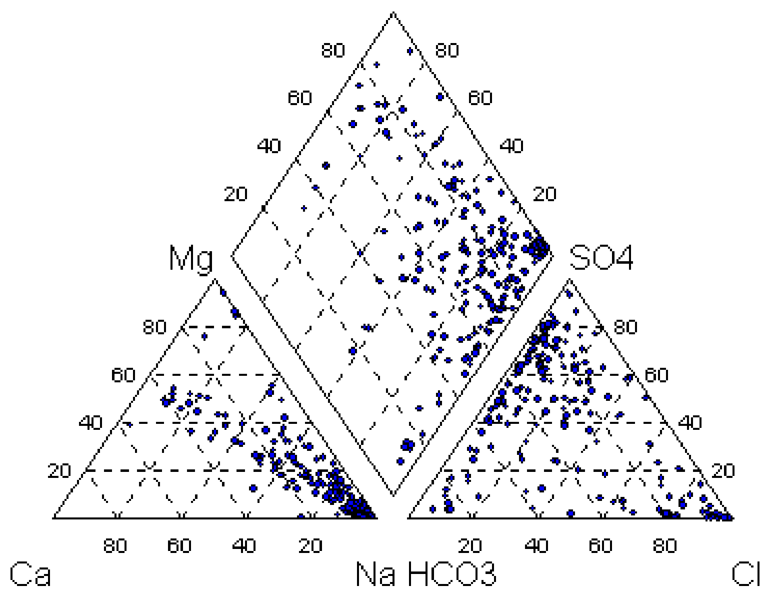
Bedrock Geology



Piper Diagrams

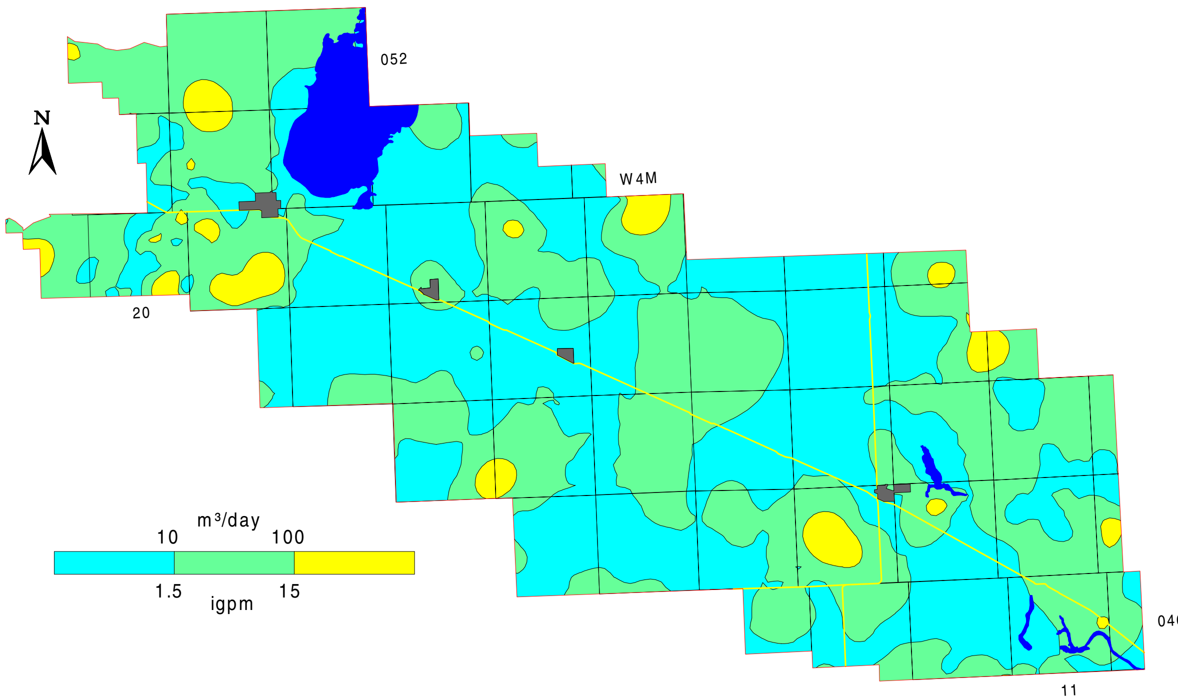


Surficial Deposits

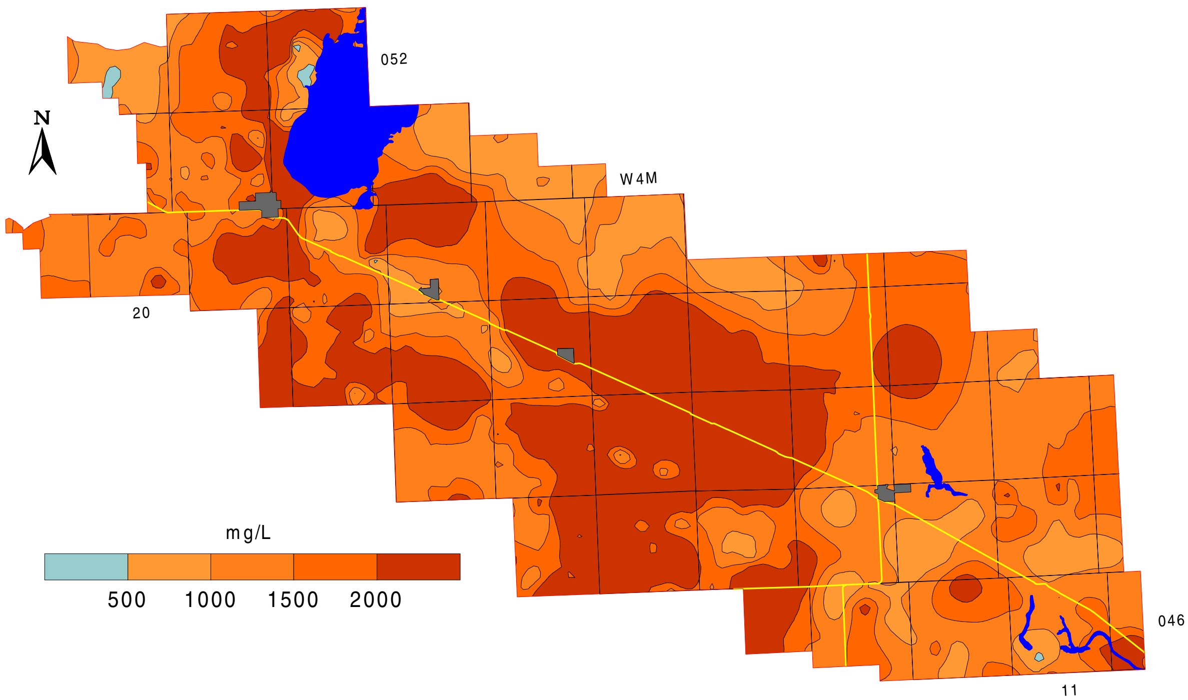


Bedrock Aquifers

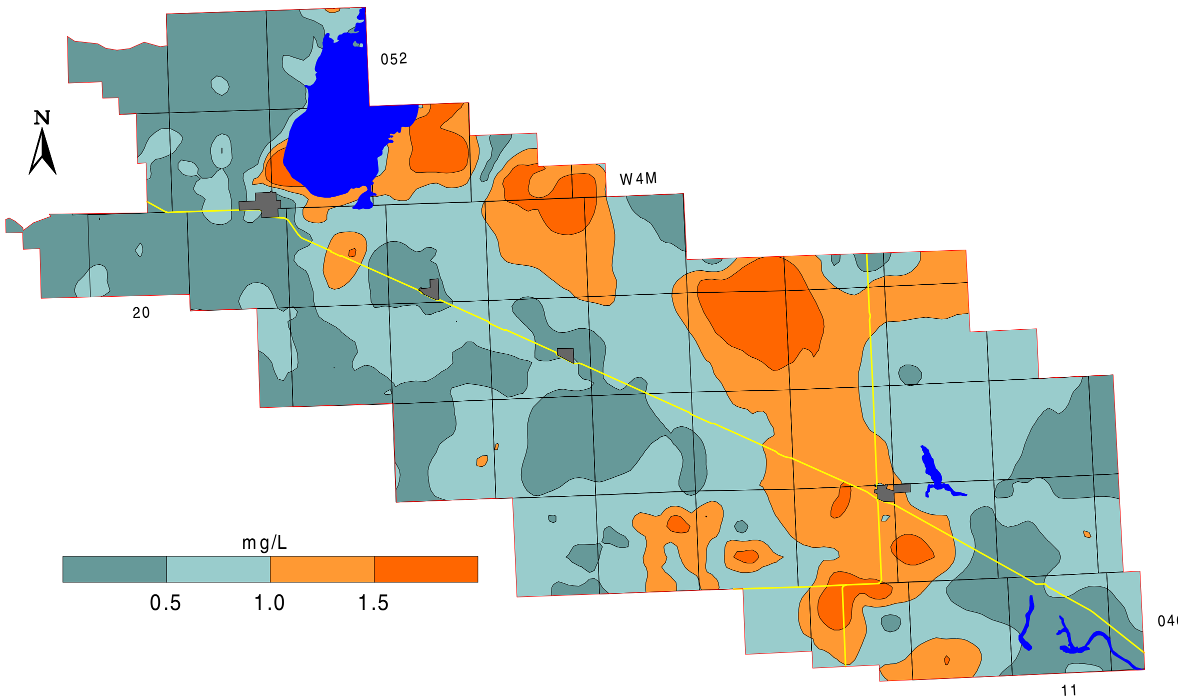
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



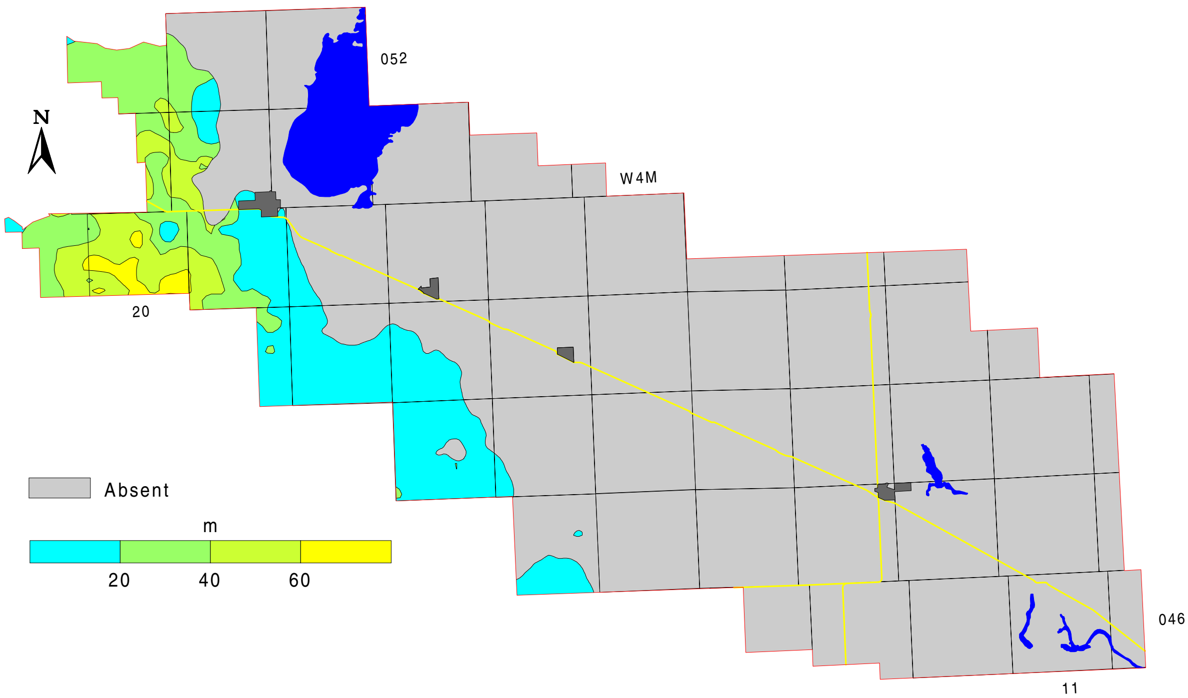
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



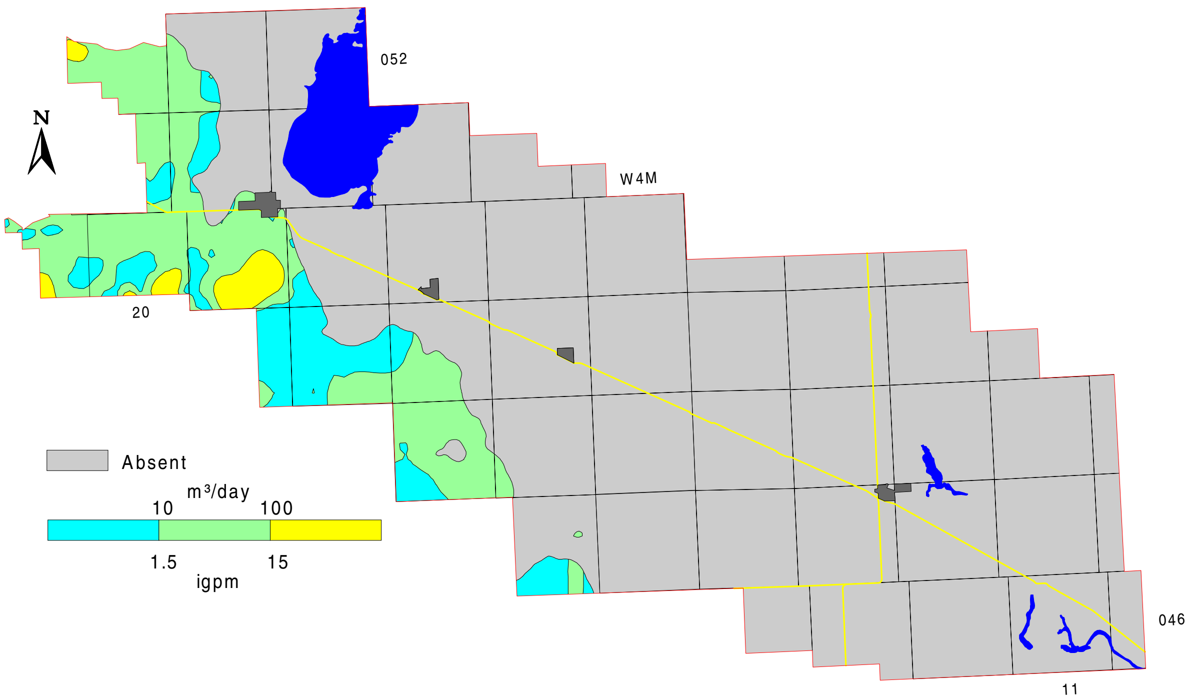
Fluoride in Groundwater from Upper Bedrock Aquifer(s)



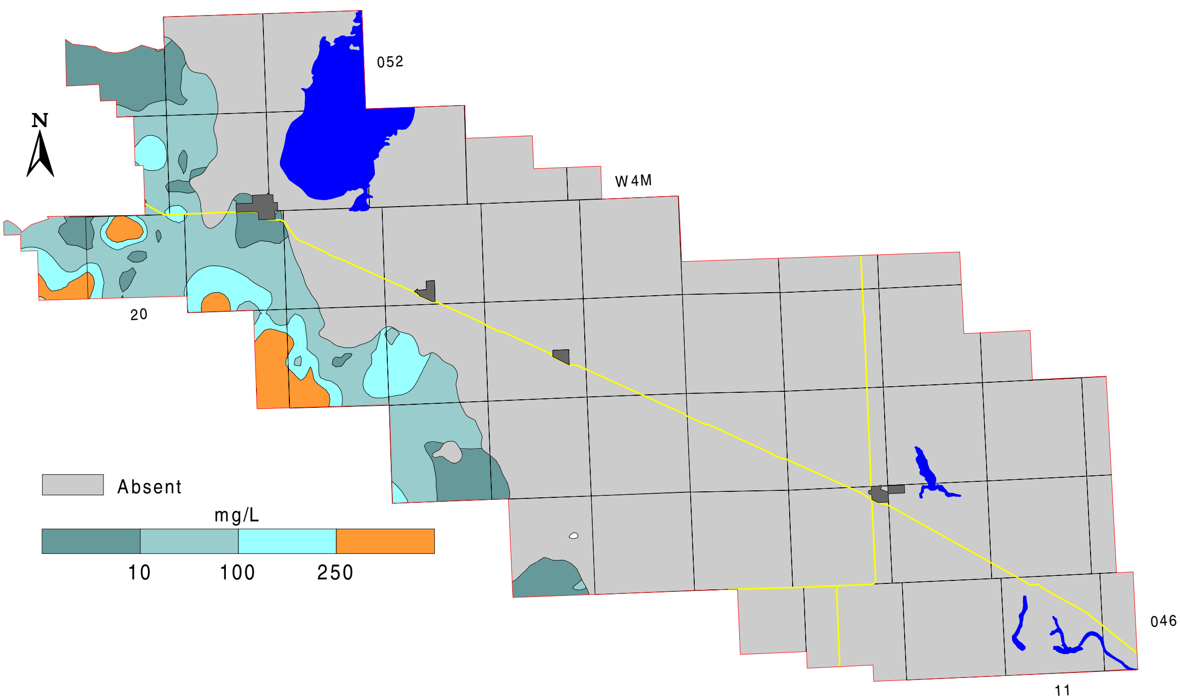
Depth to Top of Lower Horseshoe Canyon Formation



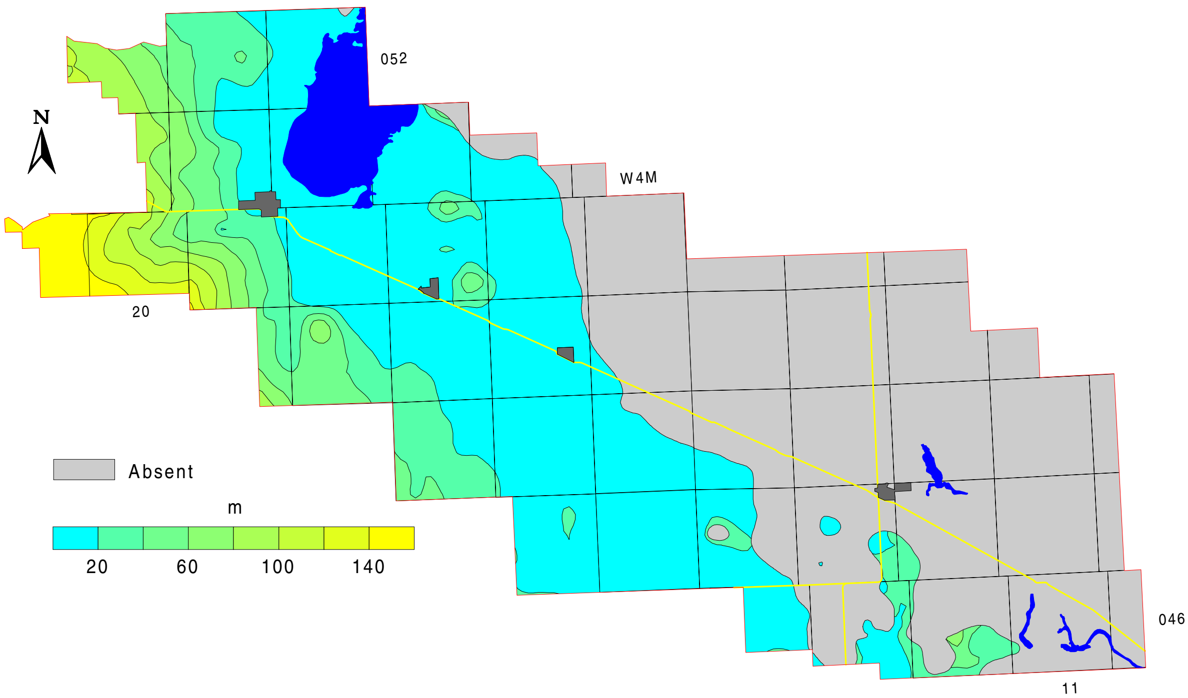
Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer



Chloride in Groundwater from Lower Horseshoe Canyon Aquifer

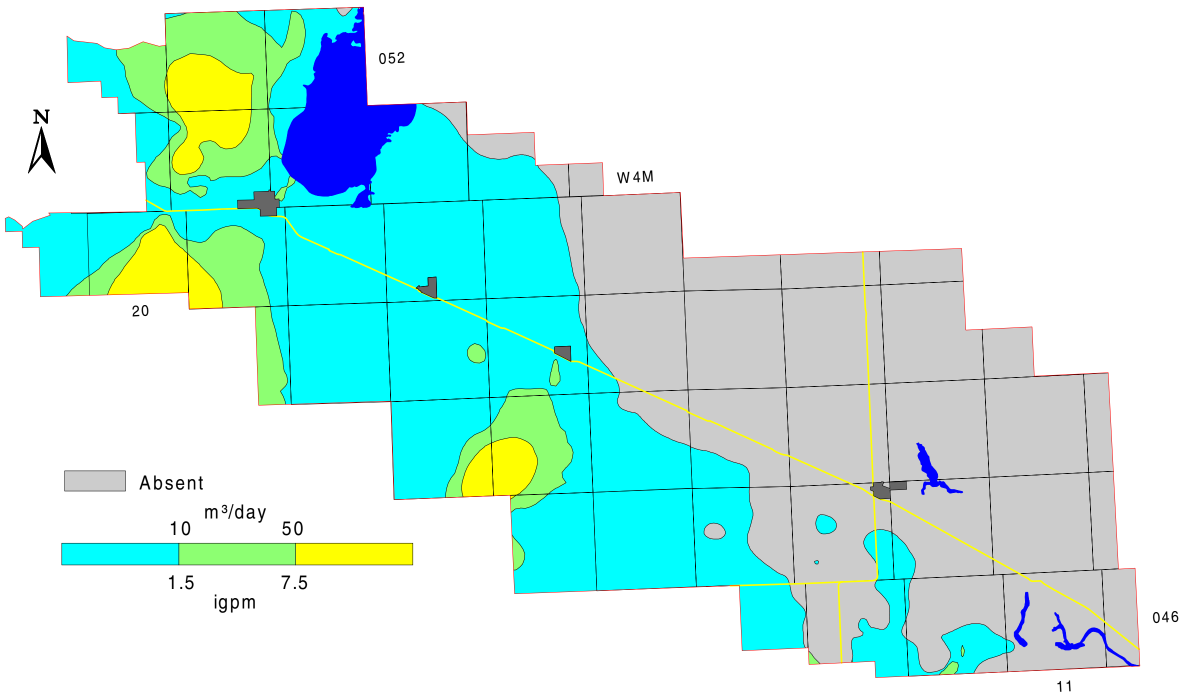


Depth to Top of Bearpaw Formation

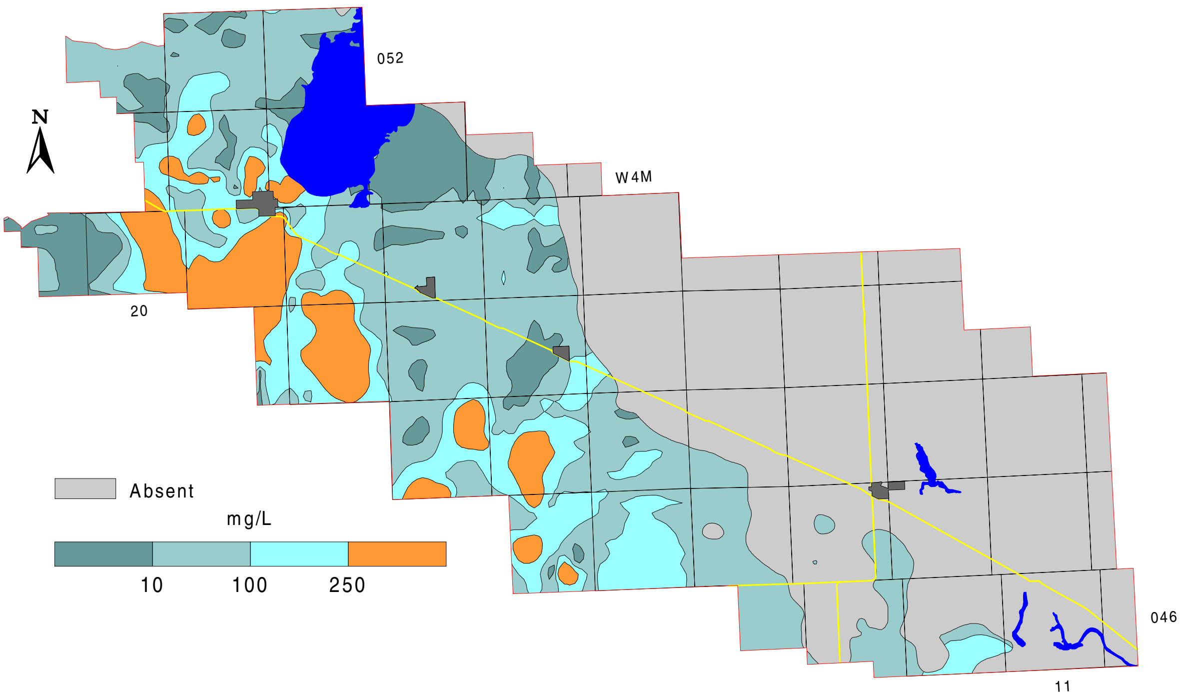


hydrogeological consultants ltd.

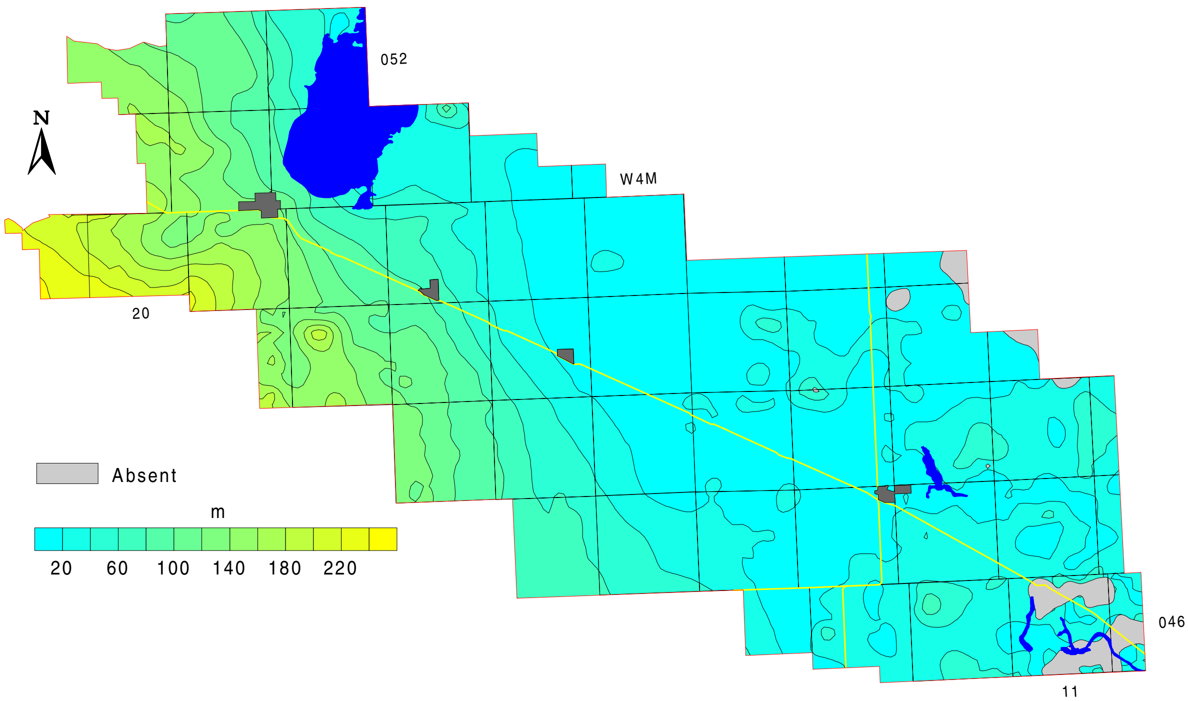
Apparent Yield for Water Wells Completed through Bearpaw Aquifer



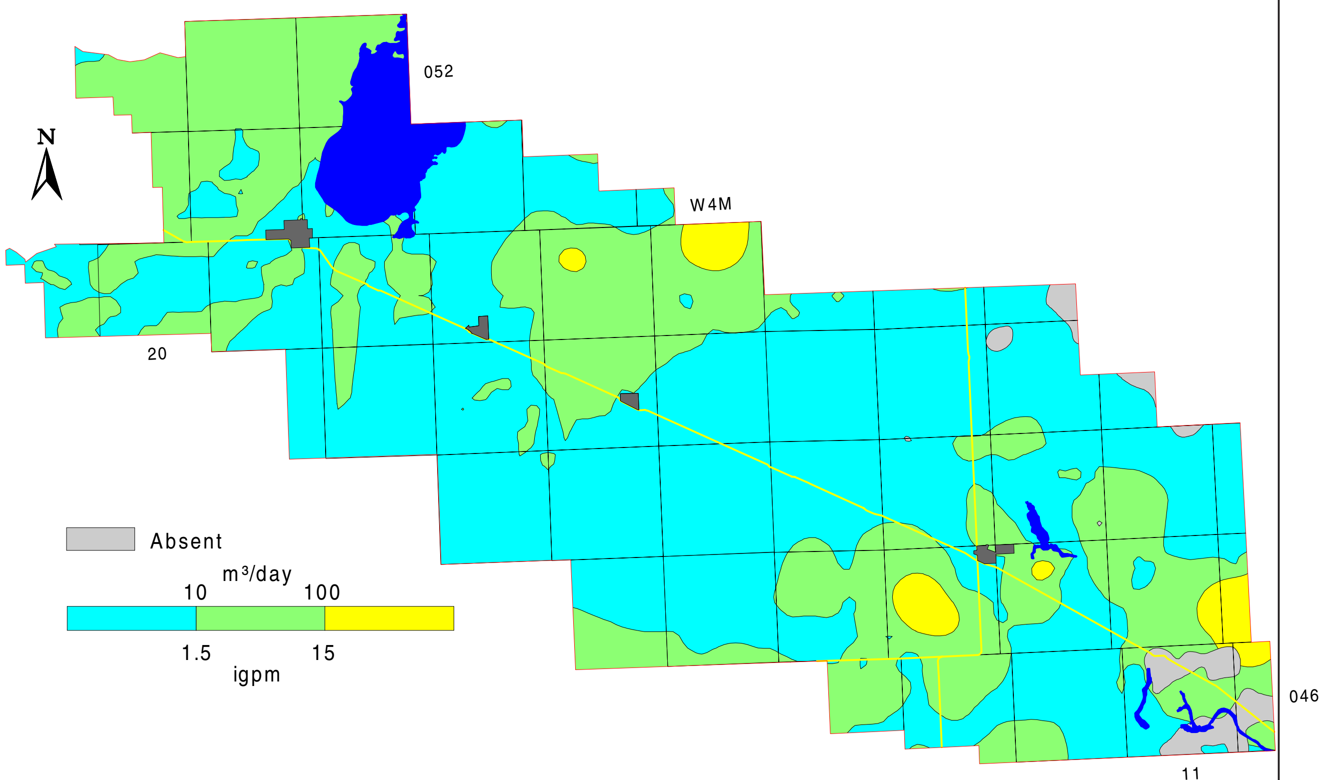
Chloride in Groundwater from Bearpaw Aquifer



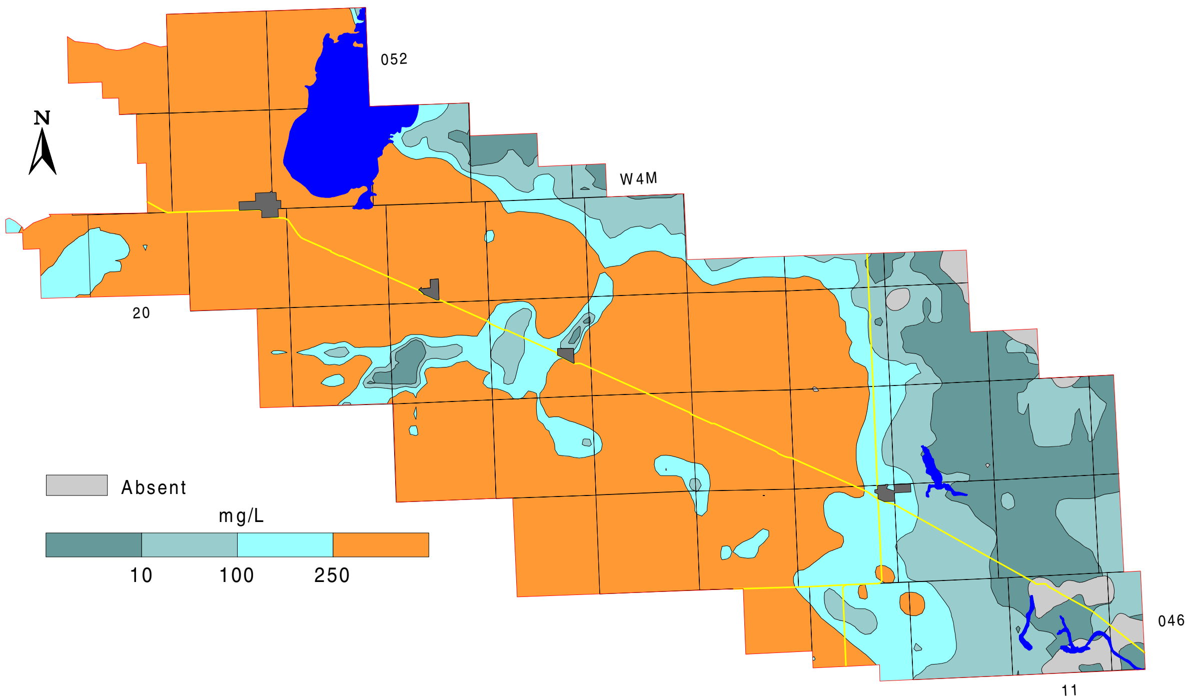
Depth to Top of Oldman Formation



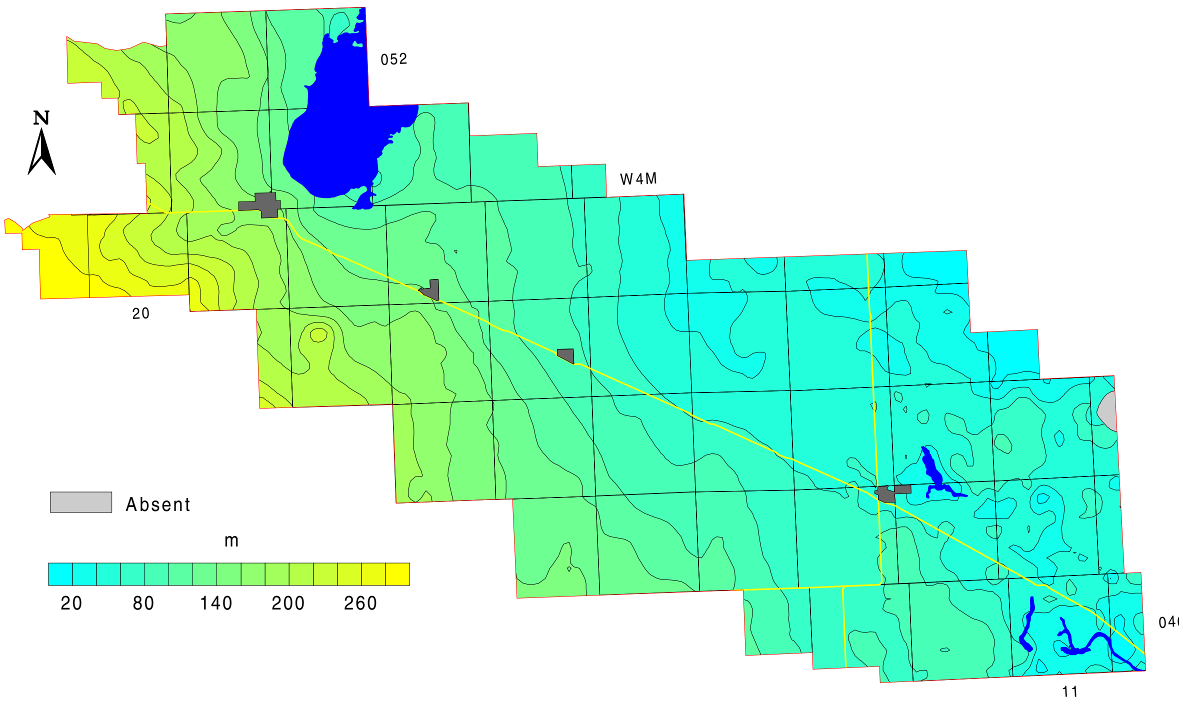
Apparent Yield for Water Wells Completed through Oldman Aquifer



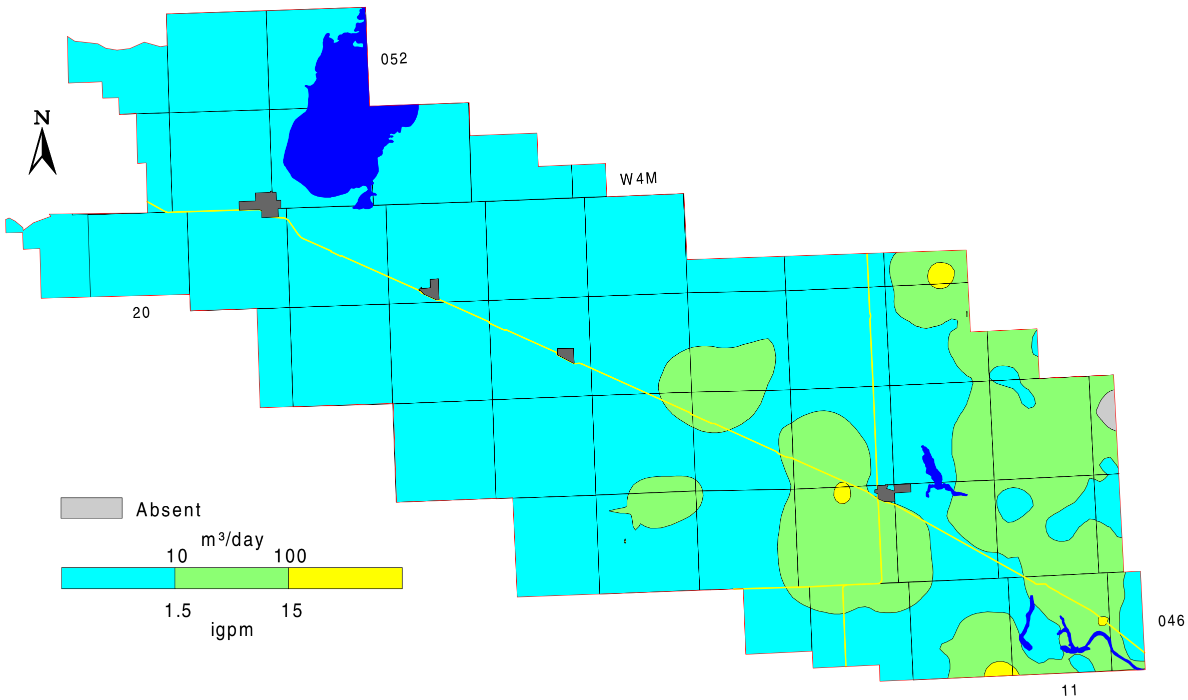
Chloride in Groundwater from Oldman Aquifer



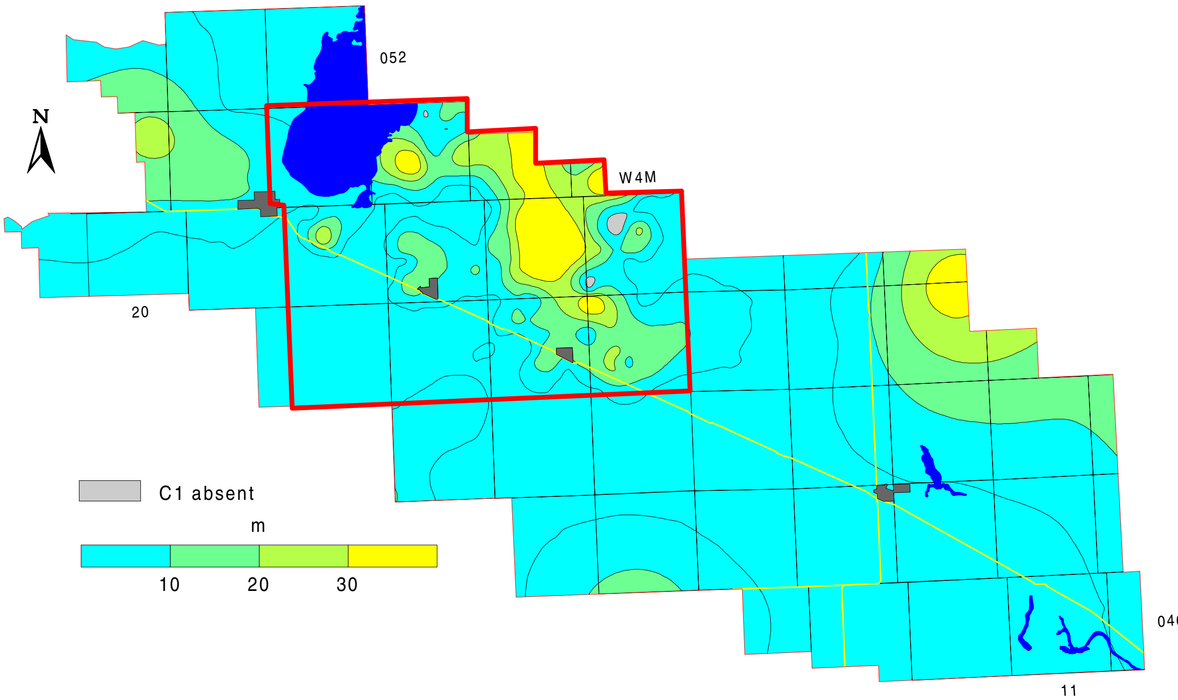
Depth to Top of continental Foremost Formation



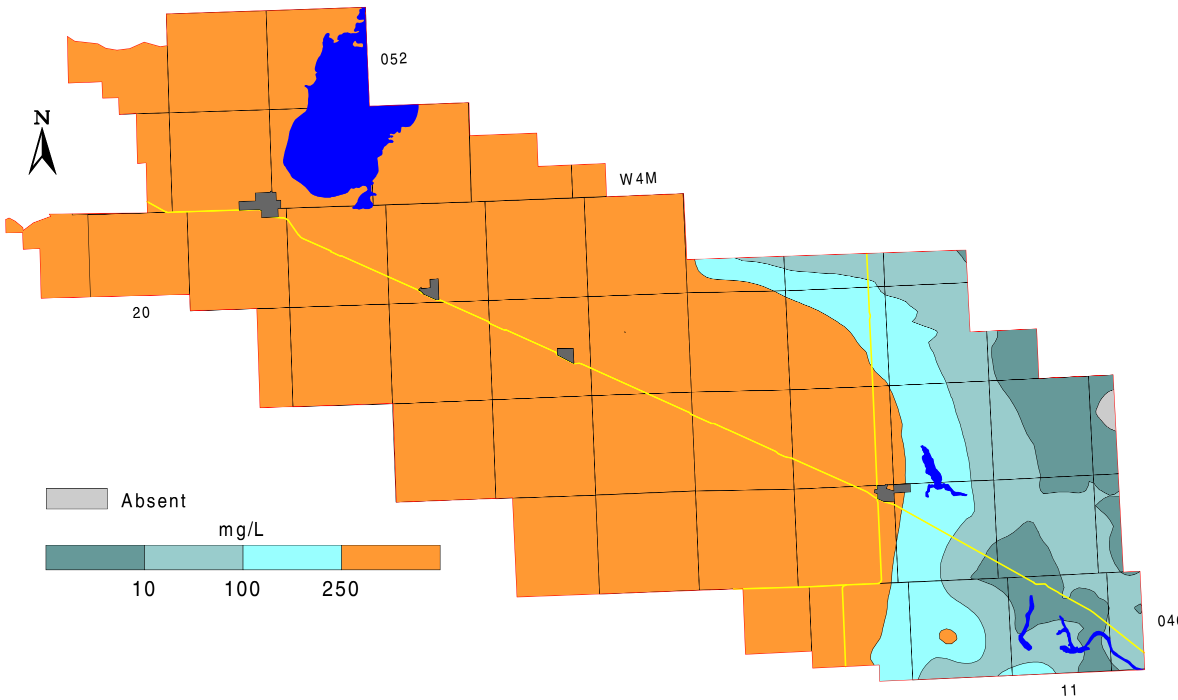
Apparent Yield for Water Wells Completed through continental Foremost Aquifer



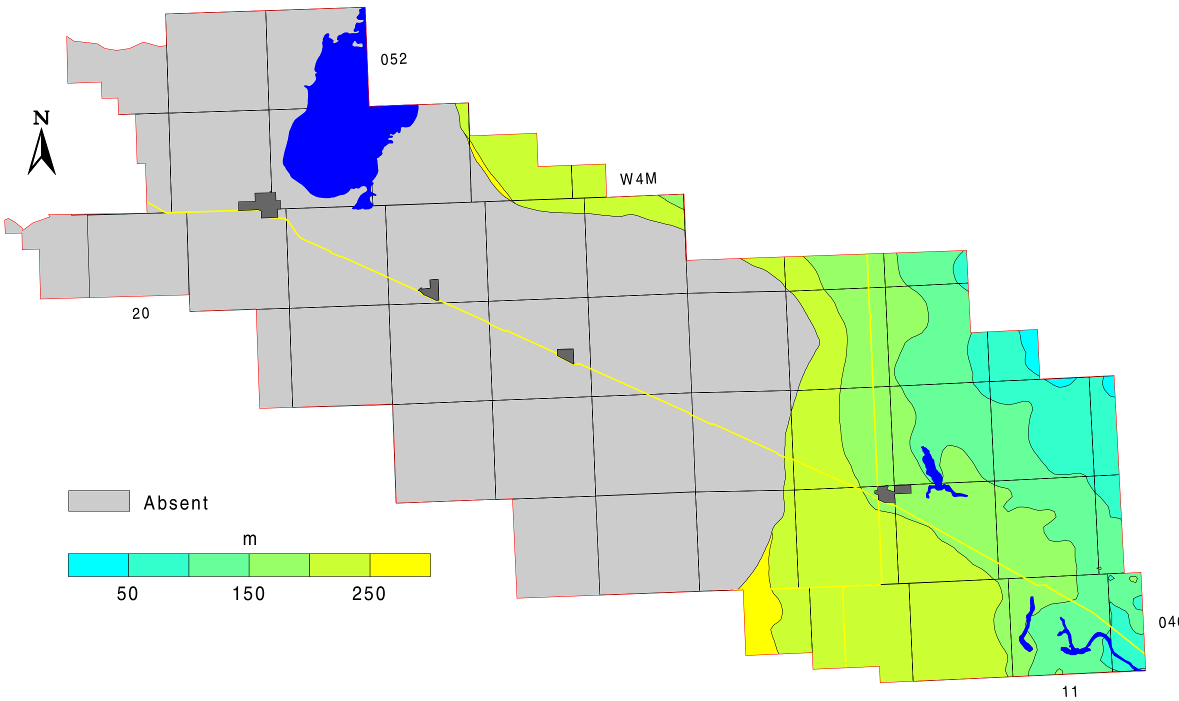
Thickness of C1



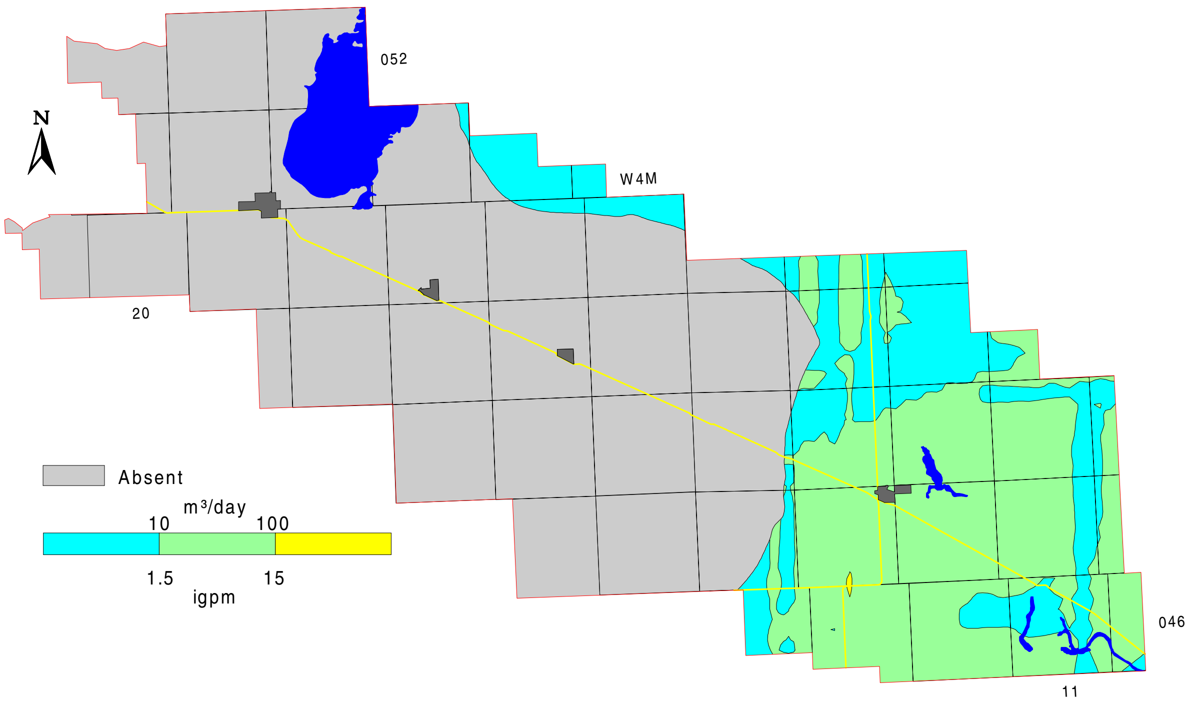
Chloride in Groundwater from continental Foremost Aquifer



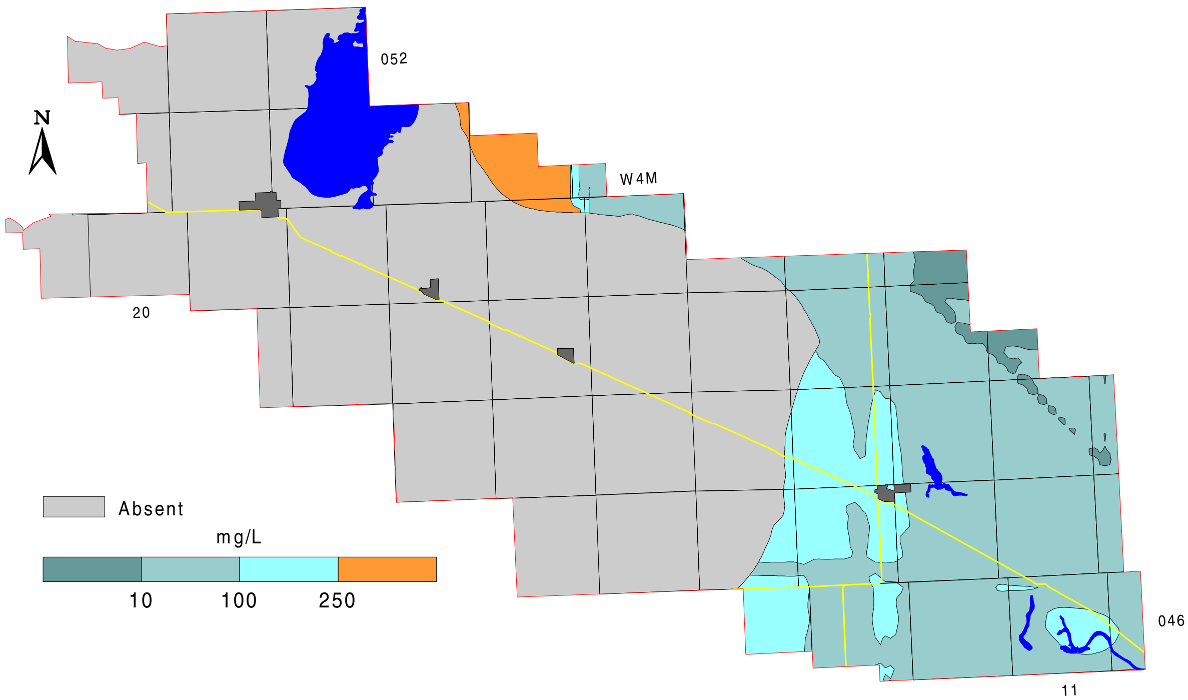
Depth to Top of marine Foremost Formation



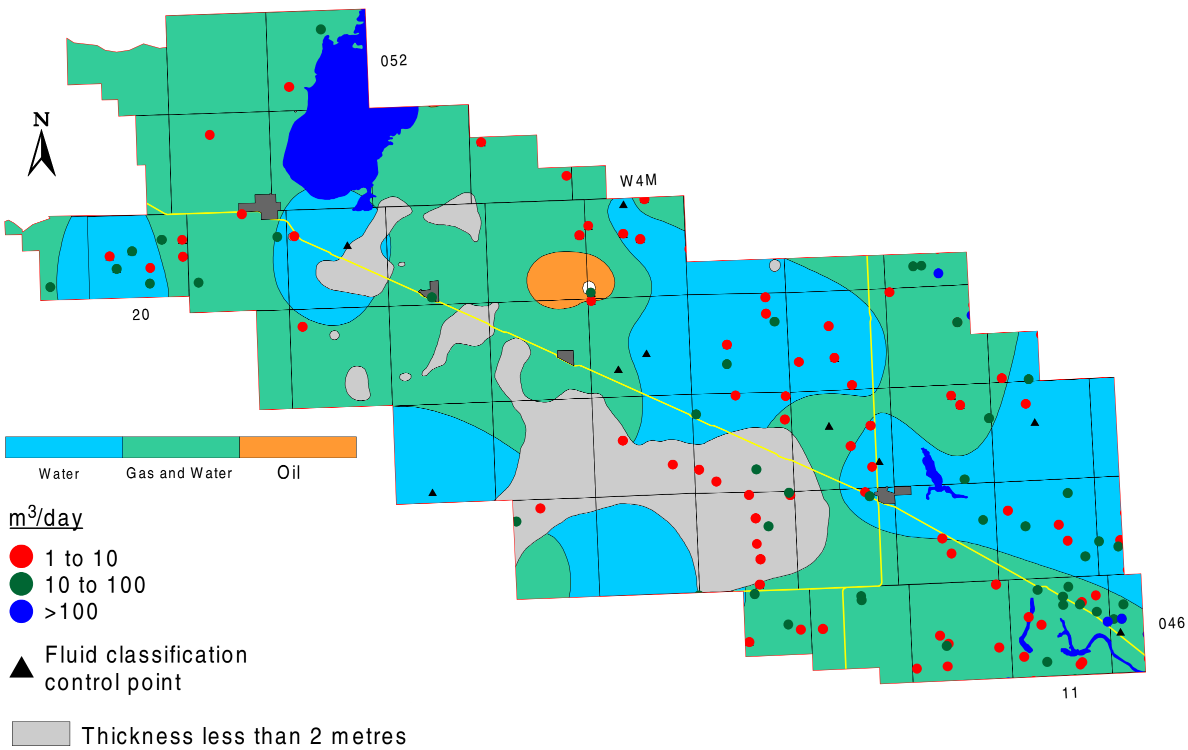
Apparent Yield for Water Wells Completed through marine Foremost Aquifer



Chloride in Groundwater from marine Foremost Aquifer

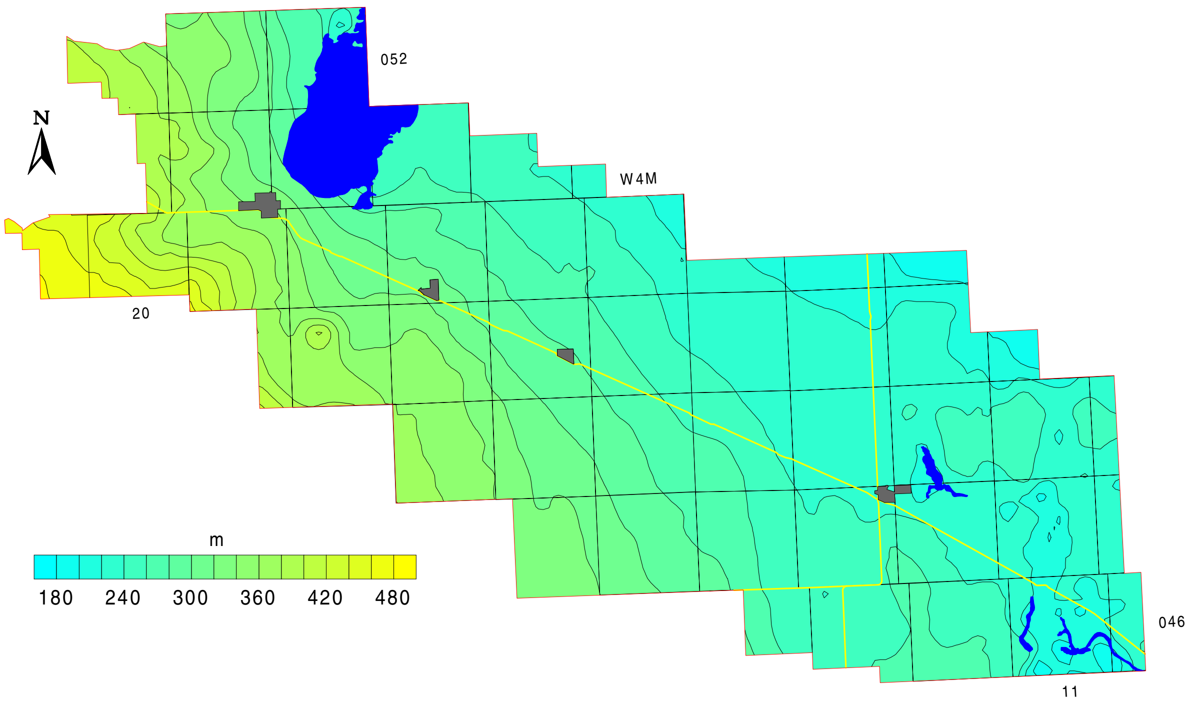


Type of Fluid Encountered in Basal Belly River Sandstone

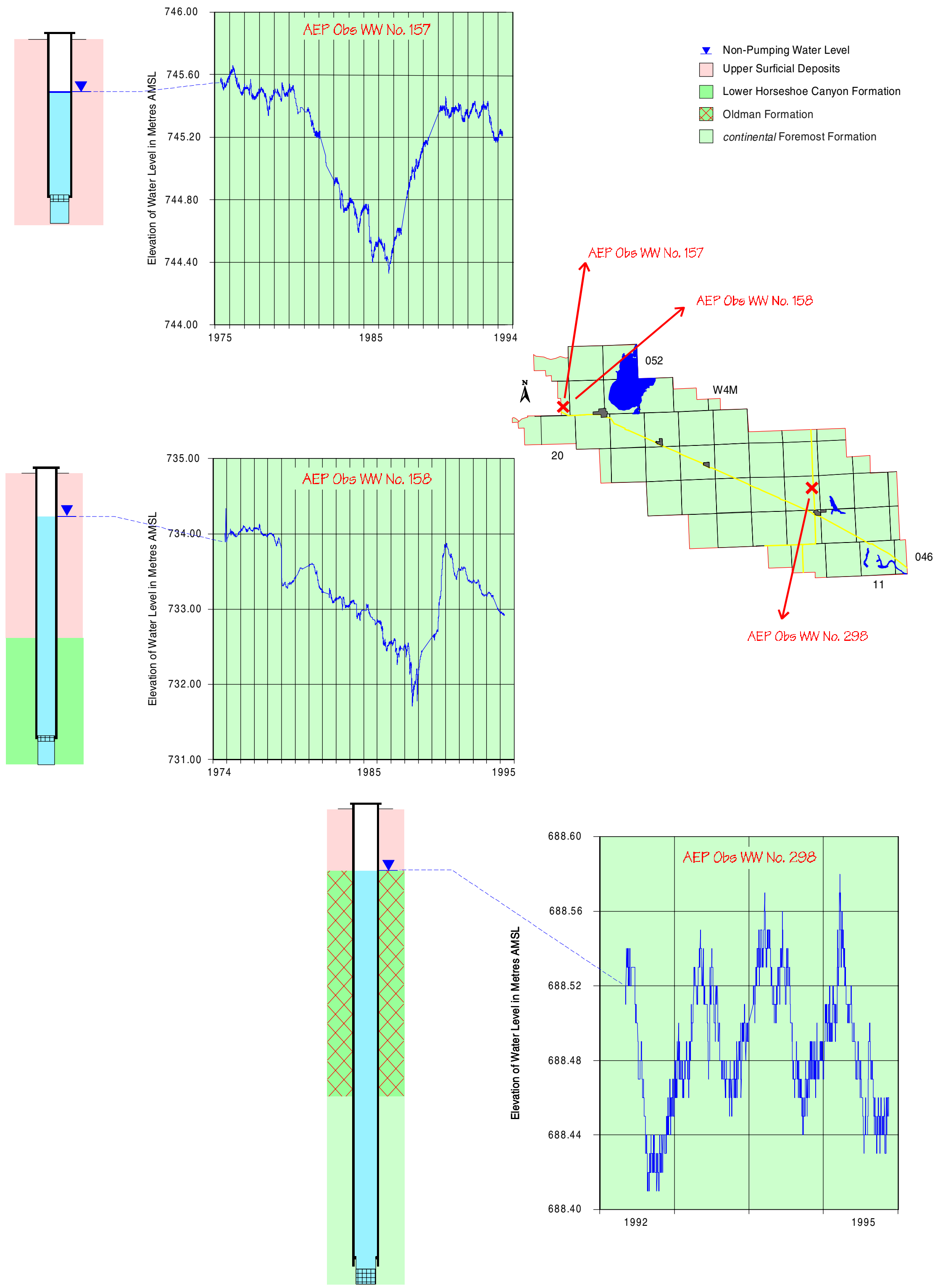


hydrogeological consultants ltd.

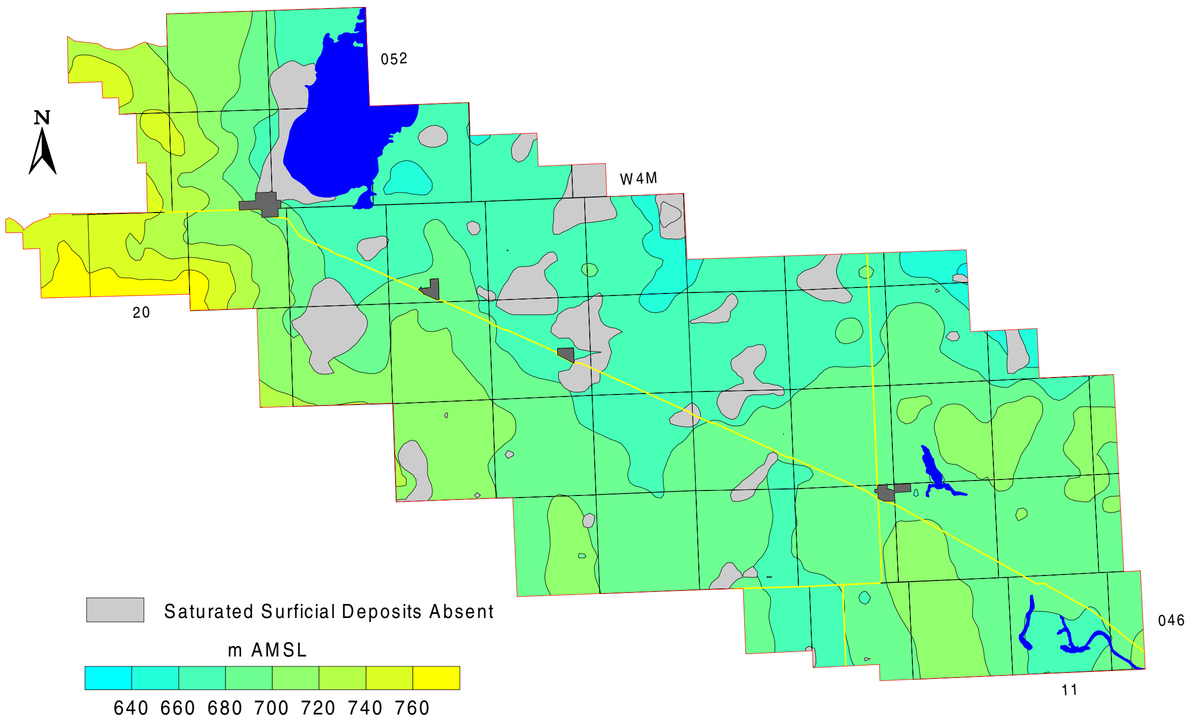
Depth to Top of Lea Park Aquitard



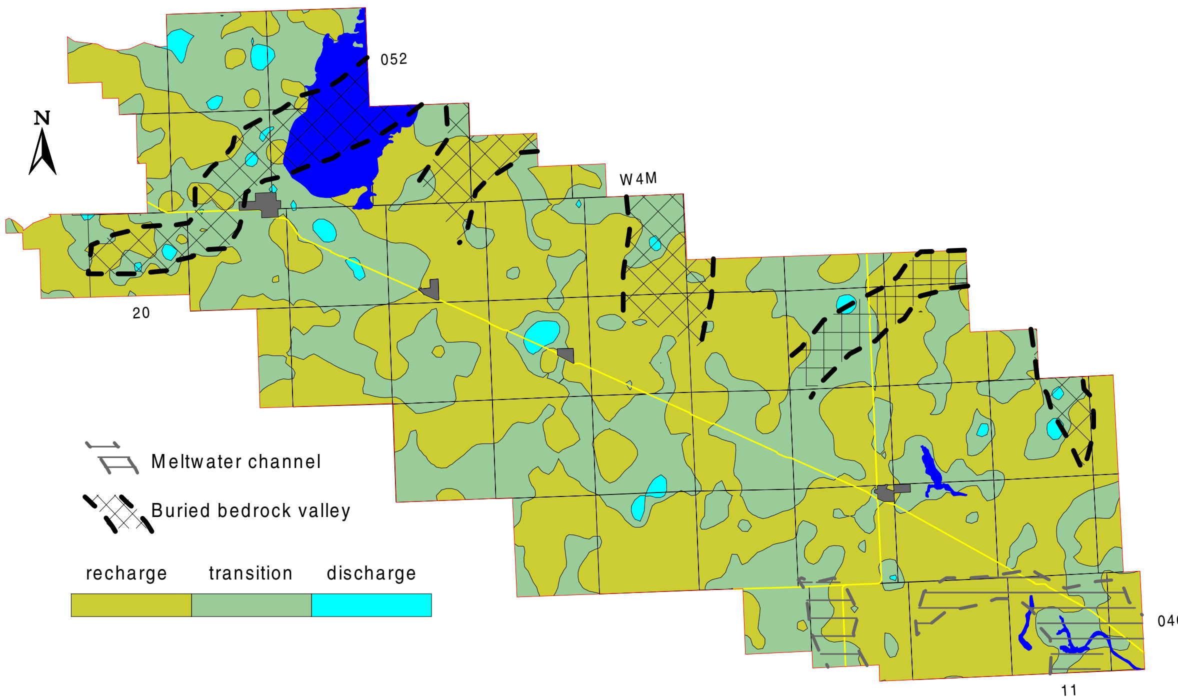
Hydrographs - AEP Observation Water Wells



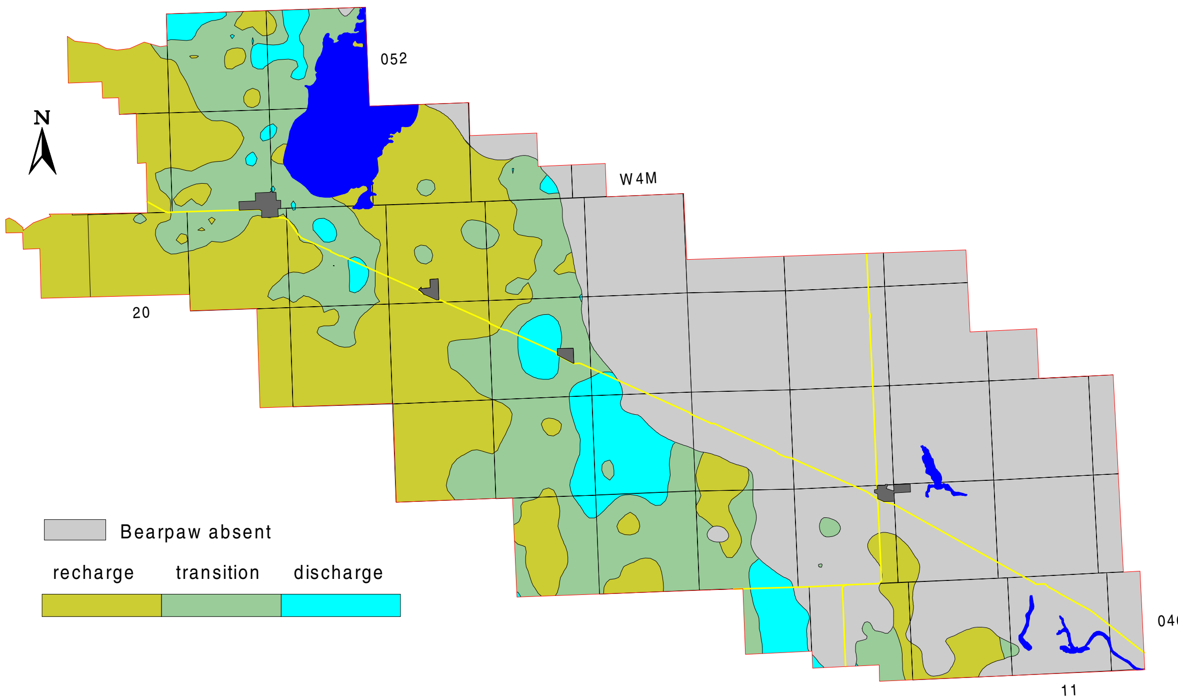
Non-Pumping Water-Level Surface in Surficial Deposits



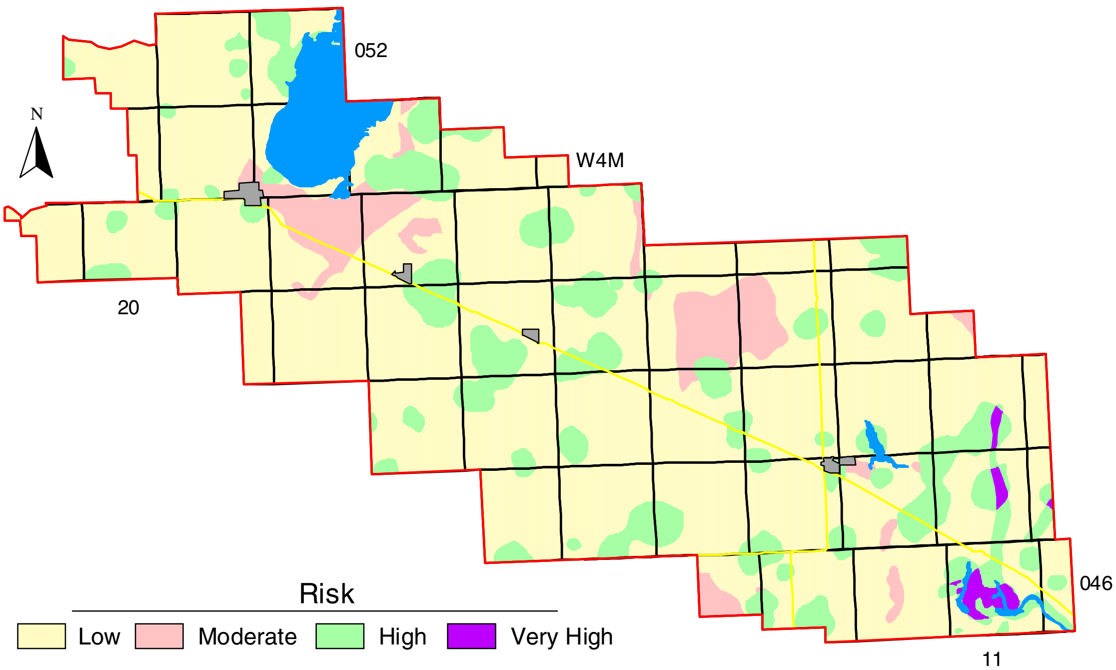
Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)



Recharge/Discharge Areas between Surficial Deposits and Bearpaw Aquifer



Risk of Groundwater Contamination



COUNTY OF BEAVER NO. 9

Appendix B

MAPS AND FIGURES ON CD-ROM

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

1) General

Index Map
Surface Casing Types used in Drilled Water Wells
Location of Water Wells
Depth of Existing Water Wells
Depth to Base of Groundwater Protection
Bedrock Topography
Bedrock Geology
Cross-Section A - A'
Cross-Section B - B'
Geologic Column
Generalized Cross-Section (for terminology only)
Risk of Groundwater Contamination
Relative Permeability
Hydrographs - AEP Observation Water Wells
Water Wells Recommended for Field Verification

2) Surficial Aquifers

a) Surficial Deposits

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

b) First Sand and Gravel

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

3) Bedrock Aquifers

a) General

Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)
Sulfate in Groundwater from Upper Bedrock Aquifer(s)
Chloride in Groundwater from Upper Bedrock Aquifer(s)
Fluoride in Groundwater from Upper Bedrock Aquifer(s)
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) Lower Horseshoe Canyon Aquifer

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

c) Bearpaw Aquifer

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

d) Oldman Aquifer

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

e) *continental* Foremost Aquifer

Depth to Top of *continental* Foremost Formation
Structure-Contour Map - Top of *continental* Foremost Formation
Non-Pumping Water-Level Surface - *continental* Foremost Aquifer
Thickness of C1
Apparent Yield for Water Wells Completed through *continental* Foremost Aquifer
Total Dissolved Solids in Groundwater from *continental* Foremost Aquifer
Sulfate in Groundwater from *continental* Foremost Aquifer
Chloride in Groundwater from *continental* Foremost Aquifer
Piper Diagram - *continental* Foremost Aquifer
Recharge/Discharge Areas between Surficial Deposits and *continental* Foremost Aquifer

f) *marine* Foremost Aquifer

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

g) Basal Belly River Sandstone Aquifer

Type of Fluid Encountered in Basal Belly River Sandstone

h) Lea Park Aquitard

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

COUNTY OF BEAVER NO. 9

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

Published by the Queen's Printer for Alberta

Distributed by:

Publication Services
11510 Kingsway
Edmonton. T5G 2Y5
427-4952
FAX 452-0668

and

Publication Services
Main Floor, McDougall Centre
455 - 6th Street S.W.
Calgary. T2P 4E8
297-6251

Alberta Regulation 123/93

Environmental Protection and Enhancement Act

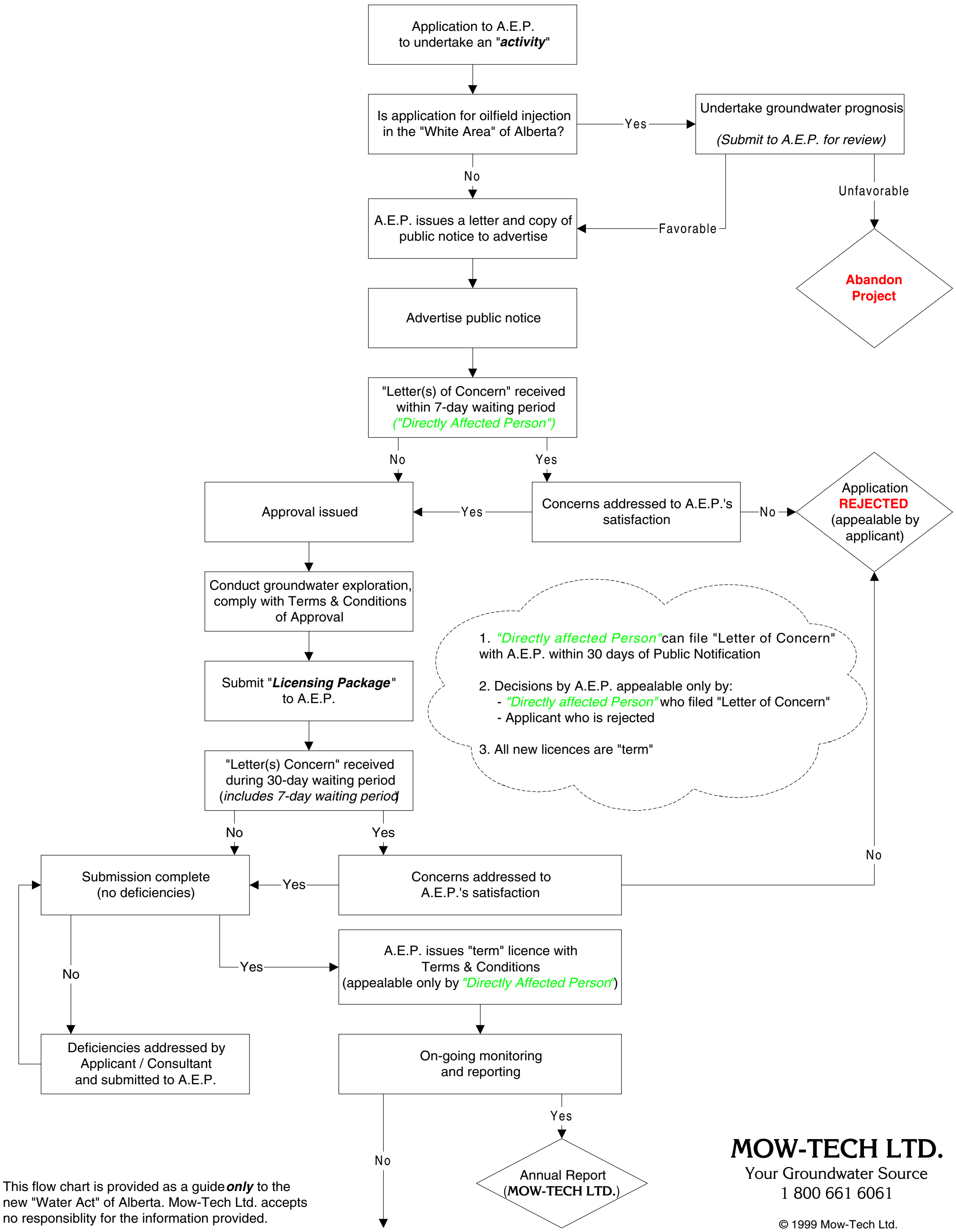
WATER WELL REGULATION

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.

Table of Contents

Water Act – Flow Chart



This flow chart is provided as a guide ***only*** to the new "Water Act" of Alberta. Mow-Tech Ltd. accepts no responsiblity for the information provided.

MOW-TECH LTD.
Your Groundwater Source
1 800 661 6061

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)

ALBERTA ENVIRONMENTAL PROTECTION

WATER WELL INSPECTORS

Jennifer McPherson (Edmonton: 780-427-6429)
Colin Samis (Lac La Biche: 780-623-5235)

GEOPHYSICAL INSPECTION SERVICE

Edmonton: 780-427-3932

COMPLAINT INVESTIGATIONS

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

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

Carl Mendosa (Edmonton: 780-492-2664)

UNIVERSITY OF CALGARY – Department of Geology and Geophysics - Hydrogeology

Larry Bentley (Calgary: 403-220-4512)

FARMERS ADVOCATE

Paul Vasseur (Edmonton: 780-427-2433)

PRAIRIE FARM REHABILITATION ADMINISTRATION

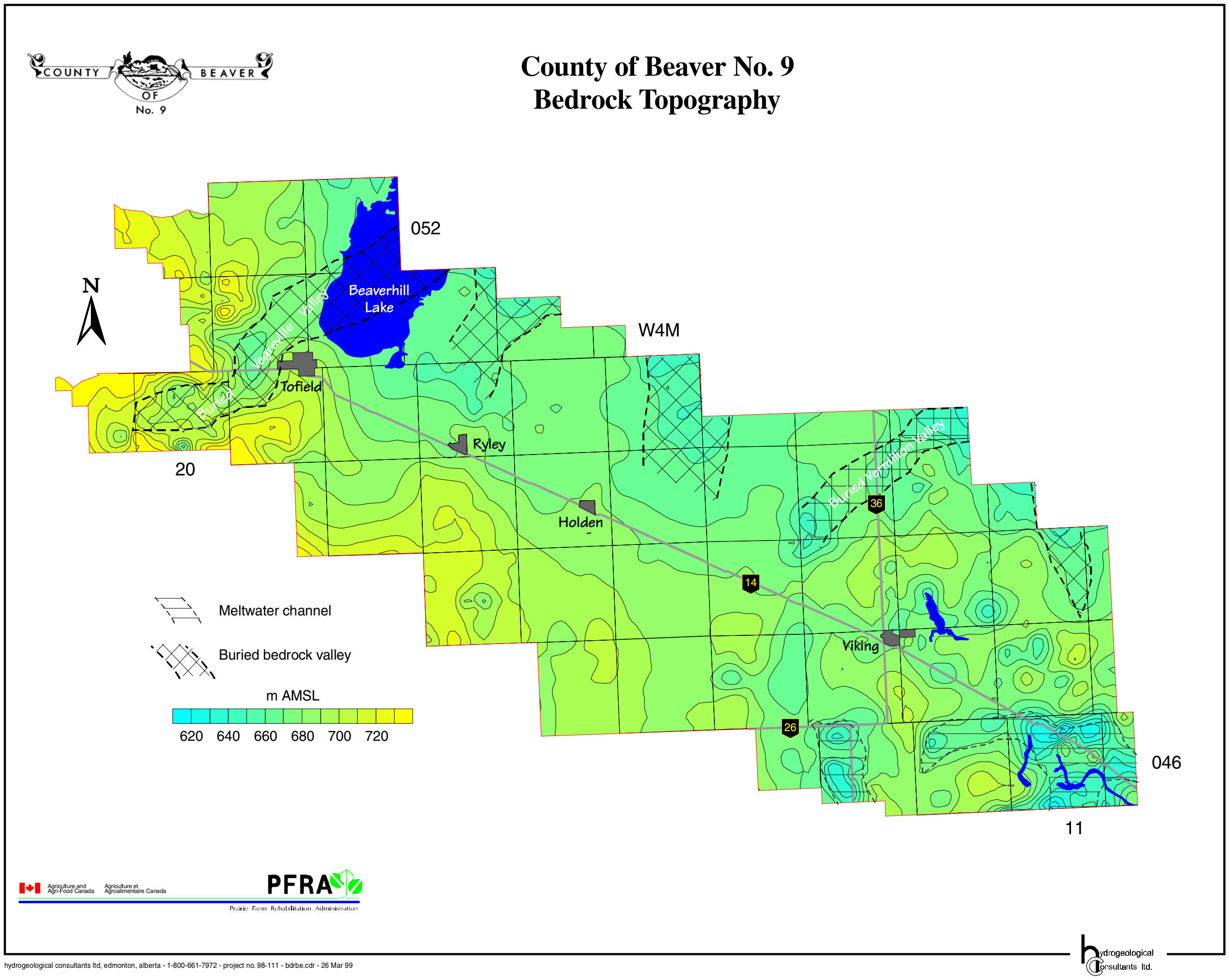
Keith Schick (Vegreville: 780 632-2919)

LOCAL HEALTH DEPARTMENTS

COUNTY OF BEAVER NO. 9

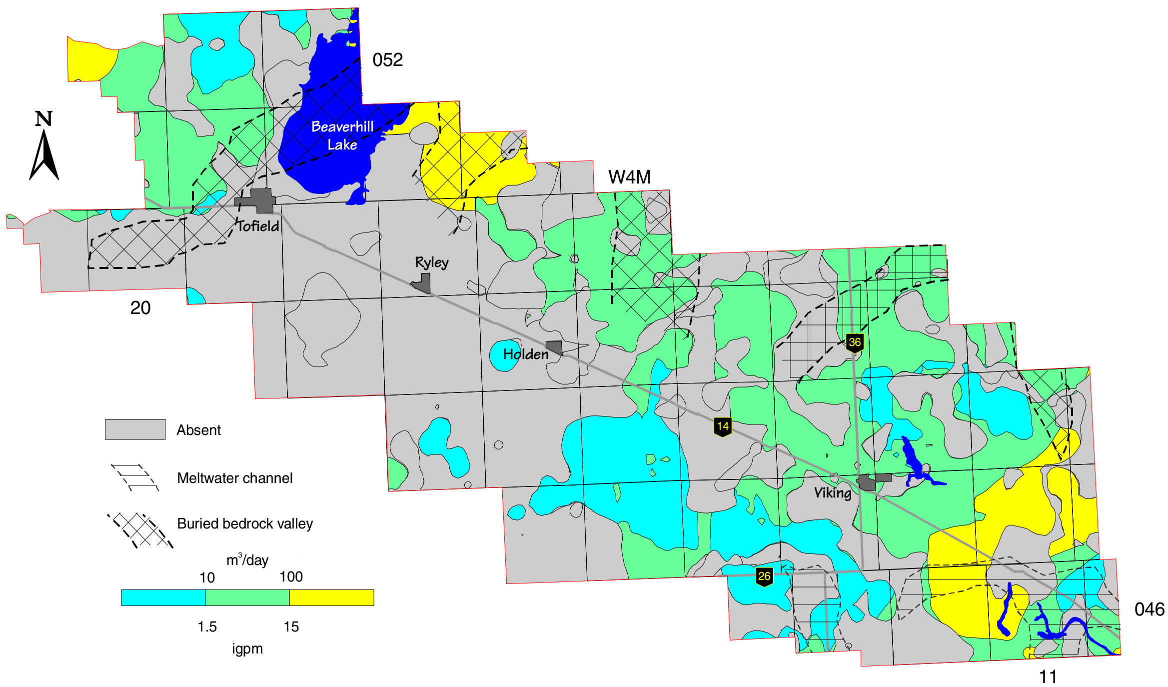
Appendix D

MAPS AND FIGURES INCLUDED AS LARGE PLOTS


County of Beaver No. 9
Bedrock Topography
COUNTY OF BEAVER No. 9
N
052
W4M
20
046
11
Beaverhill Lake
Tofield
Ryley
Holden
Viking
Buried Vegreville Valley
Buried Vermilion Valley
14
36
26
Meltwater channel
Buried bedrock valley
m AMSL
620 640 660 680 700 720
PFRA
Prairie Farm Rehabilitation Administration
hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 98-111 - bdrbe.cdr - 26 Mar 99
hydrogeological consultants ltd.

COUNTY OF BEAVER No. 9

County of Beaver No. 9
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)



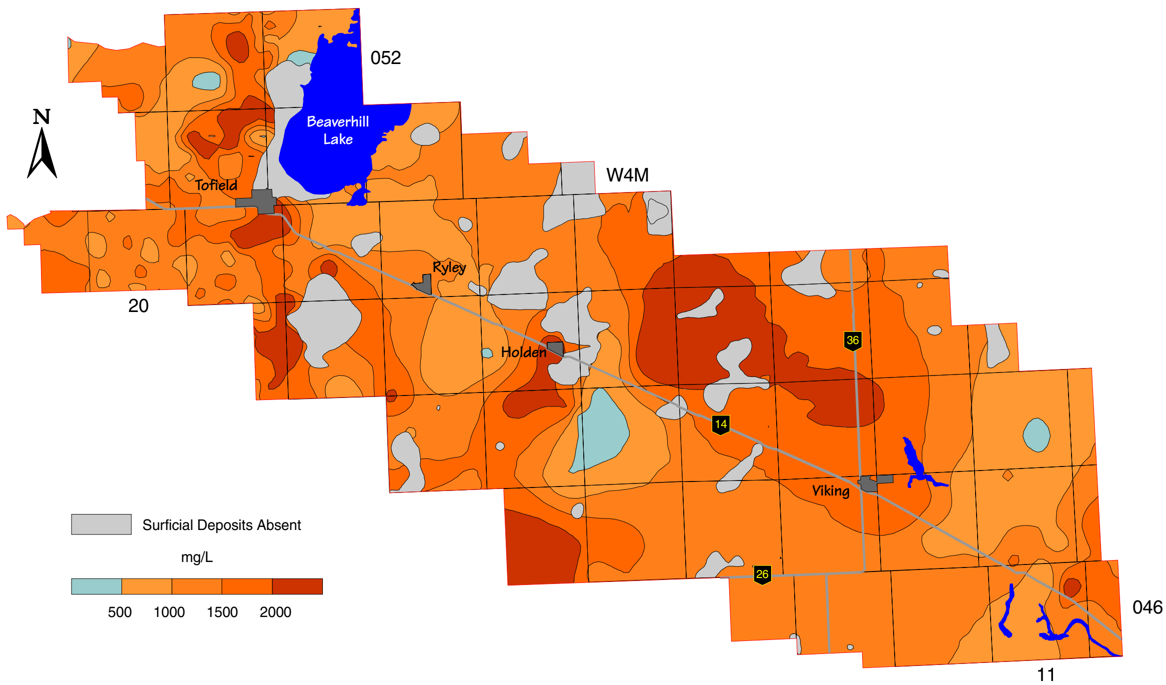
Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada

PFRA
Prairie Farm Rehabilitation Administration

hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 98-111 - sgQbe.cdr - 24 Mar 99

hydrogeological consultants ltd.

County of Beaver No. 9
Total Dissolved Solids in Groundwater from Surficial Deposits



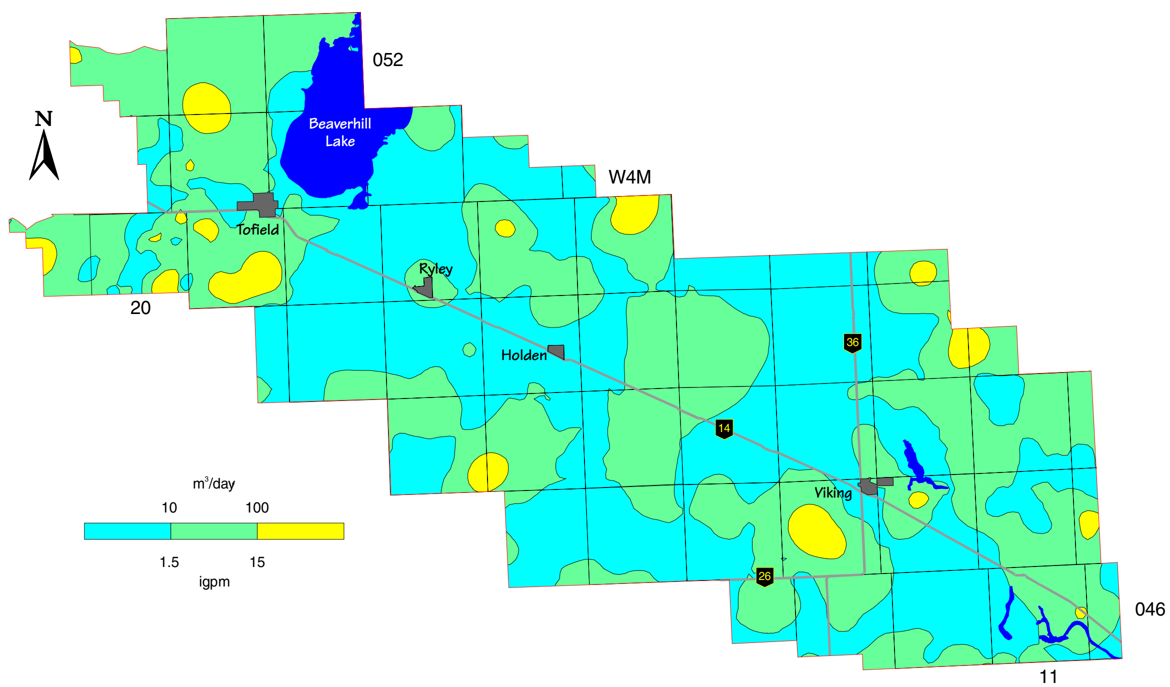
Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada

PFRA — Prairie Farm Rehabilitation Administration

hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 98-111 - srftds2be.cdr - 24 Mar99

COUNTY OF BEAVER No. 9

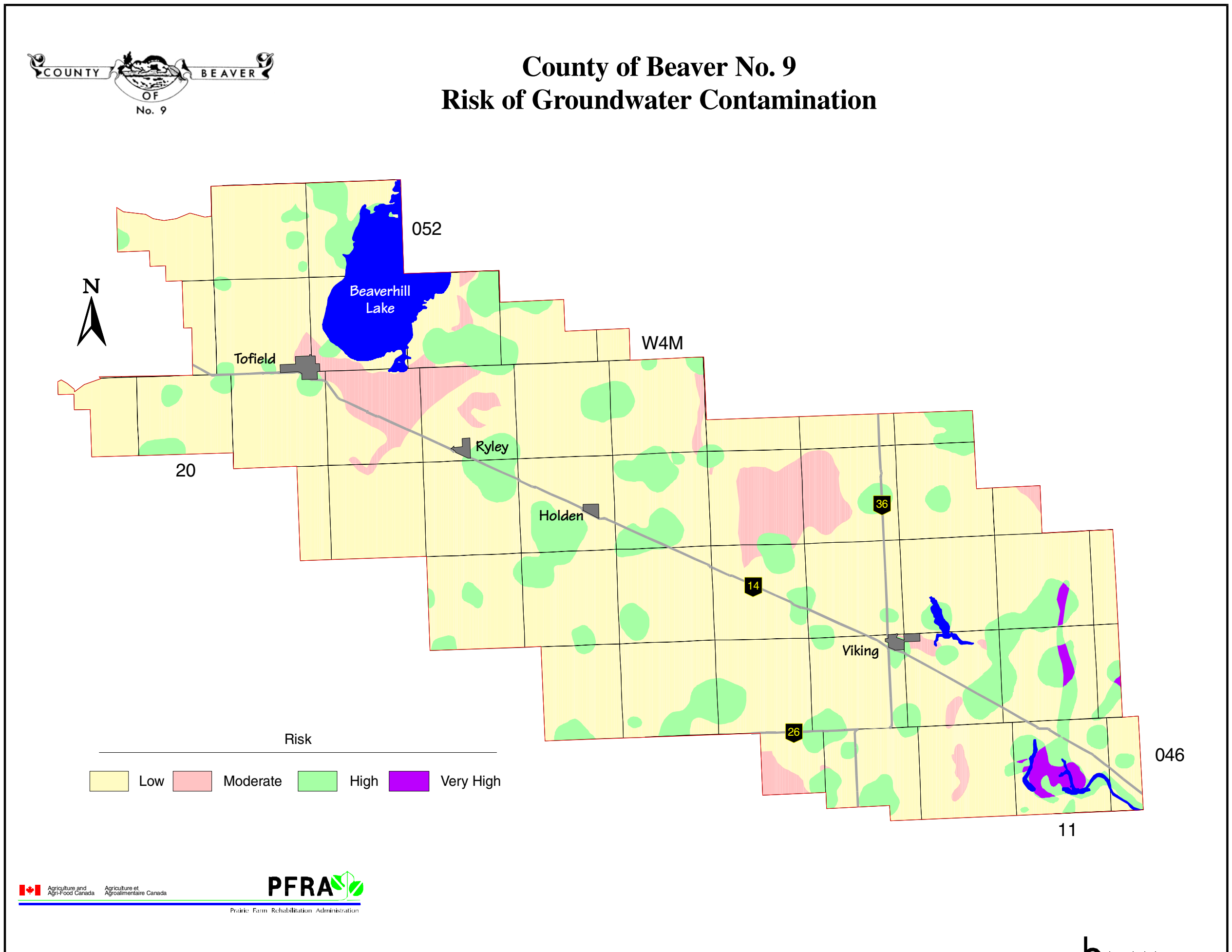
County of Beaver No. 9
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



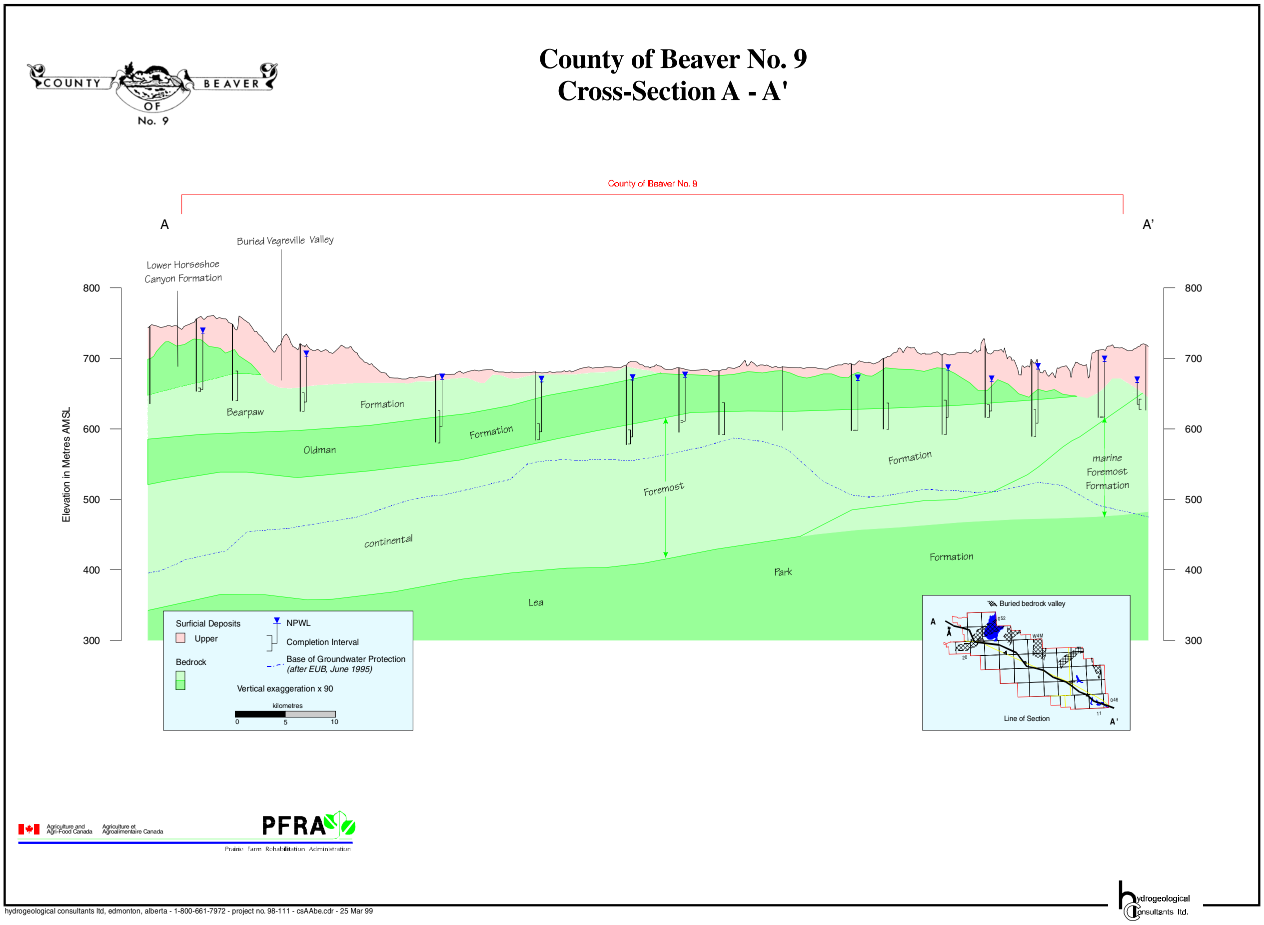
Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada
PFRA
Prairie Farm Rehabilitation Administration

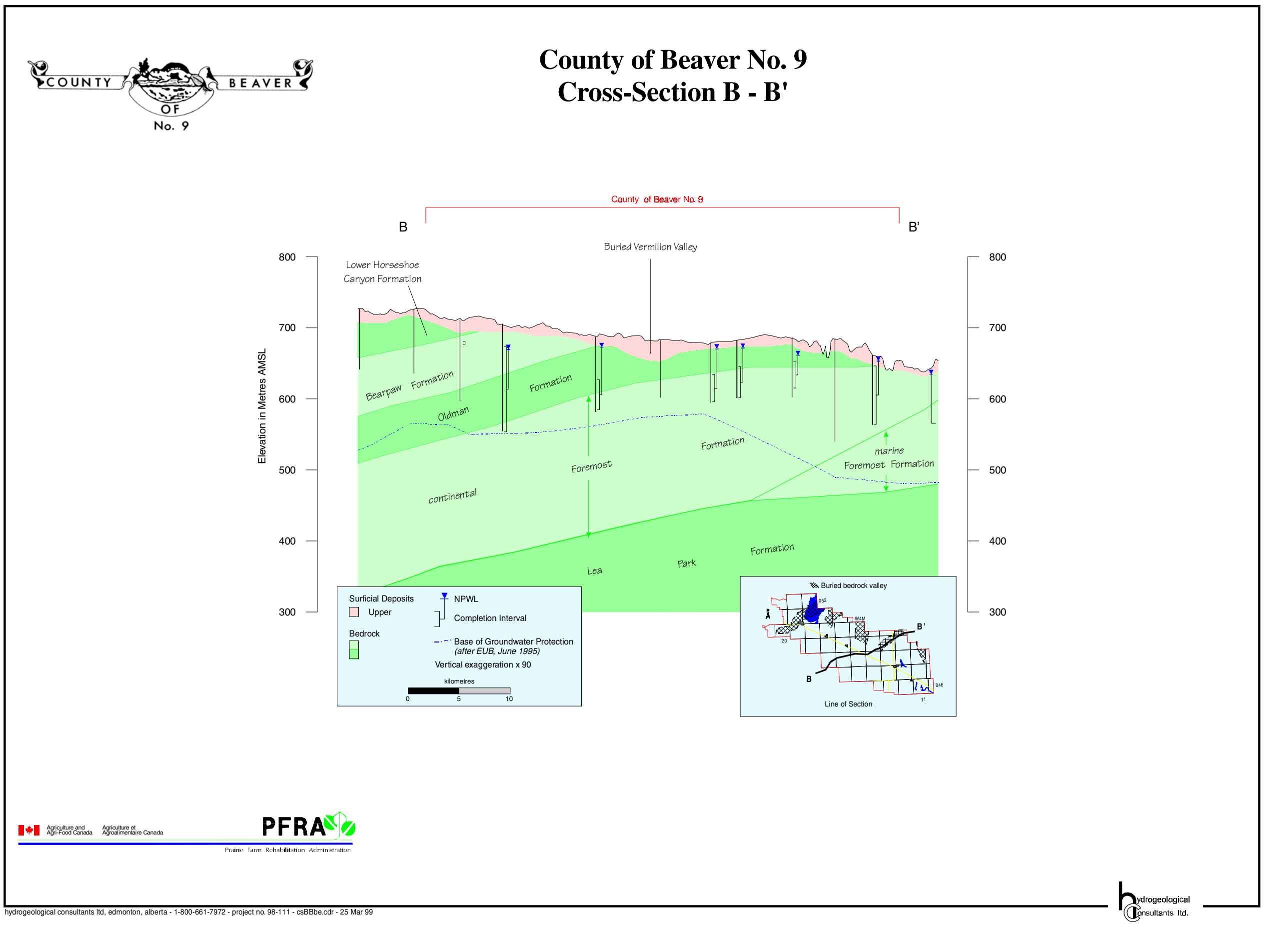
hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 98-111 - bdrQbe.cdr - 24 Mar 99

hydrogeological consultants ltd.



hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 98-111 - riskbe.cdr - 25 Mar 99


County of Beaver No. 9
Cross-Section A - A'
COUNTY OF BEAVER No. 9
County of Beaver No. 9
A
A'
Buried Vegreville Valley
Lower Horseshoe Canyon Formation
Elevation in Metres AMSL
800
700
600
500
400
300
Bearpaw
Formation
Oldman
Formation
Foremost
Formation
continental
marine Foremost Formation
Park
Formation
Lea
Surficial Deposits
Upper
Bedrock
NPWL
Completion Interval
Base of Groundwater Protection (after EUB, June 1995)
Vertical exaggeration x 90
kilometres
0
5
10
Buried bedrock valley
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. 98-111 - csAAbe.cdr - 25 Mar 99
hydrogeological consultants ltd.


County of Beaver No. 9
Cross-Section B - B'
County of Beaver No. 9
B
B'
Buried Vermilion Valley
Lower Horseshoe Canyon Formation
Elevation in Metres AMSL
800
700
600
500
400
300
Bearpaw Formation
Oldman Formation
Foremost Formation
continental
marine Foremost Formation
Lea Park Formation
Surficial Deposits
Upper
Bedrock
NPWL
Completion Interval
Base of Groundwater Protection (after EUB, June 1995)
Vertical exaggeration x 90
kilometres
0
5
10
Buried bedrock valley
Line of Section
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
PFRA
hydrogeological consultants ltd.
hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 98-111 - csBBbe.cdr - 25 Mar 99

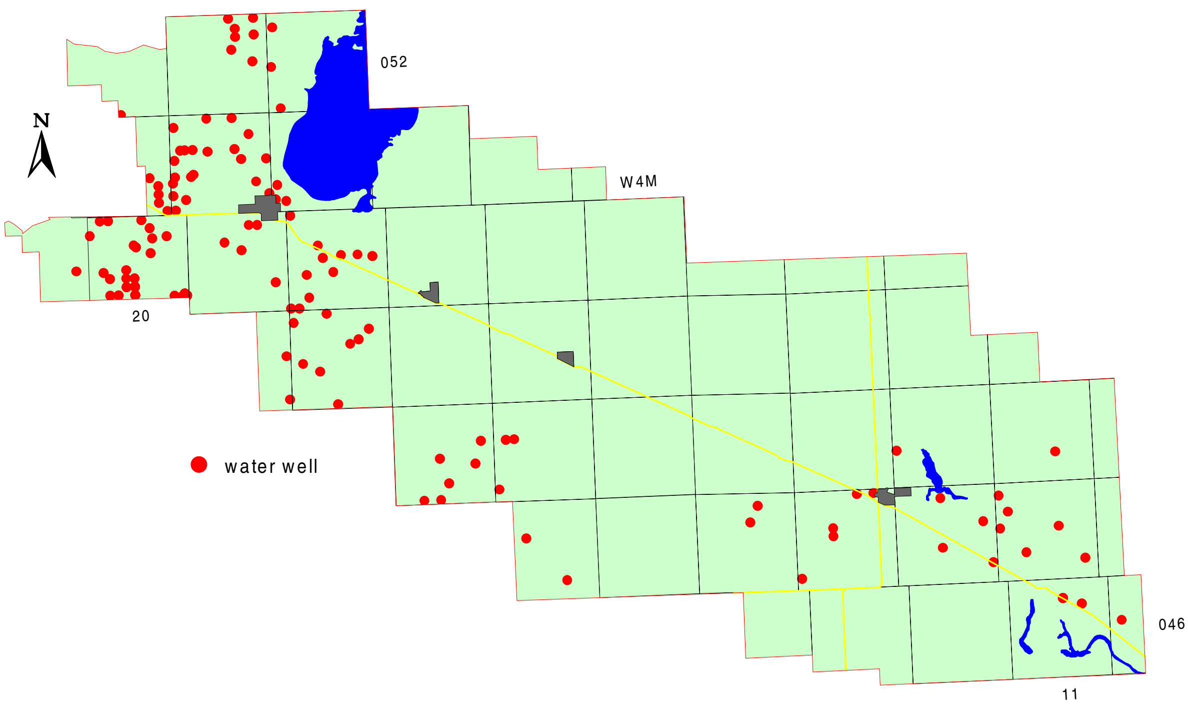
COUNTY OF BEAVER NO. 9

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	Bottom of Completion Interval Metres	Bottom of Completion Interval Feet	NPWL Metres	NPWL Feet
Adam, Terry	01-12-050-20 W4M	J & Drilling Ltd.	Mar-81	61.0	200.0	12.2	40.0
Addison, Paul	NW 34-050-20 W4M	J & Drilling Ltd.	Sep-80	57.9	190.0	12.2	40.0
Agrey, D.J.	NW 09-050-20 W4M	Servold, Harold	May-83	74.7	245.0	16.2	53.0
Asseltine	SE 09-050-20 W4M	Big Iron Drilling Ltd.	Dec-79	67.1	220.0	18.3	60.0
Bardo Rec Assoc	04-06-050-18 W4M	Whillans Jerald	Jun-78	29.9	98.0	4.3	14.0
Beaumont, George	SW 31-047-11 W4M	Losness Drilling (1975) Ltd.	Sep-86	36.0	118.0	5.2	17.0
Beaver Crk Farms	NW 33-049-18 W4M	Big Iron Drilling Ltd.	Mar-80	45.7	150.0	15.2	50.0
Bercik, Charles	NW 06-047-13 W4M	ALF's Drilling & Supplies Ltd.	Dec-80	61.9	203.0	3.4	11.0
Berrecloth, Trudy	NW 33-051-19 W4M	J & Drilling Ltd.	Jul-85	41.2	135.0	0.6	2.0
Bodnar, Thomas	SW 22-050-18 W4M	Gordon's Drilling Ltd.	Jul-86	15.2	50.0	3.1	10.0
Bolster, Alfred	NW 06-051-18 W4M	Coralta Drilling	Jun-73	79.2	260.0	14.3	47.0
Bratrud, Cliff & Ron#2	NE 16-048-17 W4M	Downey Drilling	Jul-80	39.0	128.0	18.3	60.0
Bruha, Ken	04-21-050-18 W4M	Gordon's Drilling Ltd.	Aug-82	27.7	91.0	6.1	20.0
Burbe, Charles	NW 09-050-20 W4M	Holland Drilling Ltd.	Aug-79	77.7	255.0	13.7	45.0
Camp Lake	NE 10-048-11 W4M	Gordon's Drilling Ltd.	Jun-85	10.7	35.0	3.7	12.0
Carey, Steve	NW 13-050-21 W4M	L M WW Ltd	Oct-77	67.4	221.0	8.8	29.0
Carroll, Jack	NE 09-050-20 W4M	Holland Drilling Ltd.	Dec-82	76.2	250.0	15.9	52.0
Ceretzke, Glenn	02-06-050-18 W4M	J & Drilling Ltd.	Apr-79	36.0	118.0	6.1	20.0
Chance, Gordon	NW 32-050-20 W4M	Big Iron Drilling Ltd.	Mar-77	53.3	175.0	12.2	40.0
Charpentier, J.A.	08-14-048-17 W4M	Mcnary, David M.	May-79	34.1	112.0	12.2	40.0
Charters, C.L.	01-12-051-19 W4M	J & Drilling Ltd.	May-83	42.7	140.0	15.2	50.0
Congdon, Don	SE 16-047-12 W4M	Losness Drilling (1975) Ltd.	Jun-75	74.1	243.0	21.3	70.0
Cunnings, Ron	NW 21-051-19 W4M	J & Drilling Ltd.	Mar-83	77.7	255.0	25.9	85.0
Dale, H.	SW 19-051-19 W4M	Servold & Sons Drilling	Aug-74	74.1	243.0	24.7	81.0
Daugherty, John	NW 27-046-11 W4M	ALF's Drilling & Supplies Ltd.	Dec-82	80.8	265.0	20.7	68.0
Daugherty, John W.	NW 27-046-11 W4M	Big Iron Drilling Ltd.	Oct-85	61.0	200.0	18.3	60.0
Davies, Harold	SW 17-050-20 W4M	J & Drilling Ltd.	Jul-82	64.0	210.0	11.6	38.0
Delwood Homes	SE 28-050-20 W4M	Grove Drilling Ltd	Sep-80	31.4	103.0	6.1	20.0
Dressler, Richard	04-35-052-19 W4M	Green Acres Water Well Drilli	Apr-76	36.6	120.0	19.8	65.0
Dueck, Alven	SW 23-051-19 W4M	Gordon's Drilling Ltd.	Nov-79	19.8	65.0	6.1	20.0
Dunn	04-03-052-20 W4M	Big Iron Drilling Ltd.	Jul-72	39.6	130.0	8.5	28.0
Ek, D & C	02-12-050-20 W4M	J & Drilling Ltd.	May-82	45.7	150.0	9.1	30.0
Field, Ken	SW 21-047-13 W4M	ALF's Drilling & Supplies Ltd.	Jan-81	42.7	140.0	18.3	60.0
Fraess, Floyd	01-12-050-20 W4M	KC Drilling (Leduc)	Jul-84	24.7	81.0	6.1	20.0
Freeland, Brian	04-07-051-19 W4M	Green Acres Water Well Drilli	Nov-75	70.1	230.0	16.8	55.0
Gavmont, Leo	13-30-050-20 W4M	J & Drilling Ltd.	Oct-84	54.9	180.0	12.2	40.0
Gill, A.E.	13-12-051-19 W4M	J & Drilling Ltd.	Jun-80	32.9	108.0	9.1	30.0
Gillis, Don	SE 12-047-12 W4M	ALF's Drilling & Supplies Ltd.	Jun-83	57.0	187.0	14.0	46.0
Goerzen, Brian	04-24-050-18 W4M	Gordon's Drilling Ltd.	Nov-84	14.6	48.0	4.6	15.0
Gordon, Cliff	SW 17-051-19 W4M	J & Drilling Ltd.	Jun-81	48.8	160.0	6.1	20.0
Gordon, Colin	NW 12-051-20 W4M	Boyd's Water Well Drilling	Oct-81	46.9	154.0	9.5	31.0
Gov'T. Univ. Ranch	SE 22-047-11 W4M	Losness Drilling (1975) Ltd.	Apr-77	74.7	245.0	13.1	43.0
Hagan, Jim	NW 09-050-20 W4M	Boyd's Water Well Drilling	Jul-81	73.2	240.0	9.5	31.0
Hahn, Hank	04-11-047-16 W4M	KC Drilling (Leduc)	Nov-82	8.5	28.0	3.4	11.0
Hanlon, P.	NW 32-050-20 W4M	KC Drilling (Leduc)	Oct-80	18.0	59.0	9.8	32.0
Harray, Bruce	SW 19-047-11 W4M	Losness Drilling (1975) Ltd.	Oct-74	43.3	142.0	18.0	59.0
Haugen, Olaf	04-17-050-18 W4M	KC Drilling (Leduc)	Aug-83	29.6	97.0	12.2	40.0
Haydon, Harry	SE 34-047-14 W4M	Losness Drilling (1975) Ltd.	Aug-79	58.5	192.0	8.5	28.0
Hellekson, Earl	NW 06-048-16 W4M	Big Iron Drilling Ltd.	Oct-84	32.0	105.0	10.7	35.0
Hemstock, Bill	SE 12-050-20 W4M	J & Drilling Ltd.	Aug-83	61.0	200.0	12.2	40.0
Hodgins, Warron	NW 24-047-12 W4M	Losness Drilling (1975) Ltd.	May-78	63.1	207.0	12.8	42.0
Hoffman, Don	NW 21-047-13 W4M	ALF's Drilling & Supplies Ltd.	Jul-82	49.4	162.0	16.8	55.0
Hubbard, R.S.	16-22-051-19 W4M	J & Drilling Ltd.	Oct-79	27.4	90.0	15.2	50.0
Hunter, John D.	SE 30-047-11 W4M	Losness Drilling (1975) Ltd.	Jul-84	66.1	217.0	17.7	58.0
Jansen, Bill	04-12-050-20 W4M	J & Drilling Ltd.	May-81	30.5	100.0	11.3	37.0
Jobber, David	NE 20-047-16 W4M	Big Iron Drilling Ltd.	May-84	21.3	70.0	7.6	25.0
Johansen, Harold	NE 26-049-18 W4M	Downey Drilling	Oct-74	23.8	78.0	3.1	10.0
Johnson, Bill	NW 27-046-11 W4M	Losness Drilling (1975) Ltd.	Sep-75	80.2	263.0	20.7	68.0
Juve, Walter	15-19-051-19 W4M	J & Drilling Ltd.	Oct-82	27.4	90.0	10.7	35.0
Kelly, Terry	NE 09-050-20 W4M	Boyd's Water Well Drilling	Jul-81	58.8	193.0	9.8	32.0

Water Wells Recommended for Field Verification

Owner	Location	Water Well Contractor	Date Water Well Drilled	Bottom of Completion Interval Metres	Bottom of Completion Interval Feet	NPWL Metres	NPWL Feet
Kiebiech, Andrew	NW 24-048-17 W4M	ALF's Drilling & Supplies Ltd.	Mar-78	31.1	102.0	18.3	60.0
Knudslien, Clifford	SE 01-051-20 W4M	Gordon's Drilling Ltd.	Aug-81	24.4	80.0	18.3	60.0
Knudson, Tim	SE 04-048-17 W4M	ALF's Drilling & Supplies Ltd.	Mar-86	41.5	136.0	12.8	42.0
Koreman, Shirley	NE 22-050-20 W4M	Kap's Drilling Ltd.	Nov-84	42.7	140.0	0.3	1.0
Kozak, Roy	NE 09-050-20 W4M	J & Drilling Ltd.	Apr-80	38.1	125.0	12.2	40.0
Krause, Gary	06-17-051-19 W4M	J & Drilling Ltd.	Jun-80	48.8	160.0	4.0	13.0
Kubbanus, Harvey	SE 16-050-20 W4M	McAllister Drilling Ltd.	Mar-76	85.3	280.0	31.1	102.0
Lang, Gordon	SW 08-050-20 W4M	J & Drilling Ltd.	Apr-81	89.9	295.0	24.4	80.0
Lauber, Lev	04-26-049-18 W4M	J & Drilling Ltd.	Aug-80	21.9	72.0	9.1	30.0
Laursen, Bjarne	SE 09-050-20 W4M	Gordon's Drilling Ltd.	Jul-80	70.1	230.0	7.6	25.0
Lee, Allen	NW 36-052-19 W4M	J & Drilling Ltd.	Aug-79	30.5	100.0	21.9	72.0
Lien, Donald	SW 10-048-17 W4M	Other	May-80	40.2	132.0	12.2	40.0
Lindon, Pat	SW 18-051-19 W4M	Mcauley Drilling Co. Ltd.	Jun-83	89.3	293.0	4.6	15.0
Lindstrom, Larry	NE 09-050-20 W4M	Gordon's Drilling Ltd.	Oct-81	76.2	250.0	12.2	40.0
Litwin, Don	SE 24-049-19 W4M	Gordon's Drilling Ltd.	Aug-74	23.5	77.0	10.7	35.0
Lysons, M.	NW 18-052-18 W4M	J & Drilling Ltd.	Jun-86	13.7	45.0	3.7	12.0
Mackay, Leslie #2 Well	09-18-050-20 W4M	Shank Dave & Sons	Jun-72	76.2	250.0	2.6	8.5
Mackenzie, Ernest	SW 31-051-19 W4M	Mcauley Drilling Co. Ltd.	Dec-78	88.4	290.0	24.4	80.0
Malowany, Joe	NW 20-048-16 W4M	Dave's Drilling	Oct-77	18.3	60.0	1.2	4.0
Martin, Bill	01-28-050-20 W4M	J & Drilling Ltd.	May-80	80.8	265.0	16.8	55.0
Mcallister, A.G.	11-07-051-18 W4M	McAllister Drilling Ltd.	Aug-66	98.1	322.0	4.6	15.0
Mcburney, Chuck	SE 16-050-20 W4M	Big Iron Drilling Ltd.	Feb-77	61.6	202.0	15.2	50.0
Mcginitie, Don	SW 28-050-19 W4M	J & Drilling Ltd.	May-83	48.8	160.0	16.8	55.0
Mcsloy, Jack	SE 12-050-20 W4M	J & Drilling Ltd.	Aug-82	36.6	120.0	18.3	60.0
Miller, Julian	NW 16-050-20 W4M	Holland Drilling Ltd.	Apr-81	71.6	235.0	15.2	50.0
Miskew, Marshall	SE 33-047-12 W4M	Beckett Drilling Ltd.	Sep-76	37.5	123.0	14.3	47.0
Moncur, Debbie	SW 12-051-20 W4M	Holland Drilling Ltd.	Nov-78	62.5	205.0	21.3	70.0
Nahernick, Bill	SW 06-051-19 W4M	Mel's Drilling Services 1976 L	May-79	54.9	180.0	9.8	32.0
Neufeld, Ken	NW 12-050-19 W4M	Gordon's Drilling Ltd.	Jun-79	20.7	68.0	7.6	25.0
Neville, Bob	NE 26-050-20 W4M	J & Drilling Ltd.	Nov-78	33.5	110.0	2.4	8.0
Nickerson, Roy	SW 17-051-19 W4M	Grove Drilling Enterprises (19	Jun-78	39.6	130.0	0.6	2.0
Nolan, Pat	09-06-051-18 W4M	Shumansky Waterwell Servic	Aug-80	17.1	56.0	5.5	18.0
Nolin, Rick & Teri	13-07-051-19 W4M	J & Drilling Ltd.	Oct-79	64.0	210.0	2.4	8.0
Nordstrom, Richard	SW 18-048-12 W4M	McAllister Drilling Ltd.	Jul-77	61.0	200.0	16.5	54.0
Norton, Rick	SW 35-050-19 W4M	J & Drilling Ltd.	Jun-80	9.1	30.0	3.1	10.0
Olson, J.	09-01-049-19 W4M	Servold, Harold	Jan-58	34.4	113.0	18.3	60.0
Oracheski, Lyle	SW 12-047-11 W4M	ALF's Drilling & Supplies Ltd.	Mar-86	73.2	240.0	20.4	67.0
Patterson, John	SW 27-047-14 W4M	ALF's Drilling & Supplies Ltd.	Apr-86	64.0	210.0	12.8	42.0
Patterson, N.E.	SE 16-050-18 W4M	Gordon's Drilling Ltd.	Sep-82	20.4	67.0	6.1	20.0
Peterson, Bruce#4	SE 05-048-17 W4M	ALF's Drilling & Supplies Ltd.	Aug-82	25.6	84.0	7.6	25.0
Plaizier, Peter	NW 32-050-20 W4M	Holland Drilling Ltd.	Dec-80	61.0	200.0	18.3	60.0
Pperry, Aurel	SW 17-051-19 W4M	Banks Well Service	Sep-83	73.2	240.0	3.7	12.0
Richter, Don	16-19-051-19 W4M	Shumansky Waterwell Servic	Sep-80	21.9	72.0	7.3	24.0
Riediger, Walter	NW 05-050-18 W4M	Gordon's Drilling Ltd.	Mar-86	28.4	93.0	7.6	25.0
Roddick, George	NE 35-047-13 W4M	Losness Drilling (1975) Ltd.	Feb-76	33.2	109.0	4.1	13.4
Rongom, E.	SE 19-046-10 W4M	Losness Drilling (1975) Ltd.	Mar-78	71.0	233.0	27.7	91.0
Ronsbeg, Norman	NE 19-048-16 W4M	ALF's Drilling & Supplies Ltd.	Jun-78	18.3	60.0	6.1	20.0
Roth, Joseph	SE 17-049-18 W4M	Big Iron Drilling Ltd.	Jan-81	48.8	160.0	9.1	30.0
Sagmoen, Arnold	NE 34-052-19 W4M	Holland Drilling Ltd.	Nov-84	48.8	160.0	14.3	47.0
Schaffler, Don	NW 09-050-20 W4M	Banks Well Service	Sep-79	45.7	150.0	13.4	44.0
Scoular, James	NW 01-051-20 W4M	Earnest Water Well Drilling	Aug-82	51.8	170.0	11.3	37.0
Shinniman, Geo	SE 08-050-20 W4M	Holland Drilling Ltd.	Sep-75	73.8	242.0	22.6	74.0
Simmons, Jack	06-26-046-11 W4M	Losness Drilling (1975) Ltd.	Aug-82	81.7	268.0	22.9	75.0
Sorell, E.	SW 23-051-19 W4M	Downey Drilling	Nov-66	19.8	65.0	7.6	25.0
Starchuk, Ppete	SW 17-051-19 W4M	J & Drilling Ltd.	Jun-80	27.4	90.0	3.1	10.0
Stauffer, Leonard	SW 31-049-18 W4M	Gordon's Drilling Ltd.	Sep-80	19.2	63.0	6.1	20.0
Stauffer, Milo	NW 31-050-18 W4M	Gordon's Drilling Ltd.	Nov-79	15.2	50.0	6.1	20.0
Stauffer, Russ	15-22-049-18 W4M	J & Drilling Ltd.	Aug-80	29.3	96.0	7.6	25.0
Steen, Douglas A.	SW 16-050-20 W4M	Kielbauch Drilling	Jan-77	70.1	230.0	9.1	30.0
Steinhusen, Joachin	12-26-052-19 W4M	J & Drilling Ltd.	Apr-79	39.0	128.0	6.4	21.0
Sterrat, Carig	SE 34-050-20 W4M	J & Drilling Ltd.	Nov-82	29.9	98.0	4.6	15.0

Water Wells Recommended for Field Verification

Owner	Location	Water Well Contractor	Date Water Well Drilled	Bottom of Completion Interval Metres	Bottom of Completion Interval Feet	NPWL Metres	NPWL Feet
Stewart, L.E.	16-22-052-19 W4M	Green Acres Water Well Drilli	Sep-76	50.3	165.0	27.7	91.0
Stular, Walter	NW 21-051-19 W4M	Big Iron Drilling Ltd.	Mar-83	59.4	195.0	18.3	60.0
Swanson, Carl	SE 12-050-20 W4M	J & Drilling Ltd.	Sep-86	59.4	195.0	19.8	65.0
Sware	NE 31-050-20 W4M	Servold, Harold		59.1	194.0	15.2	50.0
Thiessen, J.	NW 22-050-19 W4M	J & Drilling Ltd.	Oct-82	21.9	72.0	9.1	30.0
Tiedemann	14-20-051-19 W4M	Artesia Drilling	Jun-73	72.5	238.0	24.4	80.0
Tofield Cattle Co.	09-27-050-20 W4M	McAllister Drilling Ltd.	Mar-78	67.1	220.0	4.9	16.0
Tofield Cattle Company	NW 25-052-19 W4M	McAllister Holdings Ltd.	Dec-78	27.4	90.0	5.2	17.1
Tofield Cattle Company	04-24-052-19 W4M	McAllister Holdings Ltd.	Dec-78	26.8	88.0	5.3	17.4
U Of A Ranch	NE 08-047-11 W4M	Caribou Drilling Ltd.	Aug-69	17.7	58.0	10.1	33.0
Verkland, Fred S.	SE 34-050-20 W4M	Boyd's Water Well Drilling	Sep-80	77.7	255.0	8.2	27.0
Villenove, Dennis	01-12-050-20 W4M	Papley Drilling	Jun-75	24.4	80.0	13.4	44.0
Walker, Jim	NE 34-047-13 W4M	ALF's Drilling & Supplies Ltd.	Mar-86	68.6	225.0	25.3	83.0
Walker, Vernon	SE 06-052-18 W4M	<unknown contractor>		9.1	30.0	6.1	20.0
Warawa, V.	NE 26-051-19 W4M	Downey Drilling	Jun-61	31.7	104.0	7.9	26.0
Wardon, Gordon	16-06-051-19 W4M	J & Drilling Ltd.	Jul-79	48.8	160.0	21.3	70.0
Warner, John C.	SE 24-051-19 W4M	Kielbauch Drilling	Oct-75	61.0	200.0	15.2	50.0
Watson, Warren W.	03-31-052-18 W4M	Martin, J. Water Wells	Aug-84	14.9	49.0	0.3	1.0
Weber, Norman	NE 18-049-18 W4M	Downey Drilling	Nov-62	26.8	88.0	10.1	33.0
Wenger, Bill	SE 34-050-19 W4M	Big Iron Drilling Ltd.	Apr-76	64.0	210.0	7.6	25.0
Wiens, A.	16-20-050-18 W4M	Uhryn's Well Boring	Sep-69	6.7	22.0	3.1	10.0
Wilkerson, Thomas	SE 14-051-20 W4M	Servold & Sons Drilling	Oct-82	85.0	279.0	15.2	50.0
Willis, Skip	NW 12-051-20 W4M	Boyd's Water Well Drilling	May-83	57.3	188.0	10.1	33.0
Wood, John	NE 34-051-19 W4M	Ingle	Jul-61	23.5	77.0	8.2	27.0
Yoder, Donald	SW 23-050-18 W4M	Big Iron Drilling Ltd.	Dec-81	24.4	80.0	6.7	22.0
Zeniuk, Victor	SE 04-049-18 W4M	Big Iron Drilling Ltd.	Mar-74	45.7	150.0	45.7	150.0