M.D. of Brazeau No. 77

Part of the North Saskatchewan and Athabasca River Basins
Parts of Tp 045 to 050, R 03 to 11, W5M
Revised Regional Groundwater Assessment

Prepared for

In conjunction with

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Prairie Farm Rehabilitation Administration | Administration du rétablisseme agricole des Prairies

Canada

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1 PROJECT OVERVIEW

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

How a M.D. takes care of one of its most precious resources - groundwater - reflects the future wealth and health of its people. Good environmental practices are not an accident. They must include genuine foresight with knowledgeable planning. Implementation of strong practices not only commits to a better quality of life for future generations, but also creates a solid base for increased economic activity. **This report, even though it is regional in nature, is the first step in fulfilling a commitment by the M.D. of Brazeau No. 77 toward the management of the groundwater resource, which is a key component toward the well-being of the M.D., and is a guide for future groundwater-related projects.**

1.1 About This Report

This report provides an overview of (a) the groundwater resources of the M.D. of Brazeau No. 77, (b) the processes used for the present project and (c) the groundwater characteristics in the M.D.

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

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

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

Appendix C includes the following:

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

The Water Well Regulation deals with the wellhead completion requirement (no more water-well pits), the proper procedure for abandoning unused water wells and the correct procedure for installing a pump in a water well. The new Water Act was proclaimed 10 Jan 1999.

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

1.2 The Project

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

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

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

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

1.3 Purpose

This project is a regional groundwater assessment of the M.D. of Brazeau No. 77. The regional groundwater assessment provides the information to assist in the management of the groundwater resource within the M.D. Groundwater resource management involves determining the suitability of various areas in the M.D. for particular activities. These activities can vary from the development of groundwater for agricultural or industrial purposes, to the siting of waste storage. **Proper management ensures protection and utilization of the groundwater resource for the maximum benefit of the people of the M.D.**

The regional groundwater assessment includes:

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

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

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1 See glossary
2 See glossary

2 INTRODUCTION

2.1 Setting

The M.D. of Brazeau is situated in central Alberta. This area is part of the Alberta Plains region. The M.D. is within the North Saskatchewan and Athabasca River basins. A part of the northeastern and southeastern boundary is the North Saskatchewan River. The other boundaries follow township or section lines. The area includes parts of the area bounded by township 050, range 11, W5M in the northwest and township 045, range 03, W5M in the southeast.

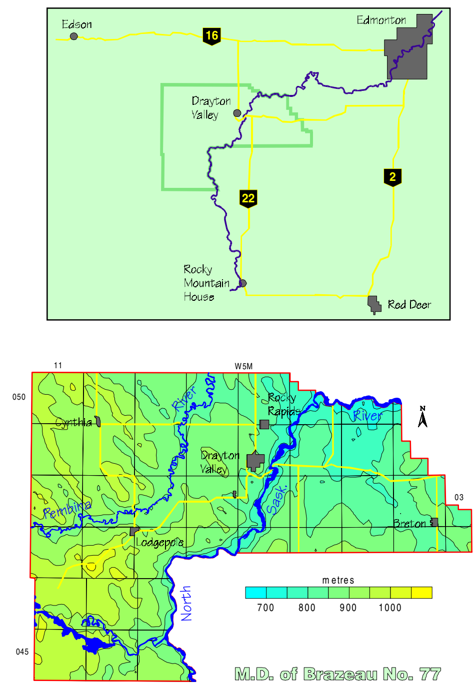

Figure 1. Index Map

Regionally, the topographic surface varies between 650 and 1,050 metres above mean sea level (AMSL). The lowest elevations occur in the North Saskatchewan River Valley in the northeastern part of the M.D.; the highest are in the southwestern part of the M.D., as shown in Figure 1.

2.2 Climate

The M.D. of Brazeau lies within the Dfb climate boundary. This classification is based on potential evapotranspiration values determined using the Thornthwaite method (Thornthwaite and Mather, 1957), combined with the distribution of natural ecoregions in the area. The ecoregions map (Strong and Legatt, 1981) shows that the M.D. is located in both the Low Boreal Mixedwood region and the Aspen Parkland region. Increased precipitation and cooler temperatures, resulting in additional moisture availability, influence this vegetation change.

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.

The mean annual precipitation averaged from three meteorological stations within the M.D. measured 571 millimetres (mm), based on data from 1961 to 1993. The mean annual temperature averaged 3.2 °C, with the mean monthly temperature reaching a high of 16.1 °C in July, and dropping to a low of -10.3 °C in January. The calculated annual potential evapotranspiration is 511 millimetres.

2.3 Background Information

There are currently records for 3,571 water wells in the groundwater database for the M. D. Of the 3,571 water wells, 2,228 are for domestic/stock purposes. The remaining 1,343 water wells were completed for a variety of uses, including industrial, municipal and observation. Based on a rural population of 6,589, there are 1.3 domestic/stock water wells per family of four. The domestic or stock water wells vary in depth from less than two metres to 155.8 metres below ground level. Lithologic details are available for 2,948 water wells.

Data for casing diameters are available for 2,420 water wells, with 2,416 indicated as having a diameter of less than 330 mm and four having a diameter of more than 400 mm. The casing diameters of greater than 400 mm are mainly bored or dug water wells and those with a surface casing diameter of less than 330 mm are drilled water wells.

There are five different materials that have been used for surface casing over the last 40 years in water wells completed in the M.D. The three most common materials are galvanized steel, steel and plastic. Steel casing was in use in the 1950s and is still used in 53% of the water wells being drilled in the M.D. Galvanized steel surface casing was used in 4% of the new water wells in the early 1950s. By the early 1970s, galvanized steel casing was being used in 56% of the water wells. From 1975 onward, there was a general decrease in the percentage of water wells using galvanized steel, with the last reported use in March 1994. Plastic casing was used for the first time in August 1970. The percentage of water wells with plastic casing has increased and in the mid-1990s, plastic casing was used in 47% of the water wells drilled in the M.D.

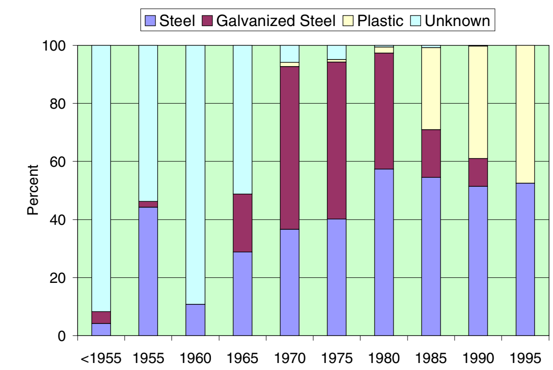

Figure 2. Surface Casing Types used in Drilled Water Wells

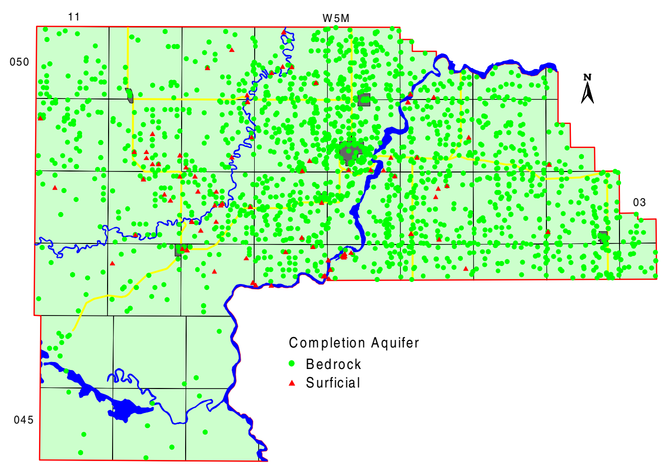

Figure 3. Location of Water Wells

There are 2,335 water well records with sufficient information to identify the aquifer in which the water wells are completed. The water wells that were not drilled deep enough to encounter the bedrock plus water wells that have the bottom of their completion interval above the bedrock surface are water wells completed in surficial aquifers. The number of water wells completed in aquifers in the surficial deposits is 4%, a total of 104 water wells, with the majority occurring in the central part of the M.D. Approximately 60% of the water wells completed in the surficial aquifers have a completion depth of less than 30 metres.

The remaining 2,231 water wells have the top of their completion interval deeper than the depth to the bedrock surface. From the above map, it can be seen that water wells completed in bedrock aquifers occur over most of the M.D.

Water wells not used for domestic needs must be licensed. At the end of 1996, 250 groundwater diversions were licensed in the M.D. Of the 250 licensed groundwater users, 175 are for industrial purposes, 56 are for agricultural purposes, and the remaining 19 are for diversion, municipal and other purposes. The total maximum authorized diversion from the water wells associated with these licences is 23,943 cubic metres per day (m^3/day); 64% percent of the authorized groundwater diversion is allotted for industrial use. The largest licensed groundwater diversion within the M.D. is for Alberta Transportation, having a “diversion” of 3,009 m^3/day. When a groundwater use is listed as “diversion”, the activity is usually related to dewatering activities; in the case of Alberta Transportation, the diversion could be related to a gravel pit.

The adjacent table shows a breakdown of the 250 licensed groundwater diversions by the aquifer in which the water well is completed. The highest diversions are for licensed water wells completed in the Dalehurst Aquifer, of which the majority of the groundwater is used for industrial purposes.

Aquifer	Licensed Groundwater Users (m³/day) Agricultural	Municipal	Industrial	Diversion	Other	Total	Percentage
Upper Sand and Gravel	10	0	88	0	0	98	0.4
Lower Sand and Gravel	0	0	913	0	0	913	4
Dalehurst	90	54	13,225	0	0	13,369	56
Upper Lacombe	212	91	433	2,789	0	3,525	15
Lower Lacombe	20	338	308	1,292	0	1,958	8
Haynes	44	0	7	659	0	710	3
Upper Scollard	0	0	40	3,009	61	3,110	13
Unknown	0	0	260	0	0	260	1
Total	376	483	15,274	7,749	61	23,943	
Percentage	1.6	2.0	63.8	32.4	0.2		

Table 1. Licensed Groundwater Diversions

Based on the 1996 Agriculture Census, the water requirement for livestock for the M.D. is in the order of 5,650 m³/day, which is fifteen times the licensed groundwater diversion for agricultural purposes. This result suggests many agricultural operations are not in compliance with the present regulations related to groundwater use.

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

Groundwaters from the surficial deposits can be expected to be chemically hard with a high dissolved iron content. The total dissolved solids (TDS) concentrations in the groundwaters from the upper bedrock in the M.D. are generally less than 1,000 milligrams per litre (mg/L). Groundwaters from the bedrock aquifers frequently are chemically soft with generally low concentrations of dissolved iron. The chemically soft groundwater is high in sodium concentration. Less than 10% of the chemical analyses indicate a fluoride concentration above 1.5 mg/L.

Constituent	Groundwater Concentrations from Bedrock Water Wells in the M.D. Minimum	Maximum	Average	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	218	1855	665	500
Sodium	207	570	191	200
Sulfate	2.9	920	115	500
Chloride	0.35	373	11.4	250
Fluoride	0.03	4	0.4	1.5

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

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

Table 2. Groundwater Concentrations from Water Wells Completed in Bedrock Aquifers

The minimum, maximum and average concentrations of TDS, sodium, sulfate, chloride and fluoride in the groundwaters from water wells completed in the bedrock in the M.D. have been compared to the Guidelines for Canadian Drinking Water Quality (GCDWQ) in Table 2. On the average, the groundwaters are below the GCDWQ; the exception is TDS, which exceeds the guideline slightly.

Alberta Environmental Protection (AEP) defines the Base of Groundwater Protection as the elevation below which the groundwater is expected to have more than 4,000 mg/L of total dissolved solids. By using the ground elevation, the bedrock surface and the Base of Groundwater Protection provided by the Alberta Energy and Utilities Board (EUB), a depth to the Base of Groundwater Protection can be determined. This depth, for the most part, would be the maximum drilling depth for a water well for agricultural purposes or for a potable water supply. Less than 0.1% of the water wells in the M.D. are completed below the Base of Groundwater Protection. If a water well is completed below the Base of Protection with the total dissolved solids of the groundwater exceeding 4,000 mg/L, then the groundwater use does not require licensing by AEP.

Over approximately 75% of the M.D., the depth to the Base of Groundwater Protection is more than 300 metres. There are only a few areas where the depth to the Base of Groundwater Protection is less than 100 metres; these areas are mainly northeast of the Town of Drayton Valley, within a few kilometres of the North Saskatchewan River (NSR) as shown on the adjacent map.

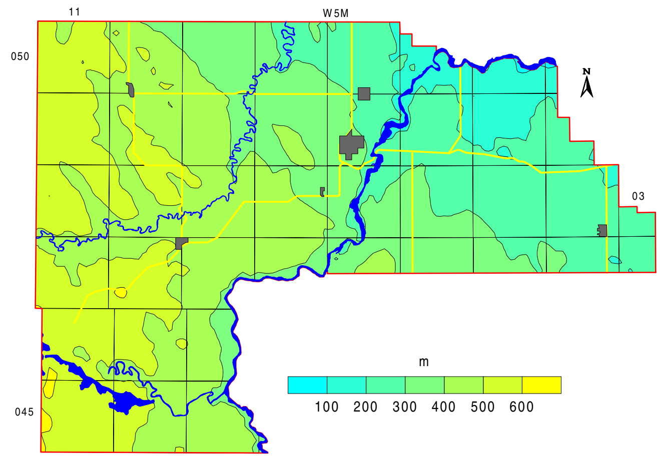

Figure 4. Depth to Base of Groundwater Protection (after EUB, 1995)

Proper management of the groundwater resource requires water-level data. These data are often collected from observation water wells. At the present time, there are three AEP-operated observation water wells within the M.D. Additional data can be obtained from some of the licensed groundwater diversions. In the past, these data for licensed diversions have been difficult to obtain from AEP, in part because of the failure of the licensee to provide the data. Within the M.D., however, there are eight groundwater-monitoring projects operated by Mow-Tech Ltd. for which meaningful water-level data are readily available.

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

3 TERMS

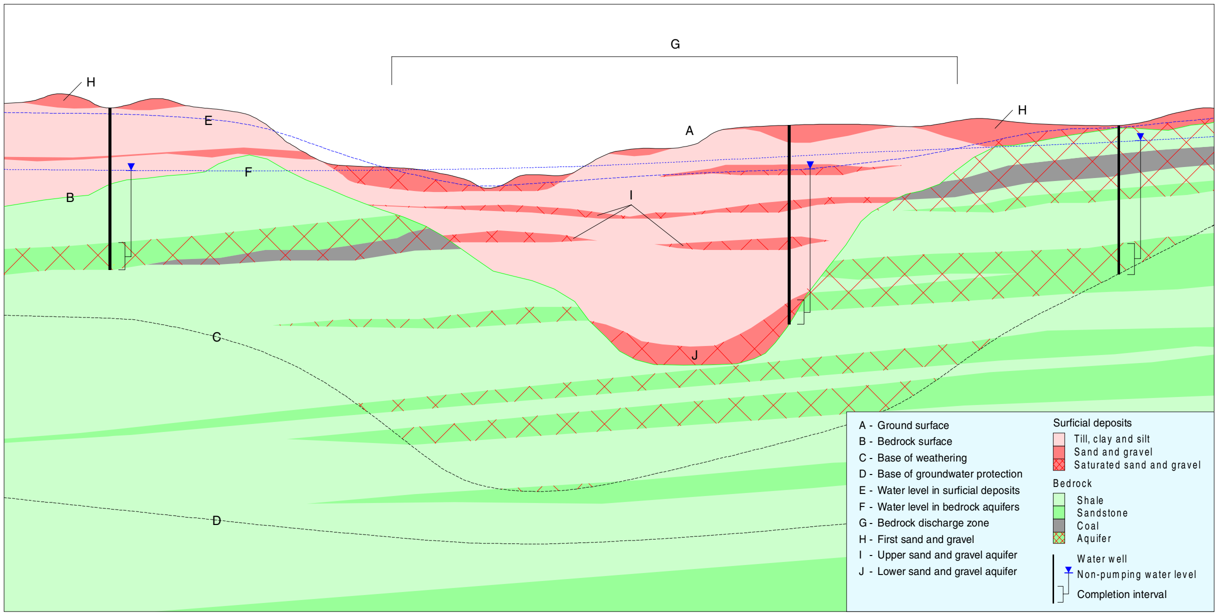

Figure 5. Generalized Cross-Section (for terminology only)

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	<20	First Sand and Gravel
				<30	Lower		
	sandstone, shale, coal	<800	Paskapoo Formation: Dalehurst Member	<300			Obed-Marsh Coal Zone
							Lower Dalehurst Coal Zone
			Paskapoo Formation: Lacombe Member	100-250	Upper		Upper Sandstone
							Middle Sandstone
							Lower Sandstone
				30-100	Lower		Lower Lacombe Coal Zone
			Paskapoo Formation: Haynes Member	20-100			
	shale, sandstone, coal	60-220	Scollard Formation	60-150	Upper	<2	Upper Ardley Coal Zone
						~20	Ardley Coal Zone (main seam)
						<1	Nevis Coal Seam
				20-80	Lower		

Figure 6. Geologic Column

4 METHODOLOGY

4.1 Data Collection and Synthesis

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

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

The main disadvantage to the database is the absence of quality control. Very little can be done to overcome this lack of quality control in the data collection, other than to assess the usefulness of control points relative to other data during the interpretation. Another disadvantage to the database is the lack of adequate spatial information. However, unlike other areas in the Province, duplicate water well IDs are not a problem in the M.D.

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. This situation has been improved for the M.D. of Brazeau. Prairie Farm Rehabilitation Administration (PFRA) has re-positioned 2,813 water wells within the M.D. using aerial photographs and subdivision plans.

The present project uses the 10TM coordinate system. This means that a record for the SE ¼ of section 02, township 048, range 04, W5M, would have a horizontal coordinate with an Easting of 35,464 metres and a Northing of 5,881,908 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 for the ground location for the records in the groundwater database, the data are processed to determine values for hydrogeological parameters. As part of the processing, obvious keying errors in the database are corrected.

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

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

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

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

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

Values for apparent transmissivity, 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 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.

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

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

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

Table 3. Risk of Groundwater Contamination Criteria

4.4 Maps and Cross-Sections

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

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

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 geological units. Appendix A includes page-size maps from the text, plus additional page-size maps and figures that support the discussion in the text. A list of maps and figures that are included on the CD-ROM is given in Appendix B.

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

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

4.5 Software

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

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

7 See glossary

5 AQUIFERS

5.1 Background

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

5.1.1 Surficial Aquifers

Surficial deposits in the M.D. are mainly less than 30 metres thick, except in areas of linear bedrock lows where the thickness of the surficial deposits can exceed 70 metres. The Buried Beverly and Onoway valleys are the two main linear bedrock lows. These linear lows are present in the central and western parts of the M.D., and trend mainly southwest to northeast. In most of the M.D., the North Saskatchewan River and the Buried Beverly Valley occupy the same linear bedrock low, and the Pembina River and the Buried Onoway Valley occupy the same linear bedrock low. Cross-section A-A’ passes across both the Buried Onoway and Beverly valleys and shows the surficial deposits being up to 80 metres thick within the valleys.

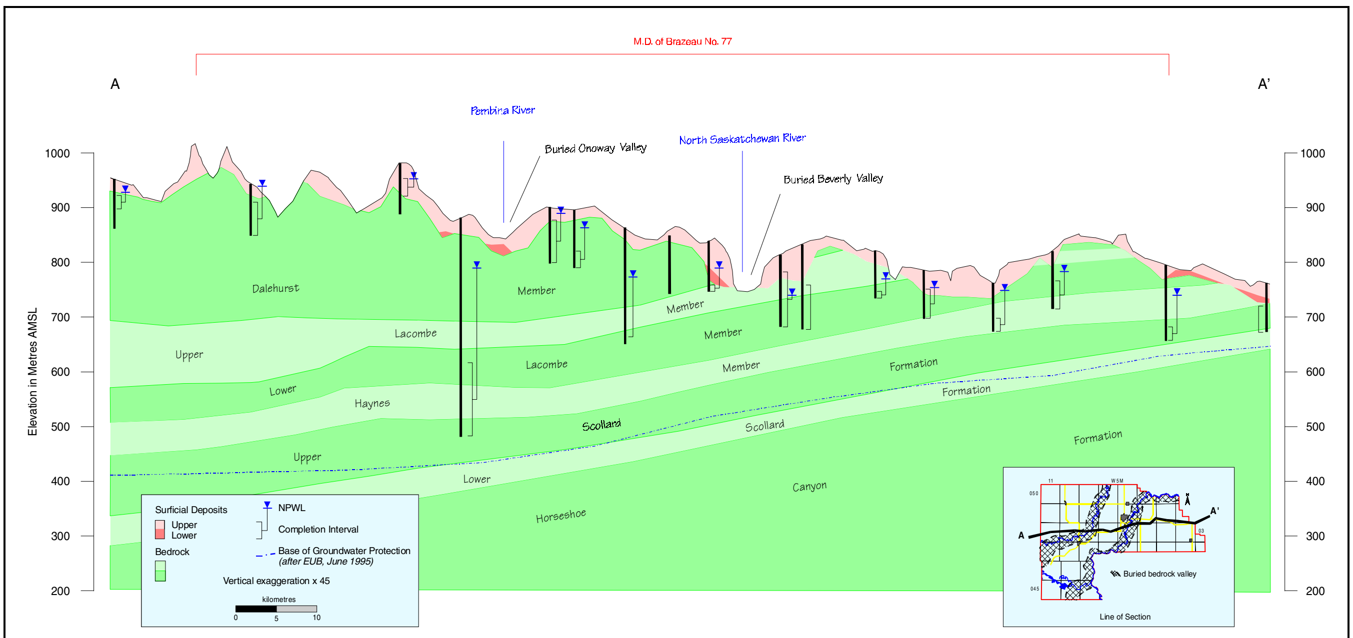

Figure 7. Cross-Section A - A'

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

For a water well with a small-diameter casing to be effective in surficial deposits and to provide sand-free groundwater, the water well must be completed with a water well screen. The groundwater from an aquifer in the surficial deposits usually has a chemical hardness of at least a few hundred mg/L and a dissolved iron concentration such that the groundwater must be treated before being used for domestic needs. Within the M.D., casing diameter information is available for 61 of the 104 water wells completed in the surficial deposits; all of these water wells have a casing diameter of less than 330 millimetres, and are assumed to have been drilled rather than bored or dug.

5.1.2 Bedrock Aquifers

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

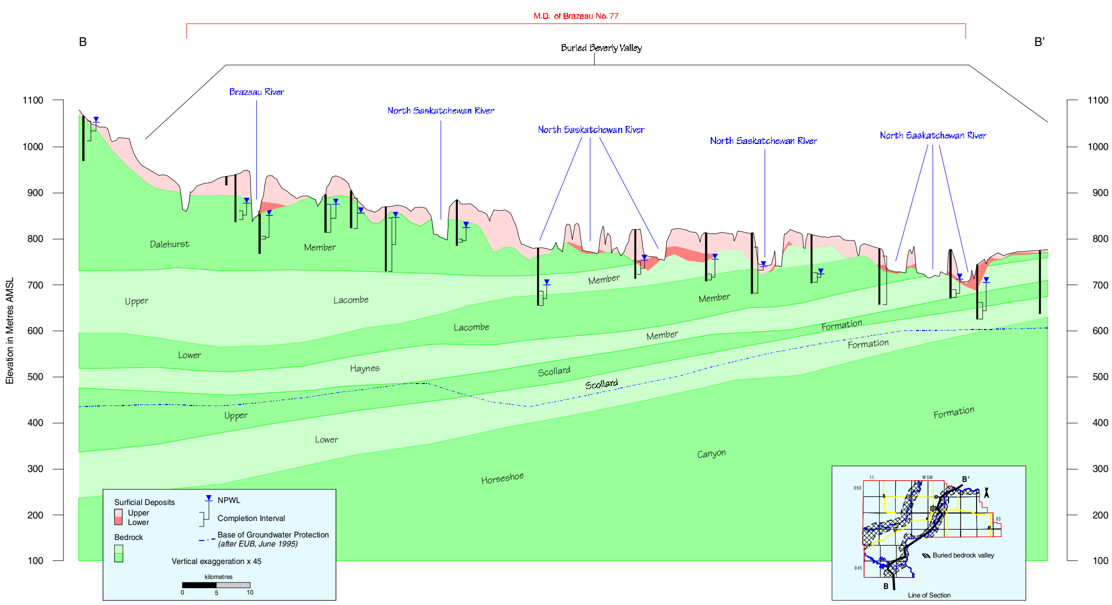

Figure 8. Cross-Section B - B'

The data for 2,231 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 2,231 water wells, more than 99% have surface casing diameters of less than 330 mm and these bedrock water wells have been mainly completed with either a slotted liner or as open hole; there were only eight bedrock water wells that were completed with a water well screen.

Throughout most of the M.D., the upper bedrock is mainly the Paskapoo Formation. In the eastern parts of the M.D., the upper bedrock can include the Scollard and Horseshoe Canyon formations. The Paskapoo Formation consists of the Dalehurst, Lacombe and Haynes members. The Horseshoe Canyon Formation underlies the Lower Scollard Formation. The Horseshoe Canyon Formation is not considered part of the upper bedrock in the Brazeau area, although in some areas it is less than 200 metres below the bedrock surface (Figure 8).

8 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[9] and lacustrine[10] deposits. The lacustrine deposits include clay, silt and fine-grained sand. The *upper surficial deposits* include the more traditional glacial deposits of till[11] and meltwater deposits. In the M.D., pre-glacial materials are expected to be present in association with parts of the Buried Beverly and Onoway valleys.

5.2.1 Geological Characteristics of Surficial Deposits

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

Over the majority of the M.D., the surficial deposits are less than 30 metres thick. The exceptions are mainly in association with the linear bedrock lows where the deposits can have a thickness of up to 80 metres. The main linear bedrock low in the M.D. has been designated as the Buried Beverly Valley, as shown on the adjacent map. This Valley trends from southwest to northeast and coincides with parts of the present-day North Saskatchewan River. The Buried Beverly Valley is approximately six to nine kilometres wide, with local bedrock relief being less than 60 metres. Sand and gravel deposits can be expected in association with this bedrock low, but the thickness of the sand and gravel deposits is expected to be mainly less than 15 metres.

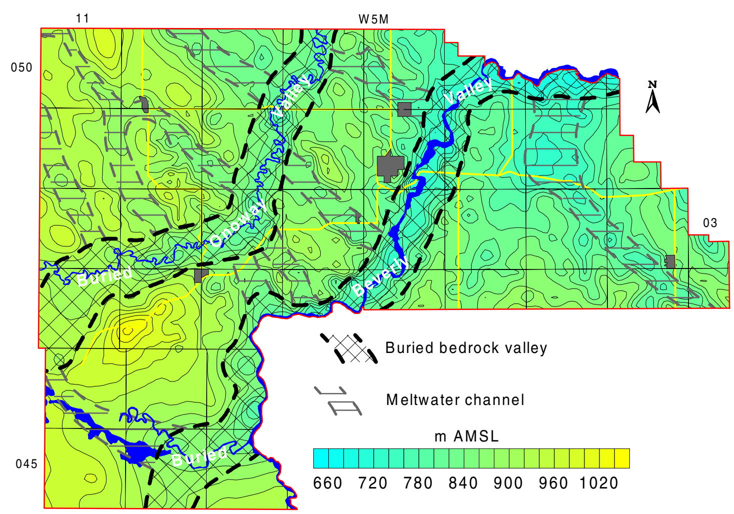

Figure 9. Bedrock Topography

A second linear bedrock low, the Buried Onoway Valley, trends from southwest to northeast and coincides with parts of the present-day Pembina River. The Buried Onoway Valley is approximately four kilometres wide, with local relief being less than 40 metres. Sand and gravel deposits associated with this linear bedrock low can be expected to be less than 15 metres thick.

9 See glossary
10 See glossary
11 See glossary

There are other linear bedrock lows shown on the bedrock topography map. These lows trend northwest to southeast in the M.D. and are indicated as being of meltwater origin. However, because sediments associated with the lower surficial deposits are indicated as being present in these linear bedrock lows, it is possible that the bedrock lows were originally tributaries to the Buried Beverly and Onoway valleys' drainage systems present in the M.D.

The lower surficial deposits are composed mostly of fluvial and lacustrine deposits. Lower surficial deposits occur over less than 25% of the M.D., in association with linear bedrock lows. The total thickness of the lower surficial deposits is mainly less than ten metres, but can be up to 25 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 Beverly and Onoway valleys. The lowest sand and gravel deposits are of fluvial origin, are usually less than five metres thick and may be discontinuous.

The upper surficial deposits are either directly or indirectly a result of glacial activity. The deposits include till, with minor sand and gravel deposits of meltwater origin, which are expected to occur mainly as isolated pockets. The thickness of the upper surficial deposits is mainly less than 30 metres. The greatest thickness of upper surficial deposits occurs mainly in association with the linear bedrock lows; there are several areas in the M.D. where these deposits are not present.

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

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 15% of the M.D., the sand and gravel deposits are more than 50% of the total thickness of the surficial deposits. The areas where the sand and gravel percentages are more than 50% in the M.D. are mainly associated with the linear bedrock lows.

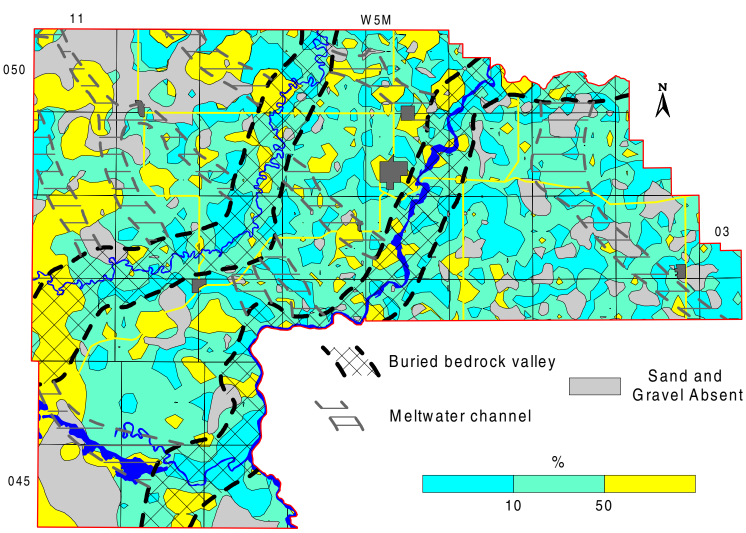

Figure 10. Amount of Sand and Gravel in Surficial Deposits

5.2.2 Sand and Gravel Aquifer(s)

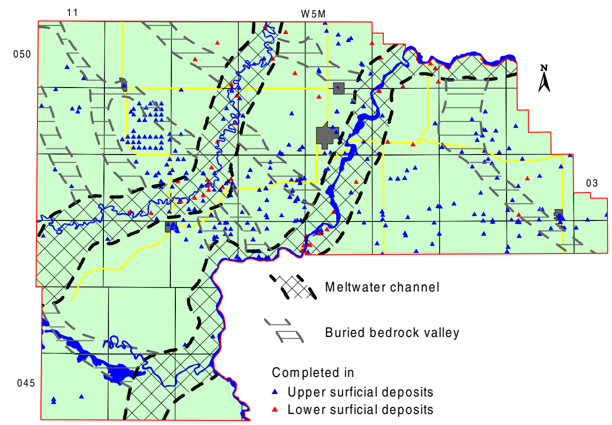

Figure 11. Water Wells Completed in Surficial Deposits

One source of groundwater in the M.D. includes aquifers in the surficial deposits. Since the sand and gravel aquifer(s) are not everywhere, the actual aquifer that is developed at a given location is usually dictated by the aquifer that is present. From the present hydrogeological analysis, 68 water wells are completed in aquifers in the lower surficial deposits and 341 are completed in aquifers in the upper surficial deposits. This number of water wells is nearly four times the number determined to be completed in aquifers in the surficial deposits, based on lithologies given on the water well drilling reports. The larger number is obtained by comparing the elevation of the reported depth of a water well to the elevation of the bedrock surface at the same location. For example, if only the depth of a water well is known, the elevation of the completed depth can be calculated. If the elevation of the completed depth is above the expected elevation of the bedrock surface at the same location, then the water well is determined to be completed in an aquifer in the surficial deposits.

The majority of the water wells completed in the upper surficial deposits in the M.D. are north of the middle of township 047, as shown in Figure 11. The majority of the water wells completed in the lower surficial deposits are located along the Buried Beverly and Onoway valleys.

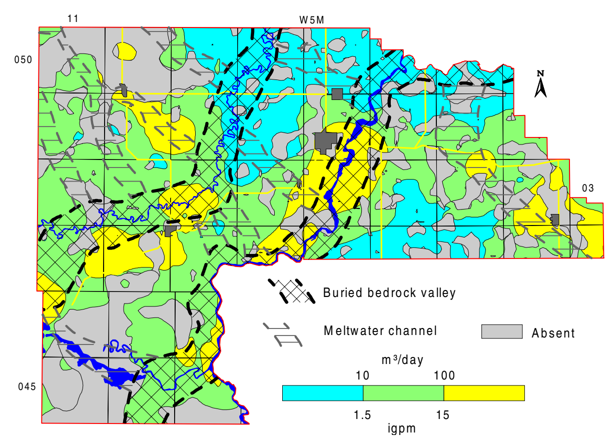

Figure 12. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)

The adjacent map shows expected yields for water wells completed in aquifers in the sand and gravel aquifer(s), based on the aquifers that have been developed by existing water wells. These data show that water wells with yields of less than 100 m³/day from sand and gravel aquifer(s) can be expected in most areas of the M.D. The most notable areas where yields of more than 100 m³/day are expected are mainly in association with linear bedrock lows. In 30% of the M.D., the sand and gravel deposits are not present or, if present, are not saturated.

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, sodium-bicarbonate or sodium-sulfate-type waters, with 90% of the groundwaters having a TDS of less than 1,000 mg/L. The groundwaters with TDS of less than 500 mg/L occur mainly in the western part of the M.D. Groundwaters from the surficial deposits are expected to have dissolved iron concentrations of greater than 1 mg/L.

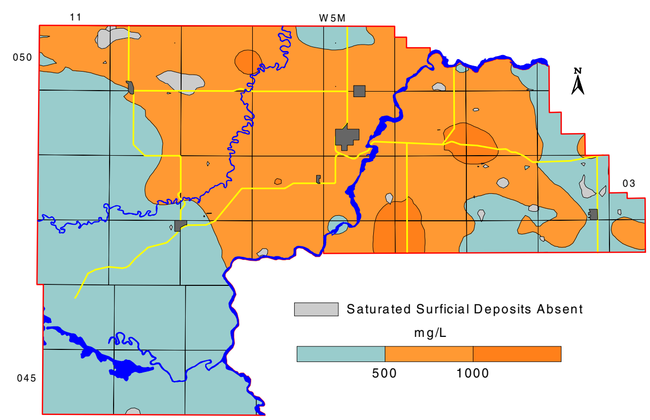

Figure 13. Total Dissolved Solids in Groundwater from Surficial Deposits

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 M.D., the chloride ion concentration is less than 30 mg/L.

Constituent	Groundwater Concentrations from Surficial Water Wells in the M.D. Minimum	Maximum	Average	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	258	1486	591	500
Sodium	6.2	346	133	200
Sulfate	8.2	469	81	500
Chloride	1.1	40	5.5	250
Fluoride	0.1	3.1	0.3	1.5

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

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

Table 4. Groundwater Concentrations from Water Wells Completed in Surficial Deposits

The minimum, maximum and average concentrations of TDS, sodium, sulfate, chloride and fluoride in the groundwaters from water wells completed in the surficial deposits in the M.D. have been compared to the Guidelines for Canadian Drinking Water Quality (GCDWQ) in the adjacent table. On the average, the groundwaters are below the GCDWQ; the exception is TDS, which exceeds the guidelines slightly.

5.2.3 Upper Sand and Gravel Aquifer

The Upper Sand and Gravel Aquifer includes saturated sand and gravel deposits in the upper surficial deposits. These aquifers can directly overlie or be close to the bedrock surface. Saturated sand and gravel deposits are not continuous but are expected over approximately 70% of the M.D.

5.2.3.1 Aquifer Thickness

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

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

The permeability of the Upper Sand and Gravel Aquifer can be high. The high permeability combined with significant thickness leads to an extrapolation of water wells with high yields; however, because the sand and gravel deposits occur mainly as hydraulically discontinuous pockets, the apparent yields of the water wells are limited. The apparent yields for water wells completed in this Aquifer are expected to be mainly less than 100 m³/day. Where the Upper Sand and Gravel Aquifer is absent and where the yields are low, the development of water wells for the domestic needs of single families may not be possible.

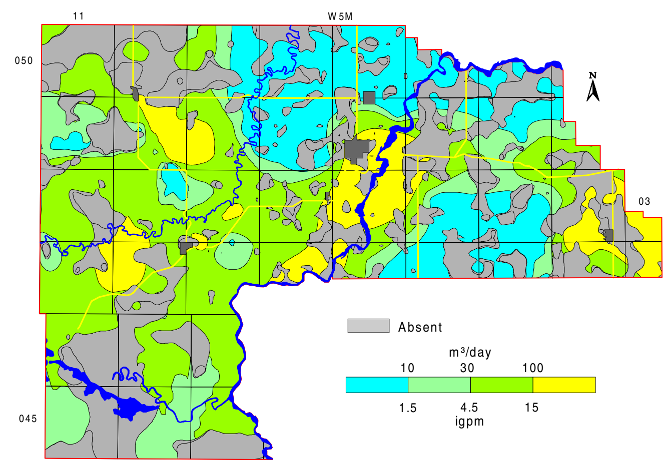

Figure 14. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

5.2.4 Lower Sand and Gravel Aquifer

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

5.2.4.1 Apparent Yield

Apparent yields for water wells completed in the Lower Sand and Gravel Aquifer range from less than 10 m³/day to more than 30 m³/day. The highest yields are expected in the Buried Onoway Valley, in townships 048 and 049, range 09, W5M.

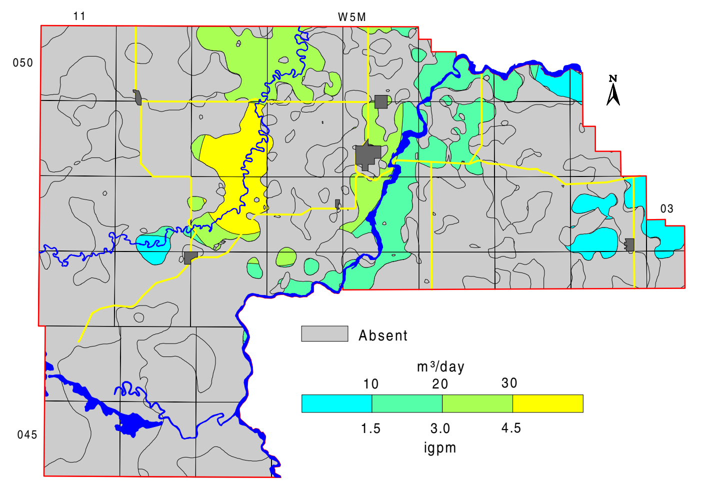

Figure 15. Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer

The Town of Drayton Valley has completed at least some of its water test holes in the Lower Sand and Gravel Aquifer associated with the Buried Beverly Valley. However, the projected long-term yields from these water test holes were not suitable for the Town's needs and water is now obtained from the North Saskatchewan River (UMA, 1971).

Yearly groundwater production records from the EUB database for two water source wells completed in the Lower Sand and Gravel Aquifer associated with the Buried Onoway Valley have average daily yields of up to 180 m³/day. The higher yields are associated with a water source well in 16-22-048-09 W5 and the lower yields are from a water source well in 14-04-048-10 W5M.

5.3 Bedrock

5.3.1 Geological Characteristics

The upper bedrock in the M.D. is the Paskapoo Formation and the Edmonton Group. The Paskapoo Formation consists of cycles of thick, tabular sandstones, siltstone and mudstone layers (Glass, 1990). The Edmonton Group consists of fresh and brackish-water deposits of fine-grained sandstone and silty shale, thick coal seams, and numerous bentonite beds (Carrigy, 1971). The maximum thickness of the Paskapoo Formation can be 800 metres, but in the M.D., the thickness is from 0 to 500 metres. The thickness of the Edmonton Group varies from 300 to 500 metres. The Edmonton Group in the M.D. includes the Scollard, Battle, Whitemud and Horseshoe Canyon formations.

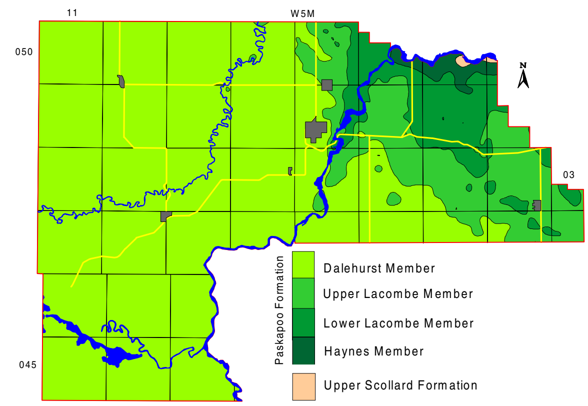

Figure 16. Bedrock Geology

The Paskapoo Formation is the upper bedrock and subcrops in all of the M.D., with the exception of a small area adjacent to the North Saskatchewan River in township 50, ranges 04 and 05, W5M. The Paskapoo Formation in central Alberta consists of the Dalehurst, Lacombe and Haynes members (Demchuk and Hills, 1991).

The Dalehurst Member is the upper bedrock and subcrops in the southwestern two-thirds of the M.D. This Member has a maximum thickness of 300 metres within the M.D. and is mostly composed of shale and siltstone with sandstone, bentonite and coal seams or zones. Two prominent coal zones within the Dalehurst are the Obed-Marsh Coal (up to 30 metres thick) and the Lower Dalehurst Coal (up to 50 metres thick). The bottom of the Lower Dalehurst Coal is the border between the Dalehurst and Upper Lacombe members.

The Lacombe Member underlies the Dalehurst Member and subcrops in most of the northeastern one-third of the M.D. The Lacombe Member has a maximum thickness of 350 metres and has two separate designations: Upper and Lower. The Upper Lacombe Member is mostly composed of shale interbedded with sandstone and has a maximum thickness of 250 metres. The Lower Lacombe Member is composed of sandstone and coal layers. In the middle of the Lower Lacombe Member there is a coal zone, which can be up to five metres thick. The Lower Lacombe Member has a maximum thickness of 100 metres.

The Haynes Member underlies the Lower Lacombe Member and subcrops in the northeastern part of the M.D, in parts of township 50, ranges 04 to 06, W5M. The Haynes Member has a maximum thickness of 100 metres and is composed mainly of sandstone with some siltstone, shale and coal.

The Scollard Formation underlies the Haynes Member and subcrops in the northeastern part of the M.D., in a small area of township 50, ranges 04 and 05, W5M. The Scollard Formation has a maximum thickness of 220 metres within the M.D. and has two separate designations: Upper and Lower. The Upper Scollard consists mainly of sandstone, siltstone, shale and coal seams or zones. Two prominent coal zones within the Upper Scollard are the Ardley Coal (up to 20 metres thick) and the Nevis Coal (up to 3.5 metres thick). The bottom of the Nevis Coal Seam is the border between the Upper and Lower Scollard formations. The Lower Scollard Formation has a maximum thickness of 40 metres and is composed mainly of shale and sandstone. Due to the limited number of control points for the Lower Scollard Formation, there will be no direct review of the Lower Scollard Formation in the text of this report, nor will maps associated with the Formation be included on the CD-ROM.

Beneath the Scollard Formation are two formations having a maximum thickness of 30 metres; the two are the Battle and Whitemud formations. The Battle Formation is composed mainly of claystone, tuff, shale and bentonite, and includes the Kneehills Member, a 2.5- to 30-cm thick tuff bed. The Whitemud Formation is composed mainly of shale, siltstone, sandstone and bentonite. The Battle and Whitemud formations are significant geologic markers, and were used in the preparation of various geological surfaces within the bedrock. Because of the ubiquitous nature of the bentonite in the Battle and Whitemud formations, there is very little significant permeability within these two formations. There will be no direct review of these formations in the test of this report.

The Horseshoe Canyon Formation underlies the Lower Scollard Formation and consists of deltaic[12] and fluvial sandstone, siltstone and shale with interbedded coal seams, bentonite and thin nodular beds of ironstone. Because of the low-energy environment in which deposition occurred, the sandstones, when present, tend to be finer grained. The lower 60 to 70 metres and the upper 30 to 50 metres of the Horseshoe Canyon Formation can include coarser grained sandstone deposits. Because the Horseshoe Canyon Formation is mainly below a depth of 200 metres below the bedrock surface in the M.D., there will be no direct review of the Horseshoe Canyon Formation in the text of this report, nor will maps associated with the Formation be included on the CD-ROM.

5.3.2 Aquifers

Of the 3,571 water wells in the database, 2,231 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 1,340 water wells, a completion depth is available for the majority. In order to make use of the 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 2,983 from 2,231. With the use of the 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 geological units based on their completion intervals. Of the 2,983 bedrock water wells, 2,714 have been assigned a specific geologic unit. The bedrock water wells are mainly completed in the Dalehurst Member, as shown in the adjacent table. Ten percent of the bedrock water wells are likely to have multiple completions, of which 90% have the top of the first completion interval less than 60 metres below ground level.

Geological Unit	No. of Water Wells
Dalehurst	1,755
Upper Lacombe	558
Lower Lacombe	316
Haynes	73
Upper Scollad	10
Lower Scollard	2
Other	269
Total	2,983

Table 5. Completion Aquifer

12 See glossary

There are 1,347 records for bedrock water wells that have apparent yield values, which is 45% of all bedrock water wells. In the M.D., water well yields in the upper bedrock aquifer(s) are mainly less than 150 m³/day. The areas of higher yields that are indicated on the adjacent figure are mainly in the western part of the M.D.

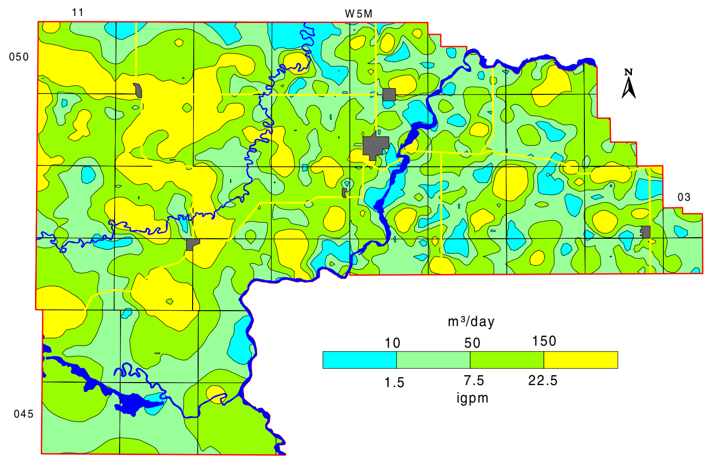

Figure 17. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

There are 1,283 apparent yield values that can be assigned to aquifers associated with specific geologic units. The majority of the water wells completed in the bedrock aquifers have apparent yields that range from 10 to 150 m³/day, as shown in the adjacent table.

Aquifer	No. of Water Wells with Values for Apparent Yields	Number of Water Wells with Apparent Yields <10 m³/day	10 to 150 m³/day	>150 m³/day
Dalehurst	830	128	529	173
Upper Lacombe	241	53	168	20
Lower Lacombe	166	47	94	25
Haynes	39	8	26	5
Upper Scollad	5	1	1	3
Lower Scollard	2	0	2	0
Totals	1,283	237	820	226

Table 6. Apparent Yields of Bedrock Aquifers

5.3.3 Chemical Quality of Groundwater

The TDS concentrations in the groundwaters from the upper bedrock aquifer(s) range from less than 500 to more than 1,000 mg/L. In more than 90% of the area, TDS values are less than 1,000 mg/L.

The relationship between TDS and sulfate concentrations shows that when TDS values in the upper bedrock aquifer(s) exceed 600 mg/L, the sulfate concentrations exceed 100 mg/L. The chloride concentrations in the groundwaters from the upper bedrock aquifer(s) are less than 10 mg/L in more than 70% of the M.D.

In 90% of the M.D., the fluoride ion concentration in the groundwater from the upper bedrock aquifer(s) is less than 1.0 mg/L.

The Piper tri-linear diagrams[13] (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.

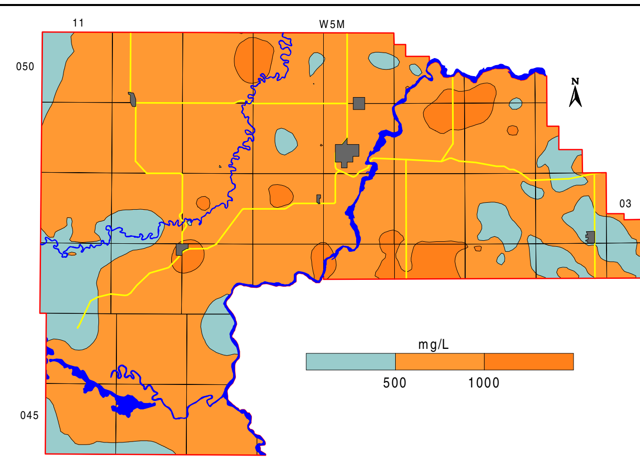

Figure 18. Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

[13] See glossary

5.3.4 Dalehurst Aquifer

The Dalehurst Aquifer comprises the porous and permeable parts of the Dalehurst Member. The Dalehurst Member subcrops under the surficial deposits in the southwestern two-thirds of the M.D. The thickness of the Dalehurst Member varies from less than 20 metres at the eastern edge of the subcrop to more than 300 metres in the western part of the M.D.; in the remaining one-third of the M.D., the Dalehurst Member has been eroded. The thickness of the Dalehurst Member decreases in the vicinity of the North Saskatchewan River Valley as a result of erosional processes.

5.3.4.1 Depth to Top

The depth to the top of the Dalehurst Member is a function of the thickness of the surficial deposits, which ranges from less than 20 metres to more than 80 metres.

5.3.4.2 Apparent Yield

The apparent yields for individual water wells completed through the Dalehurst Aquifer are mainly between 50 and 150 m³/day. The adjacent map indicates that apparent yields of more than 150 m³/day are expected mainly west of range 08, W5M.

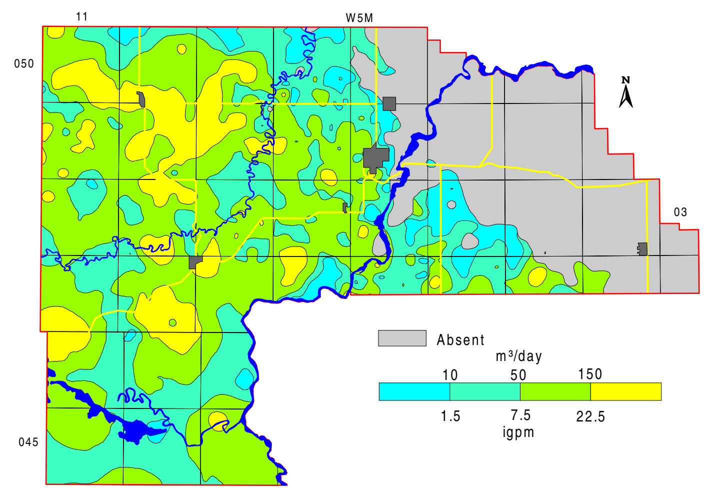

Figure 19. Apparent Yield for Water Wells Completed through Dalehurst Aquifer

Two-hundred and forty-nine water source wells (WSWs) from the EUB database have been designated as being completed in the Dalehurst Aquifer. From 1962 to 1998, a total of 68 million cubic metres of groundwater was pumped from these water source wells. The total number of WSWs varied between 35 and 249. The average daily production per WSW, assuming that each was producing the same amount, varied between 20 and 55 cubic metres per day. An Amoco Canada Petroleum Company Ltd. (Amoco) water source well in 16-05-047-09 W5M is authorized to divert 275 m³/day (Hydrogeological Consultants Ltd. (HCL), 1997b). The water source well is completed in the Dalehurst Aquifer.

5.3.4.3 Quality

The groundwaters from the Dalehurst Aquifer are mainly sodium-bicarbonate or sodium-sulfate types (see CD-ROM). The TDS concentrations are mainly between 500 and 750 mg/L. The higher values are mostly east of range 09, W5M. The sulfate concentrations are usually less than 250 mg/L. Chloride concentrations in the groundwaters from the Dalehurst Aquifer are mainly less than 10 mg/L.

Groundwater from the Amoco water source well (HCL, 1990), that is completed in the Dalehurst Aquifer, has a TDS concentration of 571 mg/L, a sulfate concentration of 30 mg/L and a chloride concentration of 2 mg/L.

5.3.5 Upper Lacombe Aquifer

The Upper Lacombe Aquifer comprises the porous and permeable parts of the Upper Lacombe Member that underlies the Dalehurst Member, and subcrops under the surficial deposits in one half of the northeastern one-third of the M.D. The thickness of the Upper Lacombe Member is mainly between 40 and 100 metres but varies from less than 20 metres at the northeastern edge to more than 160 metres in the southwestern part of the M.D.

5.3.5.1 Depth to Top

The depth to the top of the Upper Lacombe Member ranges from less than 20 metres below ground level where the Formation subcrops in the northeastern part of the M.D. to more than 320 metres in the western part of the M.D. The greatest depth is in areas where the Dalehurst Member is present.

5.3.5.2 Apparent Yield

The apparent yields for individual water wells completed through the Upper Lacombe Aquifer are mainly less than 150 m³/day, based on data from the groundwater database. The adjacent map indicates that apparent yields of more than 150 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 07, W5M, and the map indicates that expected water well yields are between 50 and 150 m³/day in this area.

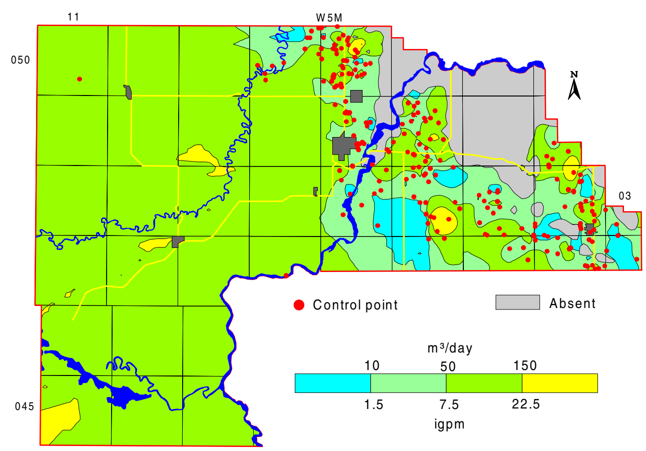

Figure 20. Apparent Yield for Water Wells Completed through Upper Lacombe Aquifer

Six water source wells from the EUB database have been designated as being completed in the Upper Lacombe Aquifer. From 1962 to 1998, a total of 4.2 million cubic metres of groundwater was pumped from these water source wells. In 1972, the groundwater production from the Upper Lacombe Aquifer was 280,000 cubic metres, using four water source wells. This average water source well diversion rate from the Upper Lacombe Aquifer in 1972 is almost four times the average daily diversion per water source well from the Dalehurst Aquifer. By 1975, the production from the Upper Lacombe Aquifer had decreased to an average of 88 m³/day per water source well, 46% of the 1975 production. Because there are no water levels to go with the production, it is not known if the decrease in production was based on water need or on the ability of the Aquifer to provide the larger quantity of groundwater on a long-term basis.

A water supply well completed for the Village of Breton in 1959 in SE 02-048-04 W5M is completed in the Upper Lacombe Aquifer. When the water supply well was drilled, the non-pumping water level was 4.3 metres below the top of casing. In 1976, the highest measured water level in the Upper Lacombe Aquifer was 4.9 metres below the top of casing at the site of a water test hole designated as WTH No. 1-76 (HCL, 1976). In 1976, the population of the Village exceeded 500, an increase of 150 from 1974. Based on a water need of 200 litres per person per day, the average water needs of the Village between 1959 and 1976 were in the order of 60 m³/day. During this same time frame, there was a water-level decline of approximately 0.6 metres in the Aquifer in which the 1959 water supply well is completed. The absence of a significant water-level decline indicates that there has been sufficient recharge to the Aquifer to sustain the Village of Breton's water needs.

An analysis of an aquifer test by Geoscience Consulting Ltd. (Geoscience, 1976) indicates the 1959 water supply well has a projected 20-year safe yield of more than 200 m^3/day. The Village of Breton is in an area designated on the map as having an apparent yield of between 10 and 50 m^3/day. The presence of a higher yield than indicated by the map helps to illustrate that the maps are regional in nature and that the hydrogeological conditions at a given location must be determined by an appropriate groundwater investigation.

A Canadian Occidental Petroleum Ltd. (COPL) water source well in 06-08-050-08 W5M is completed in the Upper Lacombe Aquifer. This water source well is authorized to divert 300 m^3/day (HCL, 1997a).

5.3.5.3 Quality

The groundwaters from the Upper Lacombe Aquifer are mainly a sodium-bicarbonate type (see CD-ROM). The TDS concentrations are expected to be mainly greater than 500 mg/L, with lower values mainly in townships 047 to 049, ranges 03, 04 and 05, W5M where the depth to the bottom of the Upper Lacombe Member is less than 50 metres. The sulfate concentrations in the groundwaters are generally less than 100 mg/L. The chloride concentrations of the groundwaters from the Upper Lacombe Aquifer range from less than 4 to a high of 13 mg/L.

Between 1965 and 1975, eighteen groundwater samples were collected from the Village of Breton 1959 water supply well completed in the Upper Lacombe Aquifer (Geoscience, 1976). The TDS concentrations ranged from 312 to 568 mg/L, sulfate concentrations ranged from 6 to 70 mg/L and chloride concentrations ranged from below the detection limit to 16 mg/L.

Groundwater from the COPL 06-08 water source well completed in the Upper Lacombe Aquifer has a TDS concentration of 514 mg/L, a sulfate concentration of 81 mg/L and a chloride concentration of 9.3 mg/L (HCL, 1995a).

5.3.6 Lower Lacombe Aquifer

The Lower Lacombe Aquifer comprises the porous and permeable parts of the Lower Lacombe Member and subcrops under the surficial deposits in nearly one half of the northeastern one-third of the M.D. The thickness of the Lower Lacombe Member is mainly between 60 and 80 metres but varies from less than 20 metres at the northeastern edge to more than 90 metres in the south-central part of the M.D.

5.3.6.1 Depth to Top

The depth to the top of the Lower Lacombe Member varies from less than 50 metres below ground level in the northeastern part of the M.D. to more than 450 metres in the southwestern part of the M.D.

5.3.6.2 Apparent Yield

The apparent yields for individual water wells completed through the Lower Lacombe Aquifer are mainly less than 10 m³/day. The lower yields presented in the central and extreme northwestern parts of the M.D. could be a result of the gridding procedure used to process a very limited number of data points. The areas where water wells with higher yields are expected are mainly where the Lower Lacombe Member subcrops under the surficial deposits and would be most subjected to weathering processes.

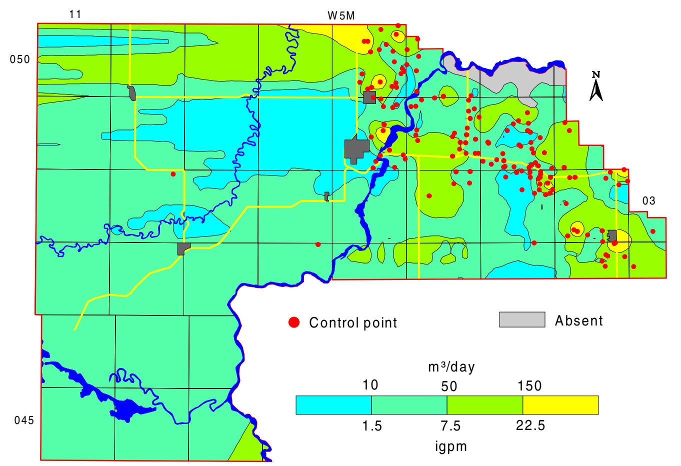

Figure 21. Apparent Yield for Water Wells Completed through Lower Lacombe Aquifer

There are four water source wells from the EUB database that have been designated as being completed in the Lower Lacombe Aquifer. From 1962 to 1998, slightly less than one million cubic metres of groundwater was diverted from these water source wells. The maximum combined production was in 1978, when the average daily production was 140 m³/day, an average of 35 m³/day from each water source well.

5.3.6.3 Quality

The groundwaters from the Lower Lacombe Aquifer are mainly a sodium-bicarbonate type (see CD-ROM). The TDS concentrations are mostly between 500 and 1,000 mg/L. The sulfate concentrations are generally less than 100 mg/L. Chloride concentrations in the groundwaters from the Lower Lacombe Aquifer range from less than 10 to more than 250 mg/L. The chloride values increase toward the western extent of the M.D.

All of the chemical parameter maps exhibit higher values in the southwestern corner of the M.D. as a result of the gridding process using limited data control.

5.3.7 Haynes Aquifer

The Haynes Aquifer comprises the porous and permeable parts of the Haynes Member. The Haynes Member underlies the Lower Lacombe Member and subcrops in the northeastern part of the M.D, in parts of township 50, ranges 04 to 06, W5M. The thickness of the Haynes Member is mainly between 40 and 80 metres but varies from less than 20 metres at the northeastern edge to more than 100 metres in townships 046 and 047, ranges 10 and 11, W5M.

5.3.7.1 Depth to Top

The depth to the top of the Haynes Member is variable, ranging from less than 50 metres in the northeastern part of the M.D. to more than 500 metres in the southwestern part of the M.D.

5.3.7.2 Apparent Yield

The adjacent map shows yields for individual water wells completed through the Haynes Aquifer are mainly between 10 and 50 m³/day. Lower yields in the extreme northwestern and southwestern parts of the M.D. could be a result of the gridding procedure used to process a very limited number of data points.

Four water source wells from the EUB database have been designated as being completed in the Haynes Aquifer. From 1962 to 1986, slightly more than one half million cubic metres of groundwater was diverted from these water source wells. The maximum combined production was in 1973, when the average daily production was 215 m³/day, an average of 54 m³/day from each water source well.

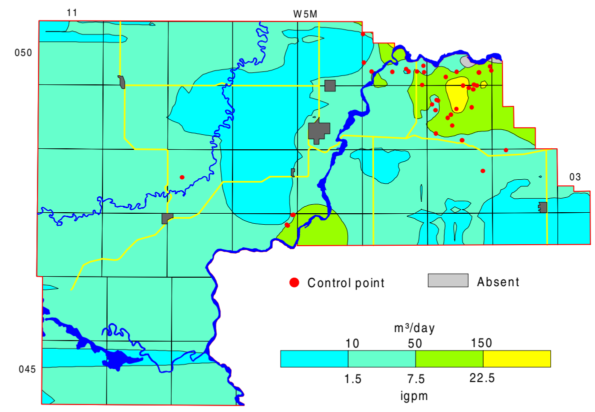

Figure 22. Apparent Yield for Water Wells Completed through Haynes Aquifer

An aquifer test conducted with a water test hole completed in the Haynes Aquifer and drilled in 14-32-048-04 W5M in 1981 (HCL, 1989) indicated a long-term yield of 75 m³/day based on a transmissivity of 0.06 m²/day. Additional data for the Haynes Aquifer are available for a water source well in the Alder Flats area, south of the M.D., in 01-17-045-07 W5M (HCL, 1995b). An extended aquifer test indicated a long-term yield of 45 m³/day based on an effective transmissivity of 0.25 m²/day.

5.3.7.3 Quality

The groundwaters from the Haynes Aquifer are mainly a bicarbonate type (see CD-ROM). The TDS concentrations are mostly between 500 and 750 mg/L. The sulfate concentrations are generally less than 250 mg/L east of the North Saskatchewan River and more than 250 west of the River. Chloride concentrations in the groundwaters from the Haynes Aquifer range from less than four to more than ten mg/L. Groundwater from the Alder Flats area water source well (HCL, 1995b), which is completed in the Haynes Aquifer, has a TDS concentration of 1,245 mg/L, a sulfate concentration of 1 mg/L and a chloride concentration of 360 mg/L. Two chemical parameter maps on the CD-ROM exhibit anomalous values as a result of the gridding process using limited data control.

5.3.8 Upper Scollard Aquifer

The Upper Scollard Aquifer comprises the porous and permeable parts of the Upper Scollard Formation which subcrops under the surficial deposits in a small area in the extreme northeastern part of the M.D. The thickness of the Upper Scollard Member increases to the southwest and can reach more than 140 metres in the southwestern part of the M.D. In general terms, the permeability of the Upper Scollard Aquifer is very low. Higher local permeability can be expected when the depth of burial is less than 100 metres and weathering processes have occurred. In the eastern two-thirds of the M.D., the Upper Scollard is above the Base of Groundwater Protection.

5.3.8.1 Depth to Top

The depth to the top of the Upper Scollard Formation is variable, ranging from less than 50 metres in the northeastern part of the M.D. to more than 550 metres in the southwestern part of the M.D.

5.3.8.2 Apparent Yield

The adjacent map was prepared using five control points from the AEP groundwater database and the summary results of DSTs from the EUB database. The apparent yields for water wells completed through the Upper Scollard Aquifer range from less than 10 to more than 150 m³/day where the Formation is the upper bedrock. However, there are little or no data for most of the M.D. due to the depth to the top of the Formation. There are no water source wells in the EUB database that are indicated as being completed in this Formation in the M.D.

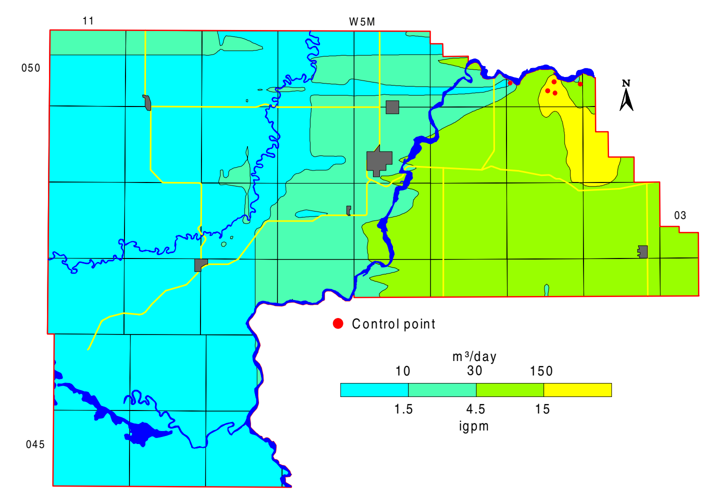

Figure 23. Apparent Yield for Water Wells Completed through Upper Scollard Aquifer

5.3.8.3 Quality

The groundwaters from the Upper Scollard Aquifer are mainly a sodium-bicarbonate type. The TDS concentrations in groundwaters from the Upper Scollard Aquifer are mainly less than 500 mg/L. The higher TDS values are in the eastern third of the M.D. The sulfate concentrations are mainly between 100 and 200 mg/L. Chloride concentrations in the groundwaters from the Upper Scollard Aquifer in the extreme eastern part of the M.D. are expected to be less than 50 mg/L.

6 GROUNDWATER BUDGET

6.1 Hydrographs

There are three locations in the M.D. 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 07-20-049-07 W5M in the vicinity of the Town of Drayton Valley Landfill and one observation water well, AEP Obs WW No. 321, is in 16-18-048-08 W5M. The hydrograph for AEP Obs WW No. 321 is shown on the adjacent figure and in Appendix A; water-level measurements for the other two Obs WWs are also shown in Appendix A, but are of limited use.

AEP Obs WW No. 321 is completed at a depth of 61.0 metres in the Dalehurst Aquifer and is located between the Pembina and North Saskatchewan rivers. Between the Pembina and NSR in townships 047 to 049, ranges 08 and 09, W5M, there are 249 water source wells that have been completed in the Dalehurst Aquifer.

Figure 24. Hydrograph - AEP Observation Water Well No. 321

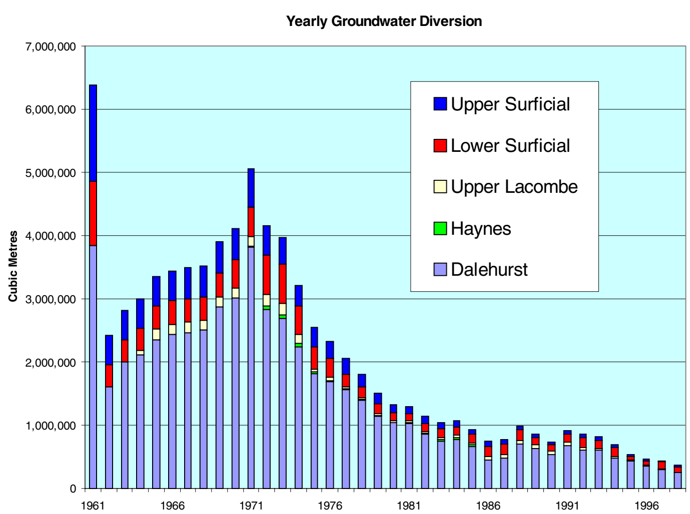

Figure 25. Annual Groundwater Production - WSWs

Within the M.D., there are 400 water source wells that have EUB Well Licences. Of the 400 water source wells, 336 have recorded groundwater production. The groundwater production record begins in 1961 and is on-going. The total groundwater production from the water source wells in 1961 was 6.3 million cubic metres. However, the 1961 value for total production is significantly higher than for 1962. The 1961 value may be a result of estimated amounts rather than measured, or it may be an estimate of the total production for all years up to the end of 1961. From 1962 to 1971, the annual production more than doubled, from 2.5 to 5.0 million cubic metres. From 1971, the annual production has decreased, to less than 0.5 million cubic metres in 1998. The adjacent graph shows the different aquifers from which the groundwater production has been obtained.

Mow-Tech Ltd. operates groundwater-monitoring projects at eight locations in the M.D. At five of the locations, data are available from at least 1990. Four of the five locations are water source wells completed in an aquifer in the Dalehurst Member and one is a water source well completed in an aquifer in the Upper Lacombe Member. The results of these groundwater-monitoring programs show that over a time span that includes up to 40 years, there has been no general lowering of water levels in the Dalehurst or the Upper Lacombe aquifers.

Aquifer Designation	Average Annual Diversion (m^3)	Number of Years	Water Level						Location
			Date	Depth (m)	Date	Depth (m)	Date	Depth (m)	
Dalehurst	17,238	33	12-Feb-66	19.8	02-Dec-88	28.7	29-Dec-98	23.6	08-15-049-09 5
Dalehurst	15,031	38	06-Oct-60	25.8	19-Jan-89	27.4	16-Jan-99	25.8	06-34-049-08 5
Dalehurst	26,440	6			09-Aug-90	15.9	24-Jul-97	16.6	16-05-047-09 5
Dalehurst	28,983	9			09-May-90	18.0	27-Jul-98	22.0	06-16-047-10 5
Upper Lacombe	57,435	35	13-Jul-64	12.2	10-Nov-88	11.3	29-Nov-98	9.6	06-08-050-08 5

Table 7. Groundwater-Monitoring Summary

The water source well completed in the Upper Lacombe Aquifer has been used to divert slightly more than two million cubic metres of groundwater between 1961 and 1998. The diversion peaked in the early 1970s with yearly production of more than 160,000 cubic metres. The maximum diversion in recent years was in 1990, when the diversion was 50,000 cubic metres. Since 1990, the annual groundwater diversion has decreased to less than 10,000 cubic metres and the water level has risen slightly more than three metres, to a level of 9.6 metres below the top of casing. The water well drilling report indicates that when the water source well was drilled in 1964, the water level was 12.2 metres below top of casing. While the water level of 12.2 metres may not be exact, the data indicate that there has been no significant lowering of the water level in the Aquifer after the diversion of more than two million cubic metres of groundwater from the Upper Lacombe Aquifer.

The total reported groundwater production from all of the WSWs in the M.D. of Brazeau from 1961 to 1998 has been 110 million cubic metres, with 74% having been obtained from aquifers in the upper bedrock and 3% from sand or gravel aquifers in the surficial deposits. The remaining 23% of the groundwater production is from aquifers that cannot be identified from the information provided by the EUB for the individual water source wells. The total production of 110 million cubic metres is 89,000 acre-feet.

6.2 Groundwater Flow

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

The flow through each aquifer assumes that by taking a large enough area, an aquifer can be considered as homogeneous, the average gradient can be estimated from the non-pumping water-level surface, and flow takes place through the entire width of the aquifer. Based on these assumptions, the estimated 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					**2,820**	**98**
Upper Sand and Gravel (Pembina Valley)	6	0.003	50	Southeast and northwest	900	
Upper Sand and Gravel (North Saskatchewan Valley)	8	0.003	80	Southeast and northwest	1,920	
Lower Sand and Gravel					**320**	**913**
Lower Sand and Gravel (Pembina Valley)	10	0.002	8	Southeast and northwest	160	
Lower Sand and Gravel (North Saskatchewan Valley)	10	0.002	8	Southeast and northwest	160	
				Surficial Deposits Total	**3,140**	**1,011**
Dalehurst						
	10	0.0125	20	Northeast	3,000	
	10	0.0125	20	Southwest - North	3,000	
	10	0.0125	25	Northwest	3,000	
	10	0.0125	25	Southeast - South	3,000	
				Total	**12,000**	**13,369**
Upper Lacombe						
	20	0.006	30	East	4,000	
	20	0.008	10	Northwest	2,000	
	20	0.003	20	Northeast	1,000	
	20	0.004	20	Southwest	2,000	
				Total	**9,000**	**3,525**
Lower Lacombe						
	15	0.004	30	East	2,000	
	15	0.005	20	Northwest	2,000	
				Total	**4,000**	**1,958**
Haynes						
	10	0.003	60	North	2,000	
				Total	**2,000**	**710**
Upper Scollard						
	45	0.003	30	Northwest	4,000	
				Total	**4,000**	**3,110**

Table 8. Groundwater Budget

The above table indicates that there is more groundwater flowing through the aquifers than has been authorized to be diverted from the individual aquifers, except for the Dalehurst Aquifer. Although values have been calculated for the flow through both the Upper Sand and Gravel Aquifer and the Lower Sand and Gravel Aquifer, there was difficulty in obtaining a reasonable value for hydraulic gradient. 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.

There is no direct link between the EUB Well Licence and the groundwater diversion authorized by AEP. Likewise, there is no direct link between the information in the AEP Groundwater Database and either the EUB Well Licence or the AEP approval. Mow-Tech Ltd. has attempted to establish the link with a reasonable degree of certainty through their groundwater database. From a total of 336 water source wells, it has been possible to link 119 and to compare the diversion reported to the EUB with the diversion authorized by AEP. The total average daily diversion in 1996 was 7,921 cubic metres. The reported diversion was 25% of the authorized diversion, with the diversion from five points exceeding the authorized diversion.

In the case of agriculture, the water requirement based on the 1996 census is 5,650 cubic metres per day, while the authorized diversion is 376 cubic metres per day.

6.2.1 Quantity of Groundwater

An estimate of the volume of groundwater stored in the sand and gravel aquifers in the surficial deposits is 0.5 to 3.0 cubic kilometres. This volume is based on an areal extent of 3,300 square kilometres and a saturated sand and gravel thickness of three metres. The variation in the total volume is based on the value of porosity that is used for the sand and gravel. One estimate of porosity is 5%, which gives the low value of the total volume. The high estimate is based on a porosity of 30% (Ozoray, Dubord and Cowen, 1990).

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

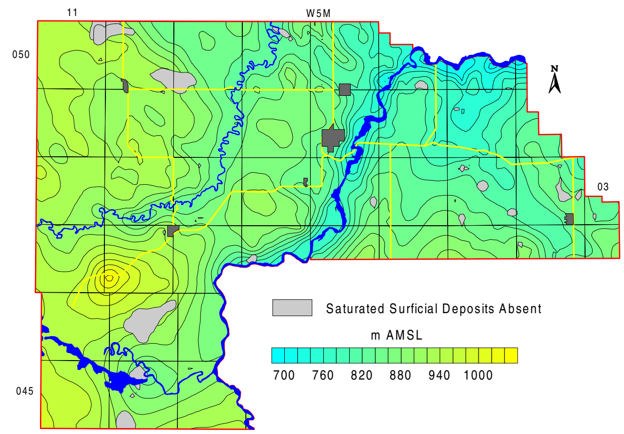

Figure 26. Non-Pumping Water-Level Surface in Water Wells Completed in Surficial Deposits

6.2.2 Recharge/Discharge

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

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

6.2.2.1 Surficial Deposits/Bedrock Aquifers

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

The adjacent map shows that, in more than 60% of the M.D., there is a downward hydraulic gradient from the surficial deposits toward the upper bedrock aquifer(s). Areas where there is an upward hydraulic gradient from the bedrock to the surficial deposits are mainly in the vicinity of the North Saskatchewan, Brazeau and Pembina river valleys. The remaining parts of the M.D. 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.

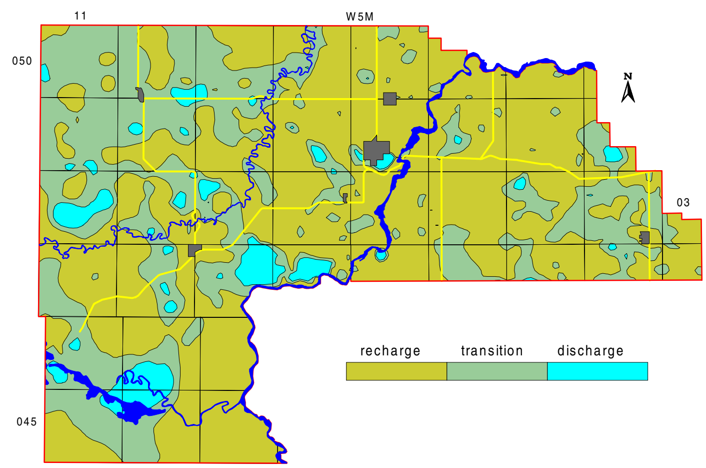

Figure 27. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)

6.2.2.2 Bedrock Aquifers

Recharge to the bedrock aquifers within the M.D. takes place from the overlying surficial deposits and from flow in the aquifer from outside the M.D. The recharge/discharge maps show that generally for most of the M.D., there is a downward hydraulic gradient from the surficial deposits to the bedrock, i.e. 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 areas identified as ones of recharge have an increased susceptibility to risk of groundwater contamination as a result of activities on the land surface.

The hydraulic relationship between the surficial deposits and the Dalehurst Aquifer indicates that in more than 50% of the M.D. where the Dalehurst Aquifer is present, there is a downward hydraulic gradient. Discharge areas for the Dalehurst Aquifer are associated with the edge of the Aquifer and the three river valleys. The hydraulic relationship between the surficial deposits and the remainder of the bedrock aquifers present in the M.D. indicates there is mainly a transitional flow.

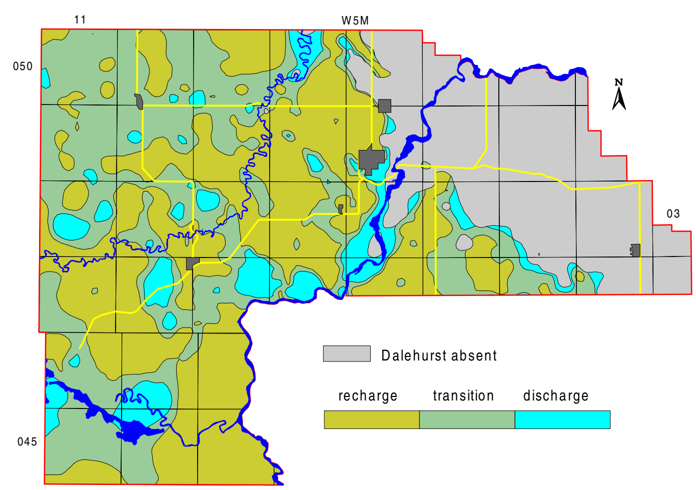

Figure 28. Recharge/Discharge Areas between Surficial Deposits and Dalehurst Aquifer

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 3,227 records in the area of the M.D. with lithological descriptions, 169 have sand and gravel within one metre of ground level. In the remaining 3,058 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.

Contamination of groundwater can occur from multiple completions within a water well. This process provides a means for an inter-aquifer exchange of groundwater. By allowing inter-aquifer exchange of groundwater, contamination of one aquifer occurs as a result of groundwater flow from another aquifer. This process also allows the draining of some aquifers and the over-supplying of others. Contamination of groundwater from unplugged seismic shot holes has not been shown to be a source of groundwater contamination in Alberta.

7.1 Risk of Groundwater Contamination Map

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

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

Table 9. Risk of Groundwater Contamination Criteria

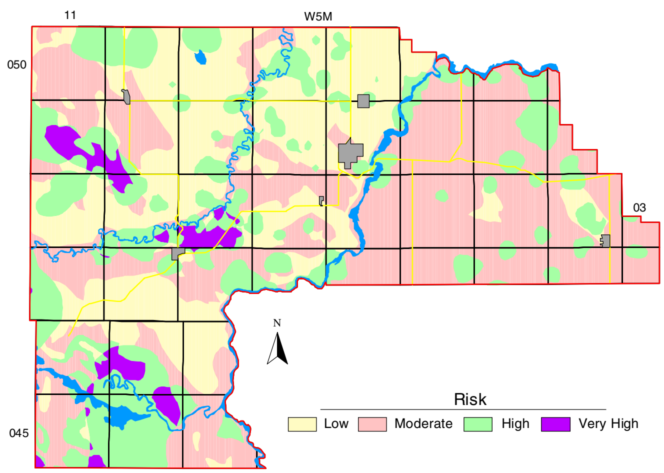

Figure 29. Risk of Groundwater Contamination

The Risk of Groundwater Contamination map shows that, in less than 30% of the M.D., there is a high or very high risk of the groundwater being contaminated. These areas would be considered the least desirable ones for a development that has a product or by-product that could cause groundwater contamination. However, because the map has been prepared as part of a regional study, the designations are a guide only; detailed hydrogeological studies must be completed at any proposed development site to ensure the groundwater is protected from possible contamination. At all locations, good environmental practices should be exercised in order to ensure that groundwater contamination would not affect groundwater quality.

8 RECOMMENDATIONS

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

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

The quality of the data in the groundwater database is affected by two factors: a) the technical training of the persons collecting the data, and b) the quality control of the data. The possible options to upgrade the database include the creation of a "super" database, which includes only verified data. The first step would be to field-verify the 52 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 it is possible to divert at least 110 million cubic metres of groundwater from aquifers in the M.D. While water-level data are sketchy, the present indications are that the diversion has had no long-term negative impact on the groundwater resource. It is recommended that a computer model be prepared in an attempt to better understand the groundwater availability in the upper bedrock aquifer(s). This would be particularly important for the Dalehurst Member between the Pembina and North Saskatchewan rivers.

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

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 52 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 PFRA to transpose the paper form to the electronic form should be used to allow for a technical review of the data and follow-up discussions with the drillers.

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

Groundwater is a renewable resource and it must be managed.

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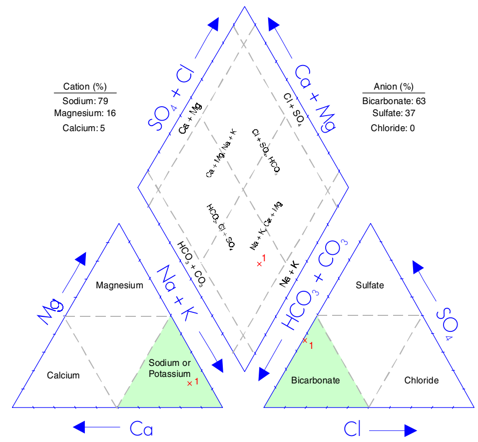
10 GLOSSARY

AEP	Alberta Environmental Protection
AMSL	above mean sea level
Aquifer	a formation, group of formations, or part of a formation that contains saturated permeable rocks capable of transmitting groundwater to water wells or springs in economical quantities.
Available Drawdown	in a confined aquifer, the distance between the non-pumping water level and the top of the aquifer
	in an unconfined aquifer (water table aquifer), two thirds of the saturated thickness of the aquifer
Deltaic	a depositional environment in standing water near the mouth of a river
DEM	Digital Elevation Model
DST	drill stem test
EUB	Alberta Energy and Utilities Board
Fluvial	produced by the action of a stream or river.
Friable	poorly cemented
GCDWQ	Guidelines for Canadian Drinking Water Quality
Hydraulic Conductivity	the rate of flow of water through a unit cross-section under a unit hydraulic gradient; units are length/time
km	kilometre
Kriging	a geo-statistical method for gridding irregularly-spaced data (Cressie, 1990)
Lacustrine	fine-grained sedimentary deposits associated with a lake environment and not including shore-line deposits
Lsd	Legal Subdivision
m	metres
mm	millimetres
m^2/day	metres squared per day
m^3	cubic metres
m^3/day	cubic metres per day
mg/L	milligrams per litre
NPWL	non-pumping water level
NSR	North Saskatchewan River
Obs WW	Observation Water Well
PFRA	Prairie Farm Rehabilitation Administration

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



Piper Tri-Linear Diagram

Surficial Deposits — includes all sediments above the bedrock

TDS — Total Dissolved Solids

Till — a sediment deposited directly by a glacier that is unsorted and consisting of any grain size ranging from clay to boulders

Transmissivity — the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient: a measure of the ease with which groundwater can move through the aquifer

Apparent Transmissivity: the value determined from a summary of aquifer test data, usually involving only two water-level readings

Effective Transmissivity: the value determined from late pumping and/or late recovery water-level data from an aquifer test

Aquifer Transmissivity: the value determined by multiplying the hydraulic conductivity of an aquifer by the thickness of the aquifer

WSW — Water Source Well or Water Supply Well

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

Apparent Yield: based mainly on apparent transmissivity

Long-Term Yield: based on effective transmissivity

11 CONVERSIONS

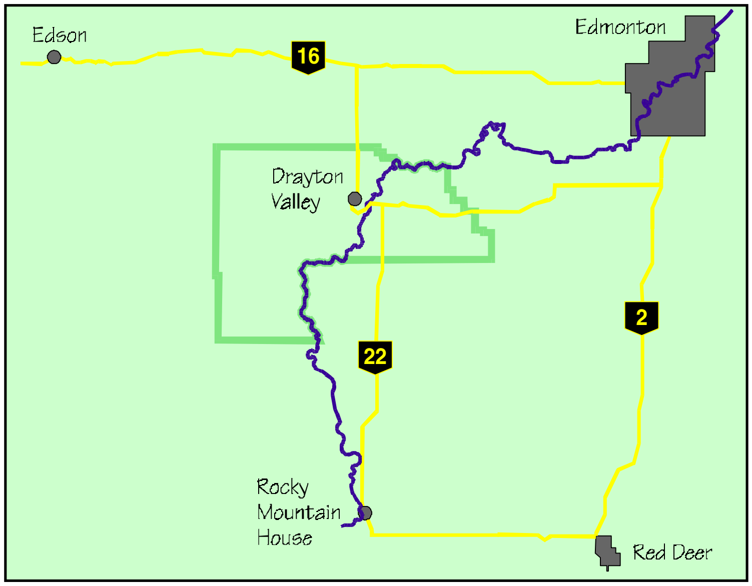
Mulitiply	by	To Obtain
Length/Area		
feet	0.304 785	metres
metres	3.281 000	feet
hectares	2.471 054	acres
centimetre	0.032 808	feet
centimetre	0.393 701	inches
acres	0.404 686	hectares
inchs	25.400 000	millimetres
miles	1.609 344	kilometres
kilometer	0.621 370	miles (statute)
square feet (ft^2)	0.092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

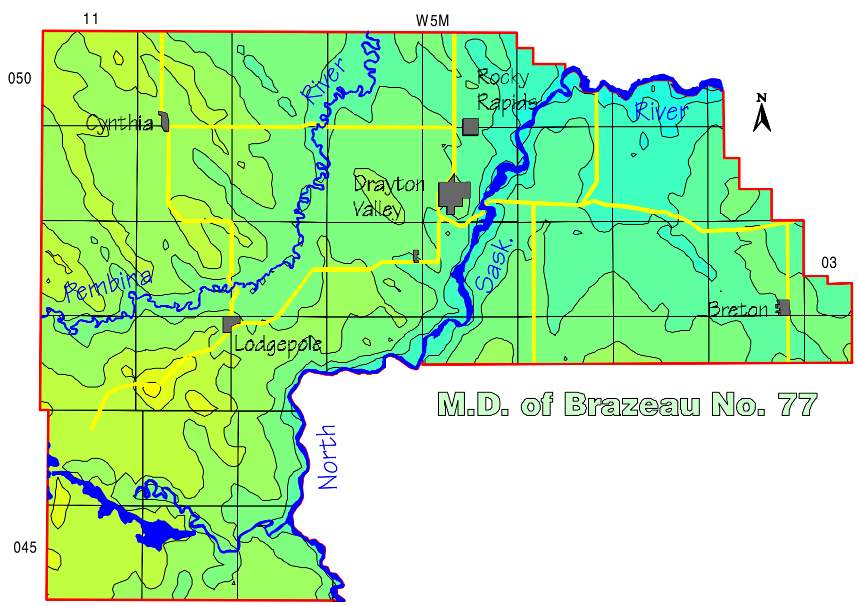
M.D. OF BRAZEAU NO. 77

Appendix A

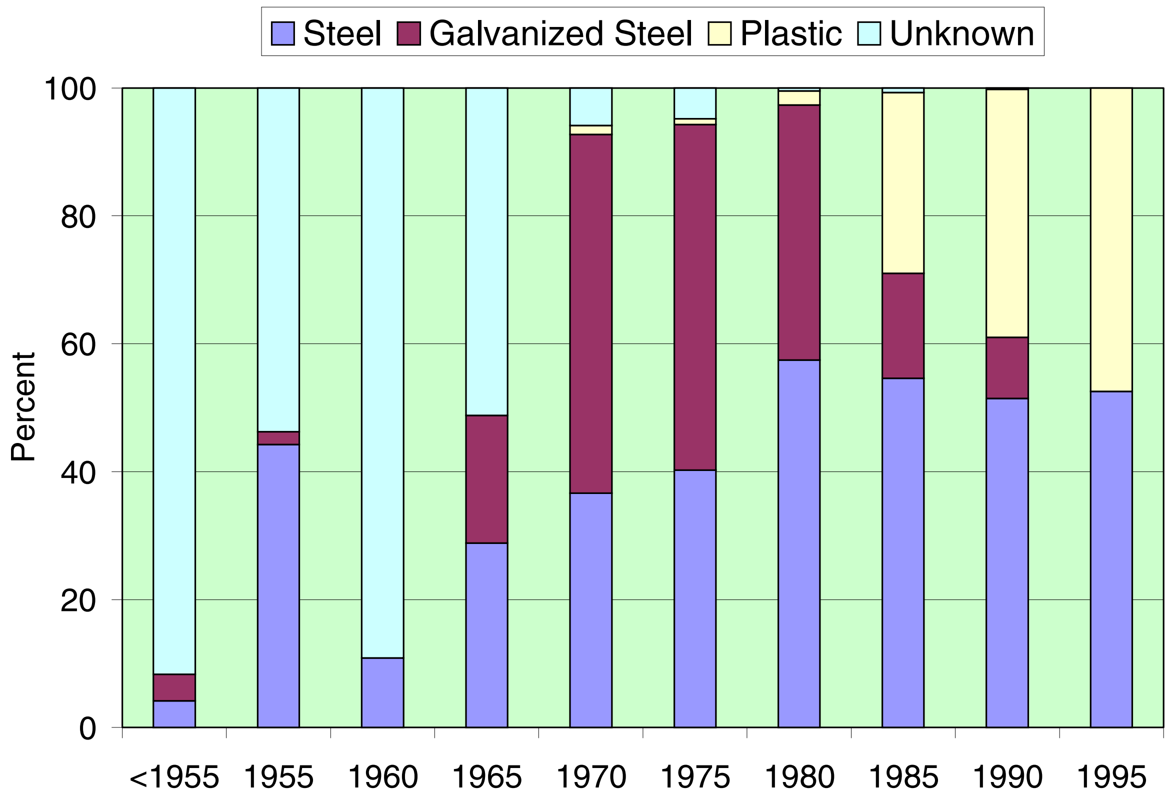
HYDROGEOLOGICAL MAPS AND FIGURES

Index Map

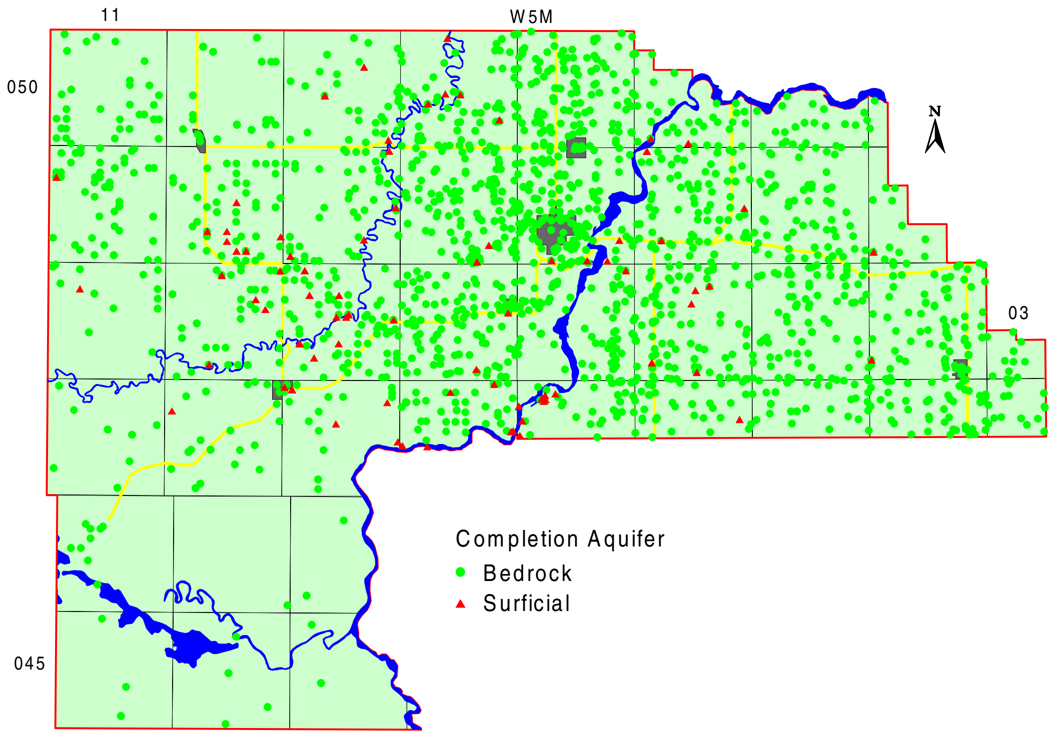

Edson
Edmonton
16
Drayton
Valley
2
22
Rocky
Mountain
House
Red Deer


11
W5M
050
045
03
N
Cynthia
River
Rocky
Rapids
River
Drayton
Valley
Sask.
Pembina
Lodgepole
Breton
North
M.D. of Brazeau No. 77

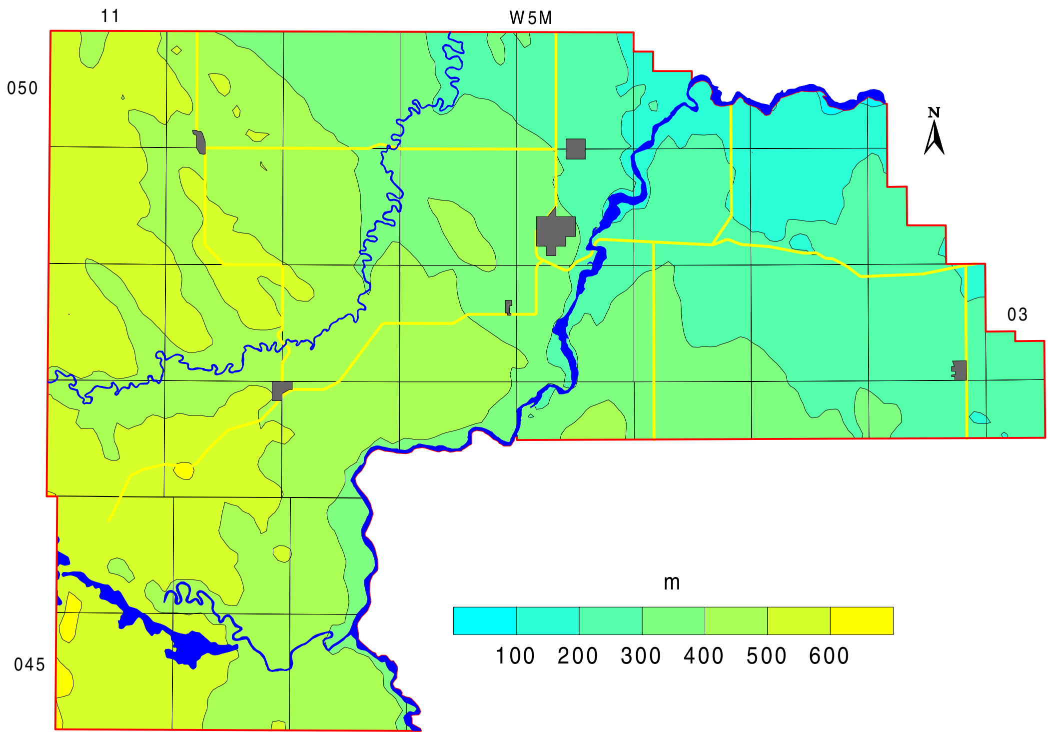
Surface Casing Types used in Drilled Water Wells

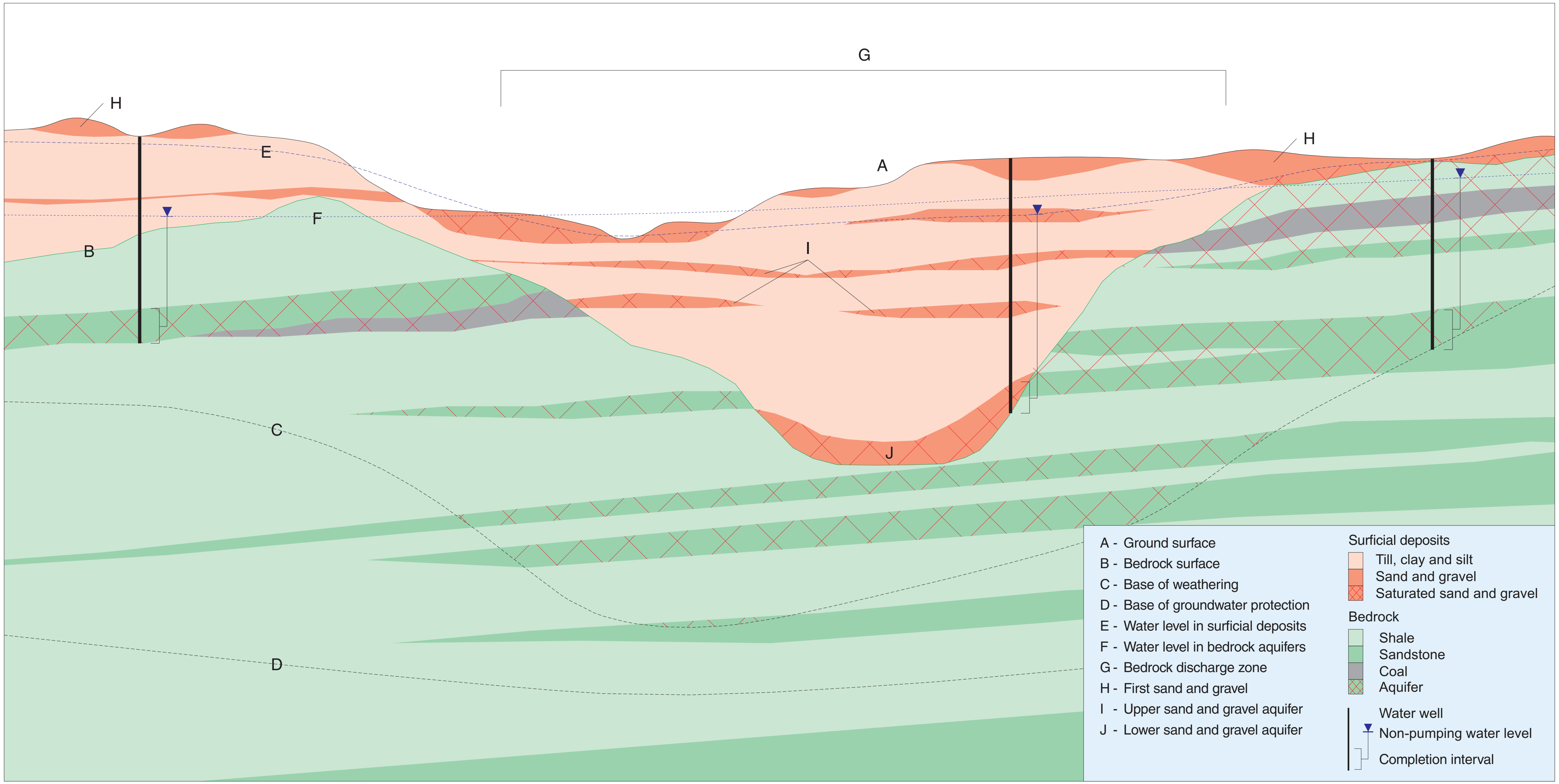


Location of Water Wells



Depth to Base of Groundwater Protection

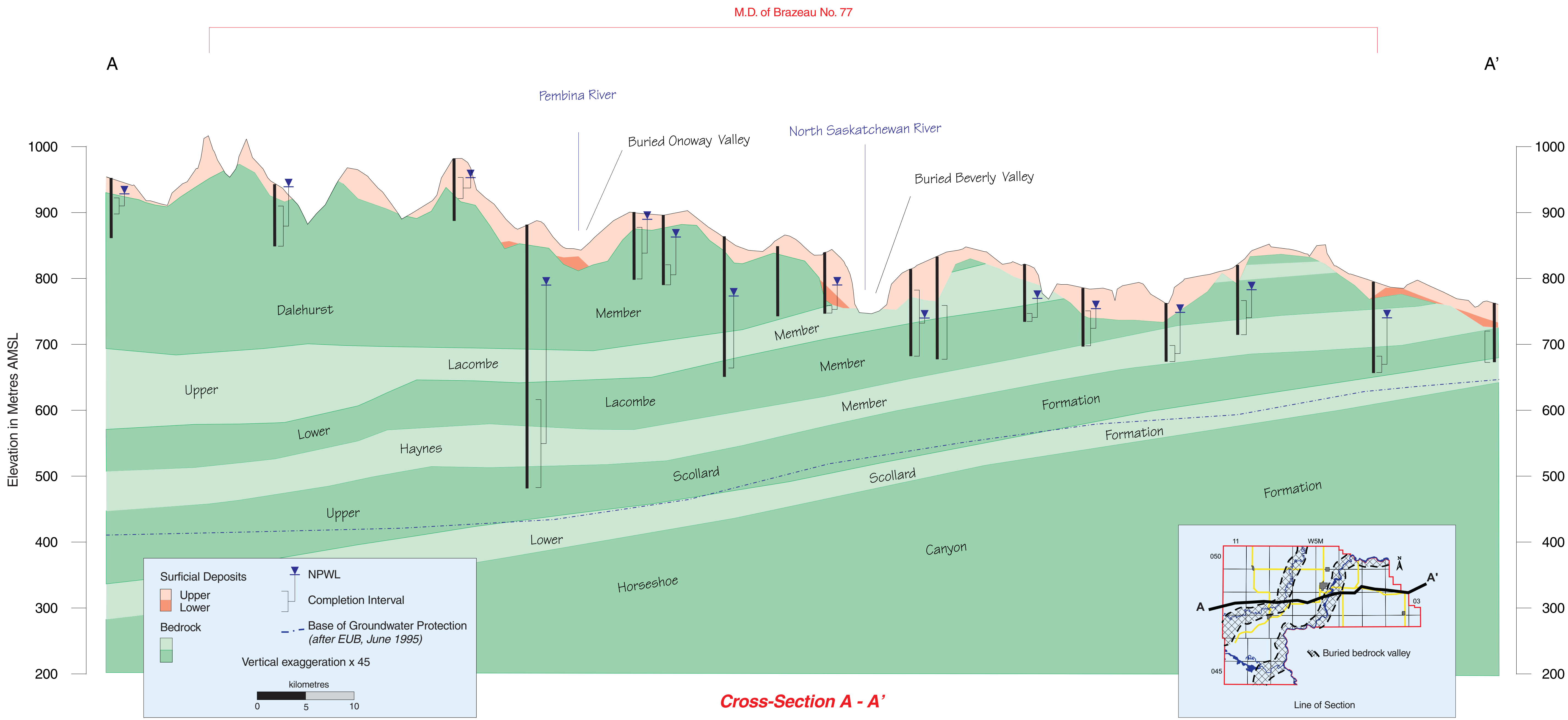




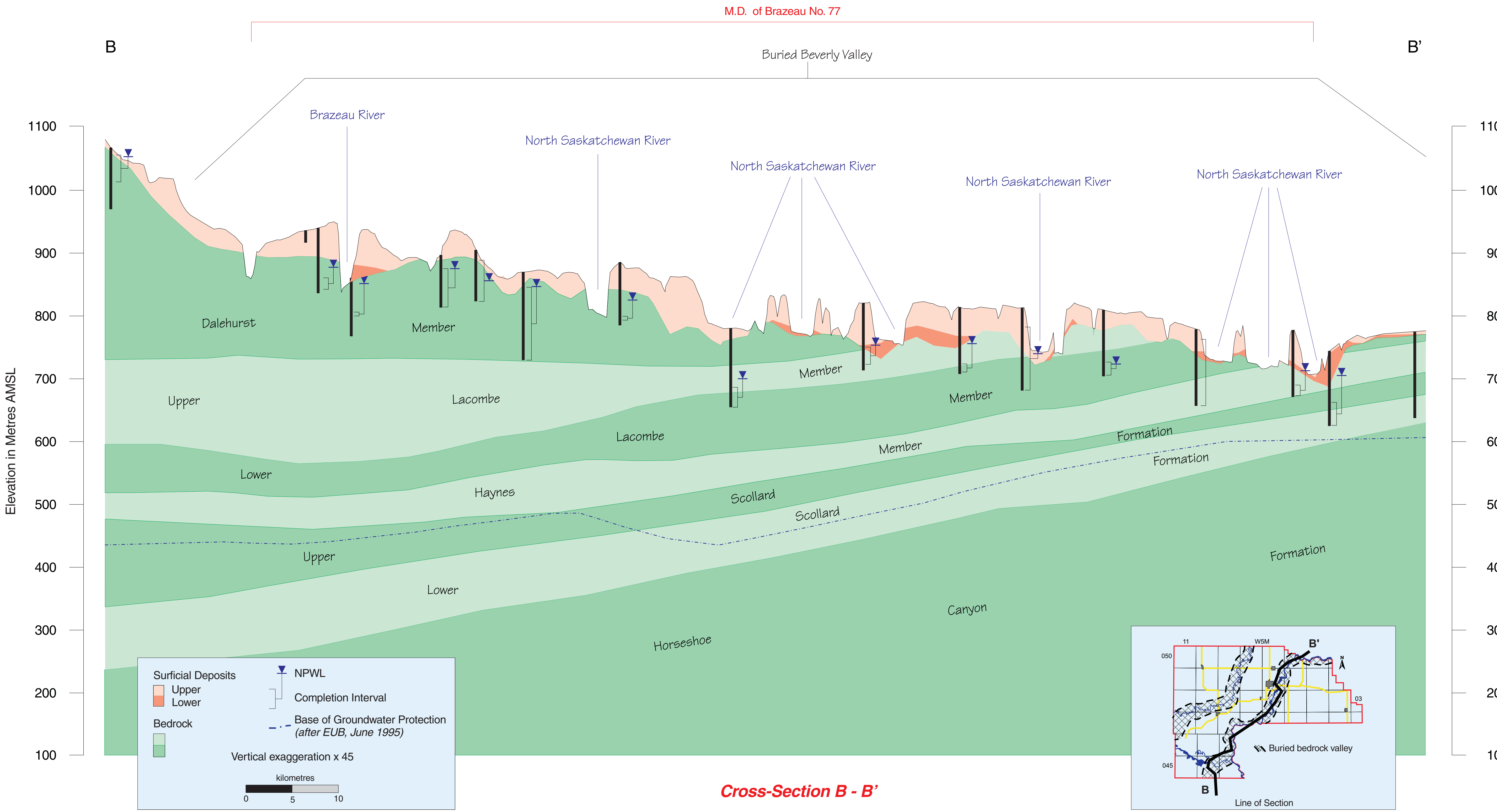
Generalized Cross-Section
(for terminology only)

		Group and Formation			Member		Zone	
Lithology	Lithologic Description	Thickness (m)	Designation		Thickness (m)	Designation	Thickness (m)	Designation
	sand, gravel, till, clay, silt	<70	Surficial Deposits		<70	Upper	<20	First Sand and Gravel
					<30	Lower		
	sandstone, shale, coal	<800	Paskapoo Formation	Dalehurst Member	<300			Obed-Marsh Coal Zone
								Lower Dalehurst Coal Zone
				Lacombe Member	100-250	Upper		Upper Sandstone
								Middle Sandstone
								Lower Sandstone
					30-100	Lower		Lower Lacombe Coal Zone
				Haynes Member	20-100			
	shale, sandstone, coal	60-220		Scollard Formation	60-150	Upper	<2	Upper Ardley Coal Zone
							~20	Ardley Coal Zone (main seam)
							<1	Nevis Coal Seam
					20-80	Lower		

Geologic Column



Cross-Section A - A'



Cross-Section B - B'

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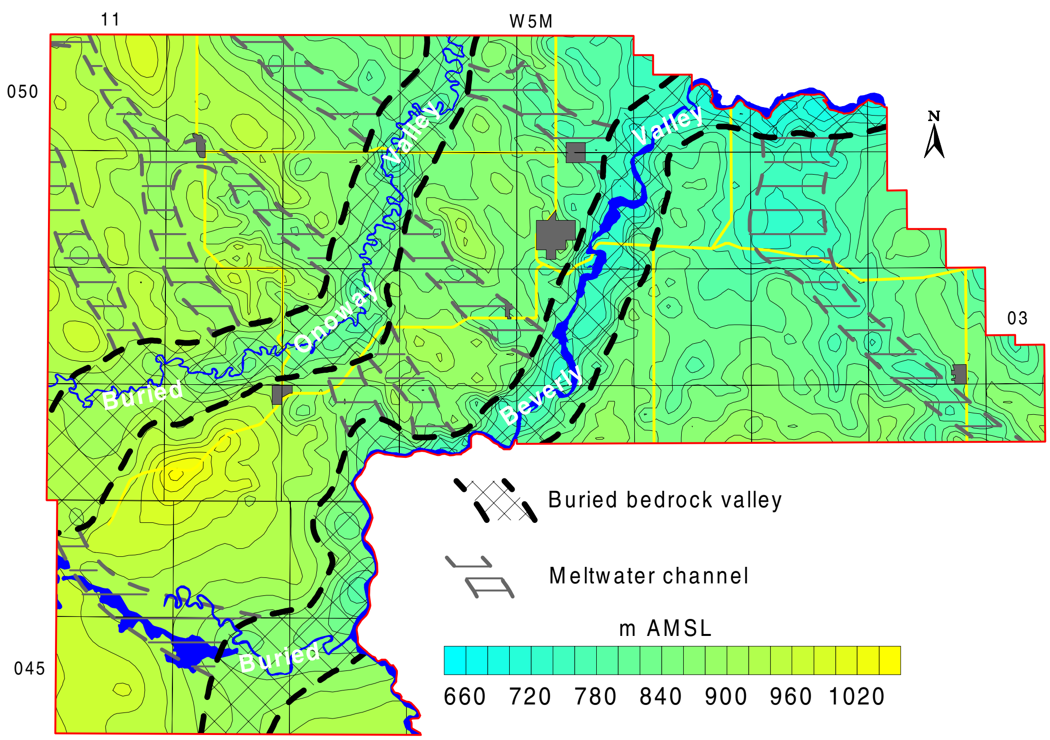
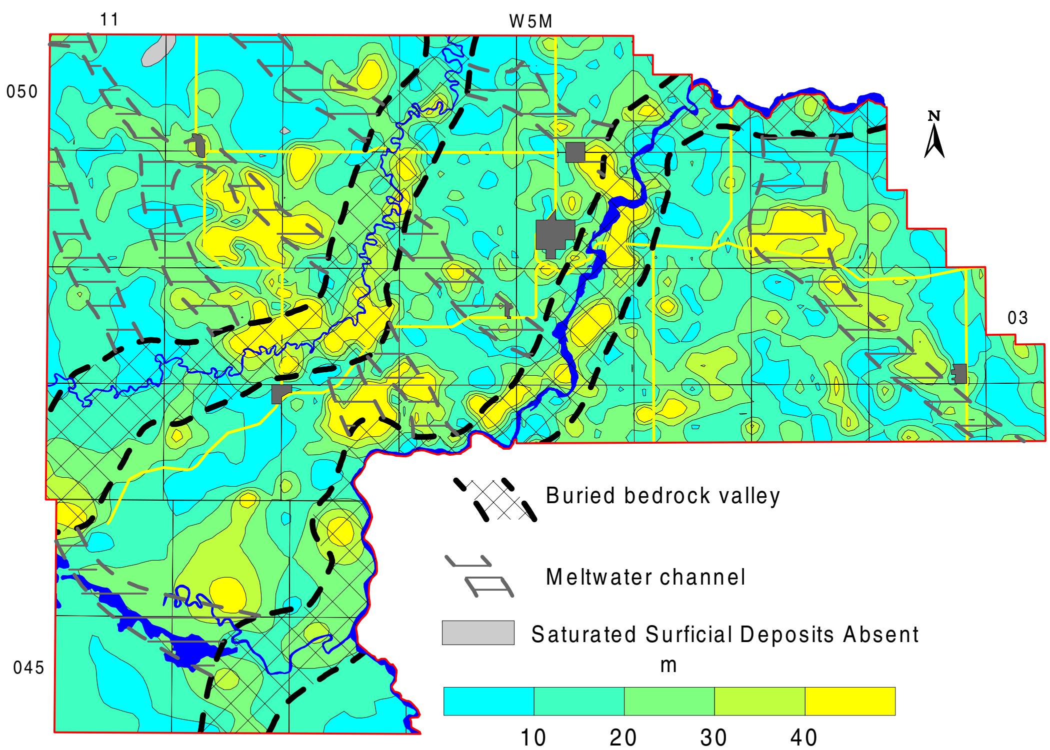
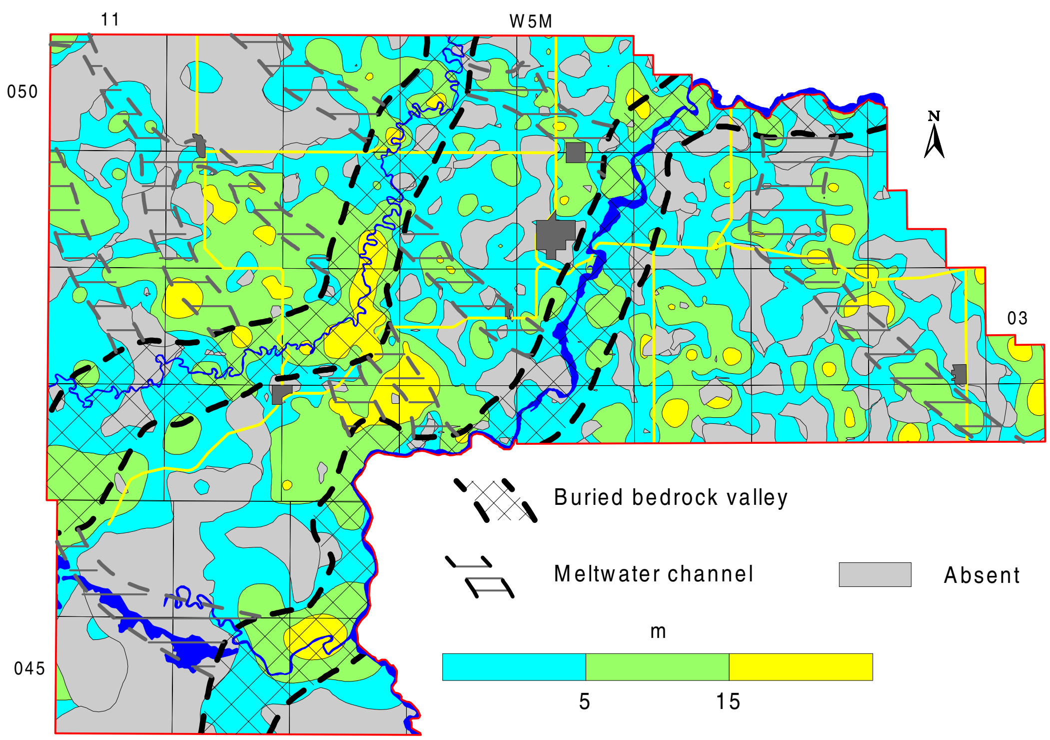
Bedrock Topography



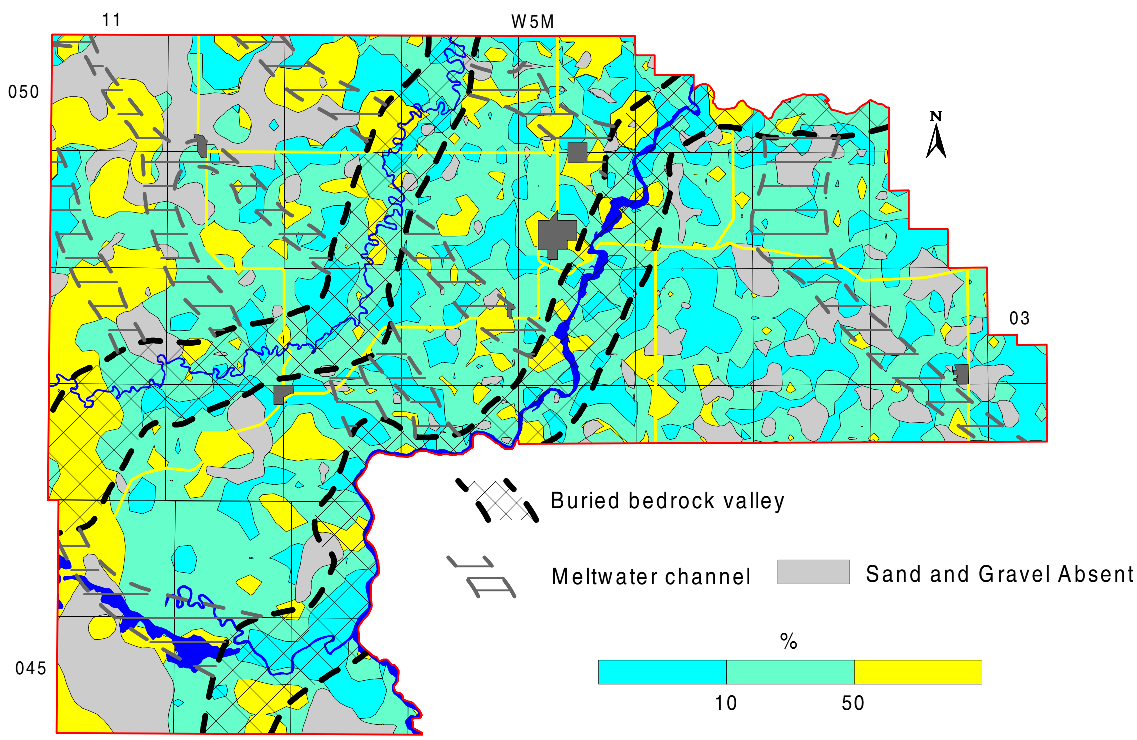
Thickness of Surficial Deposits



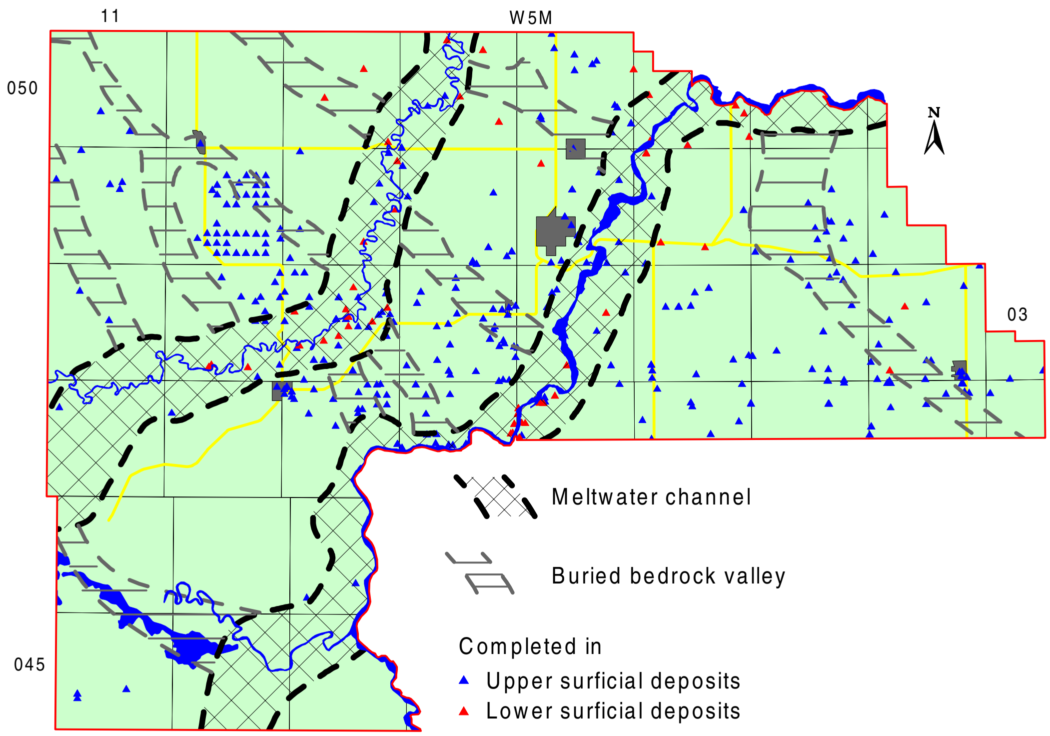
Thickness of Sand and Gravel Aquifer(s)



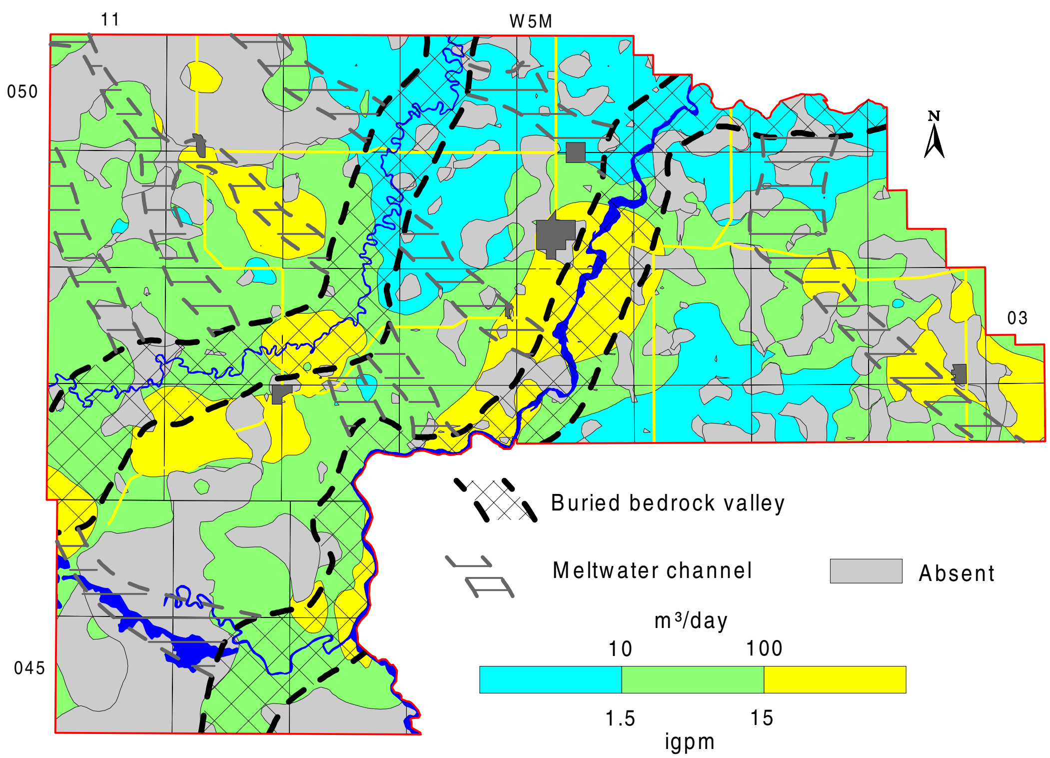
Amount of Sand and Gravel in Surficial Deposits



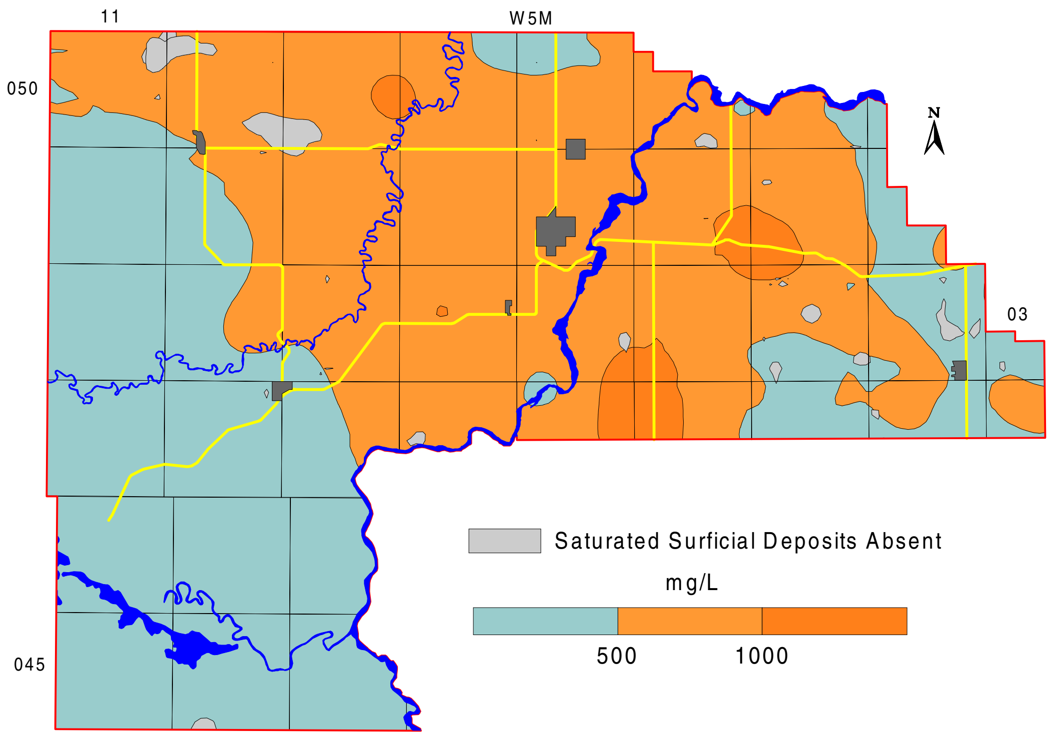
Water Wells Completed in Surficial Deposits



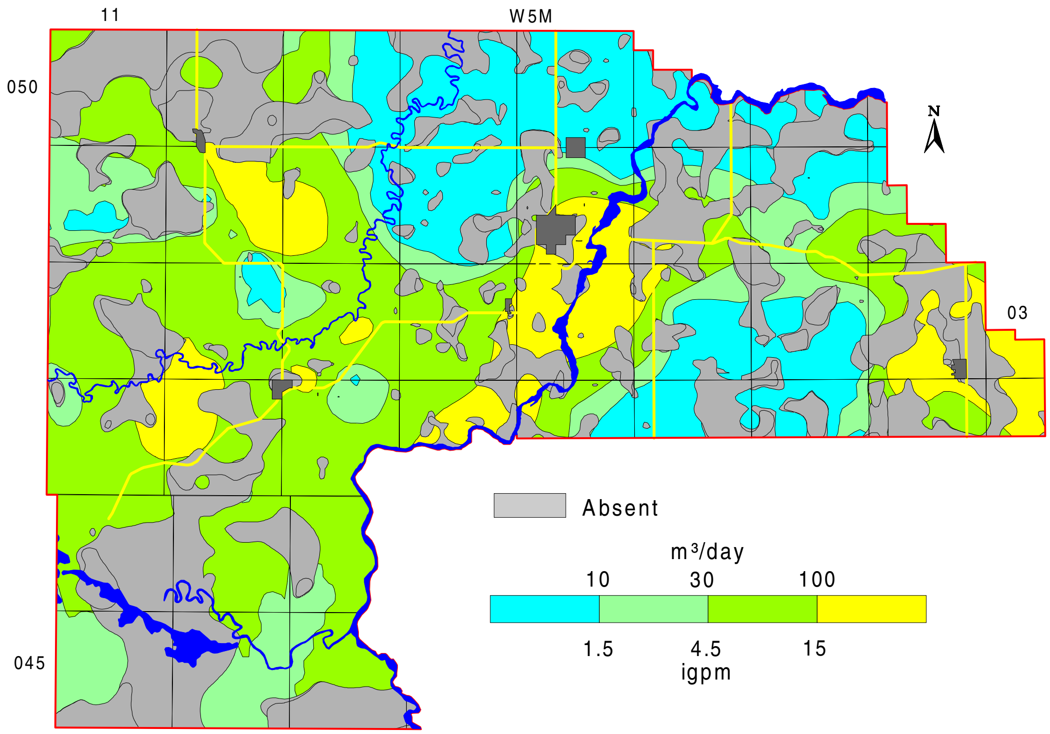
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)



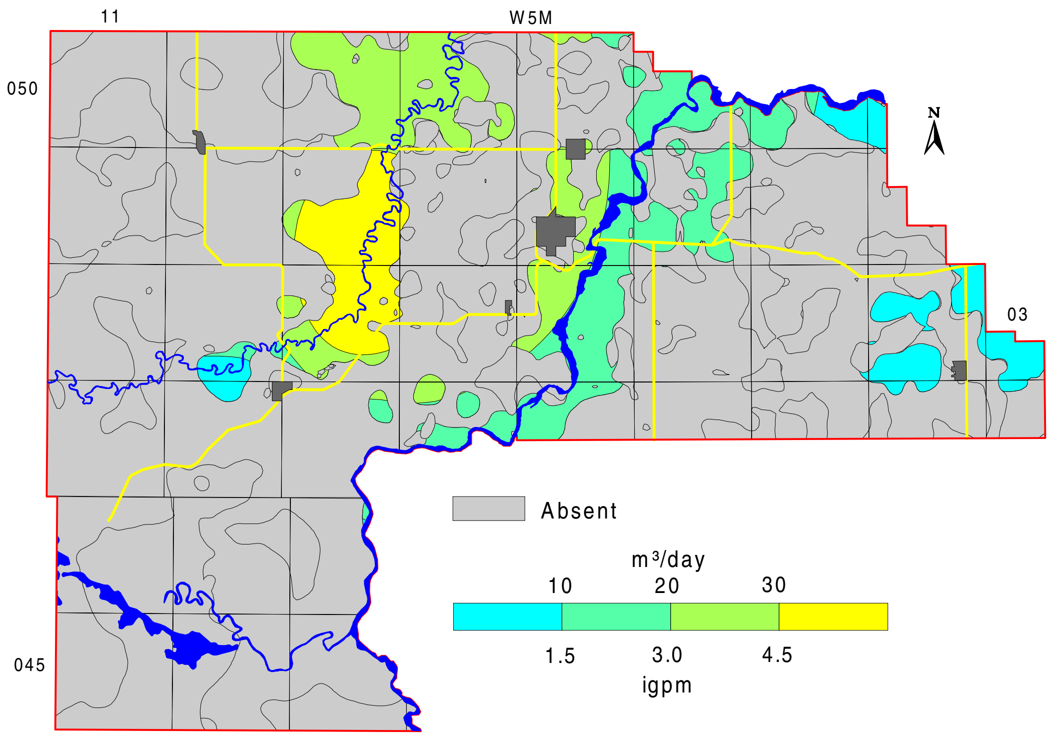
Total Dissolved Solids in Groundwater from Surficial Deposits



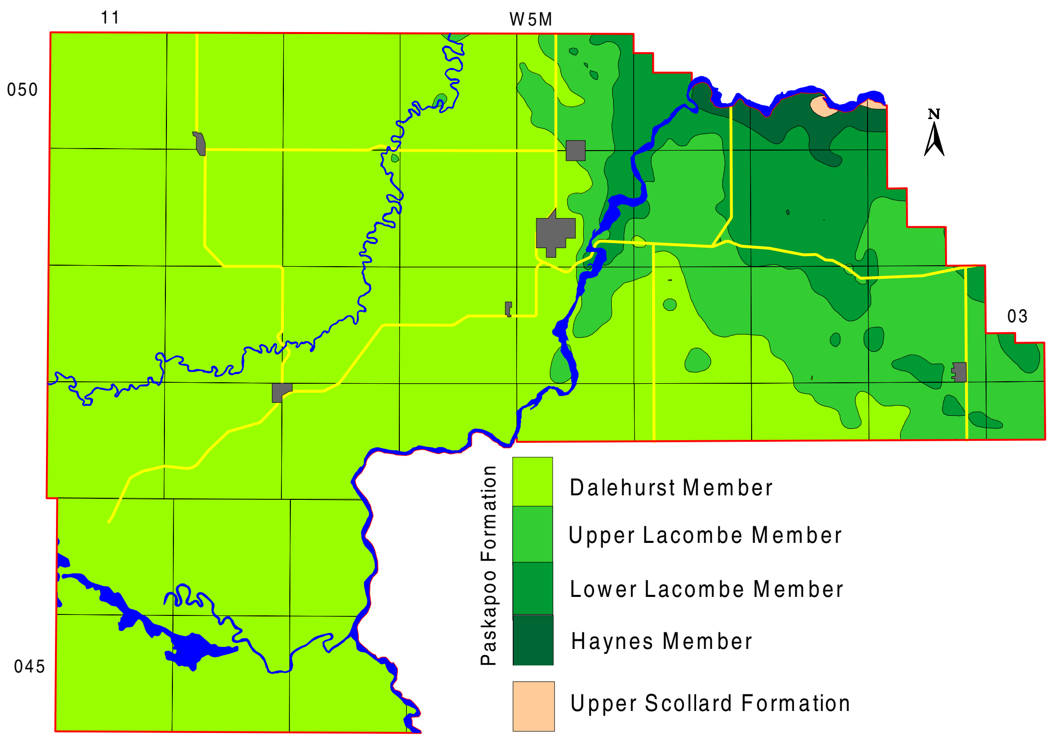
Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer



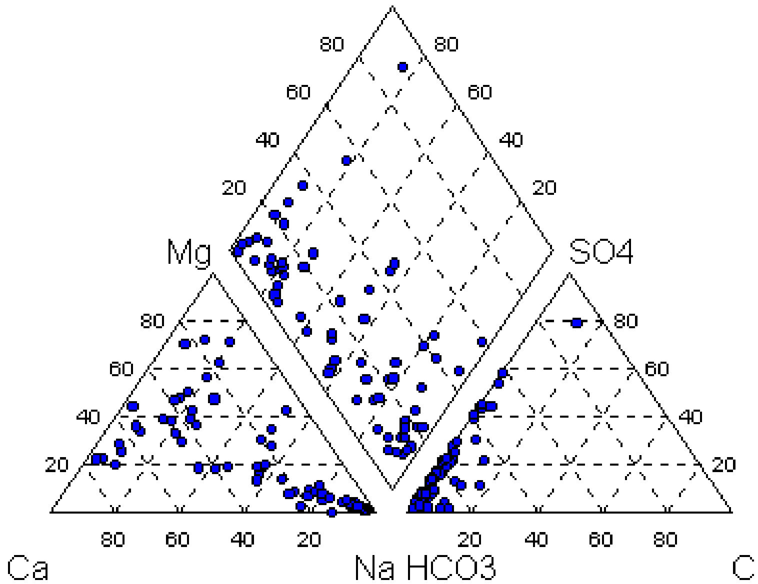
Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer



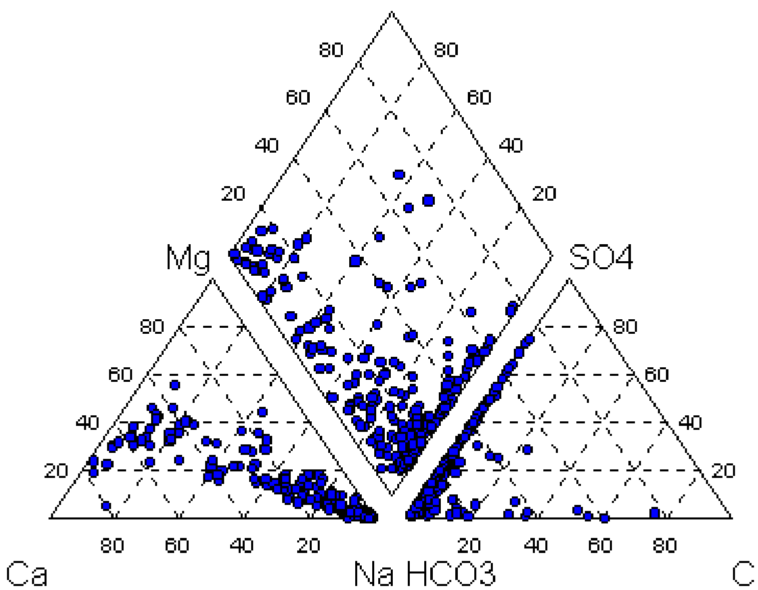
Bedrock Geology



Piper Diagrams

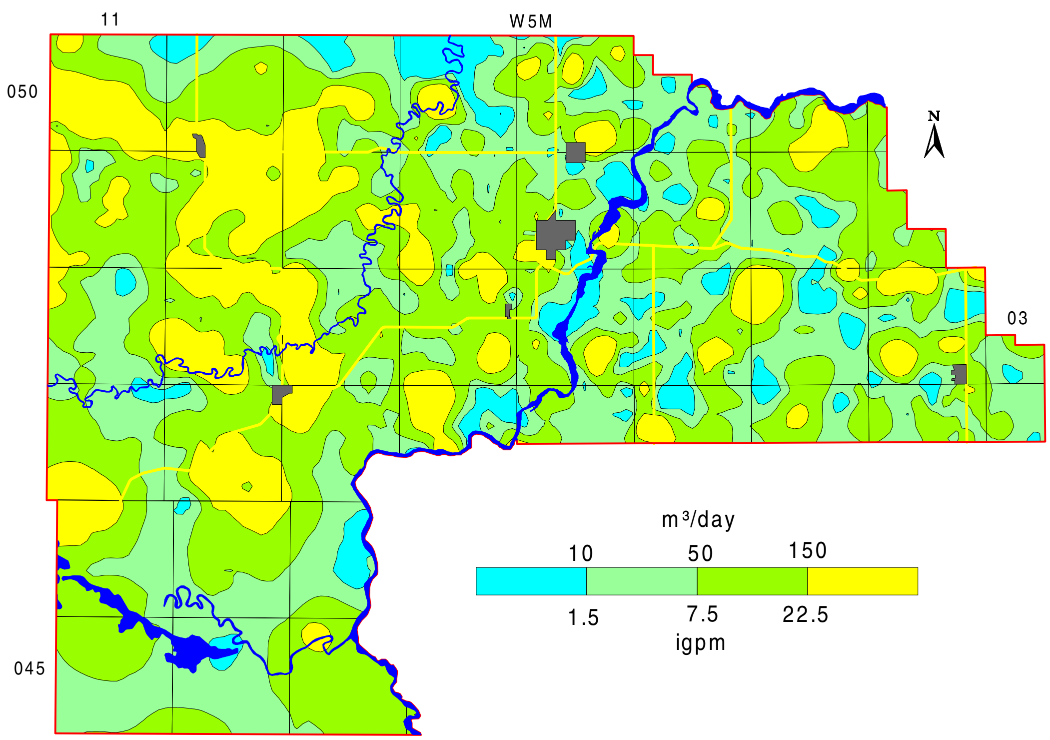


Surficial Deposits

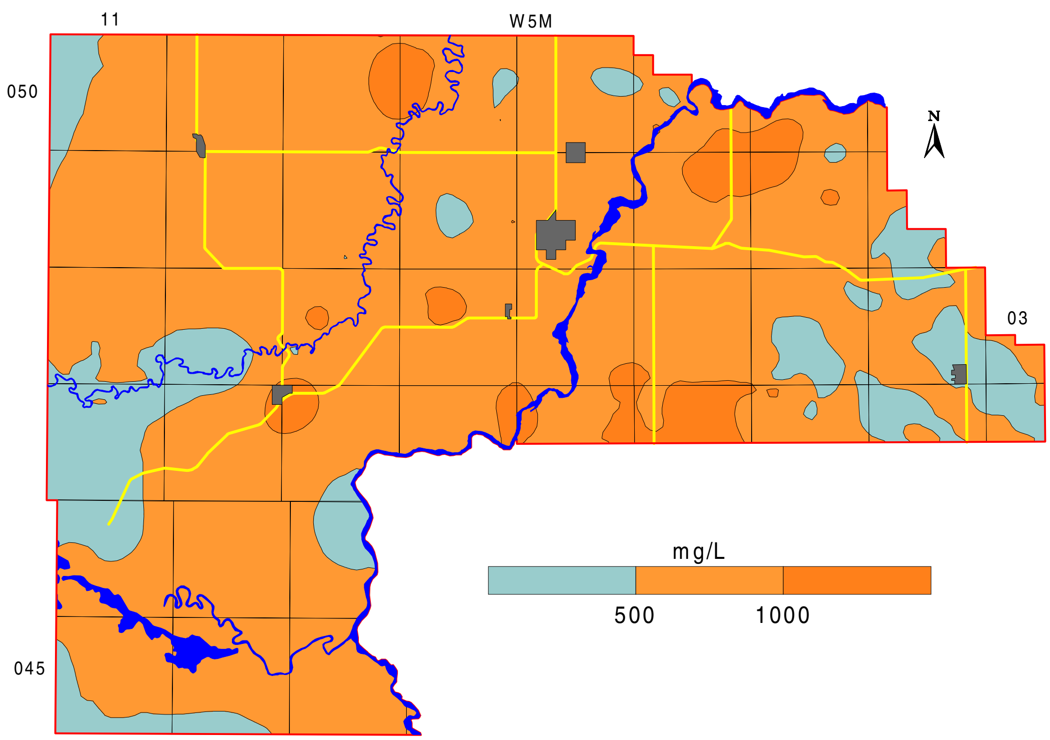


Bedrock Aquifers

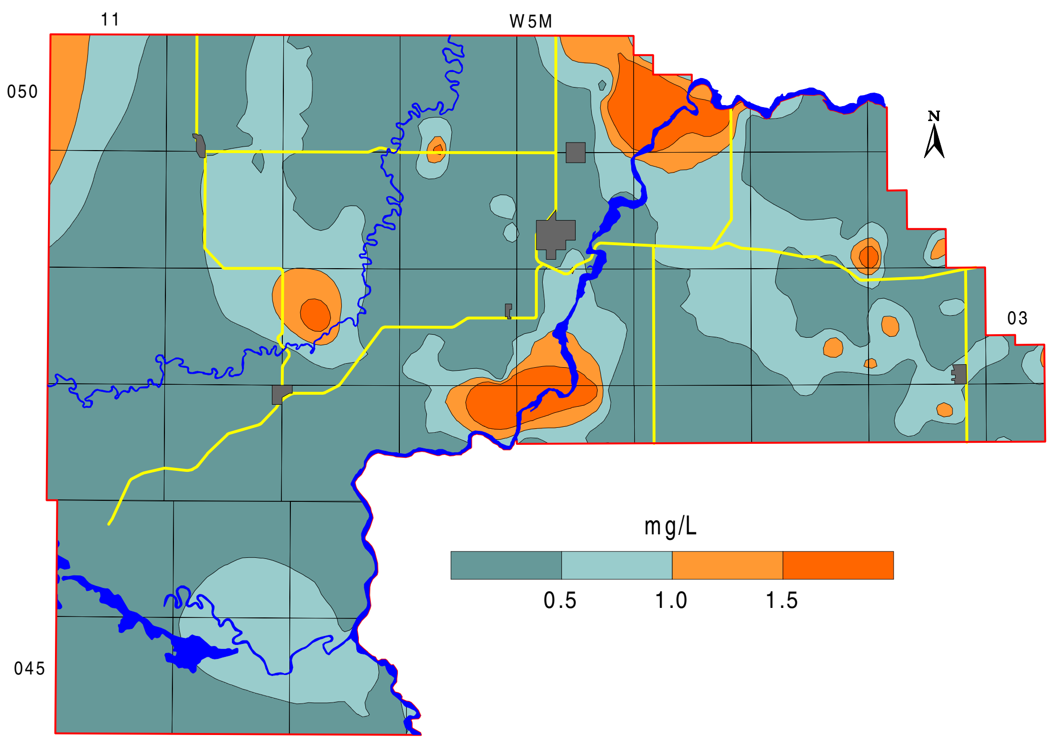
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



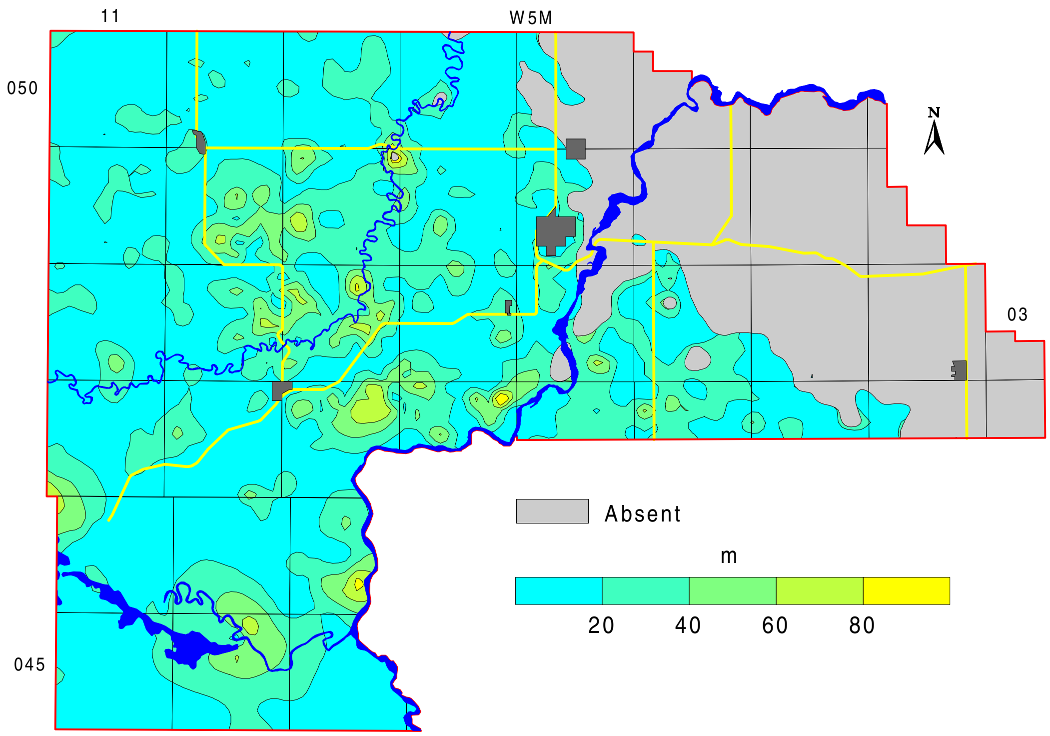
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



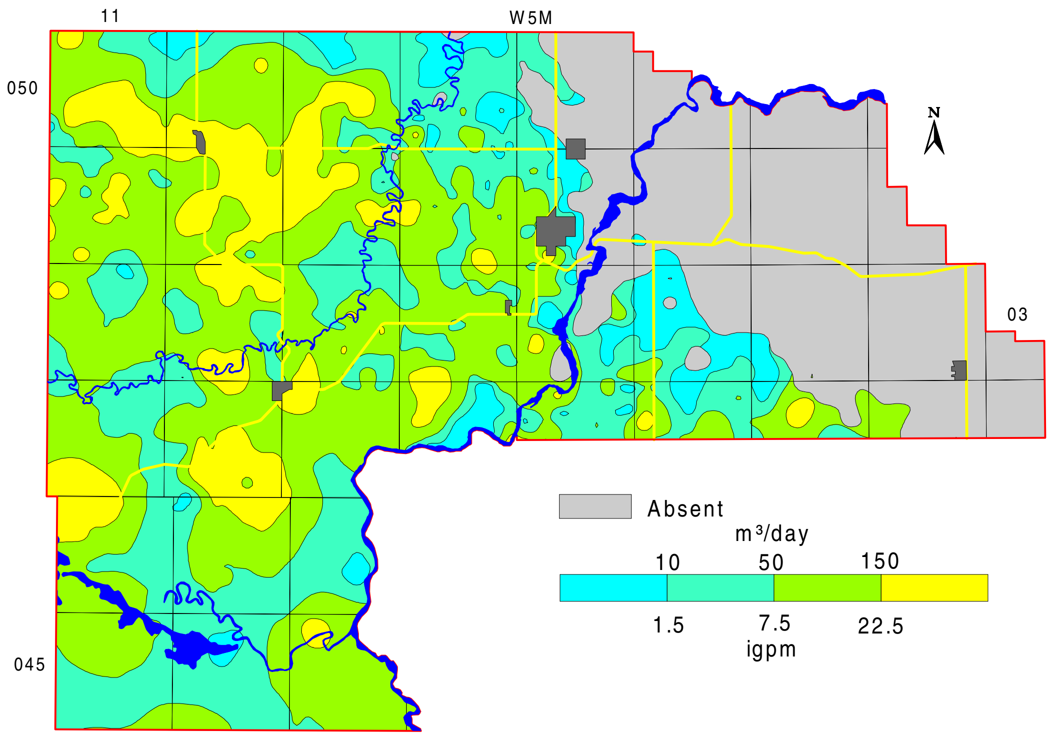
Fluoride in Groundwater from Upper Bedrock Aquifer(s)



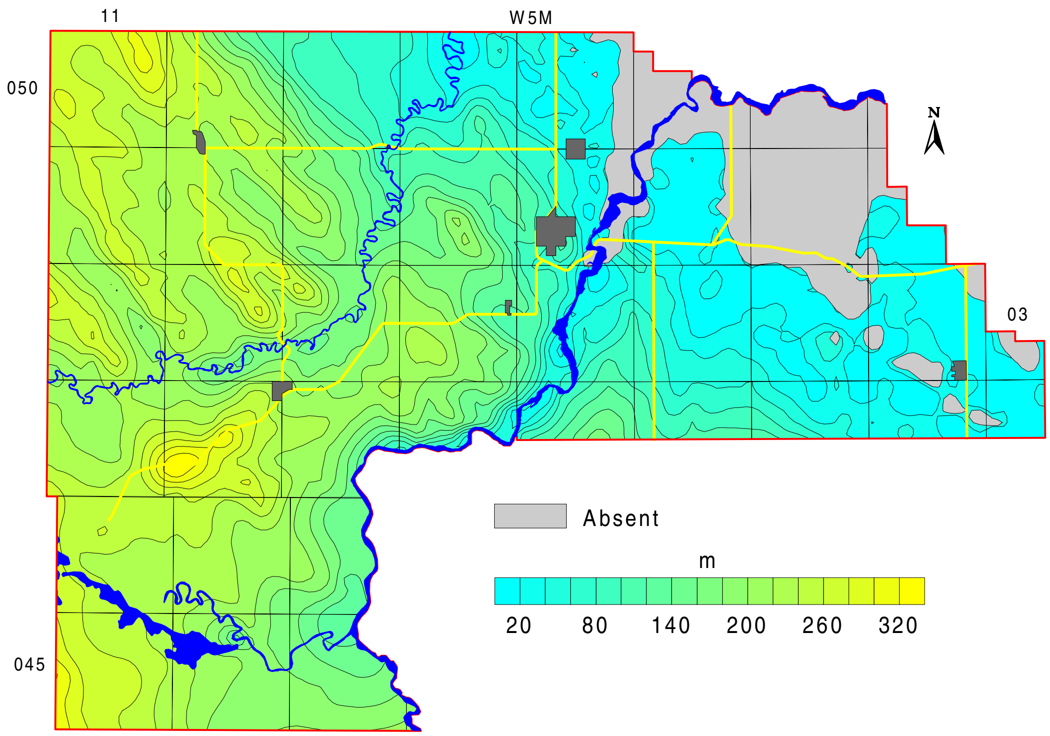
Depth to Top of Dalehurst Member



Apparent Yield for Water Wells Completed through Dalehurst Aquifer



Depth to Top of Upper Lacombe Member



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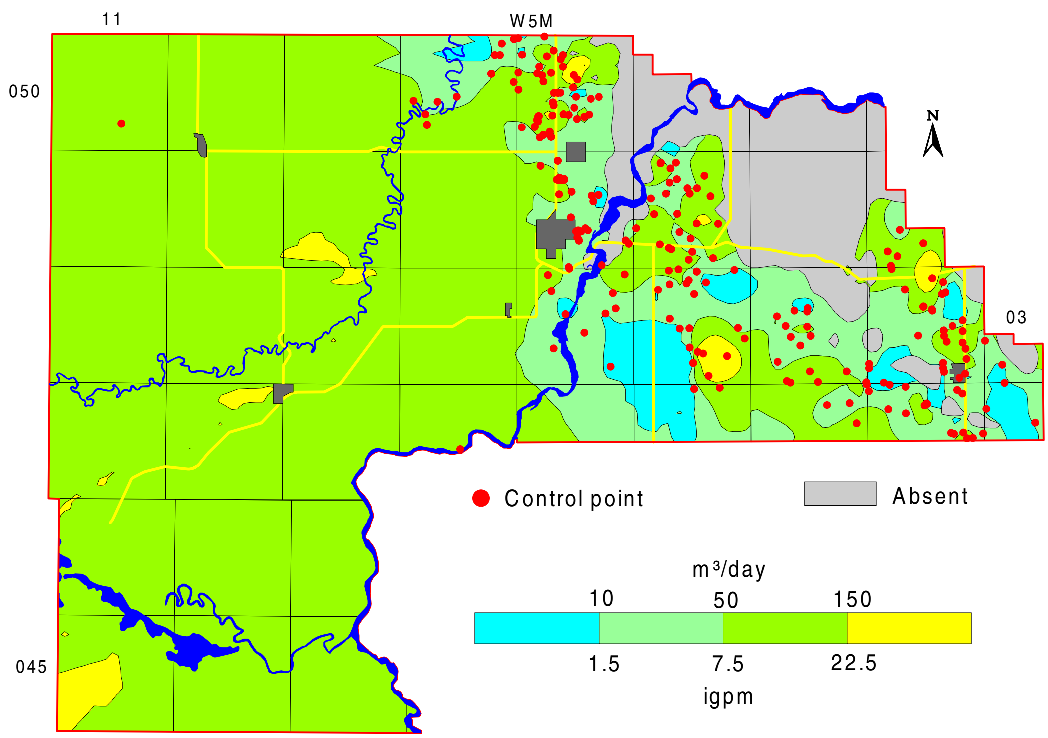
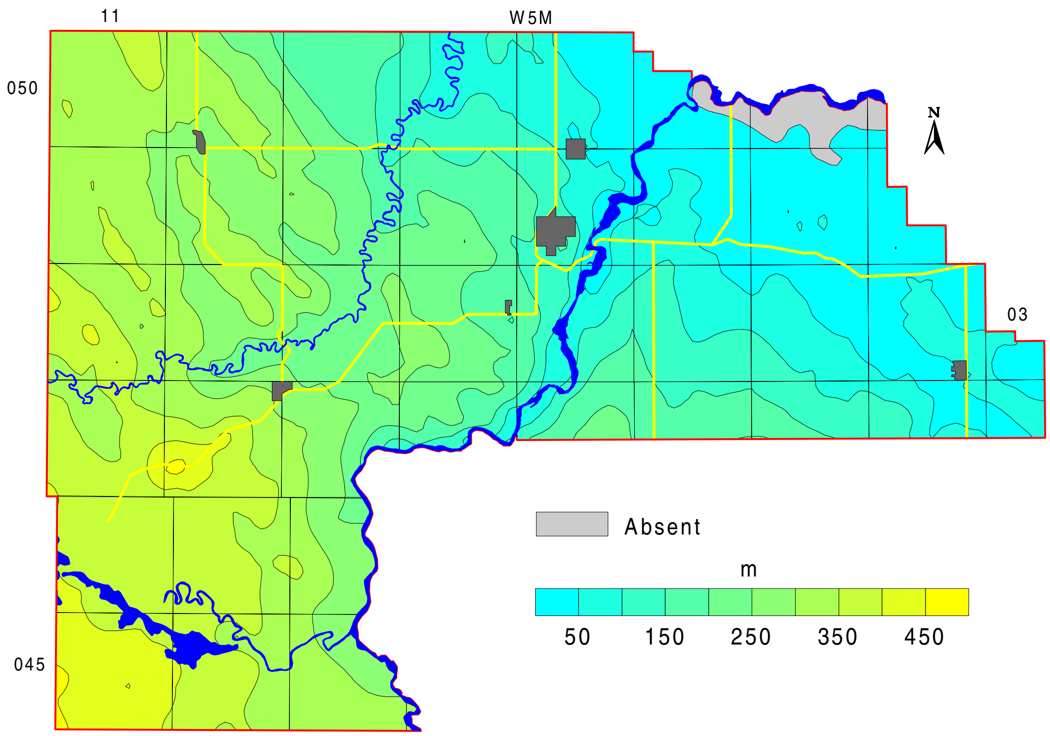
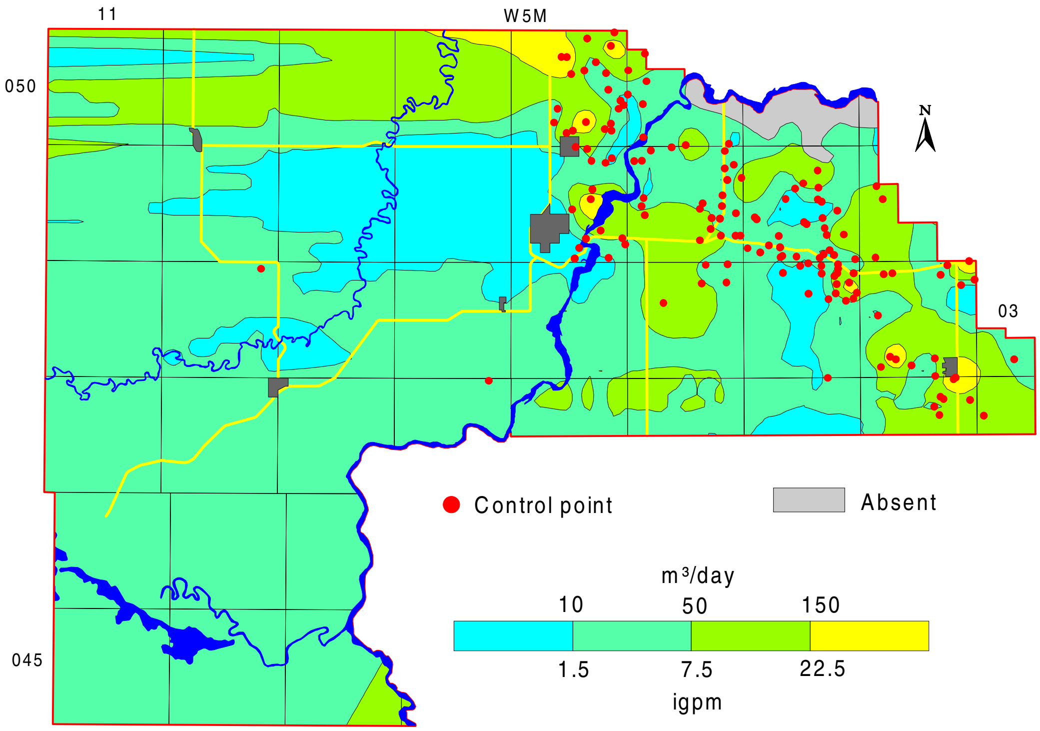
Apparent Yield for Water Wells Completed through Upper Lacombe Aquifer



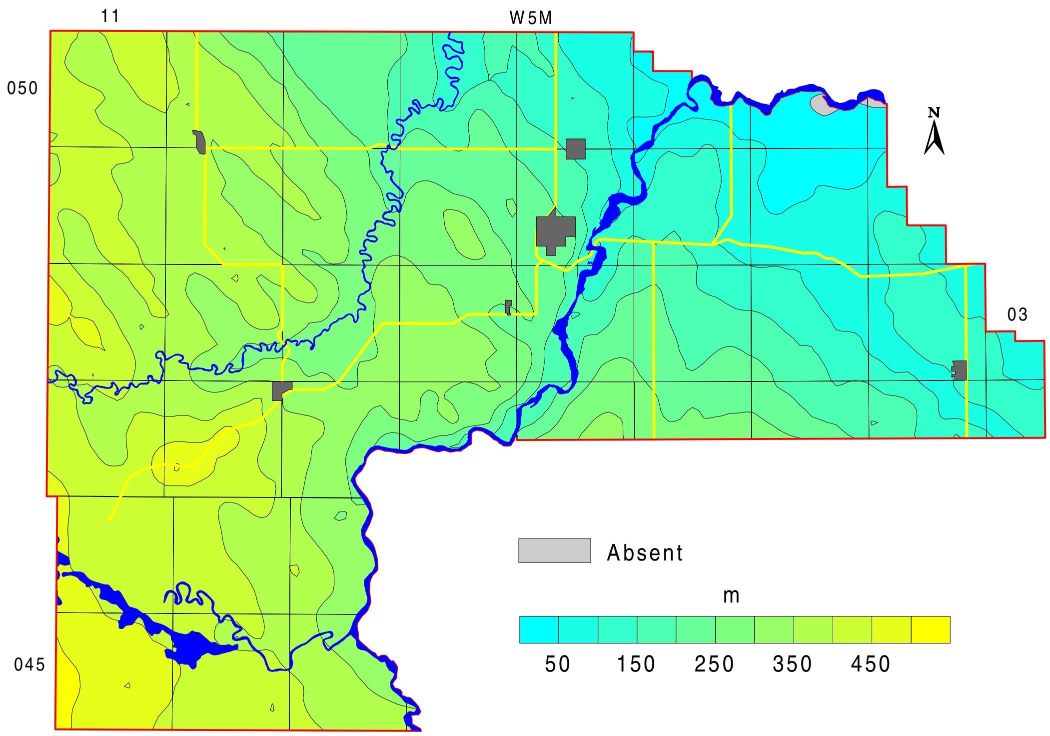
Depth to Top of Lower Lacombe Member



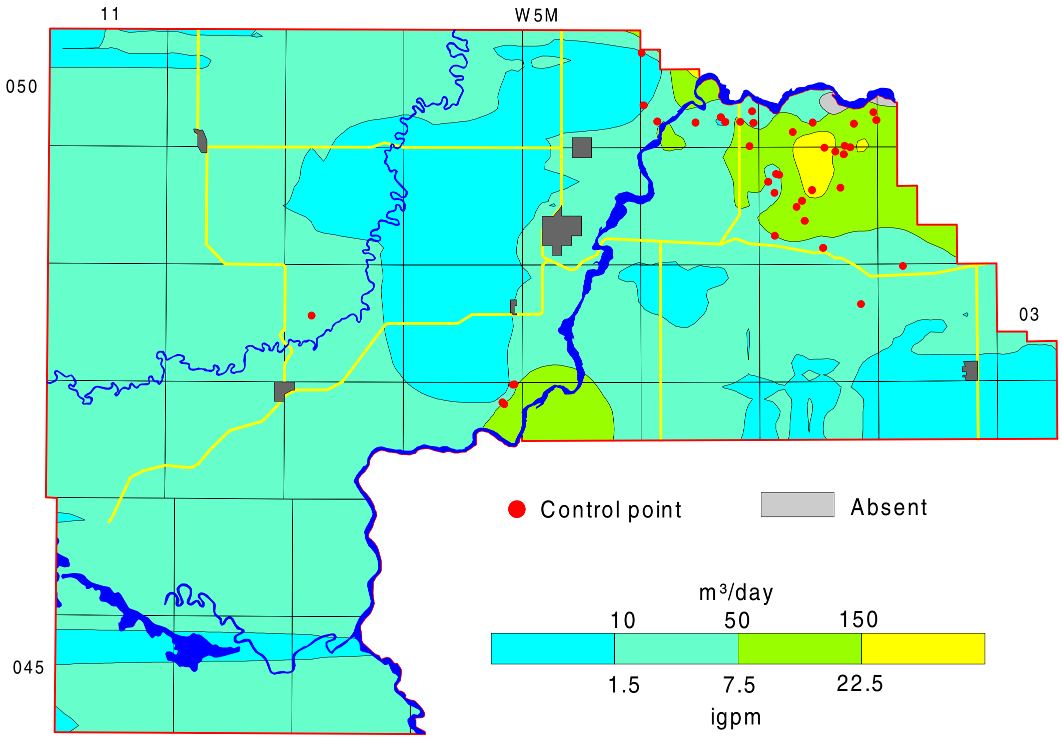
Apparent Yield for Water Wells Completed through Lower Lacombe Aquifer



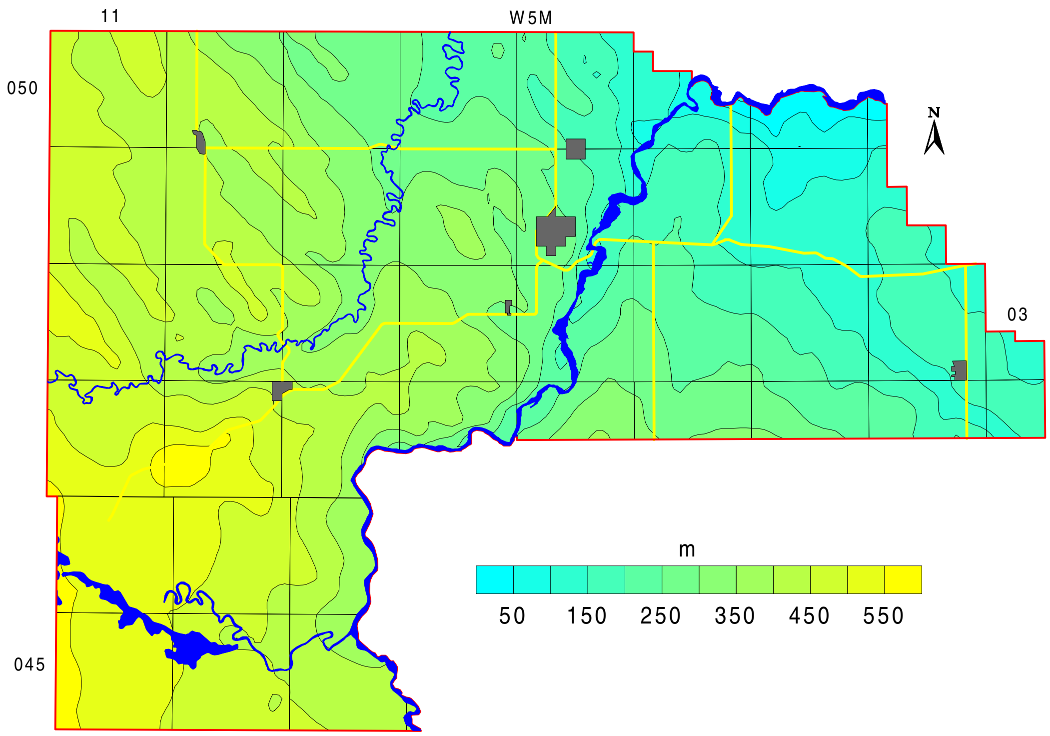
Depth to Top of Haynes Member



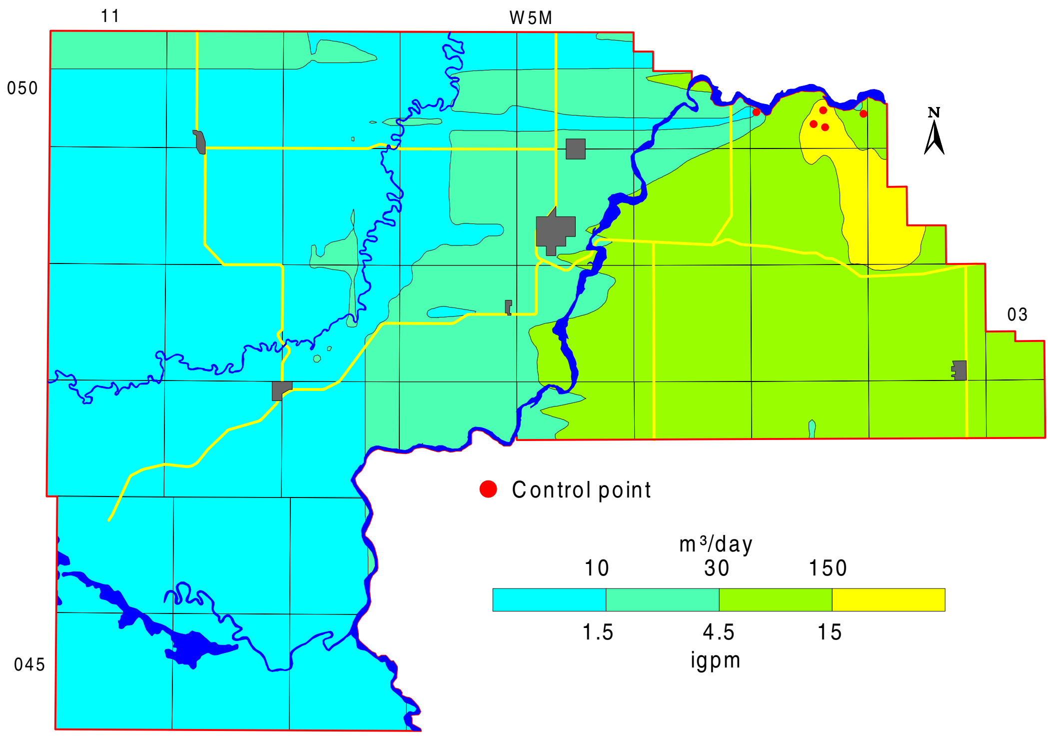
Apparent Yield for Water Wells Completed through Haynes Aquifer

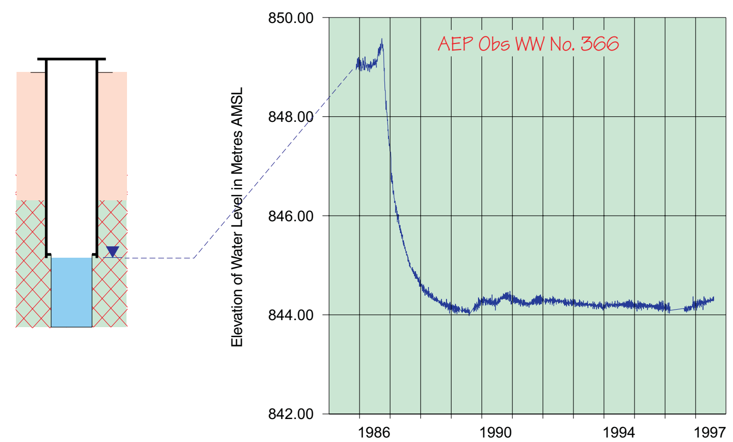


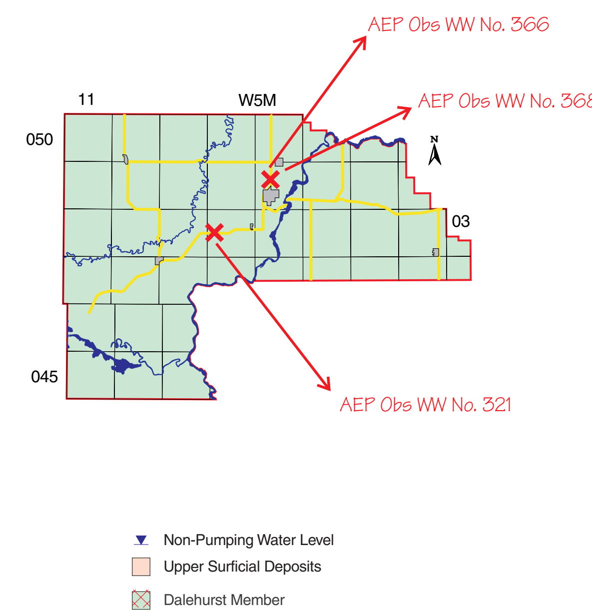
Depth to Top of Upper Scollard Formation

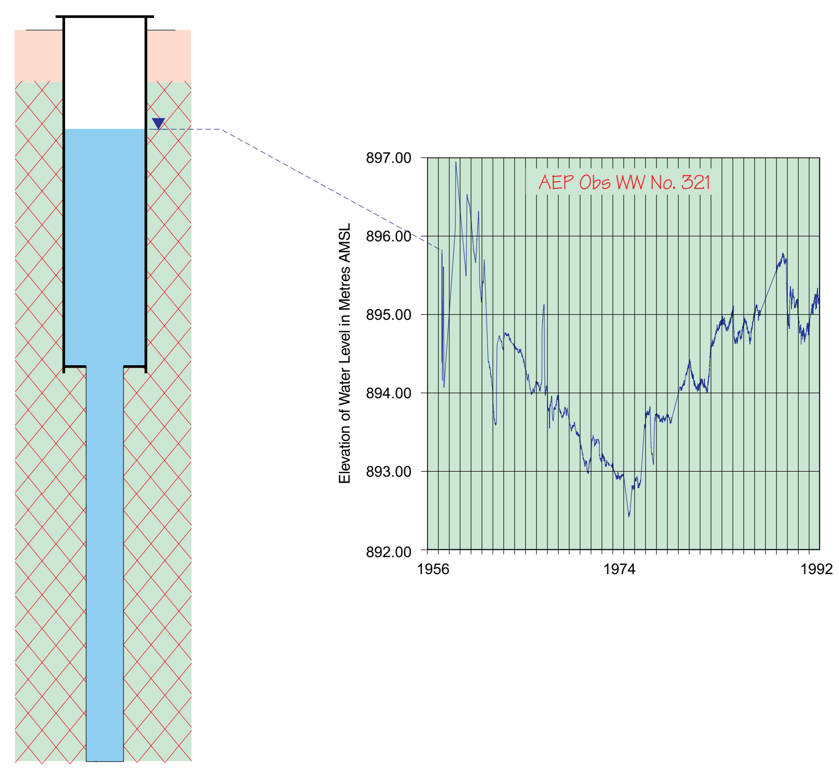


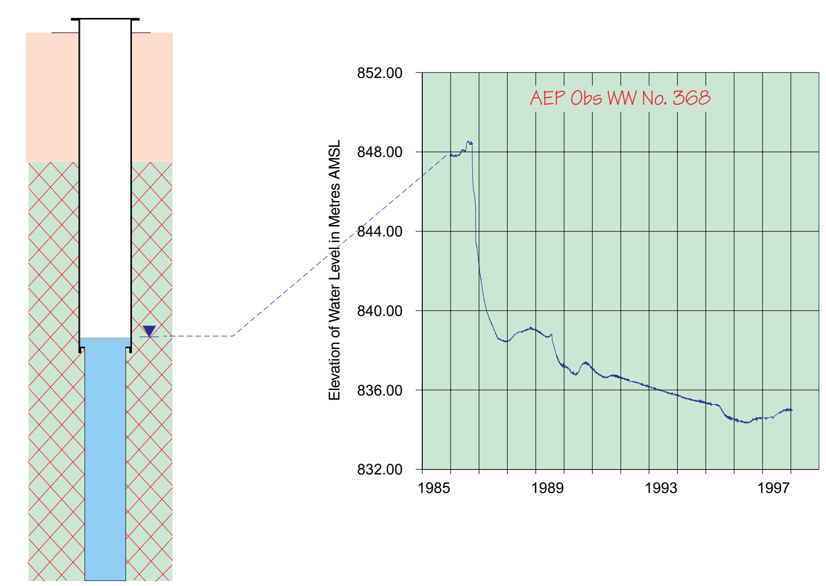
Apparent Yield for Water Wells Completed through Upper Scollard Aquifer





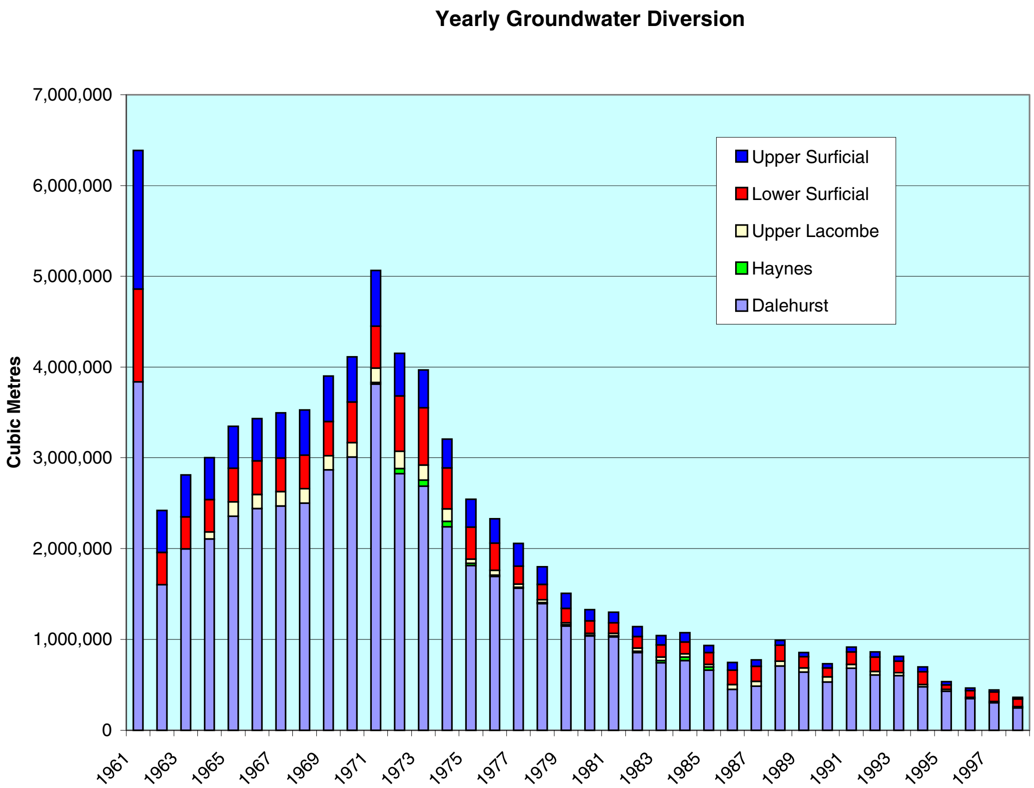




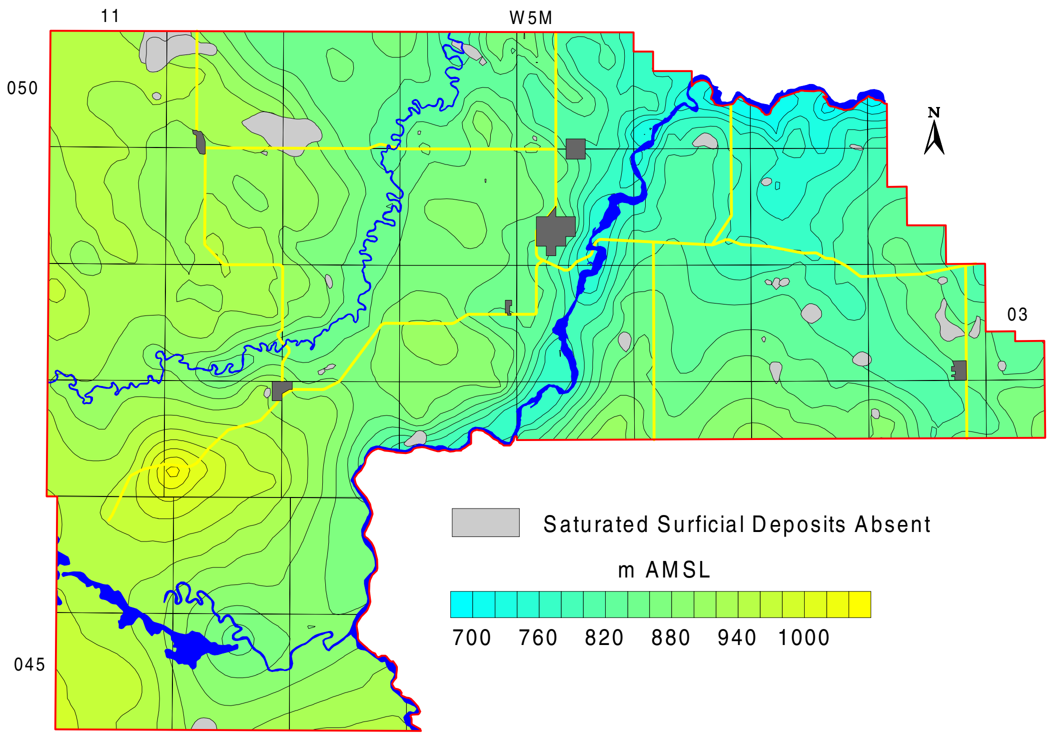


Hydrographs - AEP Observation Water Wells

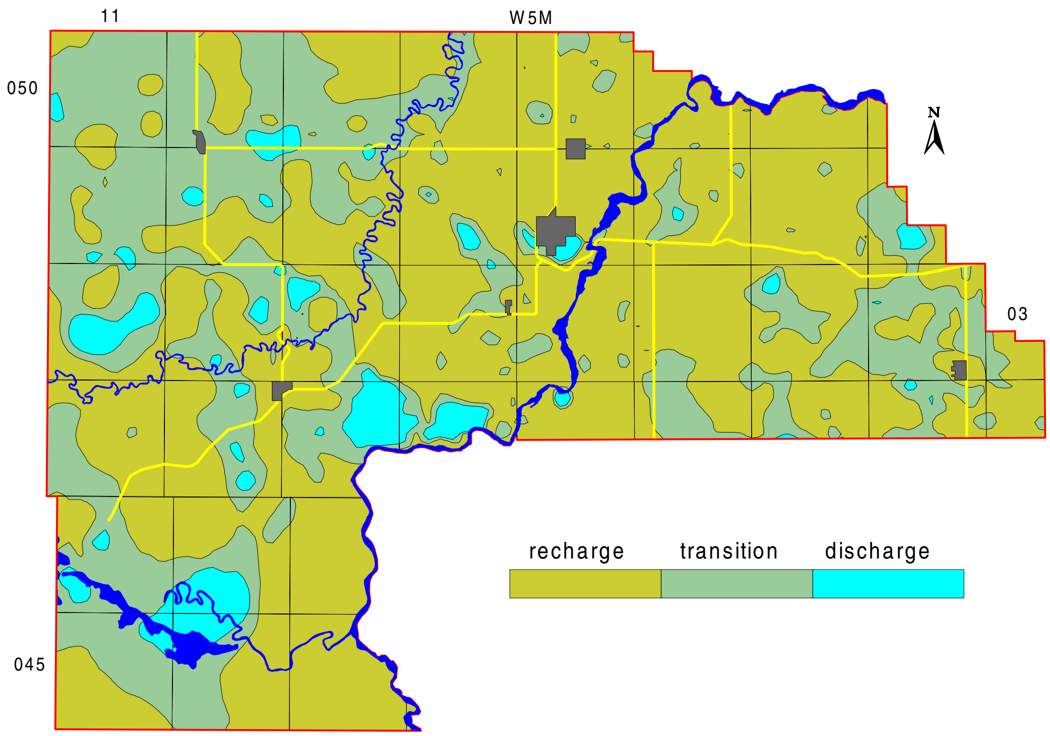
Annual Groundwater Production - WSWs



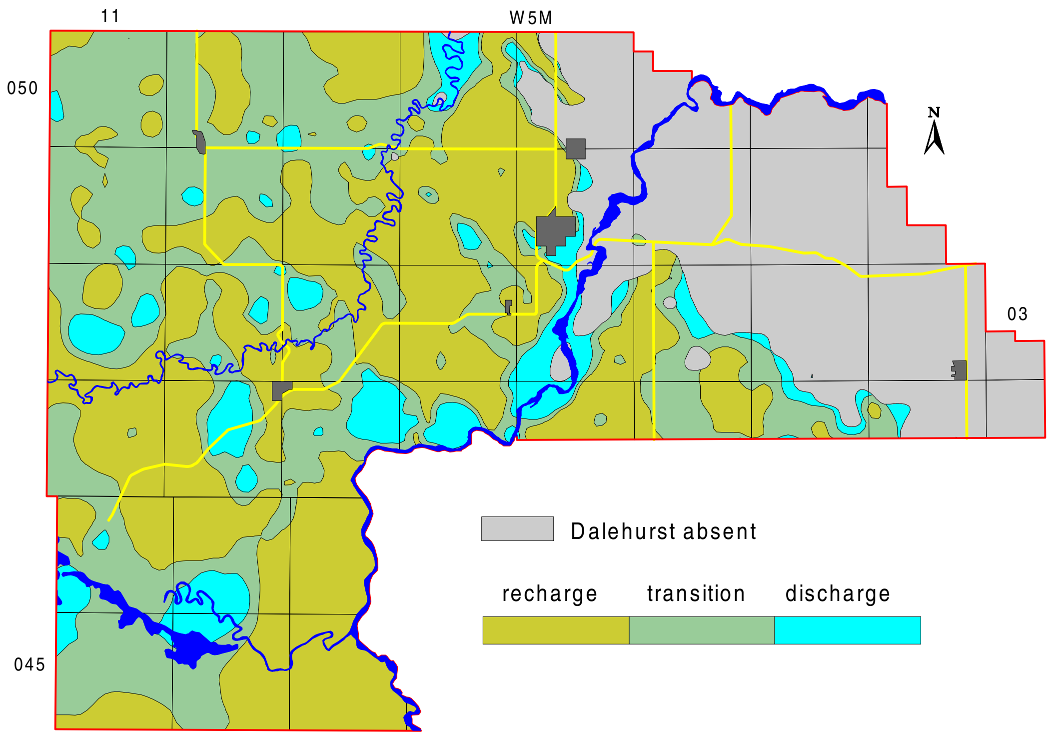
Non-Pumping Water-Level Surface in Surficial Deposits



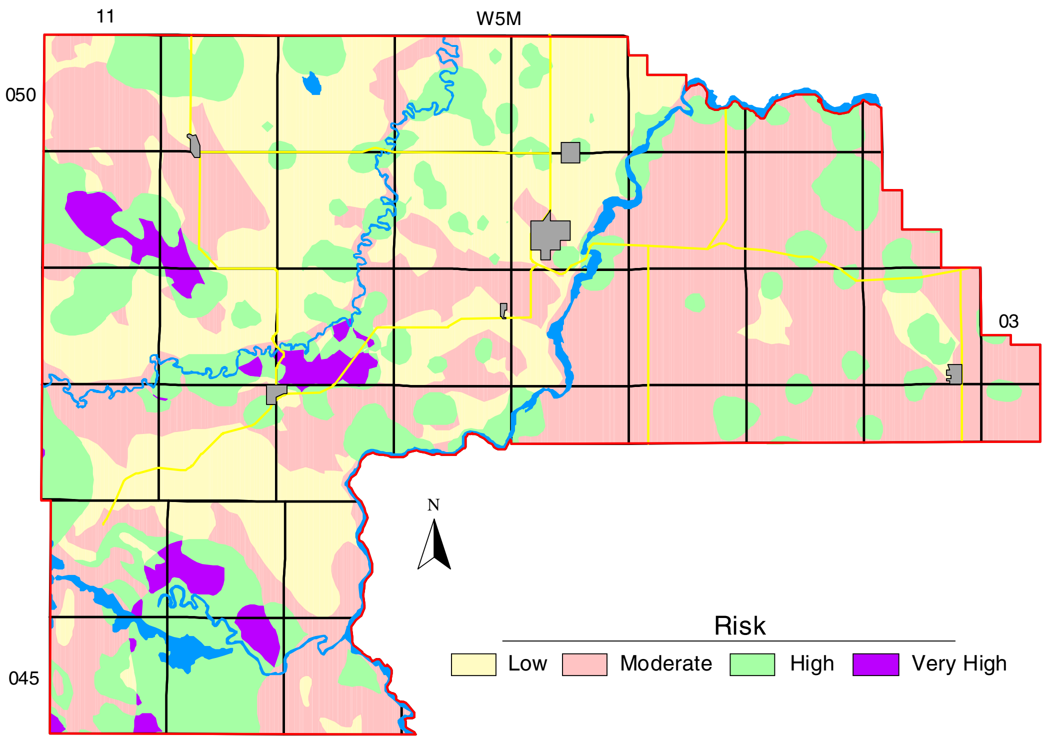
Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)



Recharge/Discharge Areas between Surficial Deposits and Dalehurst Aquifer



Risk of Groundwater Contamination



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Recharge/Discharge Areas between Surficial Deposits and Upper Scollard Aquifer

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Appendix C

GENERAL WATER WELL INFORMATION

Domestic Water Well Testing

Purpose and Requirements

The purpose of the testing of domestic water wells is to obtain background data related to:

1) the non-pumping water level for the aquifer - Has there been any lowering of the level since the last measurement?
2) the specific capacity of the water well, which indicates the type of contact the water well has with the aquifer;
3) the transmissivity of the aquifer and hence an estimate of the projected long-term yield for the water well;
4) the chemical, bacteriological and physical quality of the groundwater from the water well.

The testing procedure involves conducting an aquifer test and collecting of groundwater samples for analysis by an accredited laboratory. The date and time of the testing are to be recorded on all data collection sheets. A sketch showing the location of the water well relative to surrounding features is required. The sketch should answer the question, "If this water well is tested in the future, how will the person doing the testing know this is the water well I tested?"

The water well should be taken out of service as long as possible before the start of the aquifer test, preferably not less than 30 minutes before the start of pumping. The non-pumping water level is to be measured 30, 10, and 5 minutes before the start of pumping and immediately before the start of pumping which is to be designated as time 0 for the test. All water levels must be from the same designated reference, usually the top of the casing. Water levels are to be measured during the pumping interval and during the recovery interval after the pump has been turned off; all water measurements are to be with an accuracy of ± 0.01 metres.

During the pumping and recovery intervals, the water level is to be measured at the appropriate times. An example of the time schedule for a four-hour test is as follows, measured in minutes after the pump is turned on and again after the pump is turned off:

1,2,3,4,6,8,10,13,16,20,25,32,40,50,64,80,100,120.

For a four-hour test, the reading after 120 minutes of pumping will be the same as the 0 minutes of recovery. Under no circumstance will the recovery interval be less than the pumping interval.

Flow rate during the aquifer test should be measured and recorded with the maximum accuracy possible. Ideally, a water meter with an accuracy of better than ±1% displaying instantaneous and total flow should be used. If a water meter is not available, then the time required to completely fill a container of known volume should be recorded, noting the time to the nearest 0.5 seconds or better. Flow rate should be determined and recorded often to ensure a constant pumping rate.

Groundwater samples should be collected as soon as possible after the start of pumping and within 10 minutes of the end of pumping. Initially only the groundwater samples collected near the end of the pumping interval need to be submitted to the accredited laboratory for analysis. All samples must be properly stored for transportation to the laboratory and, in the case of the bacteriological analysis, there is a maximum time allowed between the time the sample is collected and the time the sample is delivered to the laboratory. The first samples collected are only analyzed if there is a problem or a concern with the first samples submitted to the laboratory.

Procedure

Site Diagrams

These diagrams are a map showing the distance to nearby significant features. This would include things like a corner of a building (house, barn, garage etc.) or the distance to the half-mile or mile fence. The description should allow anyone not familiar with the site to be able to unequivocally identify the water well that was tested.

In lieu of a map, UTM coordinates accurate to within five metres would be acceptable. If a hand-held GPS is used, the post-processing correction details must be provided.

Surface Details

The type of surface completion must be noted. This will include such things as a pitless adapter, well pit, pump house, in basement, etc. Also, the reference point used for measuring water levels needs to be noted. This would include top of casing (TOC) XX metres above ground level; well pit lid, XX metres above TOC; TOC in well pit XX metres below ground level.

Groundwater Discharge Point

Where was the flow of groundwater discharge regulated? For example was the discharge through a hydrant downstream from the pressure tank; discharged directly to ground either by connecting directly above the well seal or by pulling the pump up out of the pitless adapter; from a tap on the house downstream from the pressure tank? Also note must be made if any action was taken to ensure the pump would operate continuously during the pumping interval and whether the groundwater was passing through any water-treatment equipment before the discharge point.

Water-Level Measurements

How were the water-level measurements obtained? If obtained using a contact gauge, what type of cable was on the tape, graduated tape or a tape with tags? If a tape with tags, when was the last time the tags were calibrated? If a graduated tape, what is the serial number of the tape and is the tape shorter than its original length (i.e. is any tape missing)?

If water levels are obtained using a transducer and data logger, the serial numbers of both transducer and data logger are needed and a copy of the calibration sheet. The additional information required is the depth the transducer was set and the length of time between when the transducer was installed and when the calibration water level was measured, plus the length of time between the installation of the transducer and the start of the aquifer test.

All water levels must be measured at least to the nearest 0.01 metres.

Discharge Measurements

Type of water meter used. This could include such things as a turbine or positive displacement meter. How were the readings obtained from the meter? Were the readings visually noted and recorded or were they recorded using a data logger?

Water Samples

A water sample must be collected between the 4- and 6-minute water-level measurements, whenever there is an observed physical change in the groundwater being pumped, and 10 minutes before the end of the planned pumping interval. Additional water samples must be collected if it is expected that pumping will be terminated before the planned pumping interval.

Environmental Protection and Enhancement Act

Water Well Regulation

PROVINCE OF ALBERTA

ENVIRONMENTAL PROTECTION AND ENHANCEMENT ACT

WATER WELL REGULATION

Alberta Regulation 123/93

EXTRACT FROM THE ALBERTA GAZETTE

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Alberta Regulation 123/93

Environmental Protection and Enhancement Act

WATER WELL REGULATION

Filed: April 22, 1993

Made by the Minister of Environmental Protection pursuant to sections 81(1)(a) and (f), 138(a)-(e), (g), (h), (j)-(q) of the Environmental Protection and Enhancement Act.

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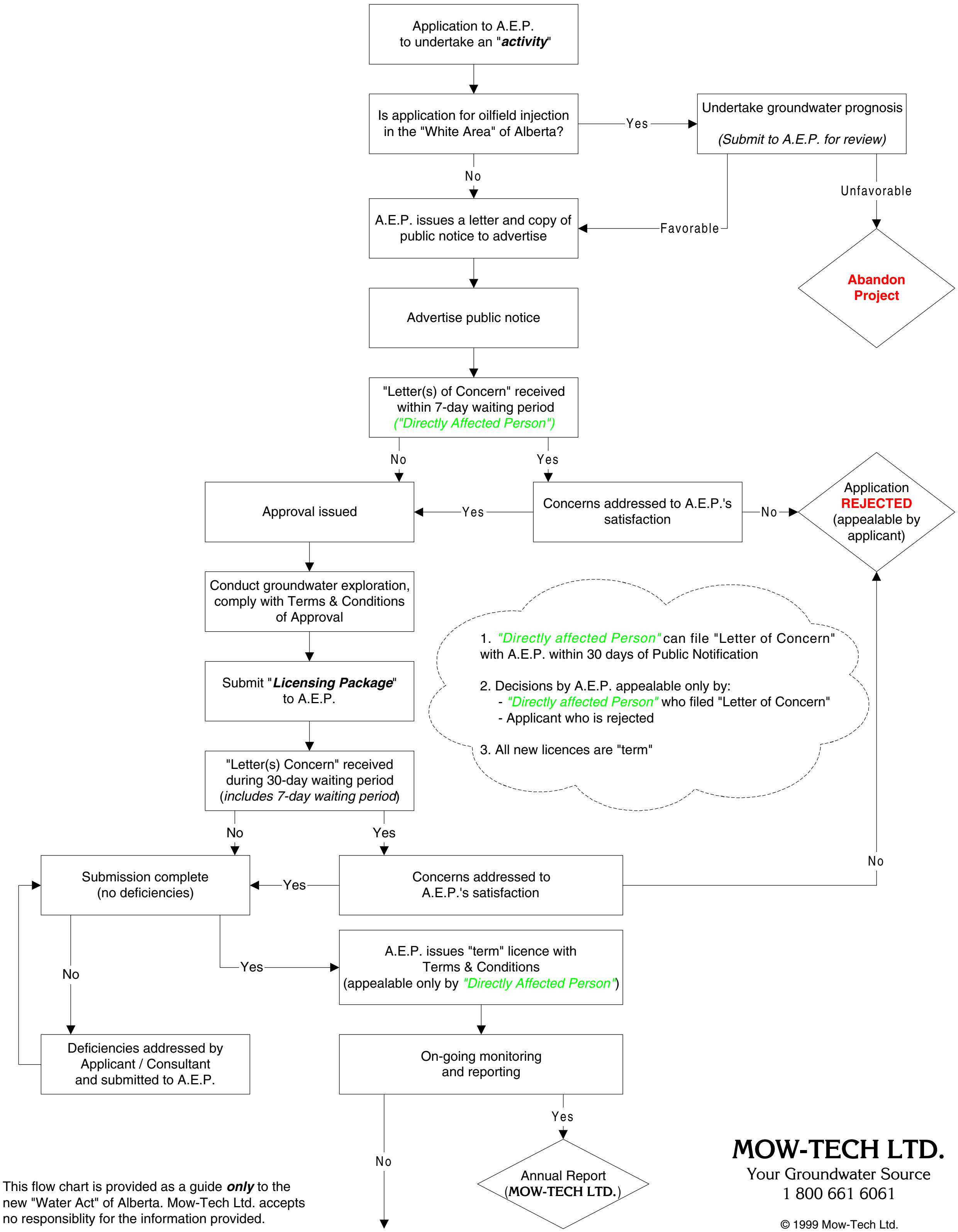
Water Act – Flow Chart



This flow chart 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

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Additional Information

VIDEOS

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

BOOKLET

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

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PRAIRIE FARM REHABILITATION ADMINISTRATION

Curtis Snell (Westlock: 780 349-3963)

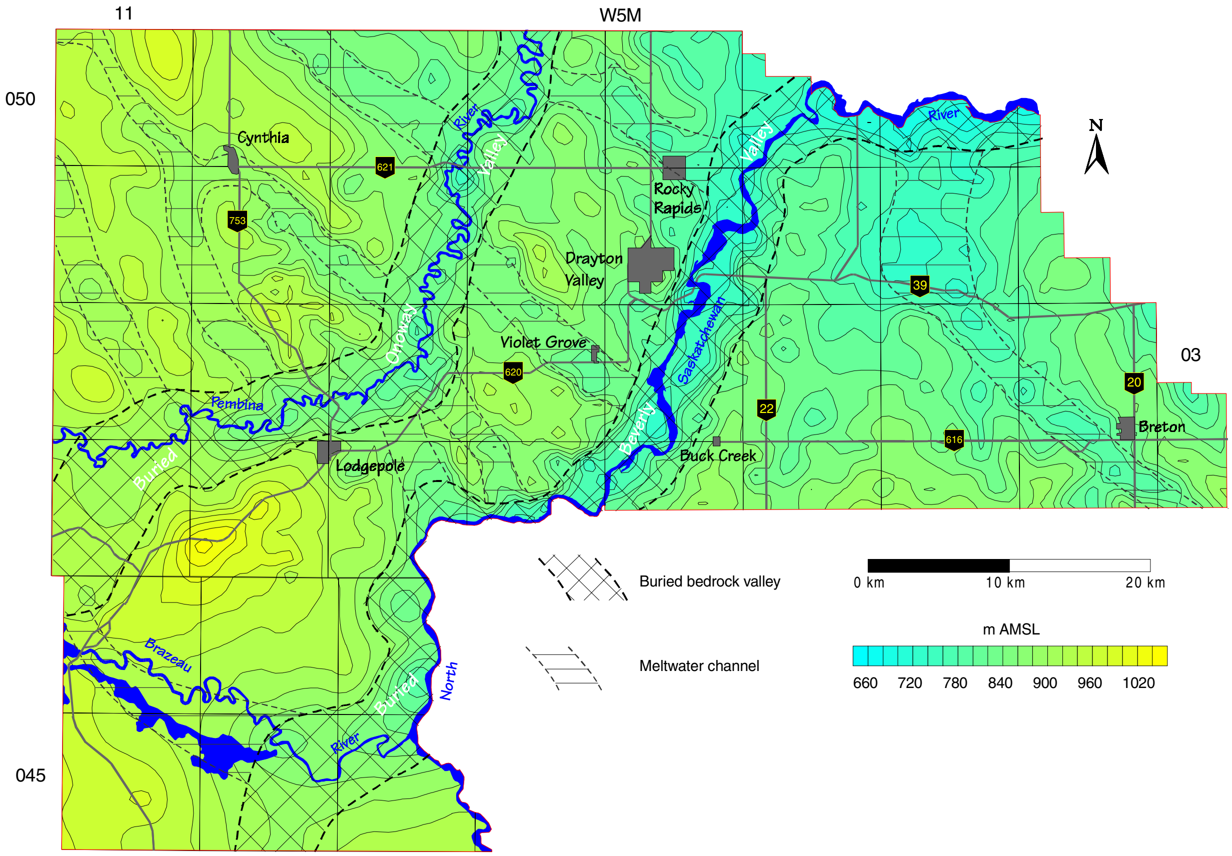
LOCAL HEALTH DEPARTMENTS

M.D. OF BRAZEAU NO. 77

Appendix D

MAPS AND FIGURES INCLUDED AS LARGE PLOTS

M.D. of Brazeau No. 77
Bedrock Topography



Agriculture and Agri-Food Canada Agriculture et Agroalimentaire Canada

PFRA Prairie Farm Rehabilitation Administration

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

hydrogeological consultants ltd.

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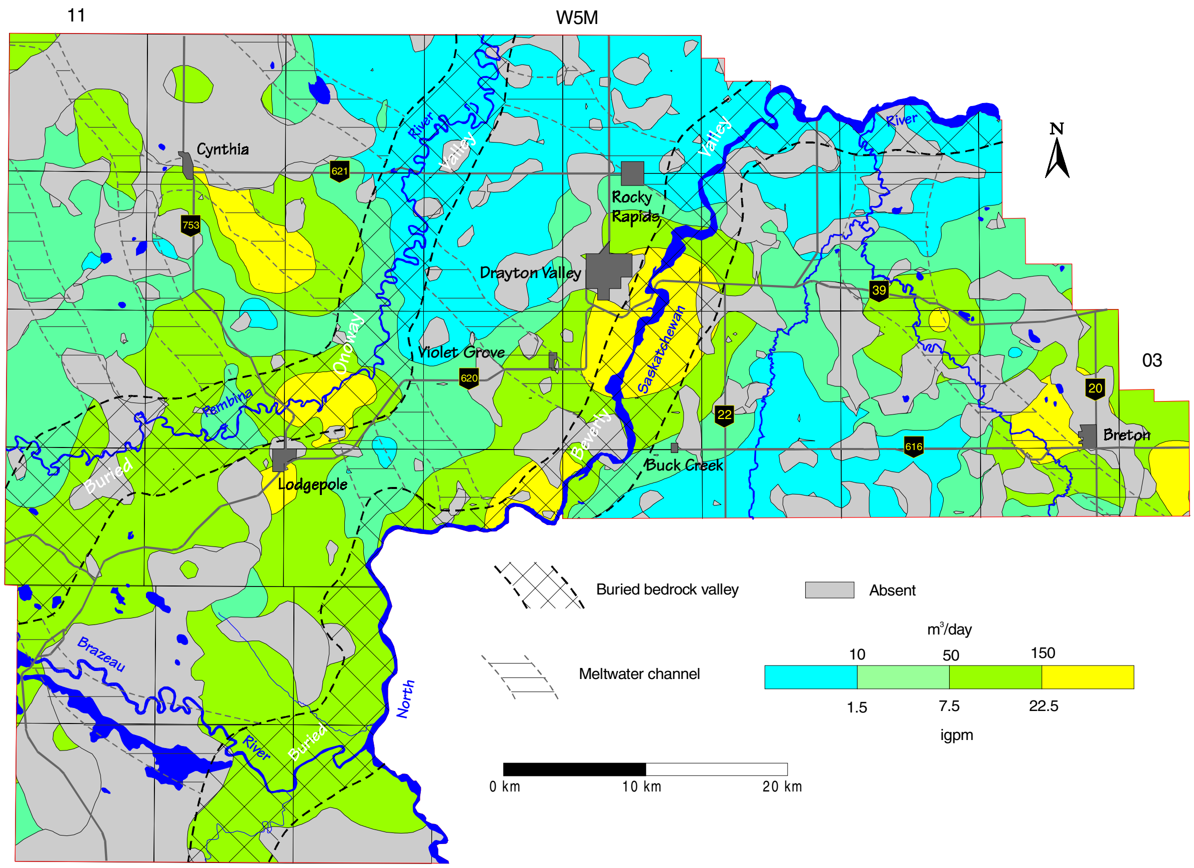
M.D. of Brazeau No. 77
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)



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

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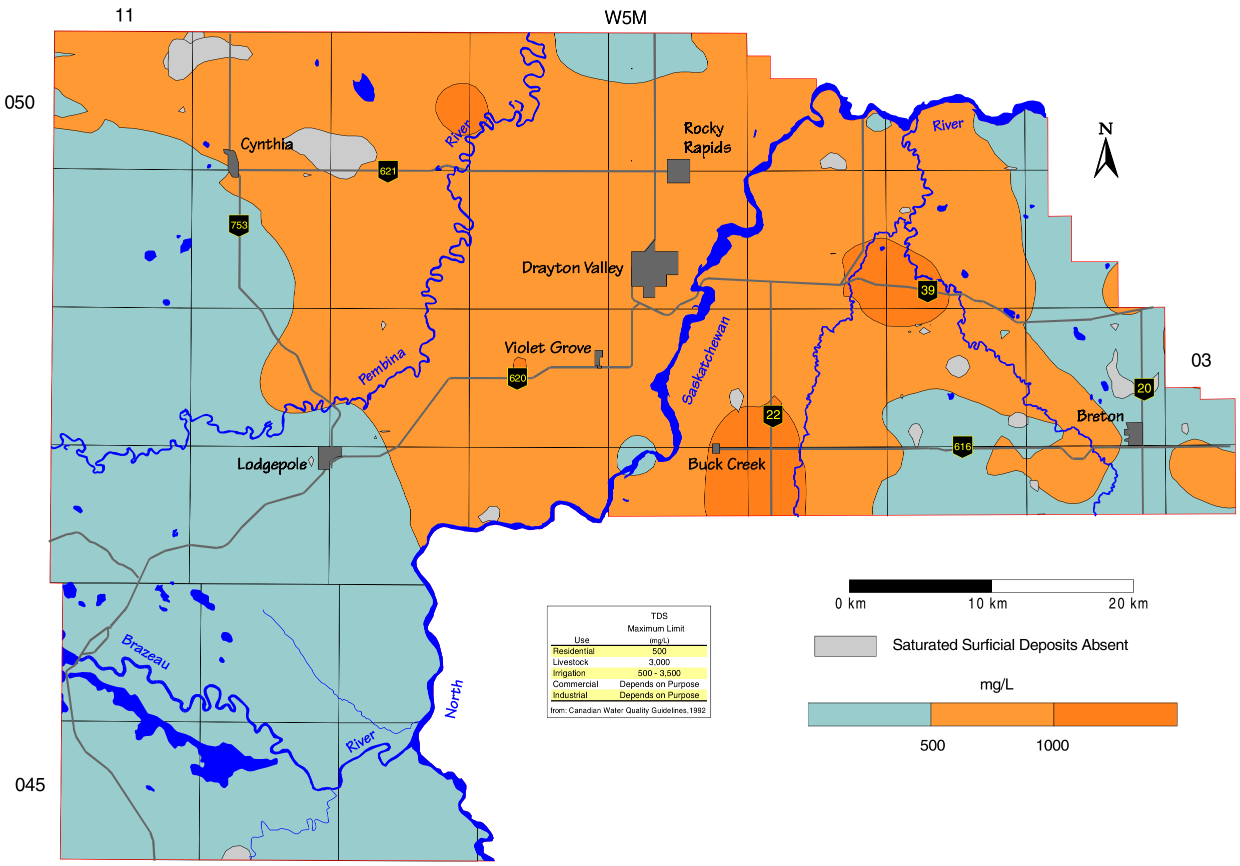
M.D. of Brazeau No. 77
Total Dissolved Solids in Groundwater from Surficial Deposits



Use	TDS Maximum Limit (mg/L)
Residential	500
Livestock	3,000
Irrigation	500 - 3,500
Commercial	Depends on Purpose
Industrial	Depends on Purpose

from: Canadian Water Quality Guidelines,1992

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

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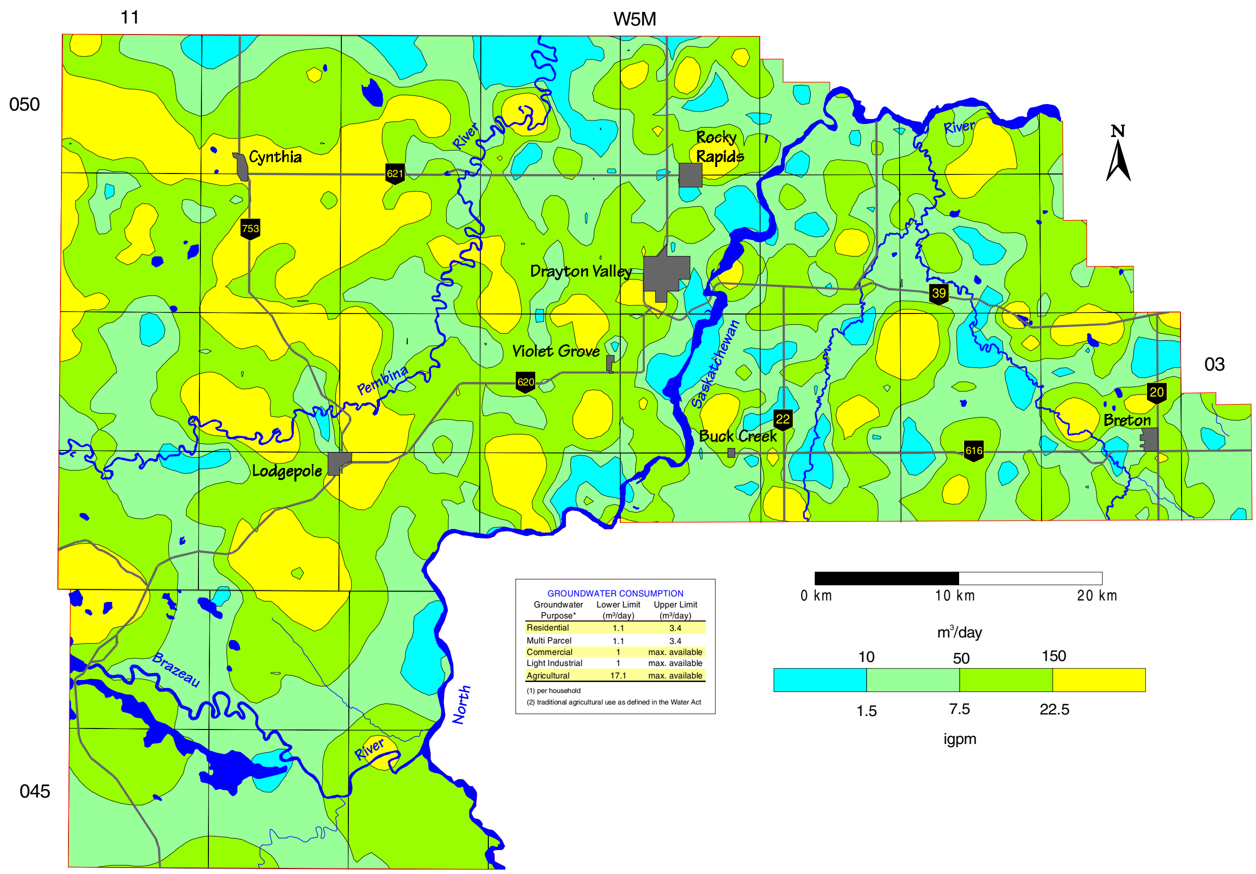
M.D. of Brazeau No. 77
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



GROUNDWATER CONSUMPTION

Groundwater Purpose*	Lower Limit (m³/day)	Upper Limit (m³/day)
Residential	1.1	3.4
Multi Parcel	1.1	3.4
Commercial	1	max. available
Light Industrial	1	max. available
Agricultural	17.1	max. available

(1) per household
(2) traditional agricultural use as defined in the Water Act

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

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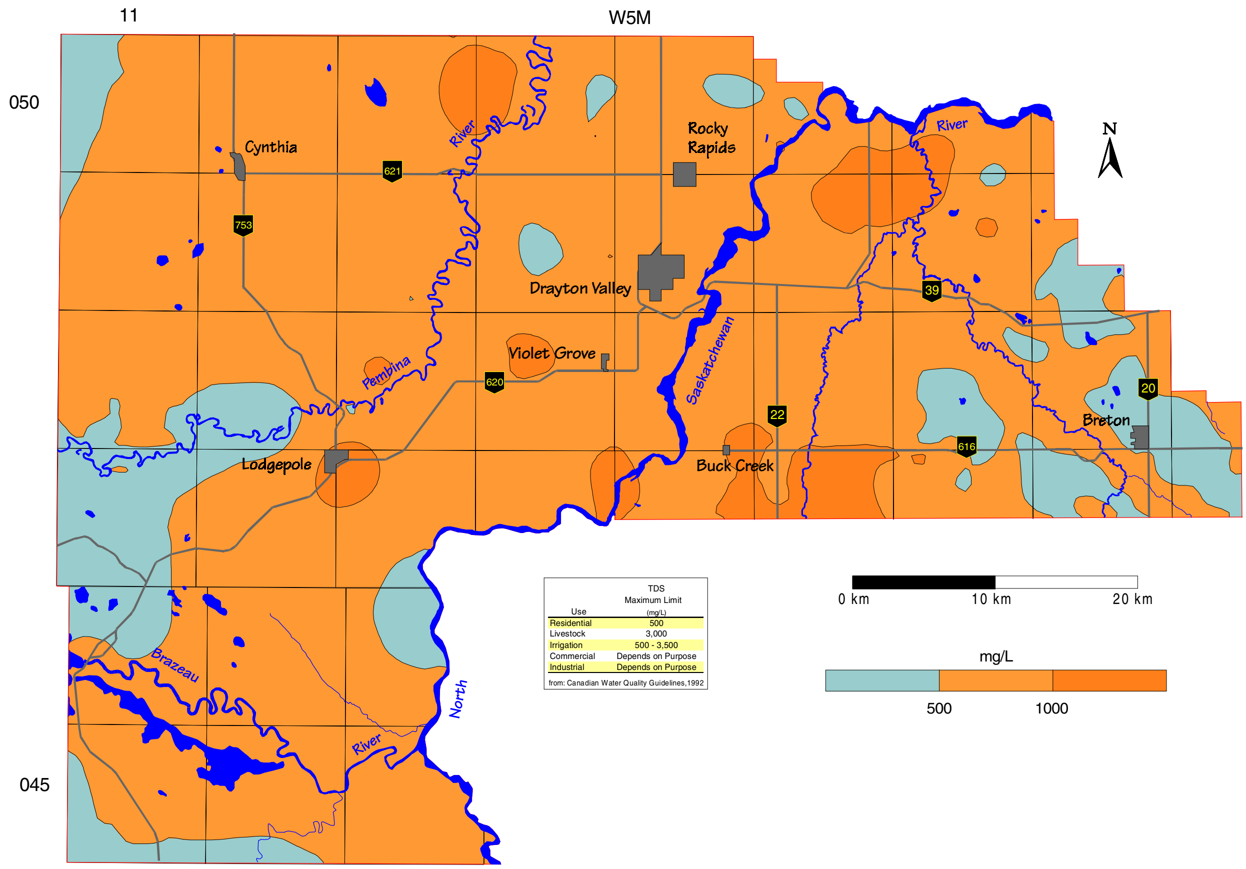
M.D. of Brazeau No. 77
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



Use	TDS Maximum Limit (mg/L)
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Industrial	Depends on Purpose

from: Canadian Water Quality Guidelines,1992

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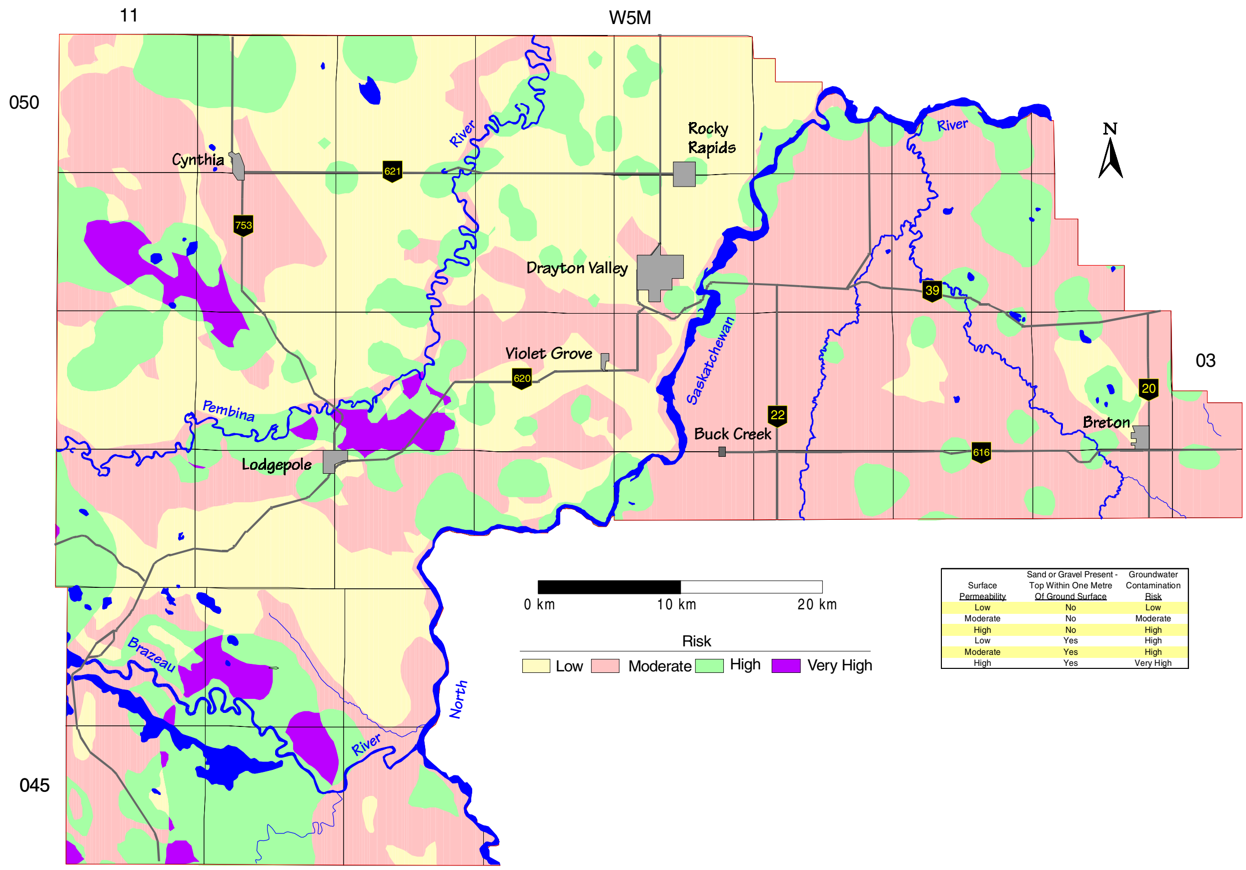
M.D. of Brazeau No. 77
Risk of Groundwater Contamination



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

Agriculture and Agri-Food Canada   Agriculture et Agroalimentaire Canada

PFRA

Prairie Farm Rehabilitation Administration

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

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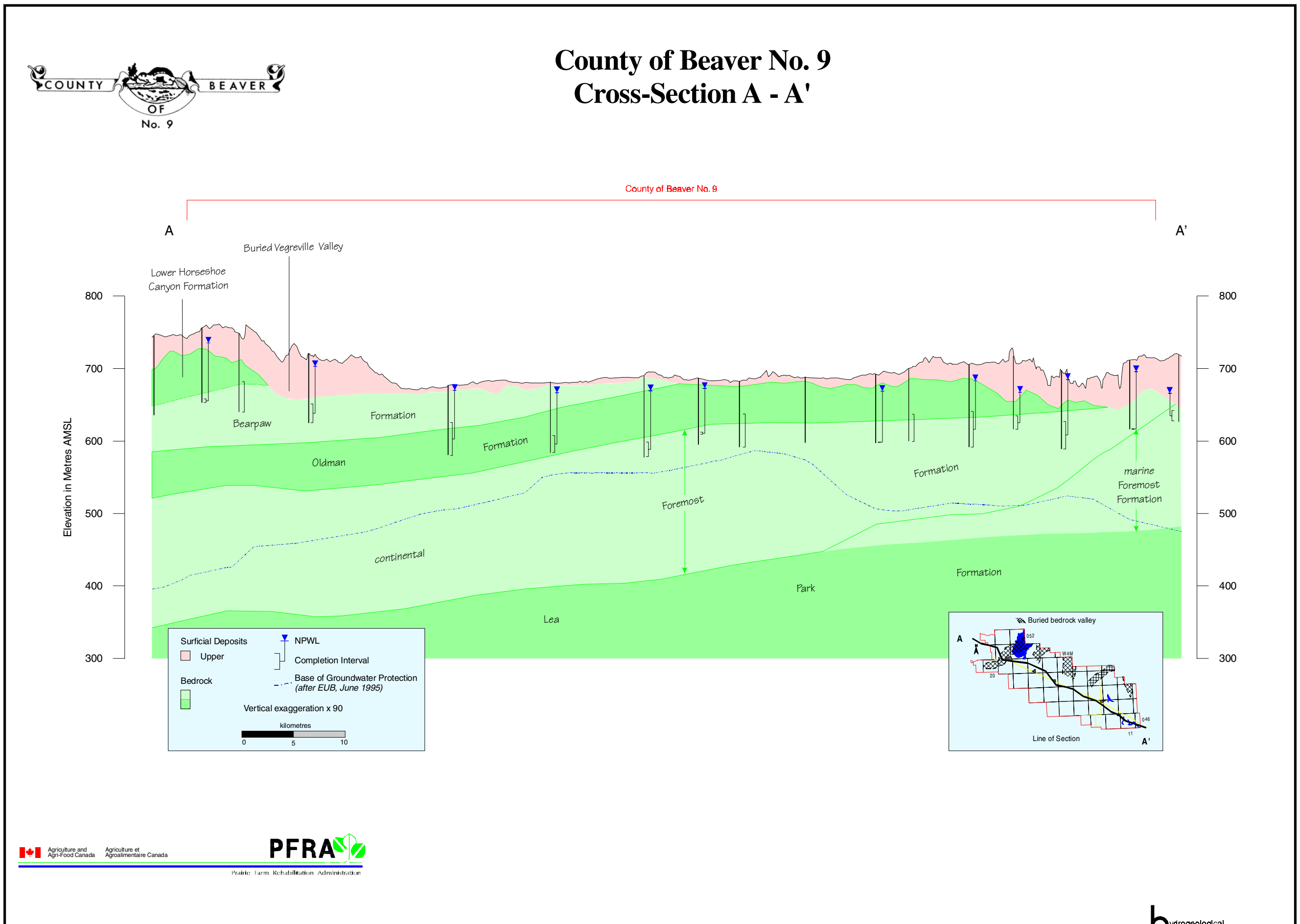

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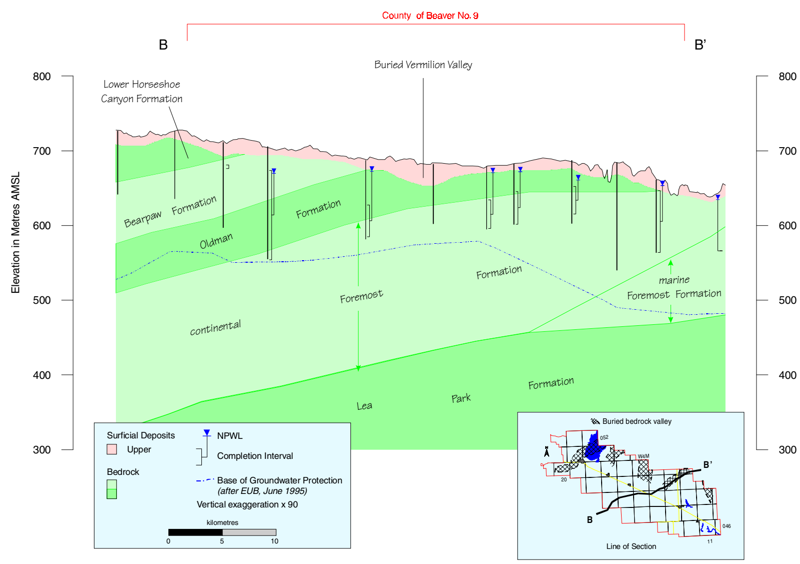
County of Beaver No. 9
Cross-Section B - B'



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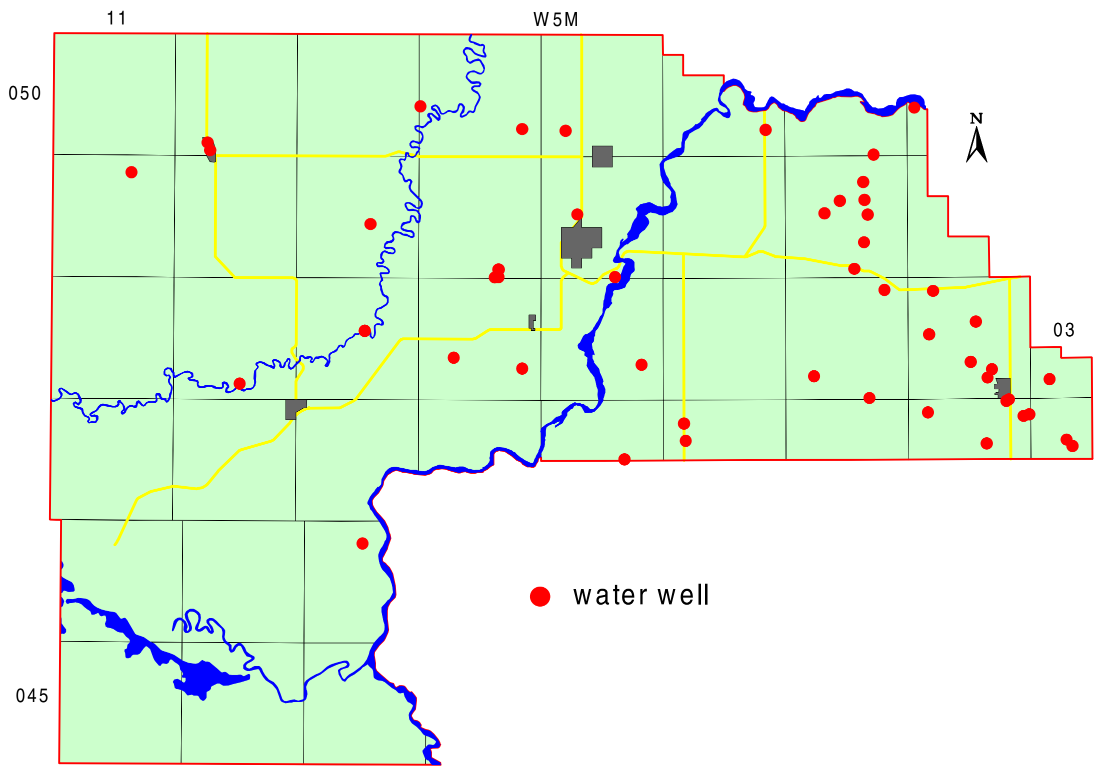
M.D. OF BRAZEAU NO. 77

Appendix E

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Water Wells Recommended for Field Verification

(details on following page)



WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Owner	Location	Water Well Contractor	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet
N O Mcitinoy	NW 03-048-10 5	Terry'S Water Wells (1980) Ltd.	Apr-75	21.3	70.0	6.7	22.0
Jim Gaudet	NW 20-047-06 5	Morrill'S Water Well Drilling Ltd.	Jun-83	51.8	170.0	9.5	31.0
Amoco Canada	28-046-09 5	Unknown Driller	Oct-69	99.1	325.0	59.4	195.0
Darrell Haight	NE 11-048-07 5	Morrill'S Water Well Drilling Ltd.	Feb-74	39.6	130.0	22.9	75.0
Amoco Canada#Hb A-78	22-048-09 5	Unknown Driller	Feb-71	33.5	110.0	4.0	13.0
Alta Env #Landfill Ow2	SE 20-049-07 5	Big Quill Drilling Ltd.	Feb-85	21.3	70.0	15.5	51.0
M. D. Of Brazeau	SE 05-050-10 5	Panky's Consolidated Ltd.	Nov-91	52.1	171.0	7.9	26.0
George Hubert	SW 23-047-07 5	Hostyn Drilling Co. Ltd.	Oct-76	54.9	180.0	43.9	144.0
Greg Hartman	SW 18-050-08 5	Morrill'S Water Well Drilling Ltd.	Jun-88	60.4	198.0	2.1	7.0
R. Guyon	SW 12-050-08 5	Wilson Fred Y	Aug-60	36.3	119.0	24.4	80.0
Randy Hamilton	12-048-08 5	Panky'S Consolidated Ltd.	Mar-83	18.3	60.0	11.6	38.0
Ken Thirsk	NW 29-047-06 5	Morrill'S Water Well Drilling Ltd.	Sep-70	54.9	180.0	13.7	45.0
Len Ulmer	SE 17-048-08 5	Darragh Lee	Jul-80	42.7	140.0	29.0	95.0
Lyle House	SE 03-049-08 5	Morrill'S Water Well Drilling Ltd.	Aug-79	57.9	190.0	29.0	95.0
Dave Ponti	SE 03-049-08 5	Morrill'S Water Well Drilling Ltd.	Mar-82	64.0	210.0	42.1	138.0
Dave Ponti	SE 03-049-08 5	Morrill'S Water Well Drilling Ltd.	Aug-81	48.8	160.0	30.5	100.0
Robert Kitching	15-049-09 5	Darragh Lee	Nov-80	39.6	130.0	15.2	50.0
Getty Oil Ltd	34-049-11 5	Panky'S Consolidated Ltd.	Jun-83	36.6	120.0	12.2	40.0
Cynthia Townsite	05-050-10 5	Other	May-56	52.1	171.0	4.8	15.8
Ralph Cook	SE 03-049-08 5	Panky'S Consolidated Ltd.	Jul-80	48.2	158.0	29.3	96.0
Bruce Cropley	SW 02-050-05 5	Hostyn Drilling Co. Ltd.	Nov-81	64.0	210.0	45.7	150.0
Don & Virginia Aronyk	SW 03-049-05 5	Hostyn Drilling Co. Ltd.	May-86	77.1	253.0	53.3	175.0
Jodi Martin	SW 12-050-06 5	Hostyn Drilling Co. Ltd.	Jun-84	70.1	230.0	57.9	190.0
S. Stenberg	35-047-04 5	Johnson Glen	Sep-79	55.8	183.0	32.9	108.0
E. Floden	NE 27-049-05 5	Hostyn Drilling Co. Ltd.	Jan-86	30.5	100.0	13.7	45.0
Arnold Briant	SW 23-049-05 5	Hostyn Drilling Co. Ltd.	May-80	44.2	145.0	24.4	80.0
C. Macdonald	NE 22-049-05 5	Hostyn Drilling Co. Ltd.	May-81	36.6	120.0	22.3	73.0
Steve Tweedle	NE 21-049-05 5	Hostyn Drilling Co. Ltd.	Sep-81	41.2	135.0	18.3	60.0
Tom Martin	SE 20-049-05 5	Hostyn Drilling Co. Ltd.	May-76	46.9	154.0	35.7	117.0
R.W. Holmgren	NE 10-049-05 5	Hostyn Drilling Co. Ltd.	Jul-74	61.0	200.0	44.2	145.0
August Sobattka	SW 32-048-04 5	Chappell, W. Drilling	May-83	39.6	130.0	0.0	0.1
L. Collicutt	NE 35-047-04 5	Johnson Glen	Jul-76	58.8	193.0	17.4	57.0
Audrey Zeiner	35-048-05 5	Hostyn Drilling Co. Ltd.	Sep-82	25.9	85.0	10.7	35.0
Latosky	03-049-07 5	Deans Ww Drlg	Aug-79	31.7	104.0	10.7	35.0
D. Cropley	18-050-04 5	Hostyn Drilling Co. Ltd.	Oct-80	39.6	130.0	22.9	75.0
Amoco Canada	22-048-09 5	Morrill'S Water Well Drilling Ltd.	Dec-70	33.5	110.0	3.7	12.0
R. Ellis	SW 20-048-04 5	Burgess, George Well Drilling Ltd		45.7	150.0	0.3	1.0
Amoco Canada	22-048-09 5	Morrill'S Water Well Drilling Ltd.	Nov-70	32.0	105.0	3.4	11.0
M. Freeson	SE 36-047-04 5	Hostyn Drilling Co. Ltd.	May-81	27.4	90.0	23.2	76.0
Jim Wheale	NW 21-047-03 5	Morrill'S Water Well Drilling Ltd.	Jun-81	45.7	150.0	32.9	108.0
Dennis Carson	NE 20-047-03 5	Hostyn Drilling Co. Ltd.	Jun-80	41.2	135.0	31.7	104.0
Freeson	36-047-04 5	Hostyn Drilling Co. Ltd.	Apr-81	22.9	75.0	15.5	51.0
Eli Myles	11-048-04 5	Hostyn Drilling Co. Ltd.	Sep-80	21.3	70.0	6.4	21.0
B. Thompson	SE 31-047-04 5	Johnson Glen	Apr-74	40.5	133.0	25.6	84.0
R. Samardzic	NE 22-047-04 5	Johnson Glen	Jun-65	12.2	40.0	6.7	22.0
E.R. Miles	SE 10-048-04 5	Hostyn Drilling Co. Ltd.	Nov-75	36.6	120.0	10.7	35.0
R. Stevenson	NE 06-048-03 5	Gemini Drlg	Jun-76	25.9	85.0	9.1	30.0
Gerard Hennaux	NW 22-048-04 5	Double H Drlg	Jun-79	18.3	60.0	7.9	26.0
R. Smith	02-048-05 5	Hostyn Drilling Co. Ltd.	Oct-76	32.0	105.0	10.7	35.0
Richert	SW 08-050-07 5	Morrill'S Water Well Drilling Ltd.	Nov-77	45.7	150.0	12.2	40.0
Loretta Westlin	08-048-05 5	Panky'S Consolidated Ltd.	Sep-83	57.9	190.0	32.0	105.0
Lenard Gusch	NW 10-048-04 5	Al'S Water Wells Ltd	Jul-75	52.4	172.0	30.5	100.0