Lakeland County Study Area

Part of the Churchill and Athabasca River Basins
Parts of Tp 062 to 070, R 09 to 17, W4M
Regional Groundwater Assessment

Prepared for Lakeland County

In conjunction with

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

Canada

Prepared by
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LAKELAND COUNTY STUDY AREA
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1. Project Overview

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

How a County takes care of one of its most precious resources - groundwater - reflects the future wealth and health of its people. Good environmental practices are not an accident. They must include genuine foresight with knowledgeable planning. Implementation of strong practices not only commits to a better quality of life for future generations, but also creates a solid base for increased economic activity. **Though this report's scope is regional, it is a first step for Lakeland County (the County) in managing their groundwater. It is also a guide for future groundwater-related projects.**

1.1 Purpose

This project is a regional groundwater assessment of Lakeland County prepared by Hydrogeological Consultants Ltd. (HCL) with financial and technical assistance from the Prairie Farm Rehabilitation Administration arm of Agriculture and Agri-Food Canada (AAFC-PFRA). The regional groundwater assessment provides the information to assist in the management of the groundwater resource within the County. Groundwater resource management involves determining the suitability of various areas in the County for particular activities. These activities can vary from the development of groundwater for agricultural or industrial purposes, to the siting of waste storage. **Proper management ensures protection and utilization of the groundwater resource for the maximum benefit of the people of the County.**

The regional groundwater assessment will:

- identify the aquifers[1] within the surficial deposits[2]
- spatially identify the main aquifers
- describe the quantity and quality of the groundwater associated with each surficial aquifer
- identify the hydraulic relationship between aquifers
- identify possible groundwater depletion areas associated with each surficial aquifer.

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

[1] See glossary
[2] See glossary

1.2 The Project

This regional study should only be used as a guide. Detailed local studies are required to verify hydrogeological conditions at given locations.

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

Task 1 - Data Collection and Review
Task 2 - Hydrogeological Maps, Figures, Digital Data Files
Task 3 - Hydrogeological Evaluation and Preparation of Report
Task 4 - Groundwater Information Query Software
Task 5 - Review of Draft Report and GIS Data Files
Task 6 - Report Presentation and Familiarization Session
Task 7 - Provision of Report, Maps, Data Layers and Query
Task 8 - Provision of Compact Disk for Sale to General Public.

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

1.3 About This Report

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

Additional technical details are available from files on the CD-ROM to be provided with the final version of this report. The files include the geo-referenced electronic groundwater database, maps showing distribution of various hydrogeological parameters, the groundwater query, ArcView files and ArcExplorer 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. A plastic County map outline is provided to overlay the maps, and contains information such as towns, main rivers, etc.

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[3]
2) a table of contents for the Water (Ministerial) Regulation under the new Water Act
3) a flow chart showing the licensing of a groundwater diversion under the new Water Act
4) interpretation of chemical analysis of drinking water
5) additional information.

The Water (Ministerial) 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 D includes page-size copies of the poster-size figures provided with this report.

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

Appendix F includes page-size copies of figures combining Lakeland County and the M.D. of Bonnyville.

[3] See glossary

2. Introduction

2.1 Setting

Lakeland County is situated in east-central Alberta. This area is part of the Alberta High Plains portion of the Interior Plains region (Ozoray, Wallick and Lytviak, 1980). The study area, defined here as 'the County', includes parts of the area bounded by townships 062 to 070, ranges 09 to 17, west of the 4th Meridian. The other County boundaries follow township or section lines. The County occupies part of the Churchill and Athasbasca River Basins.

Regionally, the topographic surface ranges from less than 550 to more than 800 metres above mean sea level (AMSL). The lowest elevations occur along La Biche River (see overlay) and the highest elevations are in the northeastern parts of the County as shown on Figure 1 and Page A-3. The area is well drained by numerous lakes and streams, the main one being Lac la Biche.

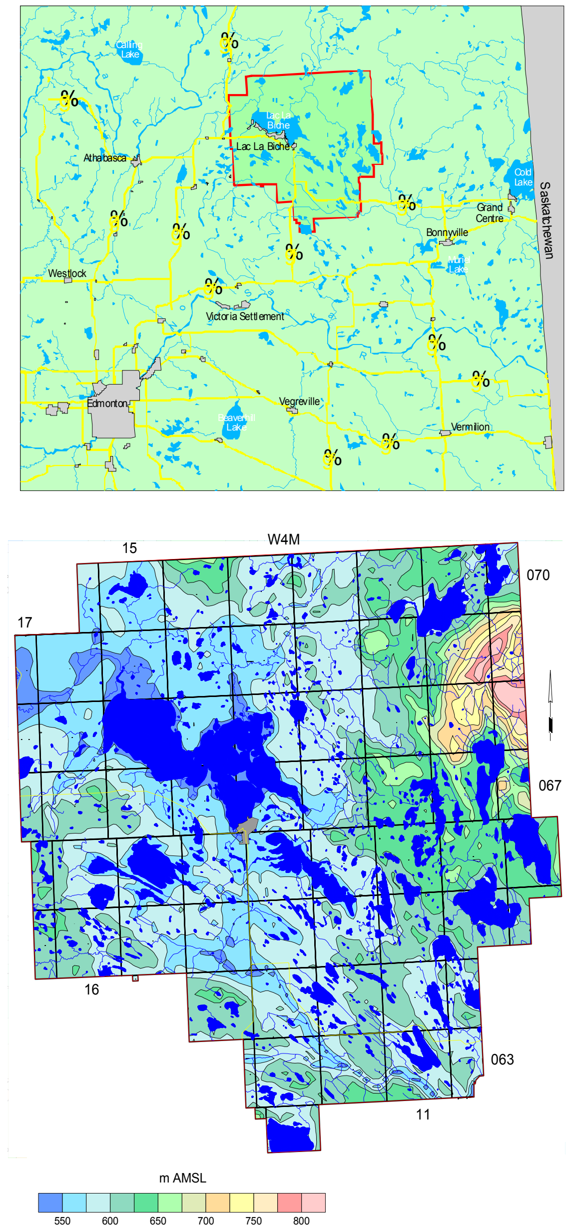

Figure 1. Index Map

2.2 Climate

Lakeland County 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 Leggatt, 1981) shows that the County is located in both the Low Boreal Mixedwood region and the Mid Boreal Mixedwood region. This vegetation change is influenced by increased precipitation and cooler temperatures, resulting in additional moisture availability.

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 two meteorological stations within the County measured 529 millimetres (mm), based on data from 1947 to 1993. The annual temperature averaged 1.4° C, with the mean monthly temperature reaching a high of 15°C in July, and dropping to a low of -19 °C in January. The calculated annual potential evapotranspiration is 491 millimetres.

2.3 Background Information

2.3.1 Number, Type and Depth of Water Wells

There are currently records for 1,770 water wells in the groundwater database for the County, of which a proposed use is available for 1,600 water wells. Of the 1,600 water wells, 1,510 are for domestic/stock purposes. The remaining 90 water wells were completed for a variety of uses, including industrial, municipal, industrial, observation, investigation and dewatering. Based on a rural population of 4,823 (Phinney, 2002), there are 1.3 domestic/stock water wells per family of four. It is unknown how many of these water wells may still be active (especially in areas where rural pipelines have been constructed in recent years). Of the 1,456 domestic or stock water wells with a completed depth, 1,198 (82%) are completed at depths of less than 50 metres below ground level. Details for lithology[4] are available for 1,033 water wells.

2.3.2 Number of Water Wells in Surficial and Bedrock Aquifers

There are 622 water well records with completion interval and lithologic information, such that the aquifer in which the water wells are completed can be identified. 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 top of the bedrock are water wells completed in surficial aquifers. Of the 622 water wells for which aquifers could be defined, 614 are completed in surficial aquifers, with 65% of these having a completion depth of less than 50 metres below ground level. From Figure 2, it can be seen that most water wells are completed in aquifers in the surficial deposits, which are the dominant aquifer and occur throughout the County. The water wells completed in the lower surficial deposits mainly occur along the linear bedrock lows. The lowest elevation of the linear bedrock low is the thalweg.

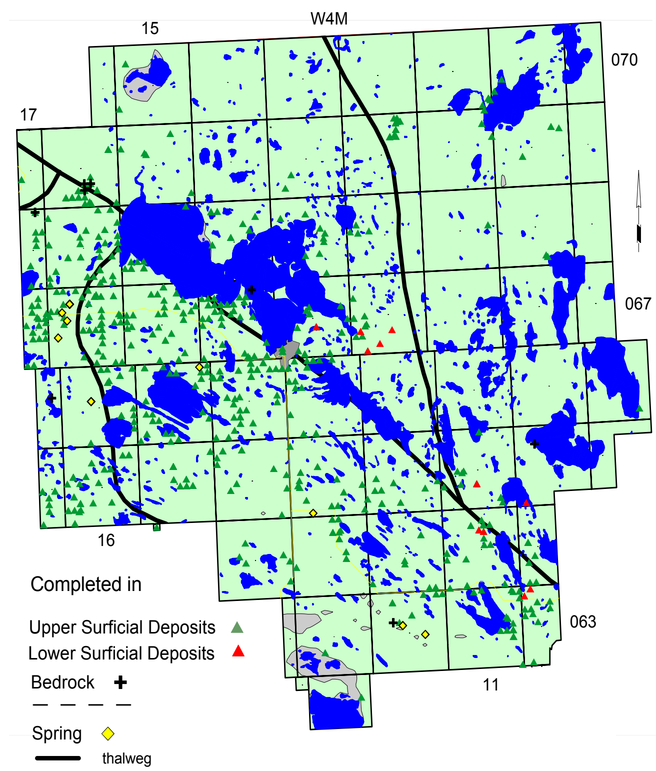

Figure 2. Location of Water Wells and Springs

The data for eight 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(s).

There are currently records for nine springs in the groundwater database; these springs generally occur in the vicinity of linear bedrock lows and mainly at a surface elevation from 550 to 600 metres AMSL. Of the seven springs having total dissolved solids (TDS) values, four have TDS concentrations of less than 400 milligrams per litre (mg/L) and three have TDS concentrations of more than 750 mg/L. The springs have total hardness values that average 307 mg/L. There is only one available flow rate in the groundwater database for the springs within the County; the flow rate of 4.6 litres per minute (lpm) is for a spring in 12-36-066-15 W4M.

[4] See glossary

2.3.3 Casing Diameter and Type

Data for casing diameters are available for 987 water wells, with 576 (58%) indicated as having a diameter of less than 275 mm and 411 water wells having a surface-casing diameter of more than 275 mm. The casing diameters of greater than 275 mm are mainly bored or dug water wells and those with a surface-casing diameter of less than 275 mm are drilled water wells. In addition to the 987 water wells that have been designated as either bored or drilled water wells based on casing diameter, another 341 water wells have been designated as bored or drilled water wells based on the drilling method only, with no casing size indicated on the water well record. Of the 341 water wells having no casing size, 165 are drilled water wells and 176 are bored water wells. Of the 1,328 drilled and bored water wells, 1,076 have a completion date and a completion depth. From before 1965 to 1969, the water wells completed in the County were mainly drilled water wells. From 1970 to 1984, the water wells completed were mainly bored or hand dug water wells, and from 1985, the completed water wells were mainly drilled water wells.

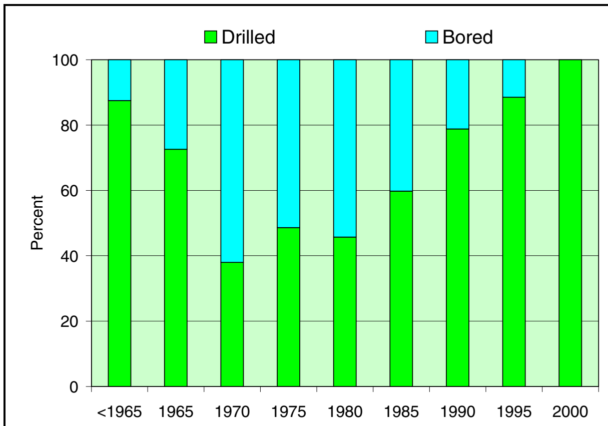

Figure 3. Casing Diameter Used in Water Wells

In the County, steel, galvanized steel and plastic surface casing materials have been used in 97% of the drilled water wells over the last 40 years. Until the mid-1960s, the type of surface casing used in drilled water wells was mainly undocumented. Steel casing was predominantly used in drilled water wells in the 1960s and 1970s but is currently being used in only 3% of the water wells drilled in the County. Galvanized steel surface casing was used in a maximum of 55% of the drilled water wells from the 1970s to the 1990s. Galvanized steel was last used in August 1995. Plastic casing was first used in June 1979, and is currently being used in 97% of the drilled water wells in the County.

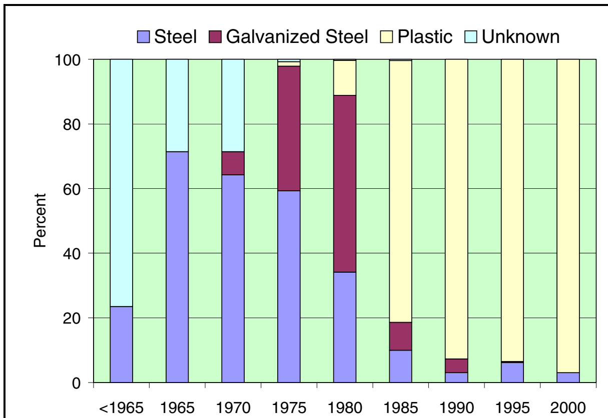

Figure 4. Surface Casing Types Used in Drilled Water Wells

2.3.4 Dry Water Test Holes

In the County, there are 2,254 records in the groundwater database. Of these 2,254 records, 147 are indicated as being dry or abandoned with "insufficient water".

2.3.5 Requirements for Licensing

Water wells used for household needs in excess of 1,250 cubic metres per year (748 imperial gallons per day[5]) and all other groundwater use must be licensed. The only groundwater uses that do not need licensing are (1) household use of up to 1,250 m³/year and (2) groundwater with total dissolved solids in excess of 4,000 mg/L. In the last update from the Alberta Environment (AENV) groundwater database in September 2001, eleven groundwater allocations were shown to be within the County. All of the 11 licensed groundwater users could be linked to the AENV groundwater database. Of the 11 licensed groundwater users, eight are for agricultural purposes, two are for municipal, and the remaining one is for recreation purposes. The total maximum authorized diversion from the water wells associated with these licences is 151 cubic metres per day (m³/day), although actual use could be less. Of the 151 m³/day, 76 m³/day (51%) is authorized for agricultural purposes, 64 m³/day

[5] see conversion table on page 56

(42%) is for municipal purposes and 10 m³/day (7%) is for recreational purposes, as shown below in Table 1. A figure showing the locations of the licensed users is in Appendix A (Page A-7) and on the CD-ROM. Table 1 also shows a breakdown of the eleven licensed groundwater allocations by the aquifer in which the water well is completed. The largest total licensed allocations are in the Empress Aquifer – Unit 3. Of the 151 m³/day licensed groundwater use in the Empress Aquifer – Unit 3, 42% of the groundwater allocation is from a water supply well in 10-36-066-15 W4M.

Aquifer **	No. of Diversions	Licensed Groundwater Users* (m³/day) Agricultural	Municipal	Recreation	Total	Percentage
Grand Centre	3	25.7	0.0	0.0	25.7	17.1
Marie Creek	1	6.8	0.0	0.0	6.8	4.5
Empress - Unit 3	5	20.3	64.0	10.1	94.4	62.7
Unknown	2	23.6	0.0	0.0	23.6	15.7
Total	11	76.4	64.0	10.1	151	100
Percentage		50.8	42.5	7	100	

* - data from AENV ** - Aquifer identified by HCL

Table 1. Licensed Groundwater Diversions

Based on the 2001 Agriculture Census, the calculated water requirement for 65,730 livestock for the County is in the order of 3,727 m³/day. This value does not include domestic animals, but does include intensive livestock use. Of the 3,727 m³/day average calculated livestock use, AENV has licensed a groundwater diversion of 76 m³/day (2%) and licensed a surface-water diversion of 156 m³/day (4%). The remaining 94% of the calculated livestock use would have to be from unlicensed sources.

2.3.6 Base of Groundwater Protection

In general, Alberta Environment defines the Base of Groundwater Protection as the elevation below which the groundwater will have more than 4,000 mg/L of total dissolved solids. By using the ground elevation, formation elevations, and Alberta Energy and Utilities Board (EUB) information indicating the formations containing the deepest useable water for agricultural needs, a value for the depth to the Base of Groundwater Protection can be determined. These values are gridded using the Kriging[6] method to prepare a depth to the Base of Groundwater Protection surface. This depth, for the most part, would be the maximum drilling depth for a water well for agricultural purposes or for a potable water supply. If a water well has total dissolved solids exceeding 4,000 mg/L, the groundwater use does not require licensing by AENV. In the County, the depth to Base of Groundwater Protection ranges from less than 50 metres to more than 250 metres below ground level in the southern part of the County, as shown on Figure 5 and on the cross-sections presented in Appendix A and on the CD-ROM. The main area where the depth to Base of Groundwater Protection is less than 50 metres is in the extreme northeastern part of the County.

[6] See glossary

Of the 1,694 water wells with completed depth data, 52 water wells are completed below the Base of Groundwater Protection. In the County, the Base of Groundwater Protection is mainly below the Milk River Formation (see Pages A-12 to A-15). In the northeastern part of the County, the Base of Groundwater Protection is at the base of the Bonnyville Formation. These 52 water wells have been posted on the adjacent figure and show that they are mainly located where the depth to Base of Groundwater Protection is more than 50 metres. Chemistry data are available for 39 of these 52 water wells; TDS concentrations are greater than 4,000 mg/L for 35 of the 39 water wells.

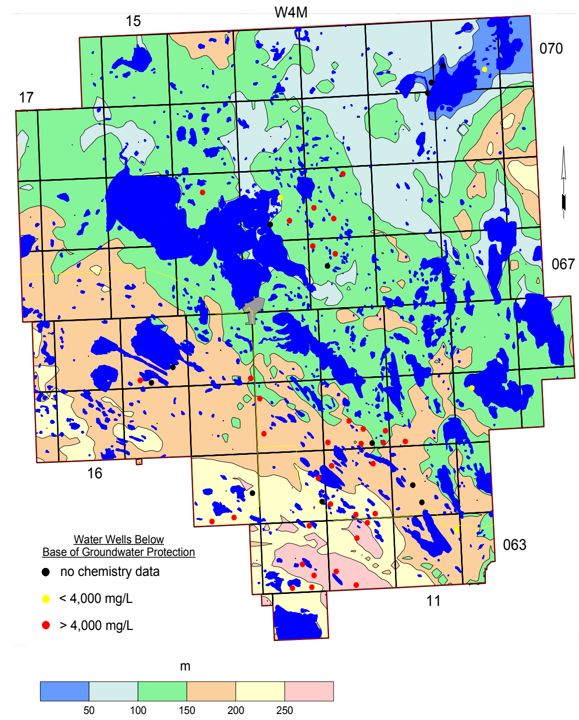

Figure 5. Depth to Base of Groundwater Protection (after EUB, 1995)

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

Even with the available sources of data, the number of water-level data points relative to the size of the County is too few to provide a reliable groundwater budget (see section 6.0 of this report). 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 (see section 7.0 of this report).

3. Terms

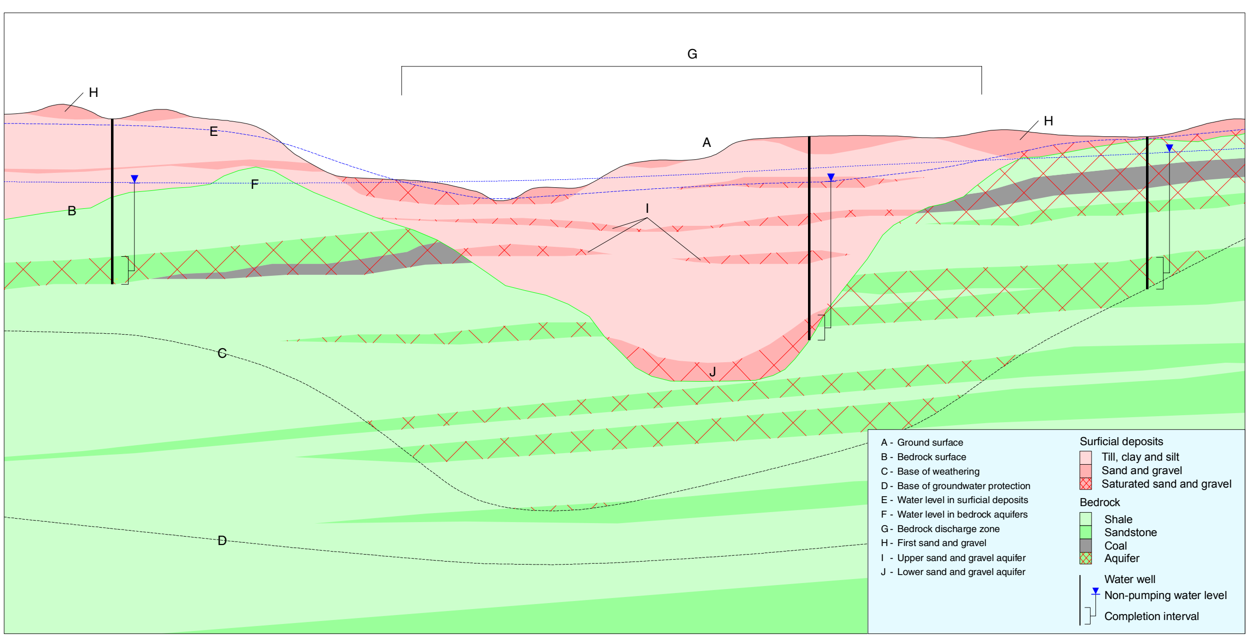

Figure 6. Generalized Cross-Section (for terminology only)

	Formation		Unit or Member		
Lithology Description	Average Thickness (m)	Designation	Average Thickness (m)	Designation	Lithology Description
diamicton	< 25	Grand Centre	< 20	Vilna Member	clayey diamicton
			< 30	Kehiwin Member	sandy diamicton
			< 10	Reita Lake Member	clayey sand diamicton
			< 10	Hilda Lake Member	clayey diamicton
sand and gravelly sand	< 25	Sand River			
diamicton	< 25	Marie Creek	10	Unit 2	sandy diamicton
			10	Unit 1	clayey diamicton
silt and clay with sand	2	Ethel Lake			
diamicton	50	Bonnyville	25	Unit 2	sandy clay diamicton
			25	Unit 1	clayey diamicton
sand and gravel	35	Muriel Lake			
clayey diamicton	5	Bronson Lake			
sand and gravel, silt and clay	70	Empress	25	Unit 3	sand and gravel
			25	Unit 2	silt and sand, minor sand and gravel
			25	Unit 1	preglacial sand and gravel (lower surficial deposits)
shale, siltstone	100-200	Lea Park Formation			
sandstone, siltstone, shale, coal	90-120	Milk River Formation			
shale, siltstone	200-1000	*undivided Colorado Group*			

Figure 7. Geologic Column
(modified after Andriashek and Fenton, 1989)

4. Methodology

4.1 Data Collection and Synthesis

The AENV 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) locations for some water wells determined during water well surveys
6) chemical analyses for some groundwaters
7) location of some flowing shot holes
8) location of some structure test holes
9) 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. Any duplicate water wells that have been identified within the County have been removed from the database used in this regional groundwater assessment.

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

The present project uses the 10TM coordinate system based on the NAD27 datum. This means that a record for the NW ¼ of section 01, township 070, range 11, W4M, would have a horizontal coordinate with an Easting of 221,235 metres and a Northing of 6,101,516 metres, the centre of the quarter section. If the water well has been repositioned by AAFC-PFRA using orthorectified aerial photos, the location will be more accurate, possibly within several tens of metres of the actual location. Once the horizontal coordinates are determined for a record, a ground elevation for that record is obtained from the 1:20,000 Digital Elevation Model (DEM); AltaLIS Ltd. provides the DEM.

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

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 sufficient information is available, individual records are assigned to specific geological units in both the bedrock and the surficial deposits; the minimum information required is a value for the depth to bedrock and a value for depth to top and bottom of the completion intervals[7].

Also, where sufficient information is available, values for apparent transmissivity[8] and apparent yield[9] are calculated, based on the aquifer test summary data supplied on the water well drilling reports. Where valid detailed aquifer test results exist, the interpreted data provide values for aquifer transmissivity and effective transmissivity. Since the last regional hydrogeological map covering most of the County was published in 1980 (Ozoray, Wallick and Lytviak), 1980), 490 values for apparent transmissivity and 300 values for apparent yield have been added to the groundwater database. With the addition of the apparent yield values, including a 0.1 - m³/day value assigned to dry water wells and water test holes, a hydrogeological map has been prepared to help illustrate the general groundwater availability across the County (Figure 8). The map is based on groundwater being obtained from all aquifers and has been prepared to allow direct comparison with the results provided on the Alberta Research Council hydrogeological maps.

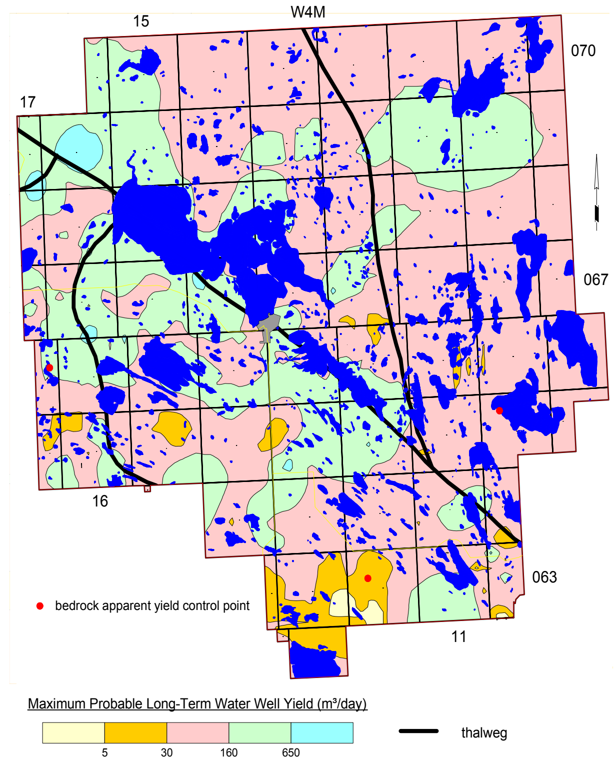

Figure 8. Hydrogeological Map

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 geologic units
3) type and intervals for various down-hole geophysical logs
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 groundwater database. The reference section of this report lists the available reports. Digital data from publications are from the Geological Atlas of the Western Canada Sedimentary Basin (Mossop and Shetsen, 1994). These data are used to support the geological interpretation of geophysical logs but cannot be distributed because of a licensing agreement. Digital data of the Cold Lake stratigraphy were received from L. D. Andriashek (Andriashek and Fenton, 1989).

[7] See glossary
[8] For definitions of Transmissivity, see glossary
[9] For definitions of Yield, see glossary

4.2 Spatial Distribution of Aquifers

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

1) Quaternary geologic formation picks provided by L. D. Andriashek
2) published structure contour maps
3) lithologs provided by the water well drillers
4) geophysical logs from structure test holes
5) geophysical logs for wells drilled by the oil and gas industry
6) data from existing cross-sections.

The aquifers are defined by mapping the tops and bottoms of individual geologic units. The values for the elevation of the top and bottom of individual geologic units at specific locations help to determine the spatial distribution of the individual surfaces. Establishment of a surface distribution digitally requires 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 method.

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

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), apparent transmissivity, and apparent water well yield. The total dissolved solids, sulfate, nitrate + nitrite (as N), chloride and total hardness concentrations from the chemical analysis of the groundwater are also assigned to applicable aquifers. **Since 1986, Alberta Health and Wellness has restricted access to chemical analysis data, and hence the database includes only limited amounts of chemical data since 1986.**

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. The representative data set included using the available data from townships 062 to 070, ranges 09 to 17, W4M, plus a buffer area of at least one township. Even when only limited data are available, grids are prepared. However, the grids prepared from the limited data must be used with extreme caution because the gridding process can be unreliable.

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

Cross-sections are prepared by first choosing control points from the database along preferred lines of section. Data from these control points are then obtained from the database and placed in an AutoCAD drawing with an appropriate vertical exaggeration. The data placed in the AutoCAD drawing include the geo-referenced lithology, completion intervals and non-pumping water levels. Data from individual geologic 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. Six cross-sections are presented in Appendix A of this report and as poster-size drawings forwarded with this report; only two (B-B’ and D-D’) are included in the text of this Report. The cross-sections are also included on the CD-ROM; page-size maps of the poster-size cross-sections are included in Appendix D of this report.

4.5 Software

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

- Acrobat 4.0
- ArcView 3.2
- AutoCAD 2000
- CorelDraw! 10.0
- Microsoft Office XP
- Surfer 7.0

5. Aquifers

5.1 Background

An aquifer is a permeable rock that is saturated. In this context, rock refers to subsurface materials, such as sand, gravel, sandstone and coal. If the non-pumping water level is above the top of the rock, this type of aquifer is an artesian aquifer. If the rock is not entirely saturated and the water level is below the top of the rock, this type of aquifer is a water-table aquifer. These types of aquifers occur in one of two general geological settings in the County. The first geological setting includes the sediments that overlie the bedrock surface. In this report, these sediments 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 geologic units, and the general chemical quality of the groundwater associated with each setting are reviewed separately.

5.1.1 Surficial Aquifers

Surficial deposits in the County are mainly less than 100 metres thick, except in areas of linear bedrock lows where the thickness of the surficial deposits can exceed 150 metres. The Buried Helena and Imperial Mills valleys are the main linear bedrock lows in the County (see Figure 11). A linear bedrock low that is not well defined in the County is the Buried Kikino Valley. The west-east cross-section D-D', Figure 9 shown below, passes across both the Buried Helena and Buried Beverly valleys and shows the surficial deposits being in the order of 100 metres thick across the Buried Imperial Mills Valley.

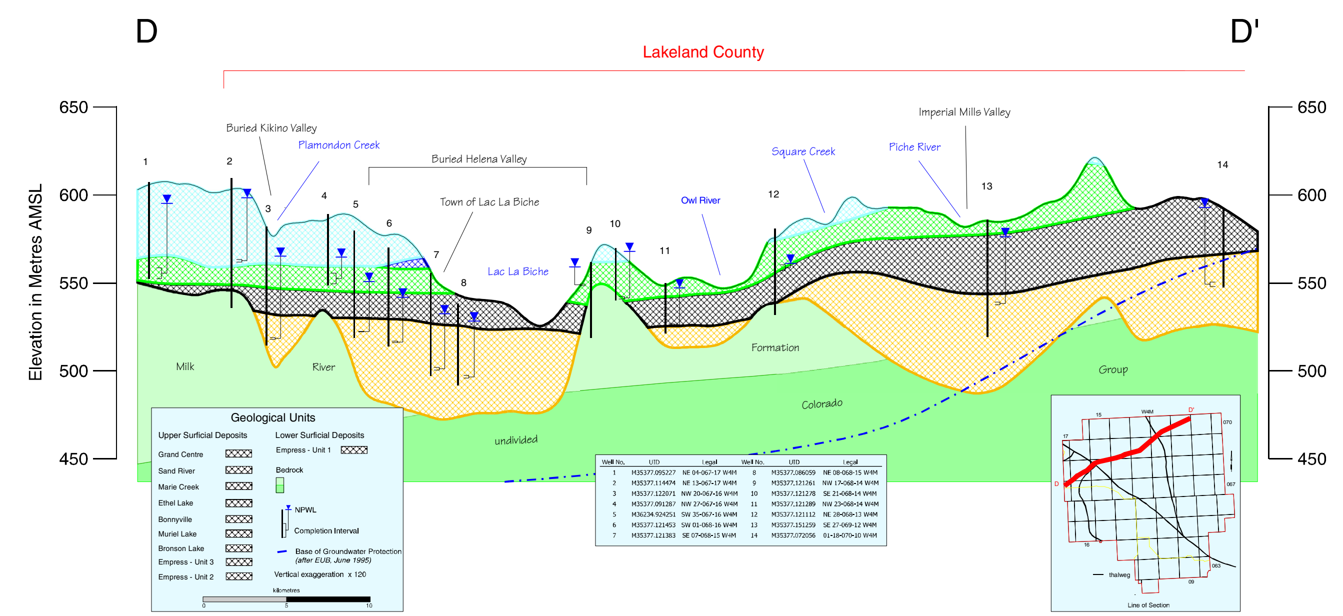

Figure 9. Cross-Section D - D'

In the County, the Base of Groundwater Protection extends below the bedrock surface but can extend into the Empress Formation, as shown on Figure 10 on the following page. A map showing the depth to the Base of Groundwater Protection is given on Page 7 of this report, in Appendix A, and on the CD-ROM.

The south-north cross-section B-B', Figure 10 shown below, passes across the Buried Helena Valley and shows the surficial deposits being in the order of 50 metres thick but can be more than 100 metres thick across the Buried Helena Valley.

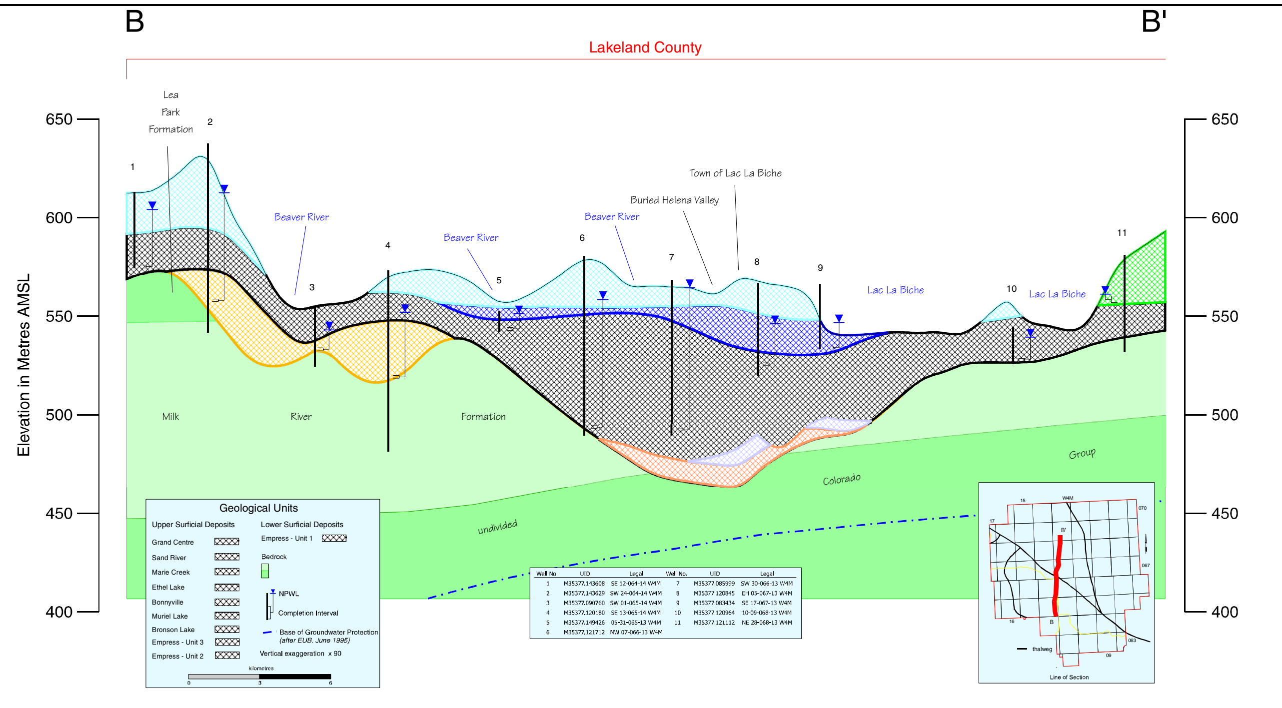

Figure 10. Cross-Section B - B'

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 non-pumping water level in water wells that are less than 20 metres deep. The base of the surficial deposits is the bedrock surface.

For a water well with a small-diameter casing to be effective in surficial deposits and to provide sand-free groundwater, the water well must be completed with a water well screen. Some water wells completed in the surficial deposits are completed in low-permeability aquifers and have a large-diameter casing. The large-diameter water wells may have been hand dug or bored and because they are completed in very low permeability aquifers, most of these water wells would not benefit from water well screens. The groundwater from an aquifer in the surficial deposits usually has a chemical hardness of at least a few hundred mg/L and a dissolved iron concentration such that the groundwater must be treated before being used for domestic needs. Within the County, casing-diameter information is available for 585 of the 614 water wells completed in the surficial deposits; 95 (16%) of the 585 water wells have a casing diameter of more than 275 millimetres, and are assumed to be bored or dug water wells.

5.1.2 Bedrock Aquifers

In the County, the upper bedrock includes the Foremost, Lea Park and Milk River formations, and the *undivided* Colorado Group, as shown above in Figure 10. Some of this bedrock contains saturated rocks that are permeable enough to transmit groundwater for a specific need. In the County, the upper bedrock aquifer(s) are of minor importance and there are only a few water wells completed in the upper bedrock.

5.2 Aquifers in Surficial Deposits

The surficial deposits are the sediments above the bedrock surface. These include pre-glacial materials, which were deposited before glaciation, and materials deposited directly or indirectly as a result of glaciation. The *lower surficial deposits* include pre-glacial fluvial[10] and lacustrine[11] deposits. The lacustrine deposits include clay, silt and fine-grained sand. The *upper surficial deposits* include the more traditional glacial deposits of till[12], meltwater deposits, and ice contact. Pre-glacial materials are expected to be mainly present in association with the buried bedrock valleys.

5.2.1 Geological Characteristics of Surficial Deposits

While the surficial deposits are treated as one hydrogeologic unit, they consist of three hydraulic parts. The first unit is the sand and gravel deposits of the lower surficial deposits, when present. These deposits are usually saturated. The second and third hydraulic units are associated with the sand and gravel deposits in the upper surficial deposits. The sand and gravel deposits in the upper surficial deposits occur mainly as pockets. The second hydraulic unit is the saturated part of these sand and gravel deposits; the third hydraulic unit is the unsaturated part of these deposits. For a graphical depiction of the above description, please refer to Figure 6, Page 7. 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.

The base of the surficial deposits is the bedrock surface, represented by the bedrock topography as shown on the adjacent map. There are four linear bedrock lows shown on the bedrock topography map. The lowest elevation of the linear bedrock low is the thalweg; the thalwegs for the linear bedrock lows in the present report are named as per Gold, Andriashek and Fenton, 1983.

Over the majority of the County, the surficial deposits are less than 100 metres thick (Page A-19). The exceptions are mainly in association with areas where buried bedrock valleys are present, where the deposits can have a maximum thickness of more than 150 metres. The main linear bedrock lows in the County are northwest-southeast-trending, are designated as the Buried Helena Valley and the Buried Imperial Mills Valley. The bedrock surface is at its lowest elevation of less than 440 metres AMSL within the Buried Helena Valley near Lac La Biche. The lowest elevation of the bedrock surface within the Buried Imperial Mills Valley is less than 480 metres AMSL.

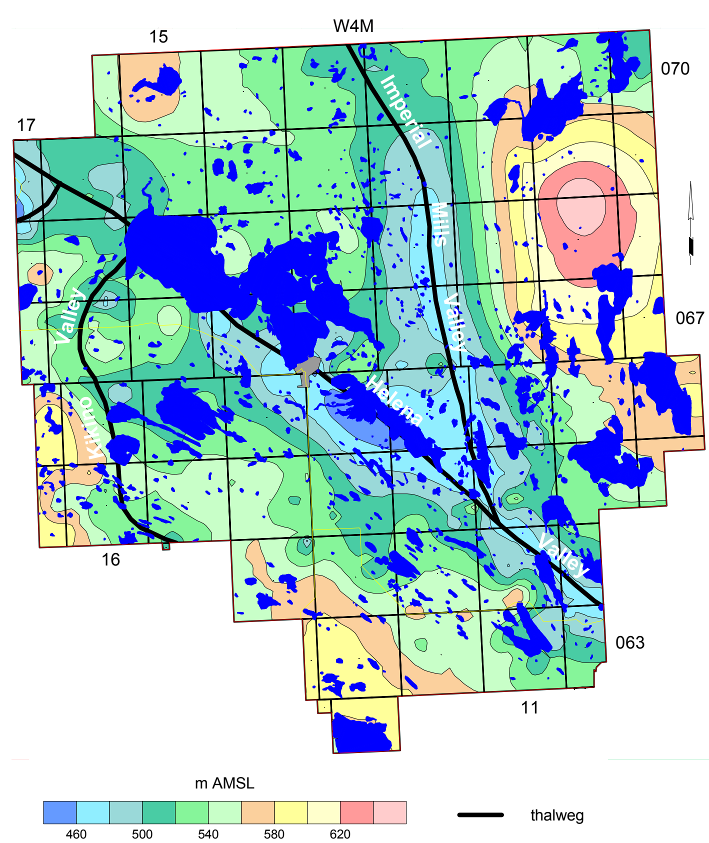

Figure 11. Bedrock Topography

10 See glossary
11 See glossary
12 See glossary

The Buried Helena Valley is the deepest and widest buried bedrock valley in the County. The Valley enters Lakeland County in township 069, range 17, W4M in the northwestern corner; the Valley extends southeast beneath Lac La Biche (Figure 11) toward township 063, range 08, W4M into the M.D. of Bonnyville before trending northeast to Cold Lake as shown on the bedrock topography map in Appendix F. The Valley is eight to twelve kilometres wide within the County, with local bedrock relief being up to 60 metres. Sand and gravel deposits can be expected in association with this bedrock low, with the sand and gravel deposits expected to be mainly less than ten metres thick.

There are three buried bedrock valleys that are tributaries to the Buried Helena Valley: Sinclair, Vermilion, and Imperial Mills valleys. The Buried Sinclair Valley and Buried Vermilion Valley are present in the M.D. of Bonnyville (see Appendix F).

The Buried Imperial Mills Valley, present in the central part of the County, trends south to join the Buried Helena Valley in township 065, range 11, W4M. The Buried Imperial Mills Valley is eight to ten kilometres wide, with local bedrock relief being up to 80 metres. Sand and gravel deposits can be expected in association with this bedrock low, and can be more than 50 metres thick where it joins the Buried Helena Valley.

The Buried Kikino Valley connects two major buried valleys, the Beverly and Helena valleys. The Buried Kikino Valley joins the Buried Beverly Valley in the County of Smoky Lake (Andriashek and Fenton, 1989). The Buried Kikino Valley is not well defined in Lakeland County, as shown by the contours on the bedrock topography map; however, Yoon and Vander Pluym (1974) indicate that the Buried Kikino Valley joins the Buried Helena Valley near Lac La Biche. The Buried Kikino Valley is generally three to five kilometres wide, with local bedrock relief ranging from 30 to 90 metres.

The lower surficial deposits are composed mostly of fluvial and lacustrine deposits. In the Sand River area (73L), the preglacial sediments have been defined by Andriashek and Fenton (1989), to include primarily preglacial sand and gravel deposits, and in this report have not been differentiated between fluvial and lacustrine deposits. The lower sand and gravels are referred to by Andriashek and Fenton as the Empress Formation - Unit 1. The Empress Formation – Unit 1 occurs in parts of the Buried Helena and Imperial Mills valleys. The Empress Formation – Unit 1 occurs in the Buried Kikino Valley south of the County near Bonnie Lake in township 060, range 13, W4M (Andriashek and Fenton, 1989). The total thickness of the Empress Formation – Unit 1 in the Buried Imperial Mills Valley is less than 15 metres.

The upper surficial deposits are either directly or indirectly a result of glacial activity. The deposits include till, with generally minor sand and gravel deposits of meltwater origin, which are expected to occur mainly as isolated pockets. Because the meltwater channels are mainly an erosional feature, the sand and gravel deposits associated with these features are considered not to be significant aquifers. The thickness of the upper surficial deposits is mainly less than 100 metres, but can be more than 100 metres near and at the junction of the Buried Helena and Imperial Mills valleys in the east-central parts of the County.

The extent of the formations that comprise the surficial deposits is limited by the data provided by Andriashek to HCL, and the figures published in Andriashek and Fenton's, "Quaternary Stratigraphy and Surficial Geology of the Sand River Area 73L" (1989). For the remainder of Lakeland County, outside the Sand River area, the extent of the surficial formations is not well defined.

Sand and gravel deposits occur throughout the County (Figure 12). The sand and gravel deposits are mainly less than ten metres thick. A thickness of more than 30 metres is expected in the Buried Imperial Mills Valley and at the junction of the Buried Helena and Imperial Mills valleys.

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 90% of the County where sand and gravel deposits are present, the sand and gravel deposits are less than 30% of the total thickness of the surficial deposits (Page A-21). The areas where sand and gravel deposits constitute more than 30% of the total thickness of the surficial deposits are mainly in the areas associated with linear bedrock lows.

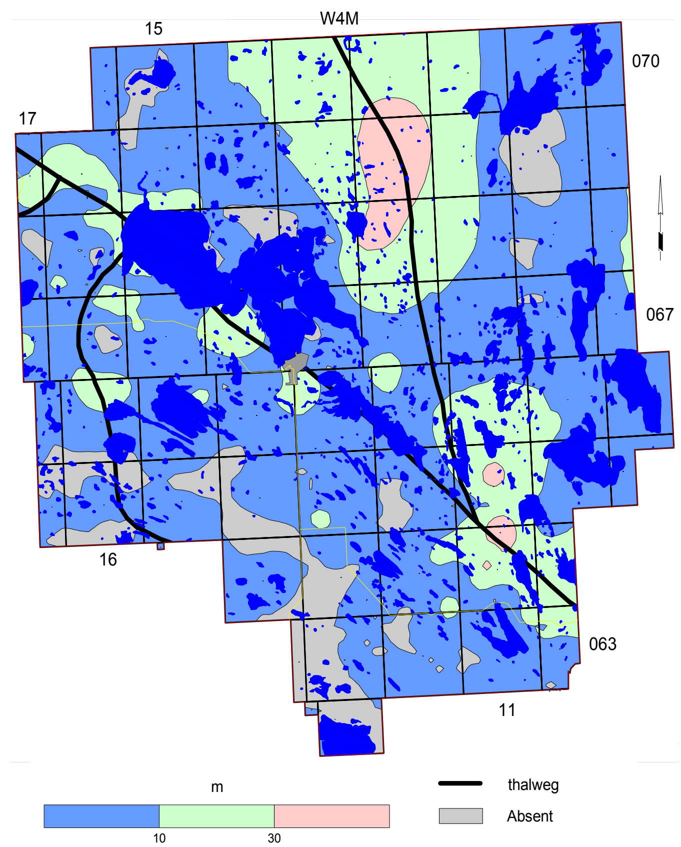

Figure 12. Thickness of Sand and Gravel Deposits

5.3 Surficial Deposits

5.3.1 Quaternary Stratigraphy

There are eight glacial formations and one preglacial formation present in the County. The eight glacial formations are: the Grand Centre, Sand River, Marie Creek, Ethel Lake, Bonnyville, Muriel Lake, Bronson Lake formations and the upper two units (Units 2 and 3) of the Empress Formation. The preglacial formation is the lower unit of the Empress Formation (Unit 1). A generalized geologic column, showing the eight formations, is illustrated on Figure 5, in Appendix A and on the CD-ROM. As previously stated on page 16, the extent of the formations that comprise the surficial deposits is limited by the digital data provided by Andriashek to HCL, and the figures published in Andriashek and Fenton's, "Quaternary Stratigraphy and Surficial Geology of the Sand River Area 73L" (1989). For the remainder of Lakeland County, outside the Sand River area, the extent of the surficial formations is not well defined and the quality of the hydrogeologic parameters associated with the individual aquifer is approximate; however, the maps for the sand and gravel aquifer(s) are more definitive.

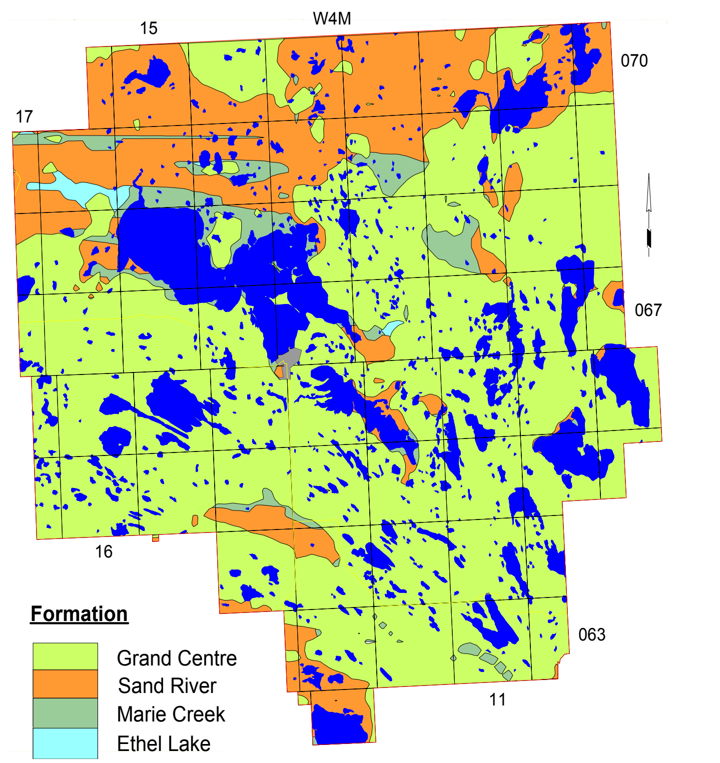

Figure 13. Surficial Geology Map

The following descriptions of the nine formations are modified from Andriashek and Fenton (1989):

"The Empress Formation is the oldest, and is divided into three units on the basis of lithology; Unit 1, preglacial sand and gravel; Unit 2, silt and clay; and Unit 3, glacial sand and gravel." The thickness of the Empress Formation is in the order of 70 metres. The Empress Formation – Unit 1 rests on the top of the Lea Park and Milk River formations and the *undivided* Colorado Group.

In the County, the sand and gravel deposits of the Empress Formation – Unit 1 are found on the floors of the Buried Helena and Buried Imperial Mills valleys that are within the Sand River area. "Unit 1 generally consists of thin (<5 metres) basal gravel overlain by sand or gravelly sand ranging in thickness from 5 to 10 metres" (see CD-ROM).

In the County, the silt and silty clay deposits of the Empress Formation – Unit 2 "are confined almost entirely to the bottoms of the valleys and channels". The Empress Formation - Unit 2 is generally thick near the confluence of the Buried Helena and Imperial Mills valleys where the Unit can be up to 15 metres thick. There will be no direct review of the Empress Formation - Unit 2 because there are no water wells in the County that are completed in the Unit; the only maps associated with the Empress Formation – Unit 2 to be included on the CD-ROM will be structure-contour maps.

In the County, the Empress Formation – Unit 3 is the lowest stratigraphic unit, all of whose sediments are of glacial origin. The sediments consist primarily of sand and gravel deposits. The determination of the areal extent and thickness of the Empress Formation – Unit 3 is the only Formation designation that differs from Andriashek and Fenton. The Empress Formation - Unit 3 directly overlies the bedrock surface in areas of bedrock highs. For this regional study, the determination of the areal extent and thickness of the Empress Formation – Unit 3 is calculated by subtracting the total thickness of the Bonnvyille, Muriel Lake and Bronson Lake formations from the top of the Bonnyville Formation.

The Bronson Lake Formation overlies the Empress Formation and consists of clayey till and glaciolacustrine clay and has an average thickness of less than ten metres. The extent of the Bronson Lake Formation is primarily in association with major buried valleys.

The Muriel Lake Formation overlies the Bronson Lake Formation and consists of glacial sand and gravel and is approximately 35 metres thick. The extent of the Muriel Lake Formation is primarily in association with major buried valleys.

There are two units that comprise the overlying Bonnyville Formation. Unit 1 overlies the Muriel Lake Formation and is composed of approximately 25 metres of clayey till. Unit 2 is composed of approximately 25 metres of sandy till. The Bonnyville Formation extends throughout the County.

The glaciolacustrine silt and clay, and minor sand and gravel deposits of the overlying Ethel Lake Formation, have an average thickness of two metres. In the County, the Ethel Lake Formation is widespread, but not continuous, and there may be minor outcrops of the Ethel Lake Formation in the County.

The overlying Marie Creek Formation is broken down into two units, each approximately 25 metres thick. Unit 2 is composed of clayey till and Unit 1 is characterized by a coarse sand deposit. The upper part of the Marie Creek Formation outcrops, as shown on Figure 13.

The overlying Sand River Formation consists of up to 25 metres of stratified sand and silt with lesser amounts of clay and gravel. The most notable area where the Formation is thickest is in the northeastern part of the County in less populated areas. The Formation is primarily recognized in outcrops and test holes.

The Grand Centre Formation is the uppermost Quaternary stratigraphic formation, exposed at surface, and is mainly less than 25 metres thick. There are four members that comprise the Grand Centre Formation and have been defined based on grain size. The four members are: the Vilna, Kehiwin, Reita Lake and Hilda Lake members. The Vilna and Hilda Lake members are clayey till deposits, and the Kehiwin and Reita Lake members are clayey till deposits overlain by postglacial stratified sand and gravel in places (Andriashek and Fenton, 1989).

5.3.2 Aquifers

Of the 622 water well records with completion interval and lithologic information, such that the aquifer in which the water wells are completed could be defined, 614 are completed in surficial aquifers.

Assigning the water well to specific geologic units is possible only if the completion interval is identified. With this information, it has been possible to designate the specific surficial aquifer of completion for 607 water wells. Of the 607 water wells, 596 are water wells completed in the upper surficial deposits and 11 are completed in the lower surficial deposits. The remaining seven of the total 614 surficial water wells are identified as being completed in more than one surficial aquifer. The water wells completed in the upper surficial deposits are mainly completed in the Bonnyville and Empress – Unit 3 aquifers, as shown in the adjacent table.

Geologic Unit	No. of Surficial Water Wells
Upper Surficial Deposits	
Grand Centre	101
Sand River	5
Marie Creek	25
Ethel Lake	77
Bonnyville	206
Muriel Lake	7
Bronson Lake	2
Empress - Unit 3	173
Empress - Unit 2	0
Total	596
Lower Surficial Deposits	
Empress - Unit 1	11
Multiple Completions	7
Total	614

Table 2. Completion Aquifer

5.3.3 Sand and Gravel Aquifer(s)

The primary sources of groundwater in the County are the 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. In the County, the thickness of the sand and gravel aquifer(s) is generally less than ten metres, but can be more than 30 metres in the Buried Imperial Mills Valley and at the junction of the Buried Helena and Imperial Mills valleys (Page A-22 and on CD-ROM). The non-pumping water-level surface in the sand and gravel aquifer(s) is a subdued replica of the topographic surface (see CD-ROM) and slopes toward Lac La Biche.

The adjacent map shows expected yields for water wells completed in sand and gravel aquifer(s). Over approximately 5% of the County, the sand and gravel deposits are not present, or if present, are not saturated; these areas are designated as grey on the adjacent map.

In the County, there are 348 surficial water wells that have apparent yield values. The locations of the control points are shown on the adjacent figure. Also shown on the adjacent map are the locations of four dry test holes. Based on the aquifers that have been developed by existing water wells, these data show that water wells with yields of more than 100 m³/day from sand and gravel aquifer(s) can be expected in one-third of the County. The most notable areas where yields of more than 100 m³/day are expected are mainly in association with the Buried Helena and Kikino valleys.

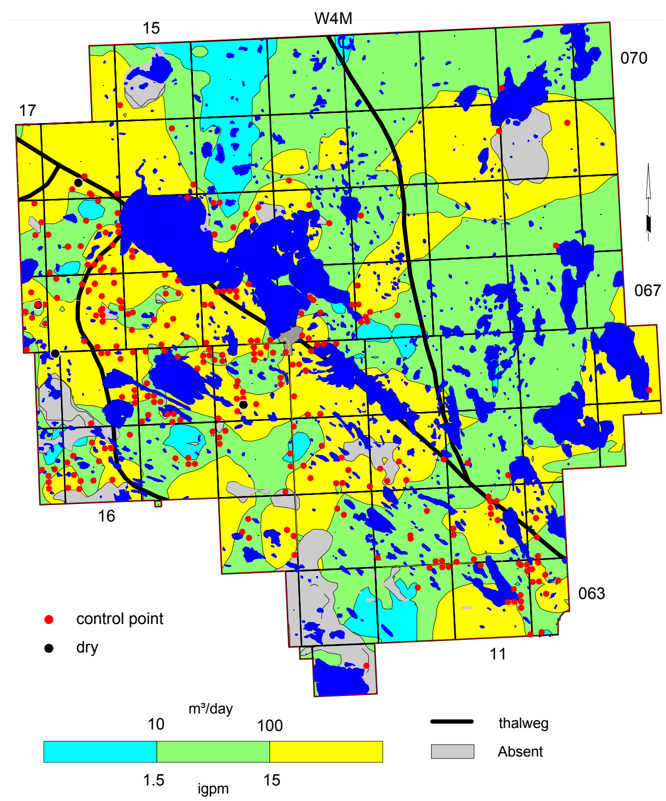

Figure 14. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)

Forty-one percent (144) of the 348 water wells completed in the sand and gravel aquifer(s) have apparent yields that are less than 50 m³/day, 25% (88) have apparent yield values that range from 50 to 150 m³/day, and 33% (115) have apparent yields that are greater than 150 m³/day, as shown in Table 3.

Aquifer	No. of Water Wells with Values for Apparent Yield	Number of Water Wells with Apparent Yields <50 m³/day	50 to 150 m³/day	>150 m³/day
Grand Centre	55	44	7	4
Sand River	2	1	1	0
Marie Creek	15	10	4	1
Ethel Lake	41	25	9	7
Bonnyvile	115	43	35	37
Muriel Lake	6	0	3	3
Bronson Lake	1	1	0	0
Empress - Unit 3	107	20	27	60
Empress - Unit 2	0	0	0	0
Empress - Unit 1	6	1	2	3
Multiple Completions	0	0	0	0
Totals	348	145	88	115

Table 3. Apparent Yield of Sand and Gravel Aquifer(s)

Chemical Quality of Groundwater from Surficial Deposits

The chemical analysis results of groundwaters from the surficial deposits indicate the groundwaters are generally chemically hard and high in dissolved iron. In Lakeland County, the groundwaters from the surficial aquifers mainly have a chemical hardness of greater than 100 mg/L (see CD-ROM).

The Piper tri-linear diagram[13] for surficial deposits (Page A-25) shows the groundwaters have no dominant cation or anion. There are 202 values for TDS in the County, with the majority of the control points in the southwestern half of the County. Of the 202 control points, more than 60% of the groundwaters from the surficial deposits have a TDS concentration of more than 1,000 mg/L. Groundwaters having TDS concentrations of less than 500 mg/L occur mainly in the northern part of the County. The highest median TDS concentrations occur below the Ethel Lake Aquifer.

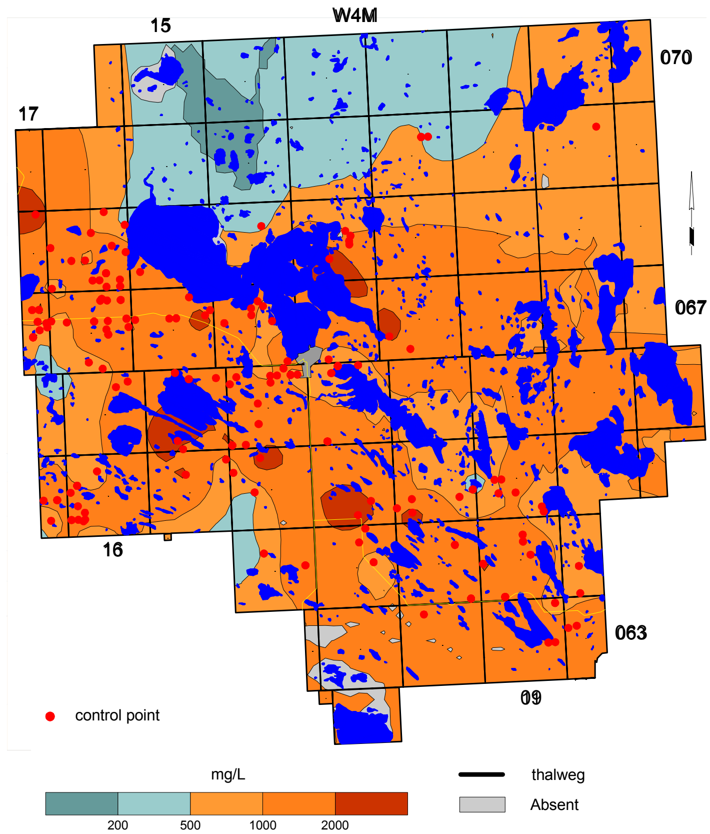

Figure 15. Total Dissolved Solids in Groundwater from Surficial Deposits

There are groundwaters with sulfate as the main anion. The groundwaters with elevated levels of sulfate generally occur in areas where there are elevated levels of total dissolved solids. There are very few groundwaters from the surficial deposits with appreciable concentrations of the chloride ion, and in 65% of the samples analyzed for surficial deposits in the County, the chloride ion concentration is less than 100 mg/L (see CD-ROM). The highest median chloride concentrations occur below the Ethel Lake Aquifer.

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	202	310	35132	1220	500
Sodium	170	5	943	230	200
Sulfate	203	0	1519	235	500
Chloride	203	0	6600	40	250
Nitrate + Nitrite (as N)	173	0	68	0.0	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Nitrate + Nitrite (as N), which is for Maximum Acceptable Concentration (MAC)
SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality Federal-Provincial Subcommittee on Drinking Water, March 2001

Table 4. Concentrations of Constituents in Groundwaters from Surficial Aquifers

In the County, 99% of the samples from surficial deposits analyzed for nitrate + nitrate (as N) concentrations are below the maximum acceptable concentration (MAC) of ten mg/L (see CD-ROM).

The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and nitrate + nitrite (as N) in the groundwaters from water wells completed in the surficial deposits in the County have been compared to the SGCDWQ in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium concentration exceed the guidelines.

[13] See glossary

5.3.4 Upper Sand and Gravel Aquifer

The Upper Sand and Gravel Aquifer includes saturated sand and gravel deposits in the upper surficial deposits. Typically, these aquifers are present within the surficial deposits at no particular depth. Saturated sand and gravel deposits in the upper surficial deposits are not usually continuous over large areas but isolated deposits are expected over approximately 95% of the County.

5.3.4.1 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 surficial deposits; and (2) the depth to the bedrock surface or the depth to the top of the lower surficial deposits when present. In the County, the thickness of the Upper Sand and Gravel Aquifer is generally less than ten metres, but can be more than 30 metres in the areas associated with linear bedrock lows (see CD-ROM).

5.3.4.2 Apparent Yield

The permeability of the Upper Sand and Gravel Aquifer can be high. The high permeability combined with significant thickness leads to an extrapolation of high yields for water wells; however, because the sand and gravel deposits occur mainly as hydraulically discontinuous pockets, the long-term yields of the water wells are expected to be less than the apparent yields. The anticipated groundwater apparent yield in the Upper Sand and Gravel Aquifer is based on the expected yields of single water well obtaining water from the total accessible seven glacial aquifers that comprise the Upper Sand and Gravel Aquifer.

The apparent yields for water wells completed through this Aquifer are expected to range from less than ten to more than 100 m³/day. Apparent yields of more than 100 m³/day occur mainly in association with the linear bedrock lows.

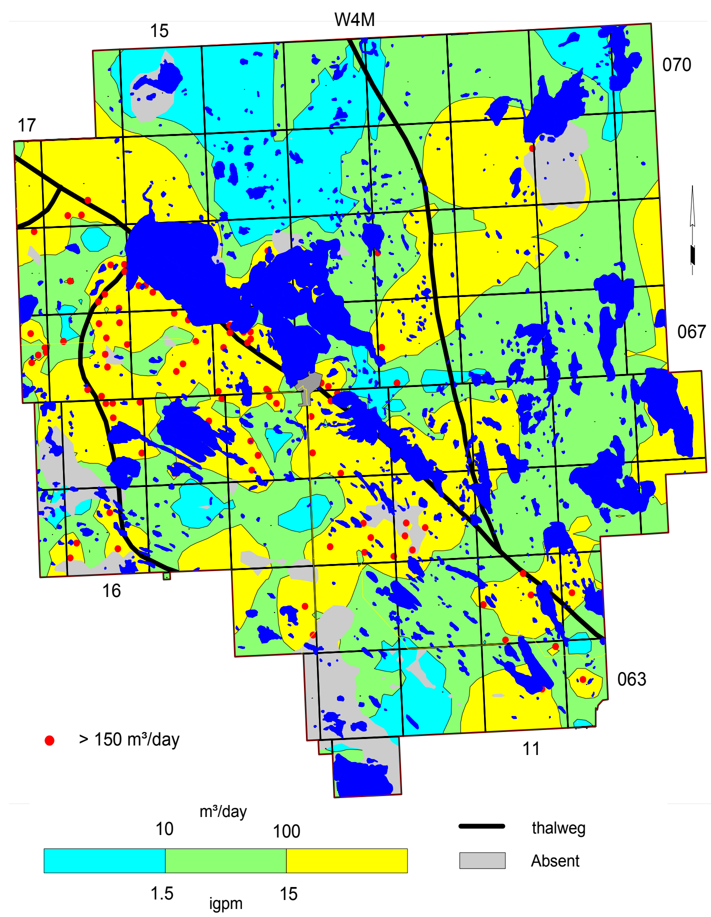

Figure 16. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

5.3.5 Grand Centre Aquifer

The Grand Centre Aquifer comprises the permeable parts of the Grand Centre Formation, is the uppermost geological unit in the area, and has a thickness that is mainly less than 25 metres.

5.3.5.1 Depth to Top

The depth to the top of the Grand Centre Formation is a function of the thickness of the postglacial stratified deposits. The Grand Centre Formation lies at the surface in most places, except where it is buried by postglacial stratified sediment (Andriashek and Fenton, 1989).

5.3.5.2 Apparent Yield

The apparent yields for individual water wells completed through the Grand Centre Aquifer are mainly in the range of 10 to 50 m³/day, with 46 (84%) of the 55 values being less than 50 m³/day (Table 3). Of the 46 values, 21 are for bored water wells. Shown on the adjacent map is the location of one dry test hole in NW 24-067-17 W4M.

In the County, there are three licensed groundwater water wells completed through the Grand Centre Aquifer, with a total authorized diversion 26 m³/day; all three licensed users are for agricultural purposes. Each of the three licensed water wells could be linked to a water well in the AENV groundwater database.

In 1974, Alberta Environment supervised the completion of seven bored water wells for the Lac La Biche Mission Settlement (Kerr, April 1978a). Of the seven bored water wells, two water wells could supply potable groundwater to the community. An aquifer test conducted with the bored water well (38-07) in 03-03-067-14 W4M indicated an apparent yield of ten m³/day.

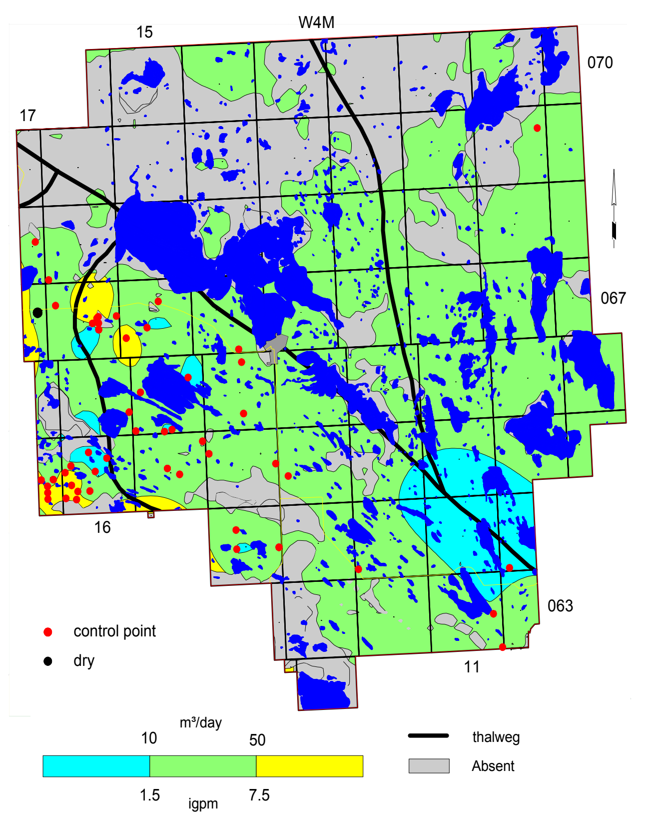

Figure 17. Apparent Yield for Water Wells Completed through Grand Centre Aquifer

5.3.5.3 Quality

The groundwaters from the Grand Centre Aquifer are a calcium-magnesium-bicarbonate type (see Piper diagram on CD-ROM). The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and nitrate + nitrite (as N) in the groundwaters from water wells completed in the Grand Centre Aquifer in the County have been compared to the SGCDWQ and median concentrations from all surficial deposits in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median value of TDS concentration exceeds the guideline.

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	All Surficial Median	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	42	327	3160	925	1220	500
Sodium	38	5	943	150	230	200
Sulfate	42	5	1519	211	235	500
Chloride	42	1	269	11	40	250
Nitrate + Nitrite (as N)	39	0	17	0.0	0.0	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Nitrate + Nitrite (as N), which is for Maximum Acceptable Concentration (MAC)
SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality Federal-Provincial Subcommittee on Drinking Water, March 2001

Table 5. Concentrations of Constituents in Groundwaters from Grand Centre Aquifer

The median concentrations of TDS, sodium, sulfate and chloride from water wells completed in the Grand Centre Aquifer are below the median concentrations from water wells completed in all surficial deposits.

A groundwater sample collected from the AENV bored water well No. 38-07 has a TDS concentration of 577 mg/L, a sodium concentration of 14, a sulfate concentration of 128 mg/L, a chloride concentration of 36 mg/L, and a nitrate as (N) concentration of 6.1 mg/L (Kerr, April 1978a).

5.3.6 Sand River Aquifer

The Sand River Aquifer comprises the permeable parts of the Sand River Formation, which underlies the Grand Centre Formation. The Sand River Formation has a thickness in the order of 25 metres. Structure contours have been prepared for the top of the Sand River Formation. The structure contours show the Sand River Formation ranges in elevation from less than 570 to more than 670 metres AMSL (see CD-ROM).

5.3.6.1 Depth to Top

The depth to the top of the Sand River Formation ranges from less than ten metres below ground level to more than 30 metres at the Formation edges (Page A-30).

5.3.6.2 Apparent Yield

In the County, there are only two control points for apparent yield for water wells completed through the Sand River Aquifer. The higher yields in the northern half of the County are the reflection of gridding a control point outside the County in township 068, range 08, W4M.

In the County, there are no licensed groundwater water wells that are completed in the Sand River Aquifer.

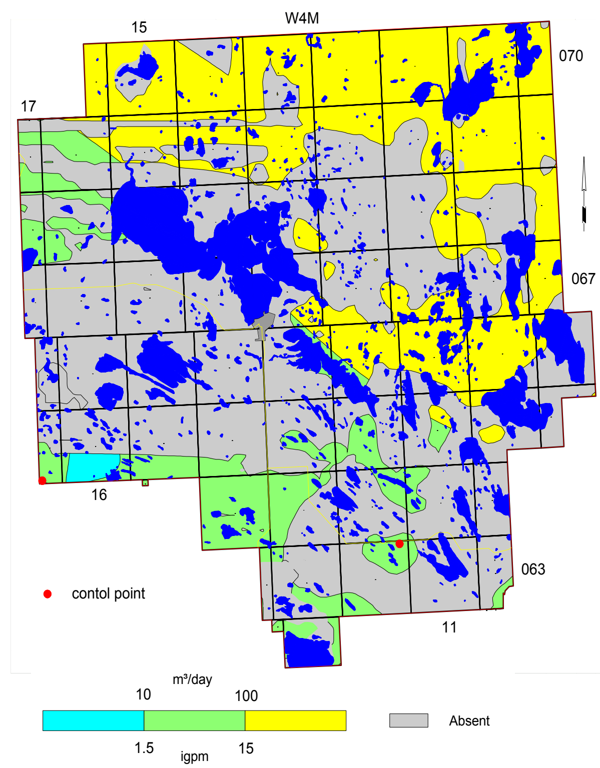

Figure 18. Apparent Yield for Water Wells Completed through Sand River Aquifer

5.3.6.3 Quality

There are sufficient data from three water wells to determine the groundwater type from the Sand River Aquifer; these data show that the groundwaters are calcium-magnesium bicarbonate and calcium-magnesium-sulfate types (see Piper diagram on CD-ROM). The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and nitrate + nitrite (as N) in the groundwaters from water wells completed in the Sand River Aquifer in the County have been compared to the SGCDWQ and median concentrations from all surficial deposits in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sulfate exceed the guidelines.

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	All Surficial Median	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	3	493	2481	2238	1220	500
Sodium	3	46	121	108	230	200
Sulfate	3	72	1462	1250	235	500
Chloride	3	3	4	4	40	250
Nitrate + Nitrite (as N)	2	0	0	0.0	0.0	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Nitrate + Nitrite (as N), which is for Maximum Acceptable Concentration (MAC)
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Table 6. Concentrations of Constituents in Groundwaters from Sand River Aquifer

The median concentrations of TDS and sulfate from the three analyses of water wells completed through the Sand River Aquifer exceed the mean TDS and sulfate concentrations of all surficial deposits.

5.3.7 Marie Creek Aquifer

The Marie Creek Aquifer comprises the permeable parts of the Marie Creek Formation, which underlies the Sand River Formation. The Marie Creek Formation has a thickness of mainly less than 30 metres (see CD-ROM). Structure contours have been prepared for the top of the Marie Creek Formation. The structure contours show the Marie Creek Formation ranges in elevation from less than 560 to more than 640 metres AMSL.

5.3.7.1 Depth to Top

The depth to the top of the Marie Creek Formation ranges from less than ten metres below ground level to more than 30 metres at the Formation edges (Page A-33).

5.3.7.2 Apparent Yield

The apparent yields for individual water wells completed through the Marie Creek Aquifer range mainly from 10 to 100 m³/day. Eighty percent of the water wells completed in the Marie Creek Aquifer have apparent yields that are less than 100 m³/day. The control points are mainly south of the Buried Helena Valley.

In the County, there is one water well that is completed in the Marie Creek Aquifer and is licensed for 6.7 m³/day for agricultural purposes This water well could be linked to a water well in the AENV groundwater database.

Extended aquifer tests conducted with two water source wells completed in the Marie Creek Aquifer in NW 20-062-03 W4M (M.D. of Bonnyville) indicated a total long-term yield of 820 m³/day from both water source wells, based on an effective transmissivity of 180 metres squared per day (m²/day) (HCL, 1988b).

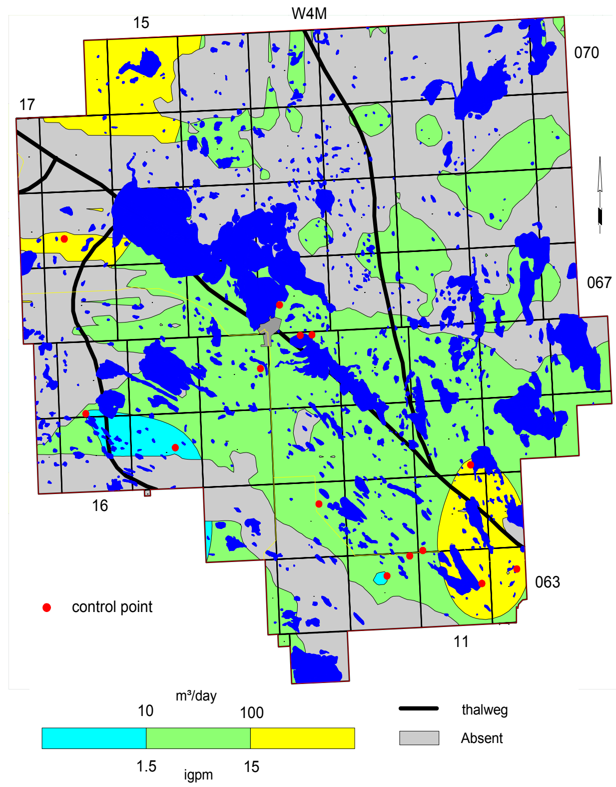

Figure 19. Apparent Yield for Water Wells Completed through Marie Creek Aquifer

5.3.7.3 Quality

The groundwaters from the Marie Creek Aquifer are mainly a calcium-magnesium-bicarbonate type (see Piper diagram on CD-ROM). The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and nitrate + nitrite (as N) in the groundwaters from water wells completed in the Marie Creek Aquifer in the County have been compared to the SGCDWQ and median concentrations from all surficial deposits in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median value of TDS exceeds the guidelines. The median concentration of sulfate from water wells completed in the Sand River Aquifer exceeds the median sulfate concentration from water wells completed in all surficial deposits.

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	All Surficial Median	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	9	415	2569	1190	1220	500
Sodium	8	6	425	50	230	200
Sulfate	9	31	1025	466	235	500
Chloride	9	1	66	3	40	250
Nitrate + Nitrite (as N)	5	0	0	0.0	0.0	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Nitrate + Nitrite (as N), which is for Maximum Acceptable Concentration (MAC)
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Table 7. Concentrations of Constituents in Groundwaters from Marie Creek Aquifer

A groundwater sample from one of the water source wells in NW 20-062-03 W4M has a TDS concentration of 352 mg/L, a sodium concentration of 28 mg/L, a sulfate concentration of 3 mg/L, a chloride concentrations of 7 mg/L, and a nitrate + nitrite (as N) of less than 0.2 mg/L.

5.3.8 Ethel Lake Aquifer

The Ethel Lake Aquifer comprises the permeable parts of the Ethel Lake Formation, which underlies the Marie Creek Formation. The Ethel Lake Formation has an average thickness of two metres but can be more than 30 metres (see CD-ROM). Structure contours have been prepared for the top of the Ethel Lake Formation. The structure contours show the Ethel Lake Formation ranges in elevation from less than 550 to more than 620 metres AMSL.

5.3.8.1 Depth to Top

The depth to the top of the Ethel Lake Formation ranges from less than 15 metres below ground level to more than 45 metres at the Formation edges (Page A-36).

5.3.8.2 Apparent Yield

The apparent yields for individual water wells completed through the Ethel Lake Aquifer range mainly from 10 to 100 m³/day. Fifty percent of the water wells completed in the Ethel Lake Aquifer have apparent yields that are less than 50 m³/day. The fewest number of control points are east of the Buried Imperial Mills Valley.

In the County, there are no licensed water wells that are completed in the Ethel Lake Aquifer.

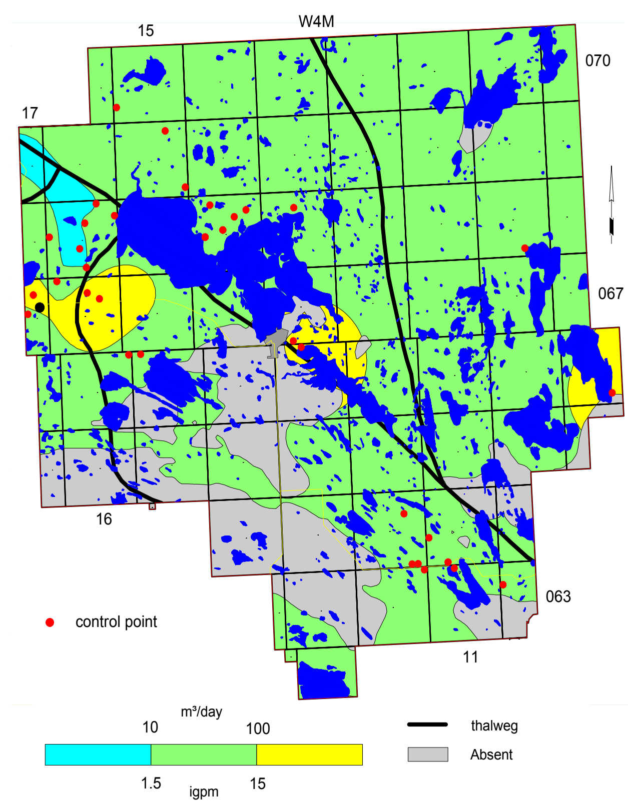

Figure 20. Apparent Yield for Water Wells Completed through Ethel Lake Aquifer

5.3.8.3 Quality

The groundwaters from the Ethel Lake Aquifer are mainly a calcium-magnesium-bicarbonate type (see Piper diagram on CD-ROM). The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and nitrate + nitrite (as N) in the groundwaters from water wells completed in the Ethel Lake Aquifer in the County have been compared to the SGCDWQ and median concentrations from all surficial deposits in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median value of TDS exceeds the guidelines.

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	All Surficial Median	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	23	332	1824	777	1220	500
Sodium	15	23	597	121	230	200
Sulfate	23	13	750	234	235	500
Chloride	23	0	212	4	40	250
Nitrate + Nitrite (as N)	16	0	1	0.0	0.0	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Nitrate + Nitrite (as N), which is for Maximum Acceptable Concentration (MAC)
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Table 8. Concentrations of Constituents in Groundwaters from Ethel Lake Aquifer

The median concentrations of TDS, sodium, sulfate and chloride from water wells completed in the Ethel Lake Aquifer are below the median concentrations from water wells completed in all surficial deposits.

5.3.9 Bonnyville Aquifer

The Bonnyville Aquifer comprises the permeable parts of the Bonnyville Formation, which underlies the Ethel Lake Formation. The Bonnyville Formation has a thickness of mainly less than 50 metres (see CD-ROM). In the County, the Bonnyville Formation is widespread. Structure contours have been prepared for the top of the Bonnyville Formation. The structure contours show that the top of the Bonnyville Formation ranges in elevation from less than 540 to more than 620 metres AMSL.

5.3.9.1 Depth to Top

The depth to the top of the Bonnyville Formation ranges from less than 30 metres below ground level to more than 60 metres (Page A-39).

5.3.9.2 Apparent Yield

The apparent yields for individual water wells completed through the Bonnyville Aquifer are mainly in the range of 10 to 100 m³/day, with more than 60% of the values being more than 50 m³/day.

In the County, there are no licensed groundwater water wells completed through the Bonnyville Aquifer.

In October and November 1973, Alberta Environment supervised the completion of four water wells for the Elinor Lake Metis Settlement (Kerr, April 1978b). The AENV water supply well (27-02) was completed from 33 to 36 metres below ground surface in the Bonnyville Aquifer. A three-hour aquifer test conducted with the water supply well indicated a long-term yield of 11.4 m³/day.

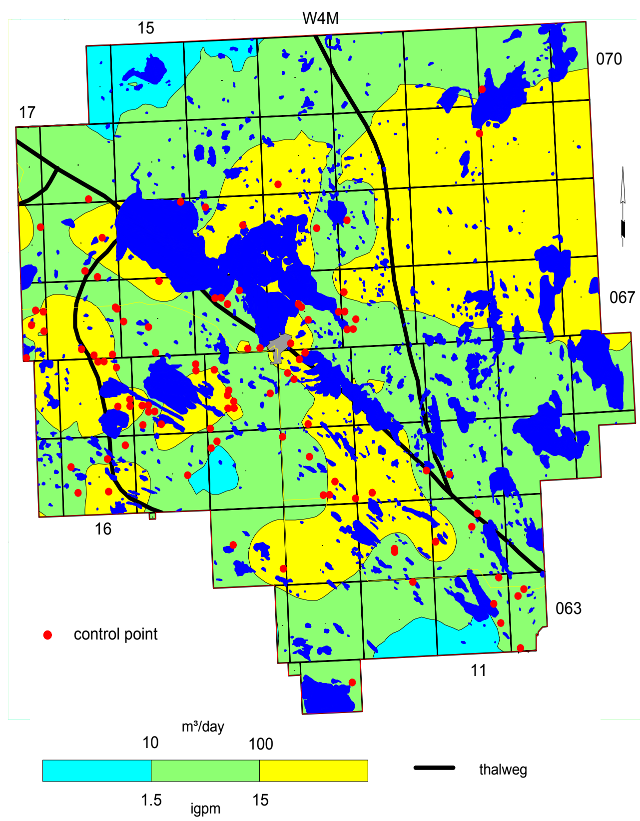

Figure 21. Apparent Yield for Water Wells Completed through Bonnyville Aquifer

5.3.9.3 Quality

The groundwaters from the Bonnyville Aquifer are mainly a bicarbonate type, with calcium-magnesium or sodium as the main cation (see Piper diagram on CD-ROM). The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and nitrate + nitrite (as N) in the groundwaters from water wells completed in the Bonnyville Aquifer in the County have been compared to the SGCDWQ and median concentrations from all surficial deposits in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines.

Constituent	No. of Analyses	Range for County in mg/L			All Surficial Median	Recommended Maximum Concentration GCDWQ
		Minimum	Maximum	Median		
Total Dissolved Solids	61	315	35132	1280	1220	500
Sodium	51	13	917	238	230	200
Sulfate	60	5	1484	279	235	500
Chloride	62	0	6600	48	40	250
Nitrate + Nitrite (as N)	53	0	68	0.0	0.0	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for
Nitrate + Nitrite (as N), which is for Maximum Acceptable Concentration (MAC)
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Table 9. Concentrations of Constituents in Groundwaters from Bonnyville Aquifer

The median concentrations of TDS, sodium, sulfate and chloride are greater than the median concentrations from water wells completed in all surficial deposits.

A groundwater sample collected from the AENV Water Supply Well No. 27-02 has a TDS concentration of 342 mg/L, a sodium concentration of 13 mg/L, a sulfate concentration of 10 mg/L, a chloride concentration of 2 mg/L, and a nitrate as (N) concentration of 0.1 mg/L (Kerr, April 1978b).

5.3.10 Muriel Lake Aquifer

The Muriel Lake Aquifer comprises the permeable parts of the Muriel Lake Formation, which underlies the Bonnyville Formation. Structure contours have been prepared for the top of the Muriel Lake Formation. The Muriel Lake Formation has a thickness of mainly less than 30 metres (CD-ROM). The structure contours show the Muriel Lake Formation ranges in elevation from less than 500 metres AMSL near Lac La Biche to more than 560 metres AMSL.

5.3.10.1 Depth to Top

The depth to the top of the Muriel Lake Formation ranges from less than 75 metres below ground level to more than 100 metres at the extreme southeastern part of the County (Page A-42).

5.3.10.2 Apparent Yield

There are six apparent yields for individual water wells completed through the Muriel Lake Aquifer. All six control points have apparent yields of more than 50 m³/day.

An extended aquifer test conducted with a water source well completed in the Muriel Lake Aquifer in 02-33-062-03 W4M (M. D. of Bonnyville) indicated a total long-term yield of greater than 300 m³/day, based on an effective transmissivity of 130 m²/day (HCL, 1985b).

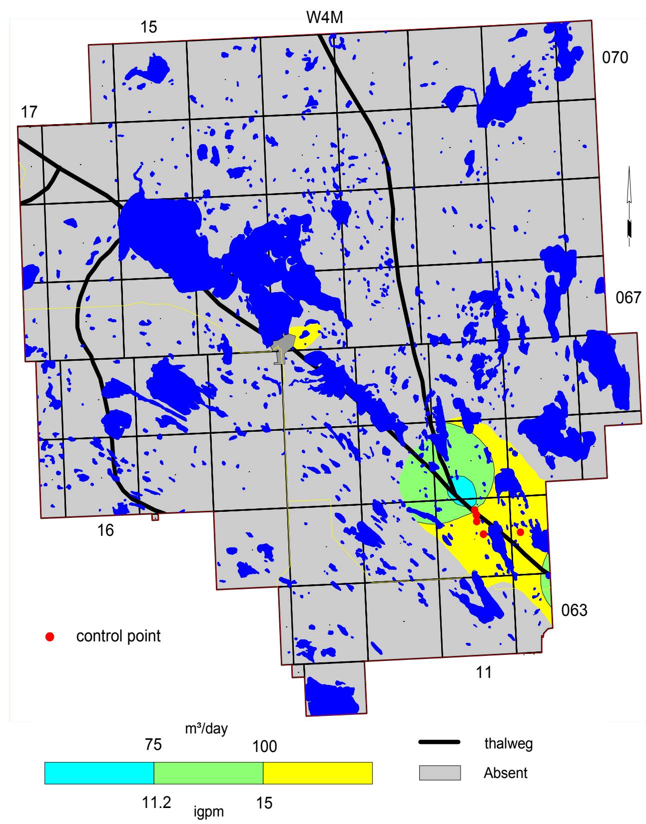

Figure 22. Apparent Yield for Water Wells Completed through Muriel Lake Aquifer
Mulk

5.3.10.3 Quality

The groundwaters from the Muriel Lake Aquifer are mainly a bicarbonate type, with calcium-magnesium or sodium as the main cation (see Piper diagram on CD-ROM). The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and nitrate + nitrite (as N) in the groundwaters from water wells completed in the Muriel Lake Aquifer in the County have been compared to the SGCDWQ and median concentrations from all surficial deposits in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median value of TDS exceeds the guidelines.

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	All Surficial Median	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	4	1164	1518	1231	1220	500
Sodium	5	142	167	164	230	200
Sulfate	4	406	653	418	235	500
Chloride	4	12	21	15	40	250
Nitrate + Nitrite (as N)	4	0	0	0.0	0.0	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Nitrate + Nitrite (as N), which is for Maximum Acceptable Concentration (MAC)
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Table 10. Concentrations of Constituents in Groundwaters from Muriel Lake Aquifer

The median concentrations of TDS and sulfate from water wells completed in the Muriel Lake Aquifer are greater than the median concentrations from water wells completed in all surficial deposits.

5.3.11 Bronson Lake Aquifer

The Bronson Lake Aquifer comprises the permeable parts of the Bronson Lake Formation, which underlies the Muriel Lake Formation. The Bronson Lake Formation has a thickness of mainly less than 15 metres (see CD-ROM). Structure contours have been prepared for the top of the Bronson Lake Formation. The structure contours show the Bronson Lake Formation ranges in elevation from less than 460 to more than 560 metres AMSL.

5.3.11.1 Depth to Top

The depth to the top of the Bronson Lake Formation ranges from less than 75 metres below ground level to more than 100 metres at the Formation edges (page A-45).

5.3.11.2 Apparent Yield

In the County, there is only one control point for apparent yields for individual water wells completed through the Bronson Lake Aquifer. The higher yields shown on the adjacent figure are the reflection of gridding a control point outside the County.

In the County, there are no licensed water wells completed in the Bronson Lake Aquifer.

5.3.11.3 Quality

In Lakeland County, there are no chemistry data for water wells completed through the Bronson Lake Aquifer.

In the M.D. of Bonnyville, there are twenty water wells with sufficient data to determine the groundwater type. The groundwaters from the Bronson Lake Aquifer in the M.D. are mainly a bicarbonate type, with calcium-magnesium or sodium as the main cation.

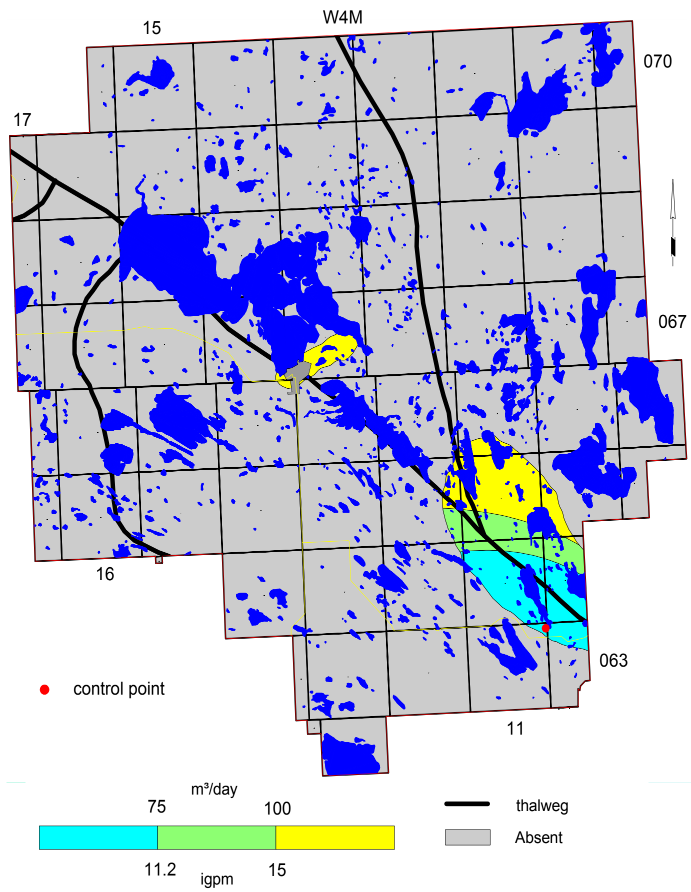

Figure 23. Apparent Yield for Water Wells Completed through Bronson Lake Aquifer

5.3.12 Empress Aquifer – Unit 3

The Empress Aquifer – Unit 3 comprises the permeable parts of the Empress Formation – Unit 3. Structure contours have been prepared for the top of the Empress Formation – Unit 3. The Empress Formation – Unit 3 has a thickness of mainly less than 50 metres (see CD-ROM). The structure contours show the Empress Formation – Unit 3 ranges in elevation from less than 500 to more than 560 metres AMSL.

5.3.12.1 Depth to Top

The depth to the top of Unit 3 ranges from less than 50 metres below ground level to more than 100 metres in parts of the north-central, northwestern and southeastern areas of the County (Page A-47).

5.3.12.2 Apparent Yield

The apparent yields for individual water wells completed through the Empress Aquifer – Unit 3 are mainly greater than 100 m³/day, with 19% of the values being less than 50 m³/day, 25% between 50 and 150 m³/day, and 56% of the values being more than 150 m³/day. Shown of the adjacent map are the locations of two dry test holes: one in SW 09-066-14 W4M and one in SE 09-069-16 W4M.

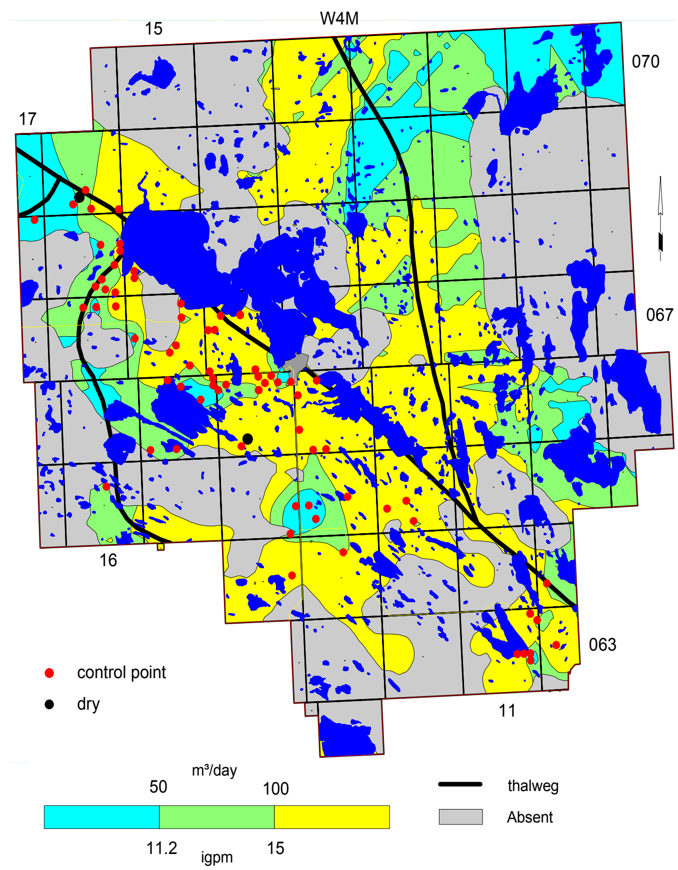

Figure 24. Apparent Yield for Water Wells Completed through Empress Aquifer – Unit 3

In the County, there are five licensed water wells that are completed in the Empress Aquifer - Unit 3, for a total authorized diversion of 94 m³/day. The highest allocation of 64 m³/day is for a water supply well in 10-36-066-15 W4M used for municipal purposes. All five licensed water wells could be linked to a water well in the AENV groundwater database.

An extended aquifer test conducted with a water supply well completed in the Empress Aquifer – Unit 3 at the Lac La Biche Airport in section 02, township 067, range 14, W4M indicated a total long-term yield of 230 m³/day, based on an effective transmissivity of 76 m²/day (HCL, December 1976c).

In 1973, Alberta Environment supervised the drilling and completion of five water supply wells for the community of Imperial Mills in sections 26 and 27, township 069, range 12, W4M. The completed depths of these water supply wells ranged from 40 to 49 metres below ground surface in the Empress Aquifer – Unit 3. The water wells were developed with air and apparent yields were estimated to range from 200 to 330 m³/day (Kerr, April 1978c).

5.3.12.3 Quality

The groundwaters from the Empress Aquifer – Unit 3 are mainly a bicarbonate type, with calcium-magnesium or sodium as the main cation (see Piper diagram on CD-ROM). The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and nitrate + nitrite (as N) in the groundwaters from water wells completed in the Empress Aquifer – Unit 3 in the County have been compared to the SGCDWQ and median concentrations from all surficial deposits in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines.

Constituent	No. of Analyses	Range for County in mg/L			All Surficial Median	Recommended Maximum Concentration GCDWQ
		Minimum	Maximum	Median		
Total Dissolved Solids	51	310	2974	1349	1220	500
Sodium	44	11	788	379	230	200
Sulfate	51	0	833	181	235	500
Chloride	51	4	1280	148	40	250
Nitrate + Nitrite (as N)	46	0	9	0.0	0.0	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for
Nitrate + Nitrite (as N), which is for Maximum Acceptable Concentration (MAC)
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Table 11. Concentrations of Constituents in Groundwaters from Empress Aquifer – Unit 3

The median values of TDS, sodium and chloride from water wells completed in the Empress Aquifer – Unit 3 are greater than the median concentrations from water wells completed in all surficial deposits.

A groundwater sample from the water supply well at the Lac La Biche Airport in section 02, township 067, range 14, W4M has a TDS concentration of 1,100 mg/L, a sodium concentration of 385 mg/L, a sulfate concentration of 1 mg/L, a chloride concentration of 310 mg/L, and a nitrate + nitrite (as N) of less than 1 mg/L (HCL, 1976c).

A groundwater sample from the Imperial Mills water supply well (25-04) in NW 26-069-12 W4M has a TDS concentration of 448 mg/L, a sodium concentration of 100 mg/L, a sulfate concentration of 14 mg/L, a chloride concentration of 20 mg/L, and a nitrate + nitrite (as N) of less than 0.1 mg/L (Kerr, April 1978c).

5.3.13 Lower Sand and Gravel Aquifer (Empress – Unit 1)

The Empress Aquifer – Unit 1 is a saturated sand and gravel deposit that occurs at or near the base of the surficial deposits in the deeper parts of the linear bedrock lows. The thickness of the Empress Formation – Unit 1 is mainly greater than ten metres but less than 15 metres (see CD-ROM). Structure contours have been prepared for the top of the Empress Formation – Unit 1. The structure contours show the Empress Formation – Unit 1 ranges in elevation from less than 480 to more than 520 metres AMSL.

5.3.13.1 Depth to Top

The depth to the top of the Empress Formation – Unit 1 is mainly between 100 and 150 metres below ground level in the County (Page A-50).

5.3.13.2 Apparent Yield

In the County, there are six control points for apparent yields for individual water wells completed through the Empress Aquifer – Unit 1.

The apparent yields for individual water wells completed through the Empress Aquifer – Unit 1 are mainly greater than 50 m³/day.

In the County, there are no licensed water wells completed in the Empress Aquifer – Unit 1.

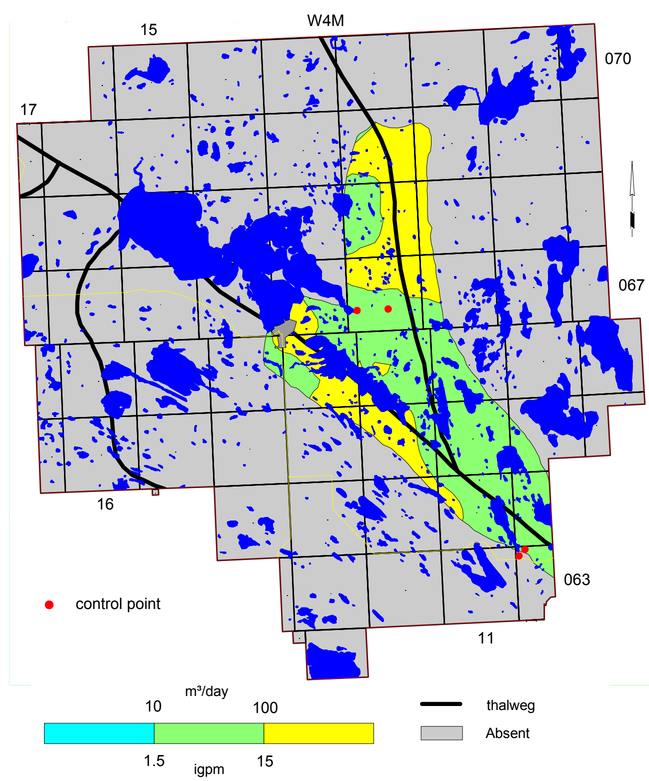

Figure 25. Apparent Yield for Water Wells Completed through Empress Aquifer – Unit 1

5.3.13.3 Quality

The groundwaters from the Empress Aquifer - Unit 1 are primarily a sodium-bicarbonate type (see Piper diagram on CD-ROM). The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and nitrate + nitrite (as N) in the groundwaters from water wells completed in the Empress Aquifer – Unit 1 in the County have been compared to the SGCDWQ and median concentrations from all surficial deposits below in Table 12. Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines.

Constituent	No. of Analyses	Range for M.D. in mg/L Minimum	Maximum	Median	All Surficial Median	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	5	1054	2202	1295	1220	500
Sodium	5	134	740	377	230	200
Sulfate	5	100	344.38	323	235	500
Chloride	5	17	909	103	40	250
Nitrate + Nitrite (as N)	5	0	0	0.0	0.0	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for
Nitrate + Nitrite (as N), which is for Maximum Acceptable Concentration (MAC)
SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality
Federal-Provincial Subcommittee on Drinking Water, March 2001

Table 12. Concentrations of Constituents in Groundwaters from Empress Aquifer – Unit 1

The median concentrations of TDS, sodium, sulfate and chloride from water wells completed in the Empress Aquifer – Unit 1 exceed the median concentrations from water wells completed in all surficial deposits.

5.4 Bedrock

5.4.1 Geological Characteristics

In the County, the uppermost bedrock is the Lea Park Formation, consisting mainly of dark grey shales of marine origin. At locations where deep bedrock valleys occur, the Lea Park Formation has been eroded, exposing the Milk River Formation and the *undivided* Colorado Group (Pages A-12 to A-17). The Milk River Formation and Colorado Group are a marine shale of upper Cretaceous Age; the base of the marine shales is at an elevation of approximately 300 metres AMSL. Neither the Lea Park Formation, the Milk River Formation or the *undivided* Colorado Group contains any aquifers that would be suitable for the development of groundwater supplies, since they are considered essentially impermeable.

There will be no direct review of the Lea Park Formation, the Milk River Formation or the *undivided* Colorado Group in the text of this report; the only maps associated with the Lea Park Formation and the *undivided* Colorado Group to be included on the CD-ROM will be structure-contour maps.

6. Groundwater Budget

6.1 Hydrographs

In the County, there are two observation water wells that are part of the AENV regional groundwater-monitoring network where water levels are being measured and recorded with time. These observation water wells are completed in surficial deposits near linear bedrock lows (Page A-54). The two AENV Obs WWs have been monitored since 1985.

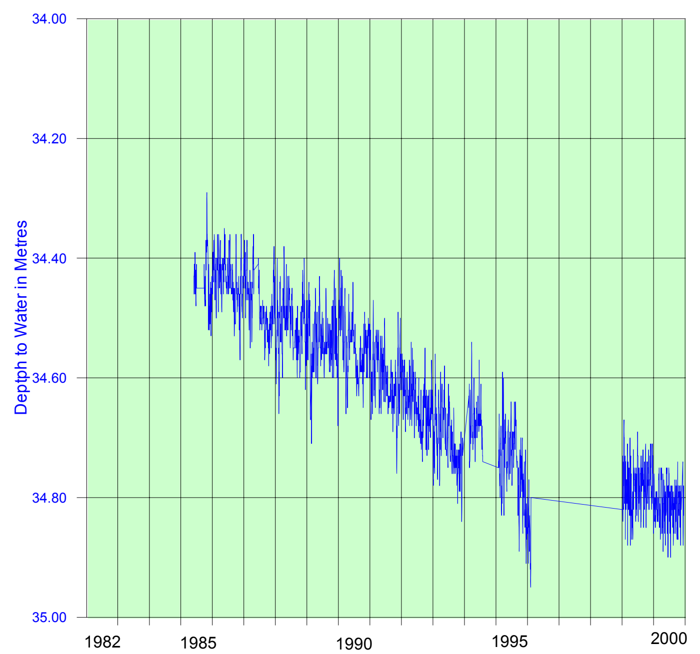

Figure 26. AENV Obs WW No. 191

Alberta Environment Obs WW No. 190 in SW 27-064-11 W4M is completed from 78.6 to 84.7 metres below ground surface in the Muriel Lake Aquifer. AENV Obs WW No. 191 in SW 27-064-11 W4M is completed from 104.5 to 114.3 metres below ground surface in the Empress Aquifer – Unit 1. These observation water wells are located southeast of the junction of the Buried Helena and Imperial Mills valleys near Rich Lake and are primarily used to monitor the water level in the Buried Helena Valley.

The AENV Obs WW Nos. 190 and 191 hydrographs show annual cycles of recharge in late spring/early summer and a decline throughout the remainder of the year. Overall annual fluctuations in AENV Obs No. 190 range from approximately 0.05 to more than 0.1 metres (Page A-54), and in AENV Obs WW No. 191 range from approximately 0.01 to 0.2 metres, as shown above in Figure 26. From 1985 to 1995, there has been a net decline in the water level of in the order of 0.5 metres in both observation water wells. From 1995 to 1998, there has been a slight rise in the water levels of 0.1 metres in AENV Obs WW No. 190, as shown on Figure 27. There was a break in the monitoring record in AENV Obs WW No. 191 from mid-1996 to 1999. From 1999 to the end of the available monitoring data in 2000, there was a decline in the water level of 0.05 metres.

In order to determine if the fluctuations were responding to precipitation, the two AENV Obs WWs were compared to the precipitation data measured at the Venice weather station located southwest of Lac La Biche. The Venice weather station has the most complete data set per year in the County.

The comparison in Figure 27 shows that the water-level decline in AENV Obs WW No. 190 from 1985 to 1991 parallels the changes in total annual precipitation measured at the Venice weather station. In 1992 and 1993, the annual precipitation increases, but the water level continues to decline at the sites of AENV Obs WW Nos. 190 and 191.

This water-level decline may be in response to groundwater diversion from a nearby user.

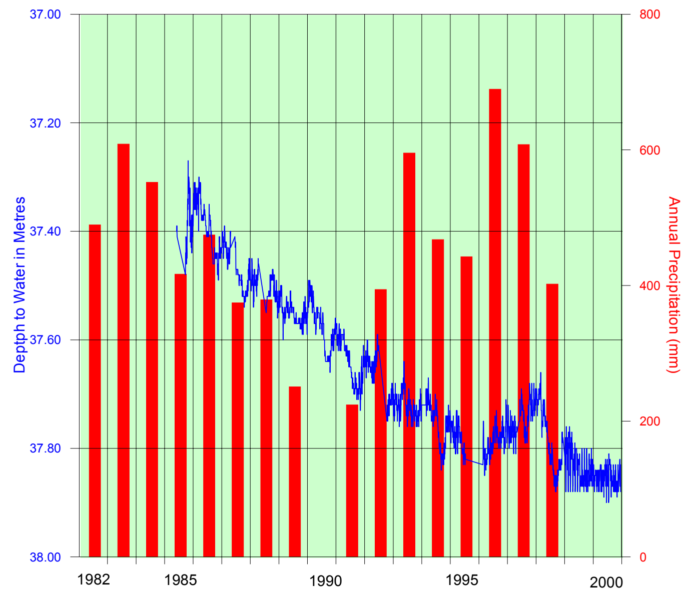

Figure 27. Annual Precipitation vs Water Levels in AENV Obs WW No. 190

6.2 Estimated Water Use from Unlicensed Groundwater Users

An estimate of the quantity of groundwater removed from each geologic unit in Lakeland County must include both the licensed diversions and the unlicensed use. As stated previously on page 6 of this report, the daily water requirement for livestock for the County based on the 2001 census is estimated to be 3,727 cubic metres. Of the 3,727 m³/day required for livestock, 232 m³/day has been licensed by Alberta Environment, which includes both surface water and groundwater. To obtain an estimate of the quantity of groundwater being diverted from the individual geologic units, it has been assumed that the remaining 3,495 m³/day of water required for livestock watering is obtained from unlicensed groundwater use. In the groundwater database for the County, there are records for 1,510 water wells that are used for domestic/stock purposes. These 1,510 water wells include both licensed and unlicensed water wells. Of the 1,510 water wells, 122 water wells are used for stock, 390 are used for domestic/stock purposes, and 998 are for domestic purposes only.

There are 512 water wells that are used for stock or domestic/stock purposes (Table 13). There are eight licensed groundwater users for agricultural (stock) purposes, giving 504 unlicensed stock water wells. (Please refer to Table 1 on page 6 for the breakdown by aquifer of the eight licensed stock groundwater users). By dividing the number of unlicensed stock and domestic/stock water wells (504) into the quantity of groundwater required for stock purposes that is not licensed (3,495 m³/day), the average unlicensed water well diverts 6.9 m³/day for stock purposes. Because of the limitations of the data, no attempt has been made to compensate for dugouts, springs or inactive water wells, and the average stock use is considered to be 6.9 m³/day per stock water well.

Groundwater for household use does not require licensing. Under the Water Act, a residence is protected for up to 3.4 m³/day. However, the standard groundwater use for household purposes is 1.1 m³/day. Since there are 1,338 water wells serving a population of 4,823, the domestic use per water well is 0.9 m³/day.

To obtain an estimate of the groundwater from each geologic unit, there are three possibilities for a water well. A summary of the possibilities and the quantity of water for each use is as follows:

Domestic 0.9 m³/day
Stock 6.9 m³/day
Domestic/stock 7.8 m³/day

Based on using all available domestic, domestic/stock, and stock water wells and corresponding calculations, the following table was prepared. The table shows a breakdown of the 1,510 unlicensed and licensed water wells used for domestic, stock, or domestic/stock purposes by the geologic unit in which each water well is completed. The final column in the table equals the total amount of unlicensed groundwater that is being used for both domestic and stock purposes. The data provided in the table below indicate that there is an estimated 4,683 m³/day to be diverted from unlicensed domestic, stock, or domestic/stock water wells.

Aquifer Designation	*Unlicensed and Licensed Groundwater Diversions* Number of Domestic	Daily Use 0.9 m³/day	Number of Stock	Daily Use (6.9 m³/day)	Number of Domestic and Stock	Daily Use (7.8 m³/day)	Totals m³/day	*Licensed Groundwater Diversions* Totals (m³/day)	*Unlicensed Groundwater Diversions* Totals m³/day
Grand Centre	36	31	13	90	48	375	496	25.7	470
Sand River	3	3	0	0	2	16	19	0	19
Marie Creek	12	10	2	14	9	70	94	6.8	87
Ethel Lake	33	29	10	69	22	172	270	0	270
Bonnyvile	110	96	16	111	68	531	738	0	738
Muriel Lake	0	0	0	0	6	47	47	0	47
Bronson Lake	0	0	0	0	2	16	16	0	16
Empress - Unit 3	90	78	17	118	46	359	555	20.3	535
Empress - Unit 2	0	0	0	0	0	0	0	0	0
Empress - Unit 1	3	3	2	14	4	31	48	0	48
Multiple Completions	3	3	1	7	2	16	26	0	26
Bedrock	9	8	0	0	0	0	8	0	8
Unknown	699	607	61	423	181	1,412	2,442	23.6	2,418
Totals	998	868	122	846	390	3,045	4,759	76	4,683

Table 13. Unlicensed and Licensed Groundwater Diversions

By assigning 0.9 m³/day for domestic use, 6.9 m³/day for stock use and 7.8 m³/day for domestic/stock use, and using the total maximum authorized diversion associated with any licensed water well that can be linked to a record in the database, a map has been prepared that shows the estimated groundwater use in terms of volume (licensed plus unlicensed) per section per day for the County (not including springs).

There are 2,036 sections in the County. In 75% (1,530) of the sections in the County, there is no domestic or stock or licensed groundwater user. The range in groundwater use for the remaining 506 sections is from 1 m³/day to more than 90 m³/day, with an average use per section of 38 m³/day (5.8 igpm). The estimated water well use per section is more than 30 m³/day in 19 of the 506 sections. There is at least one licensed groundwater user in four of the 19 sections. The most notable areas where water well use of more than 30 m³/day is expected to occur are mainly in the vicinity of licensed groundwater users and linear bedrock lows, as shown on Figure 38.

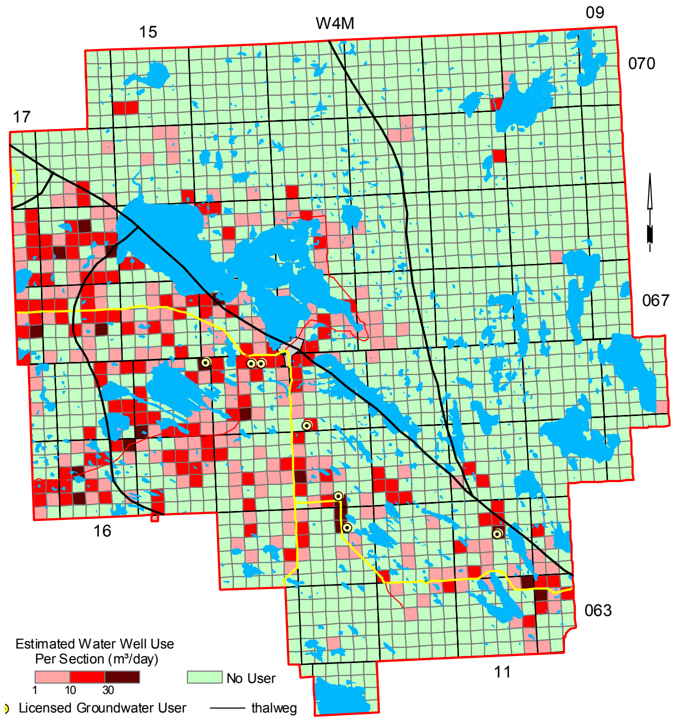

Figure 28. Estimated Water Well Use Per Section

Groundwater Use within Lakeland County (m³/day)		%
Domestic/Stock (licensed and unlicensed)	4,683	*99*
Municipal (licensed)	64	*1*
Recreation	7	*0*
Total	4,754	*100*

Table 14. Total Groundwater Diversions

In summary, the estimated total groundwater use within Lakeland County is 4,754 m³/day, with the breakdown as shown in the adjacent table. An estimated 2,466 m³/day is being withdrawn from unknown aquifer units. The remaining 2,288 m³/day has been assigned to specific aquifer units. Approximately 3% of the total estimated groundwater use is from licensed water wells.

6.3 Groundwater Flow

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

The flow through each aquifer assumes that by taking a large enough area, an aquifer can be considered as homogeneous, the average gradient can be estimated from the non-pumping water-level surface, and flow takes place through the entire width of the aquifer; flow through the aquifers takes into consideration hydrogeological conditions outside the County border. Based on these assumptions, the estimated lateral groundwater flow through the individual aquifers has been summarized in Table 15:

Aquifer/Area	Trans (m^2/day)	Gradient (m/m)	Width (m)	Flow (m^3/day)	Aquifer Flow (m^3/day)	Licensed Diversion (m^3/day)	Unlicensed Diversion (m^3/day)	Total (m^3/day)
Lower Sand and Gravel					2,500	0	48	48
Empress - Unit 1					2,500			
central	45	0.0018	13,000	1032				
southeast	45	0.0030	11,000	1485				
Upper Surficial Deposits					24,300	127	1,712	2,309
Grand Centre					3,600	25.7	470	496
northeast	10	0.004	46,000	1937				
southwest	10	0.002	75,000	1667				
Sand River					800	0	19	19
east	10	0.002	25,000	526				
north	10	0.002	20,000	316				
Marie Creek					2,100	6.8	87	94
east	20	0.001	40,000	1067				
southeast	20	0.001	40,000	1000				
Ethel Lake					4,800	0	270	270
east	27	0.003	55,000	3713				
west	27	0.002	20,000	1080				
Bonnyville					5,300	0	738	738
east	21	0.002	65,000	2409				
southwest	21	0.002	70,000	2940				
Muriel Lake					200	0	47	47
southeast	15	0.002	10,000	225				
Bronson Lake					3,400	0	16	16
southwest	17	0.005	20,000	1700				
northeast	17	0.005	20,000	1700				
Empress - Unit 3					4,100	94.4	535	629
east	20	0.001	60,000	1714				
west	20	0.003	40,000	2400				

Table 15. Groundwater Budget

Table 15 indicates that there is more groundwater flowing through the aquifers than has been authorized to be diverted from the individual aquifers. The calculations of flow through individual aquifers as presented in the above table are very approximate and are intended only as a guide for future investigations.

6.3.1 Quantity of Groundwater

An estimate of the volume of groundwater stored in the surficial deposits is 0.1 to 0.75 cubic kilometres. This volume is based on an areal extent of 500 square kilometres and a saturated thickness of five metres. The variation in the total volume is based on the value of porosity that is used for the surficial deposits. One estimate of porosity is 5%, which gives the low value of the total volume. The high estimate is based on a porosity of 30% (Ozoray, Dubord and Cowen, 1990).

The adjacent water-level map has been prepared from water levels associated with water wells completed in aquifers in the surficial deposits. The water levels from these water wells were used for the calculation of the saturated thickness of the surficial deposits. In areas where the elevation of the water-level surface is below the bedrock surface, the surficial deposits are not saturated (indicated by light grey areas on the map). The water-level map for the surficial deposits shows a general flow in the direction of the topographic surface with flow being generally toward Lac La Biche.

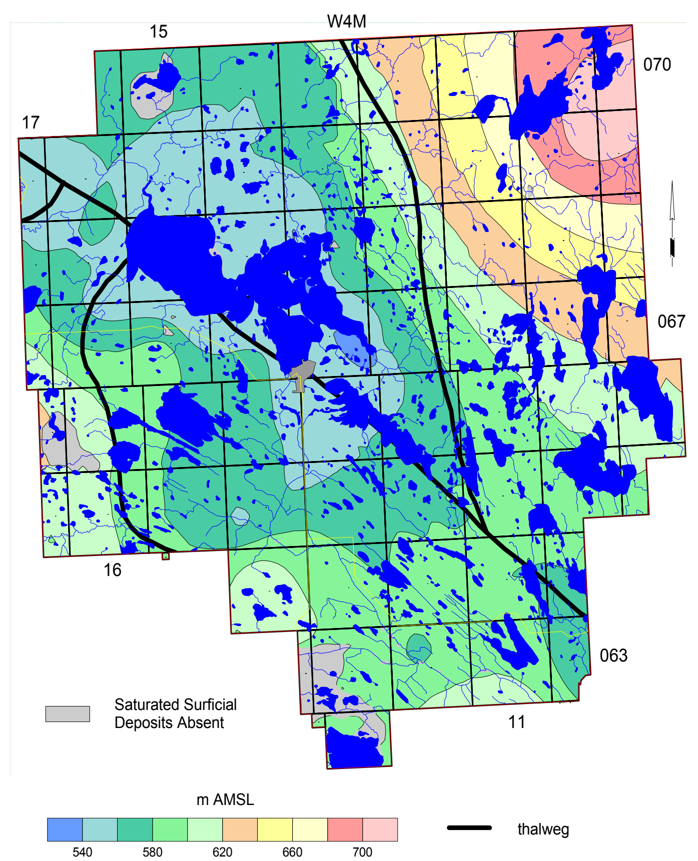

Figure 29. Non-Pumping Water-Level Surface Based on Water Wells Less than 20 metres Deep

6.3.2 Recharge/Discharge

The hydraulic relationship between the groundwater in surficial deposits and groundwater in the bedrock was not investigated because of the lack of control due to the low permeability of the upper bedrock. Instead, the hydraulic relationship between the uppermost surficial deposits and the Lower Sand and Gravel Aquifer was considered.

6.3.2.1 Uppermost Surficial Deposits/Lower Sand and Gravel Aquifer

The hydraulic gradient between the uppermost surficial deposits and the Lower Sand and Gravel Aquifer (Empress Aquifer – Unit 1) has been determined by subtracting the elevation of the non-pumping water-level surface associated with water wells completed in the Lower Sand and Gravel Aquifer from the elevation of the non-pumping water-level surface determined for all surficial water wells completed above a depth of 20 metres. Where the water level in the uppermost surficial deposits is at a higher elevation than the water level in the Lower Sand and Gravel Aquifer, there is the opportunity for groundwater to move from the uppermost surficial deposits into the Lower Sand and Gravel Aquifer. This condition would be considered as an area of recharge to the Lower Sand and Gravel Aquifer and an area of discharge from the uppermost surficial deposits. The amount of groundwater that would move from the uppermost surficial deposits to the Lower Sand and Gravel Aquifer is directly related to the vertical permeability of the sediments separating the two 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.

When the hydraulic gradient is from the Lower Sand and Gravel Aquifer to the uppermost surficial deposits, the condition is a discharge area from the Lower Sand and Gravel Aquifer, and a recharge area to the uppermost surficial deposits.

The recharge classification shown on Figure 30 is used where the water-level surface in the uppermost surficial deposits is more than 15 metres above the water-level surface in the Lower Sand and Gravel Aquifer. The discharge areas are where the water level in the uppermost surficial deposits is more than ten metres lower than the water level in the Lower Sand and Gravel Aquifer. When the water level in the uppermost surficial deposits is between ten and 15 metres below the water level in the Lower Sand and Gravel Aquifer, the area is classified as a transition, that is, no recharge and no discharge.

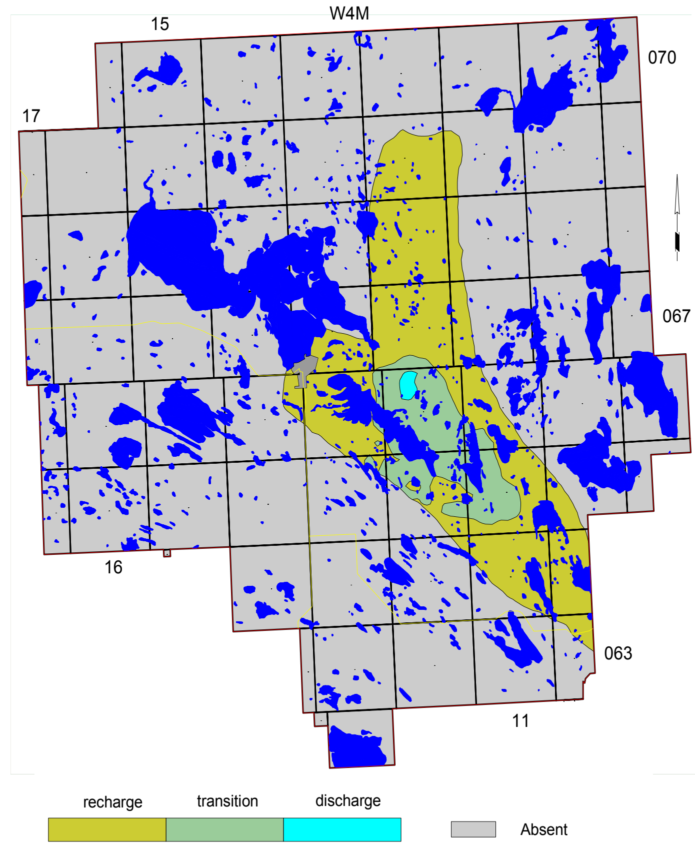

Figure 30. Recharge/Discharge Areas in Lower Sand and Gravel Aquifer

Figure 30 shows that, in most areas where the Lower Sand and Gravel is present in the County, there is a downward hydraulic gradient from the uppermost surficial deposits toward the Lower Sand and Gravel Aquifer (i. e. recharge). Areas where there is an upward hydraulic gradient from the Lower Sand and Gravel Aquifer to the uppermost surficial deposits (i. e. discharge) are mainly near the junction of the Buried Helena and Imperial Mills valleys. The discharge in this area may be due to the groundwater flow being impeded in the Buried Imperial Mills Valley by the deposits or the hydraulic gradient in the Buried Helena Valley. As a result, there is no opportunity for groundwater to move from the uppermost surficial deposits to the Lower Sand and Gravel Aquifer.

The remaining parts of the Lower Sand and Gravel Aquifer in the County are areas where there is a transition condition.

6.4 Areas of Groundwater Decline

In order to determine the areas of potential groundwater decline in the sand and gravel aquifer(s), the available non-pumping water-level elevation for each water well completed in the sand and gravel aquifer(s) was first sorted by location, and then by date of water-level measurement. The dates of measurements were required to differ by at least 365 days. Only the earliest and latest control points at a given location were used.

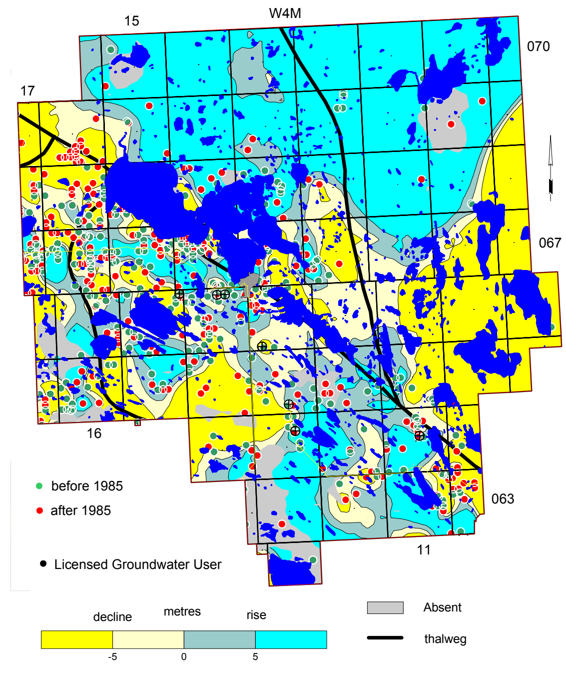

Figure 31. Changes in Water Levels in Sand and Gravel Aquifer(s)

The areas of groundwater decline in the sand and gravel aquifer(s) have been calculated by determining the frequency of non-pumping water level control points per five-year periods from 1960 to 2000. There were no control points before 1955. Of the 606 surficial water wells with a non-pumping water level and date, 290 are from water wells completed before 1985 and 316 are from water wells completed after 1985. Where the earliest water level (before 1985) is at a higher elevation than the latest water level (after 1985), there is the possibility that some groundwater decline has occurred. Where the earliest water level is at a lower elevation than the latest water level, there is the possibility that the groundwater has risen at that location. The water level may have risen as a result of recharge in wetter years or may be a result of the water well being completed in a different surficial aquifer. In order to determine if the water-level decline is a result of groundwater use by licensed users, the licensed groundwater users were posted on the maps.

Estimated Water Well Use (m³/day)	*% of Area of Affected*
<10	*19*
10 to 30	*6*
>30	*1*
no use	*74*

Table 16. Water-Level Decline of More than 5 Metres in the Sand and Gravel Aquifers

Figure 31 indicates that in 30% of the County, it is possible that the non-pumping water level has declined. Of the eleven licensed groundwater users, most occur in areas where a water-level decline may exist. Six percent of the areas where there has been a water-level decline of more than five metres corresponds to where the estimated water well use is between 10 and 30 m³/day per section; 1% of the declines occurred where the estimated water well use is more than 30 m³/day per section; 19% of the declines occurred where the estimated water well use is less than 10 m³/day per section; the remaining 74% occurred where there is no groundwater use per section, as shown previously on Figure 28. The areas of groundwater decline (where there are sufficient control points) in the sand and gravel aquifer(s) where there is no estimated water well use suggest that groundwater diversion is not having an impact and that the decline may be due to variations in recharge to the aquifer.

7. 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
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 117 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. It is recommended that the 117 water wells be field-verified, water levels be measured, a water sample be collected for analysis, and a short aquifer test be conducted. An attempt to update the quality of the entire database is not recommended.

Before an attempt is made to provide a major upgrade to the level of interpretation provided in this report, the accompanying maps and the groundwater query, it is recommended that the 117 water wells listed in Appendix E for which water well drilling reports are available be subjected to the following actions (see pages C-2 to C-3):

1) The horizontal location of the water well should be determined within ten 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 five and 115 minutes of pumping, and analyzed for major and minor ions.

This additional information would provide a baseline to be used for comparison to either existing chemical analyses or aquifer tests, or to determine if future monitoring would be necessary if significant changes in the aquifer parameters had occurred.

A list of the 117 water wells that could be considered for the above program is given in Appendix E and on the CD-ROM.

While there are a few areas where water-level data are available, on the overall, there are an insufficient number of water levels to set up a groundwater budget. One method to obtain additional water-level data is to solicit the assistance of the water well owners who are stakeholders in the groundwater resource. In the M.D. of Rocky View and in Flagstaff County, water well owners were being provided with a tax credit if they accurately measured 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. Monitoring of water levels in domestic and stock water wells is a practice that is recommended by PFRA in the “Water Wells That Last for Generations” manual and accompanying videos (Alberta Agriculture, Food and Rural Development, 1996).

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

In addition to the data collection associated with the existing water wells, all available geophysical logs should be interpreted to establish a more accurate spatial definition of individual aquifers.

There is also a need to provide the water well drillers with feedback on the reports they are submitting to the regulatory agencies. The feedback is necessary to allow for a greater degree of uniformity in the reporting process. This is particularly true when trying to identify the bedrock surface. One method of obtaining uniformity would be to have the water well drilling reports submitted to the AENV Resource Data Division in an electronic form. The money presently being spent by AENV to transpose the paper form to the electronic form should be used to allow for a technical review of the data and follow-up discussions with the drillers.

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

In summary, for the next level of study, the database needs updating. The updating of information for existing water wells requires more details for the water wells listed in Appendix E; the additional information for new water wells is mainly better spatial control.

Groundwater is a renewable resource and it must be managed.

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9. Conversions

Multiply	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
inches	25.400 000	millimetres
miles	1.609 344	kilometres
kilometre	0.621 370	miles (statute)
square feet (ft^2)	0.092 903	metres (m^2)
metres (m^2)	10.763 910	square feet (ft^2)
metres (m^2)	0.000 001	kilometres (km^2)
Concentration		
grains/gallon (UK)	14.270 050	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	0.219 974	ipgm
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 (m^3/day)	0.152 759	igpm
Pressure		
psi	6.894 757	kpa
kpa	0.145 038	psi
Miscellaneous		
Celsius	F° = 9/5 (C° + 32)	Fahrenheit
Fahrenheit	C° = (F°- 32) * 5/9	Celsius
degrees	0.017 453	radians
US$	0.000 000	Canadian$

10. Glossary

AAFC-PFRA — Prairie Farm Rehabilitation Administration arm of Agriculture and Agri-Food Canada

Aquifer — a formation, group of formations, or part of a formation that contains saturated permeable rocks capable of transmitting groundwater to water wells or springs in economical quantities

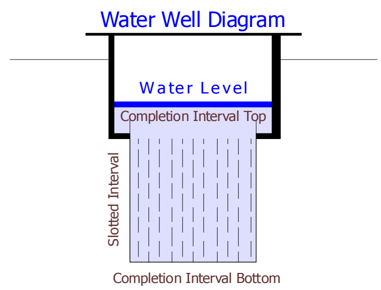
Aquitard — a confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer

Available Drawdown — in a confined aquifer, the distance between the non-pumping water level and the top of the aquifer

in an unconfined aquifer (water table aquifer), two thirds of the saturated thickness of the aquifer

Borehole — includes all "work types" except springs

Completion Interval — see diagram



Completion Interval

Dewatering — the removal of groundwater from an aquifer for purposes other than use

Dfb — one of the Köppen climate classifications; 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.

Evapotranspiration — a combination of evaporation from open bodies of water, evaporation from soil surfaces, and transpiration from the soil by plants (Freeze and Cherry, 1979)

Facies — the aspect or character of the sediment within beds of one and the same age (Pettijohn, 1957)

Fluvial — produced by the action of a stream or river

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

Lithology — description of rock material

Lsd — Legal Subdivision

m — metres

mm — millimetres

m^2/day — metres squared per day

m^3 — cubic metres

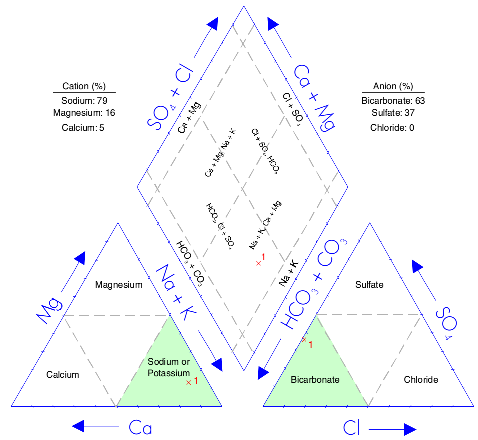
m^3/day — cubic metres per day

mg/L — milligrams per litre

Median
the value at the center of an ordered range of numbers

Obs WW
Observation Water Well

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

Rock
earth material below the root zone

Surficial Deposits
includes all sediments above the bedrock

Thalweg
the line connecting the lowest points along a stream bed or valley; *longitudinal profile*

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

Water Well
a hole in the ground for the purpose of obtaining groundwater; "work type" as defined by AENV includes test hole, chemistry, deepened, well inventory, federal well survey, reconditioned, reconstructed, new, old well-test

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

AENV
Alberta Environment

AMSL
above mean sea level

BGP
Base of Groundwater Protection

DEM	Digital Elevation Model
DST	drill stem test
EUB	Alberta Energy and Utilities Board
GCDWQ	Guidelines for Canadian Drinking Water Quality
NPWL	non-pumping water level
TDS	Total Dissolved Solids
WSW	Water Source Well or Water Supply Well

Depth to Top of Bronson Lake Formation 45
Apparent Yield for Water Wells Completed through Bronson Lake Aquifer 46
Depth to Top of Empress Formation – Unit 3 47
Apparent Yield for Water Wells Completed through Empress Aquifer – Unit 3 48
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Changes in Water Levels in Sand and Gravel Aquifer(s) 60
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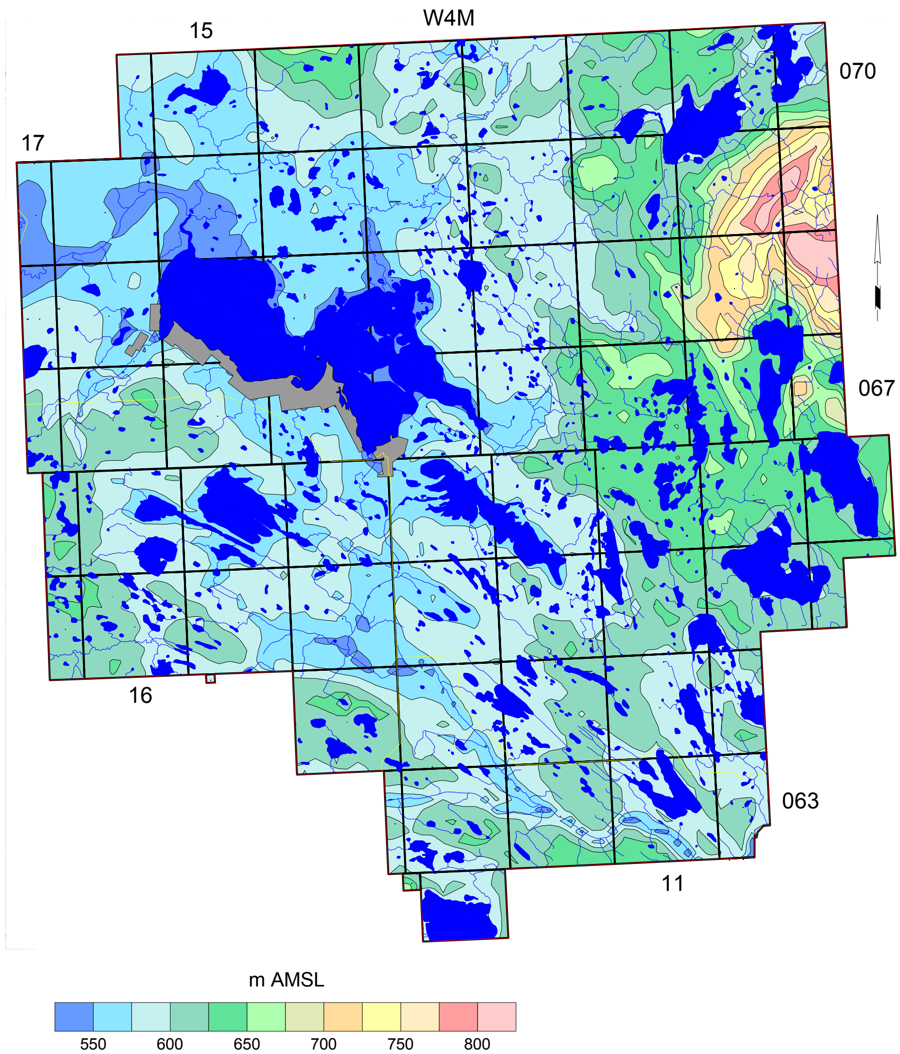
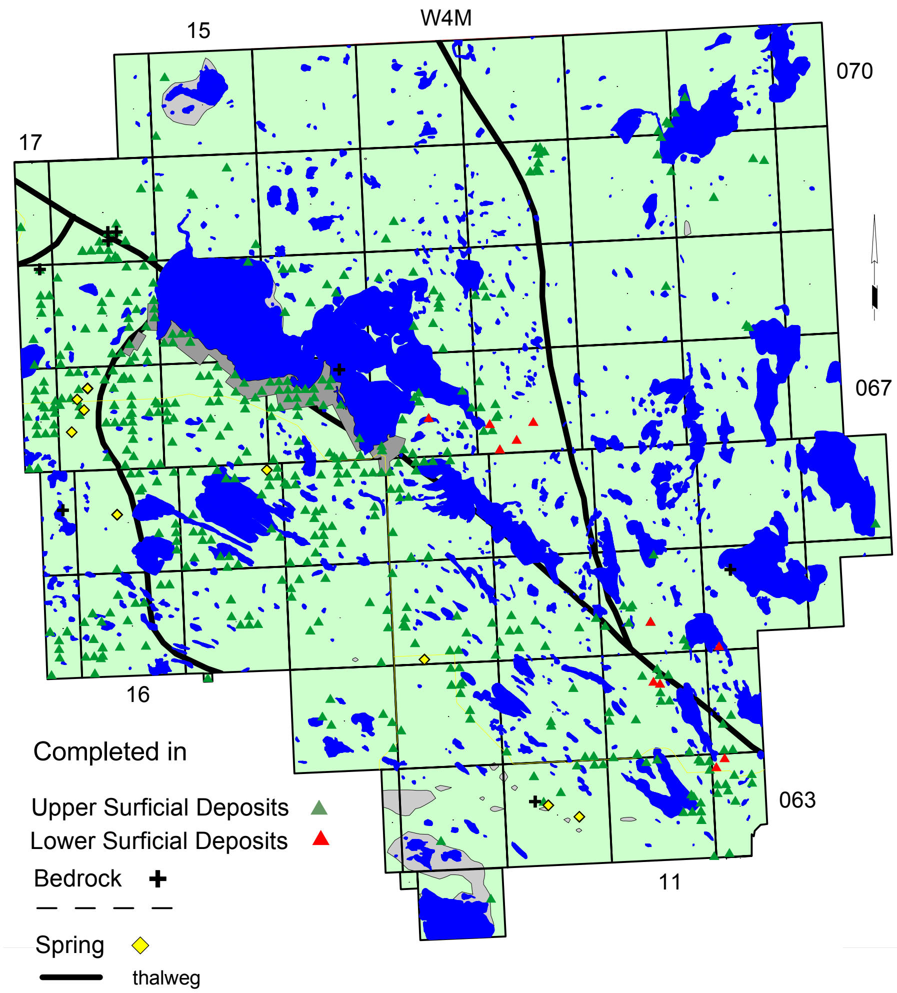
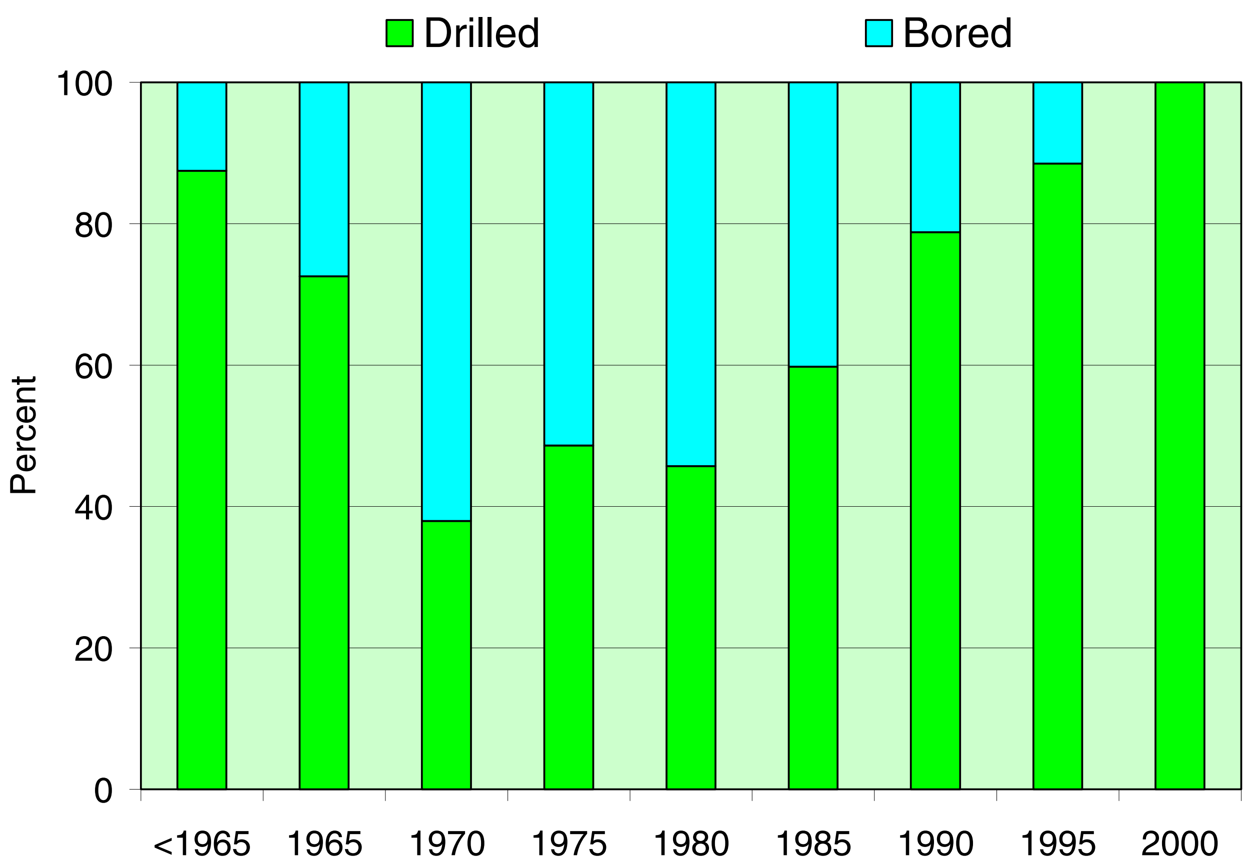
Surface Topography



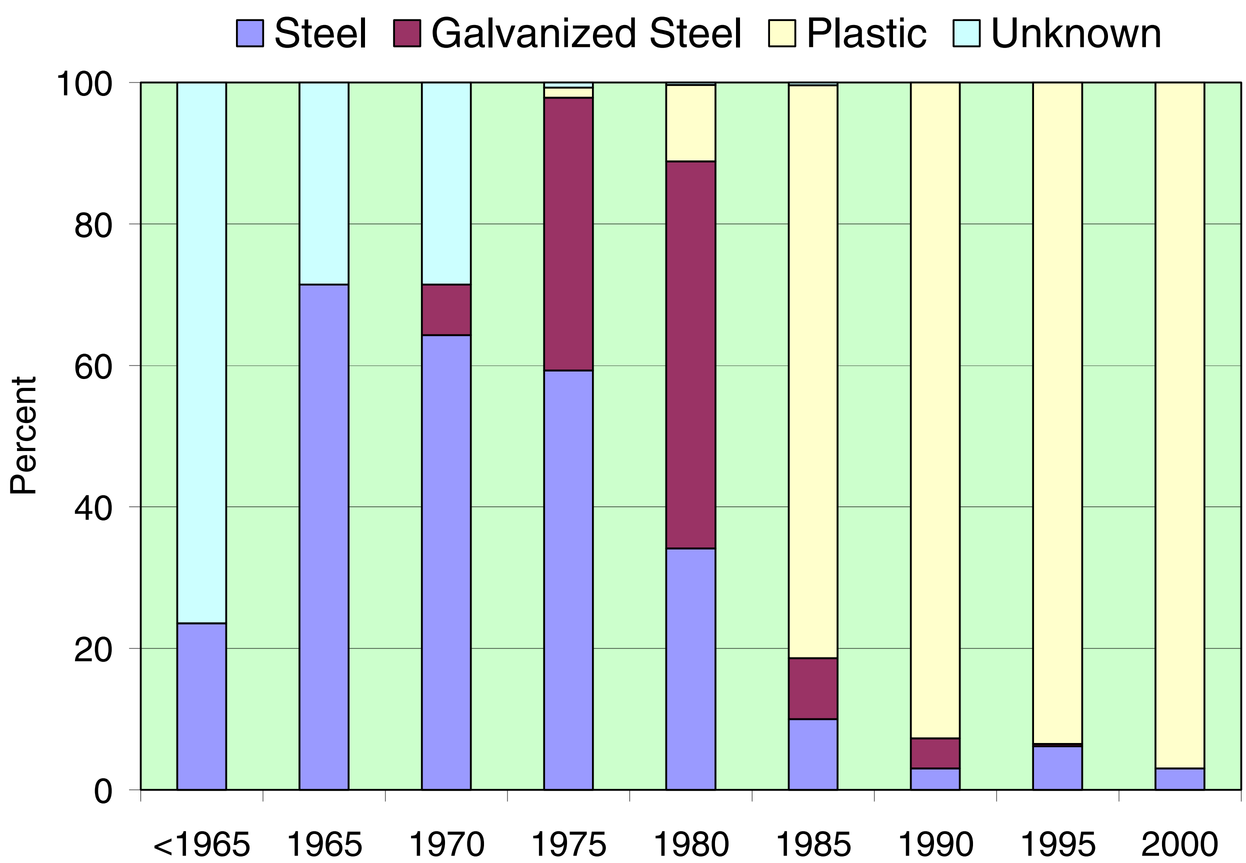
Location of Water Wells and Springs



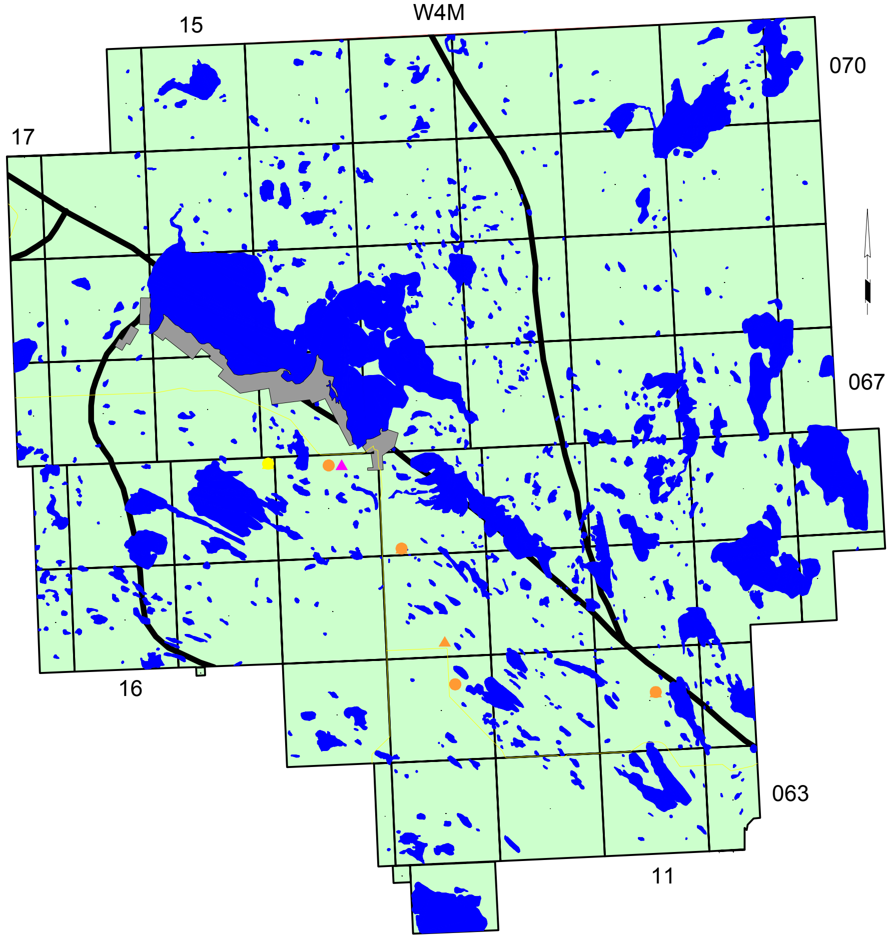
Casing Diameter Used in Water Wells



Surface Casing Types used in Drilled Water Wells



Licensed Water Wells

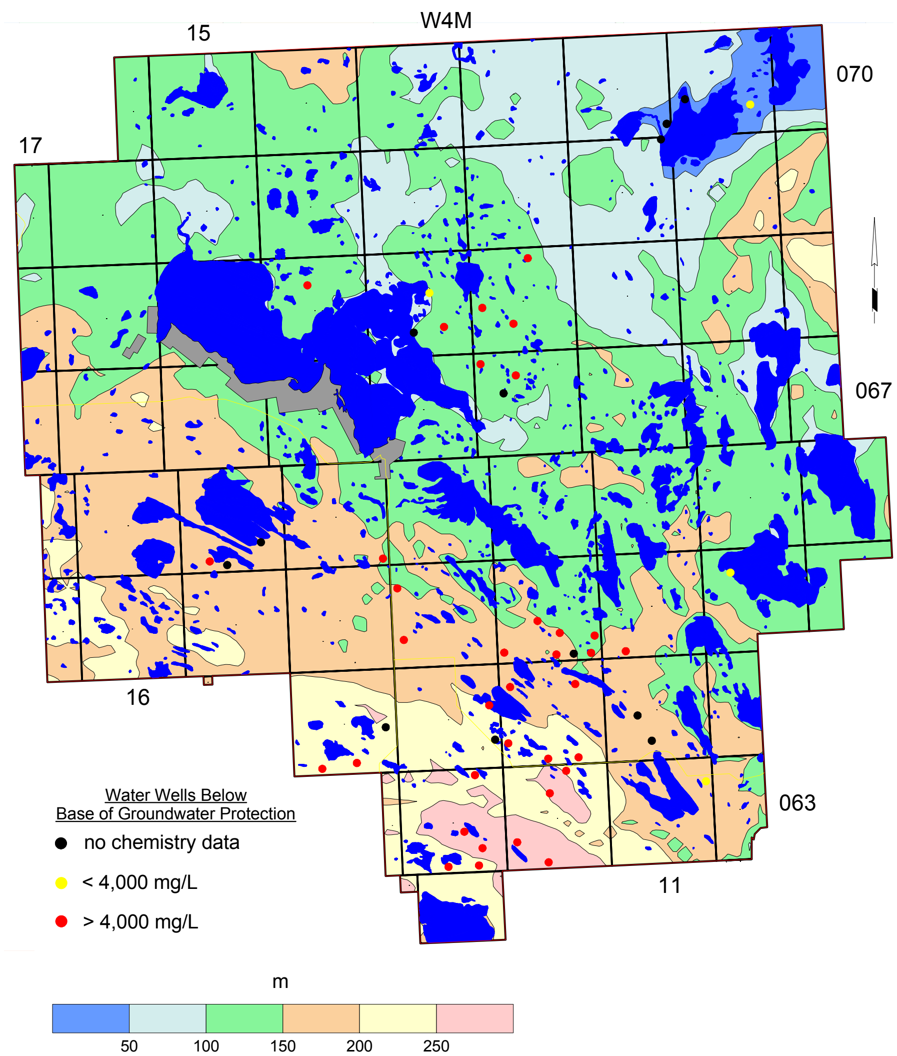


Licensed Groundwater Users (m³/day)

	agricultural	municipal	recreation
< 10	(5)	(1)	(0)
10 to 100	(3)	(1)	(1)
> 100	(0)	(0)	(0)

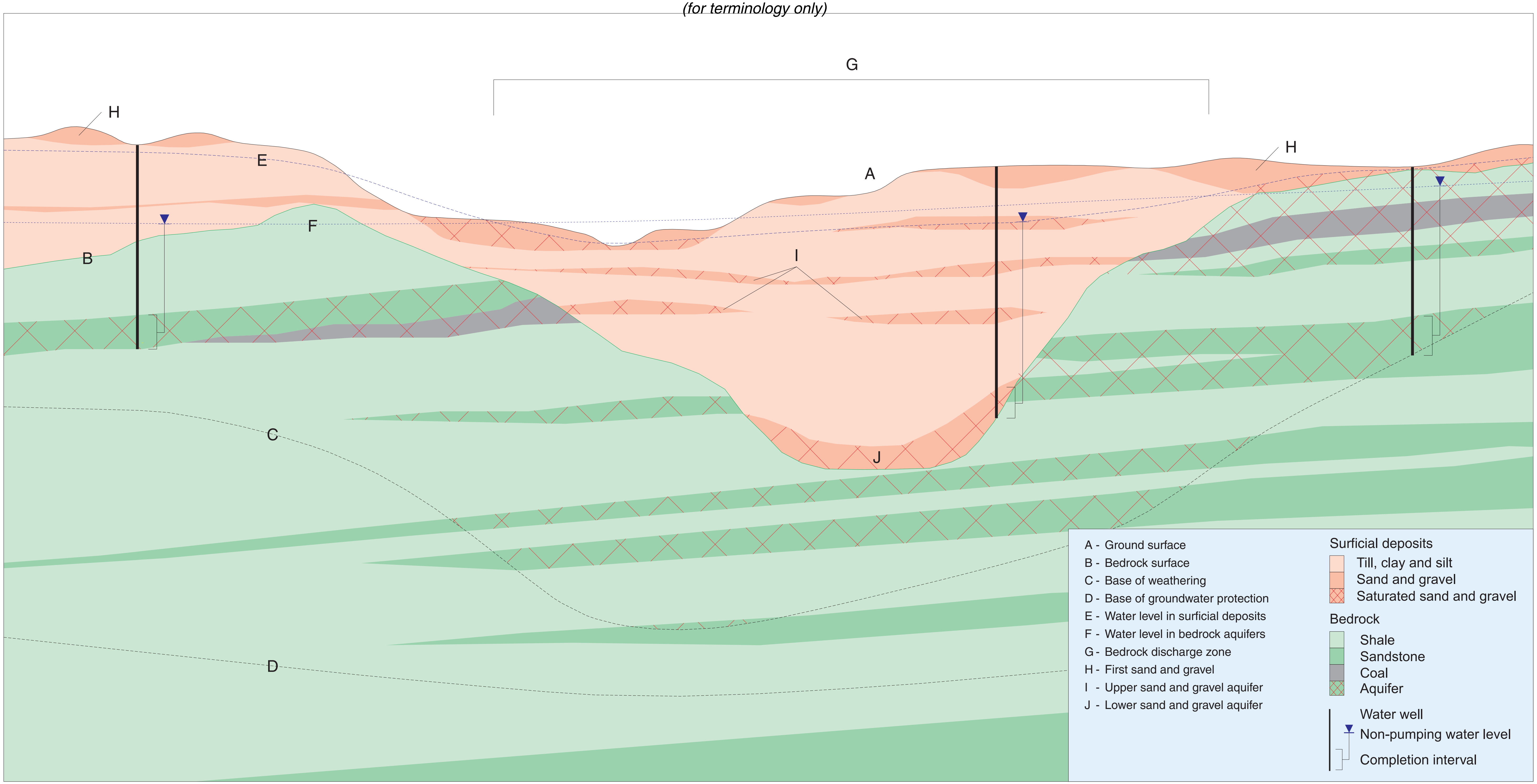
Depth to Base of Groundwater Protection

(modified after EUB, 1995)



Generalized Cross-Section

(for terminology only)



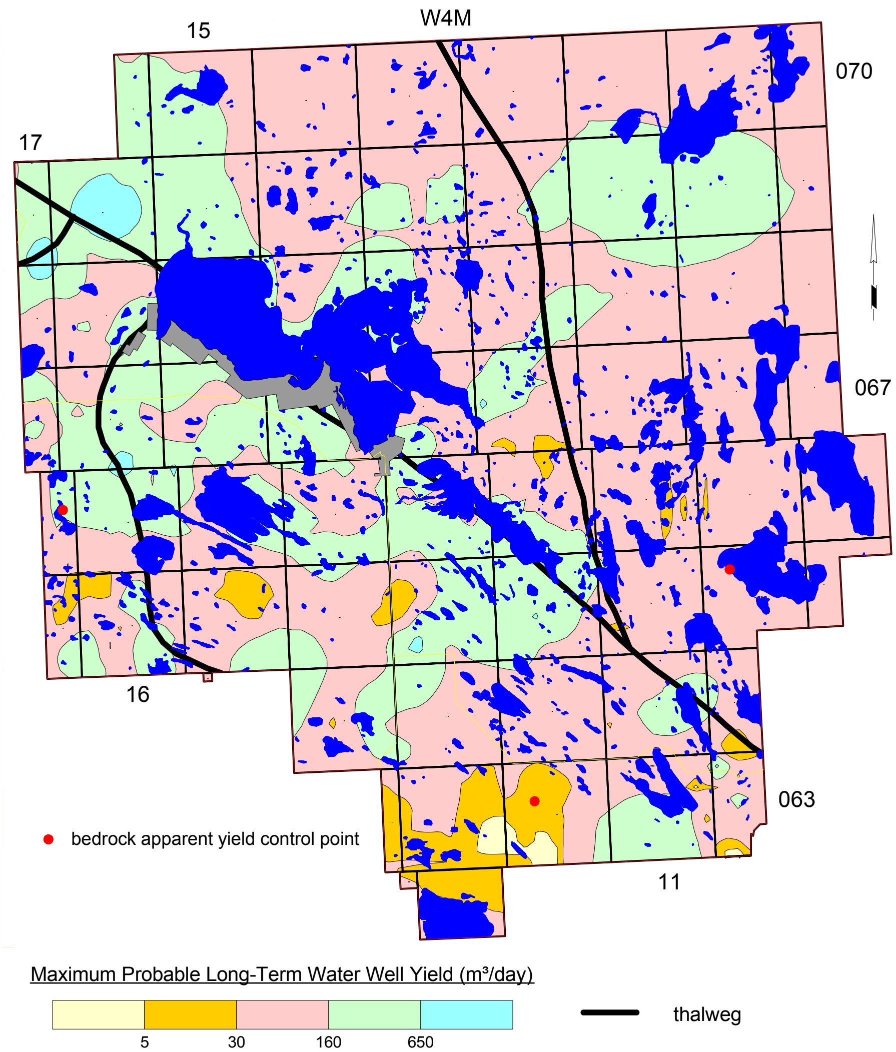
Geologic Column

(modified after Andriashek and Fenton, 1989)

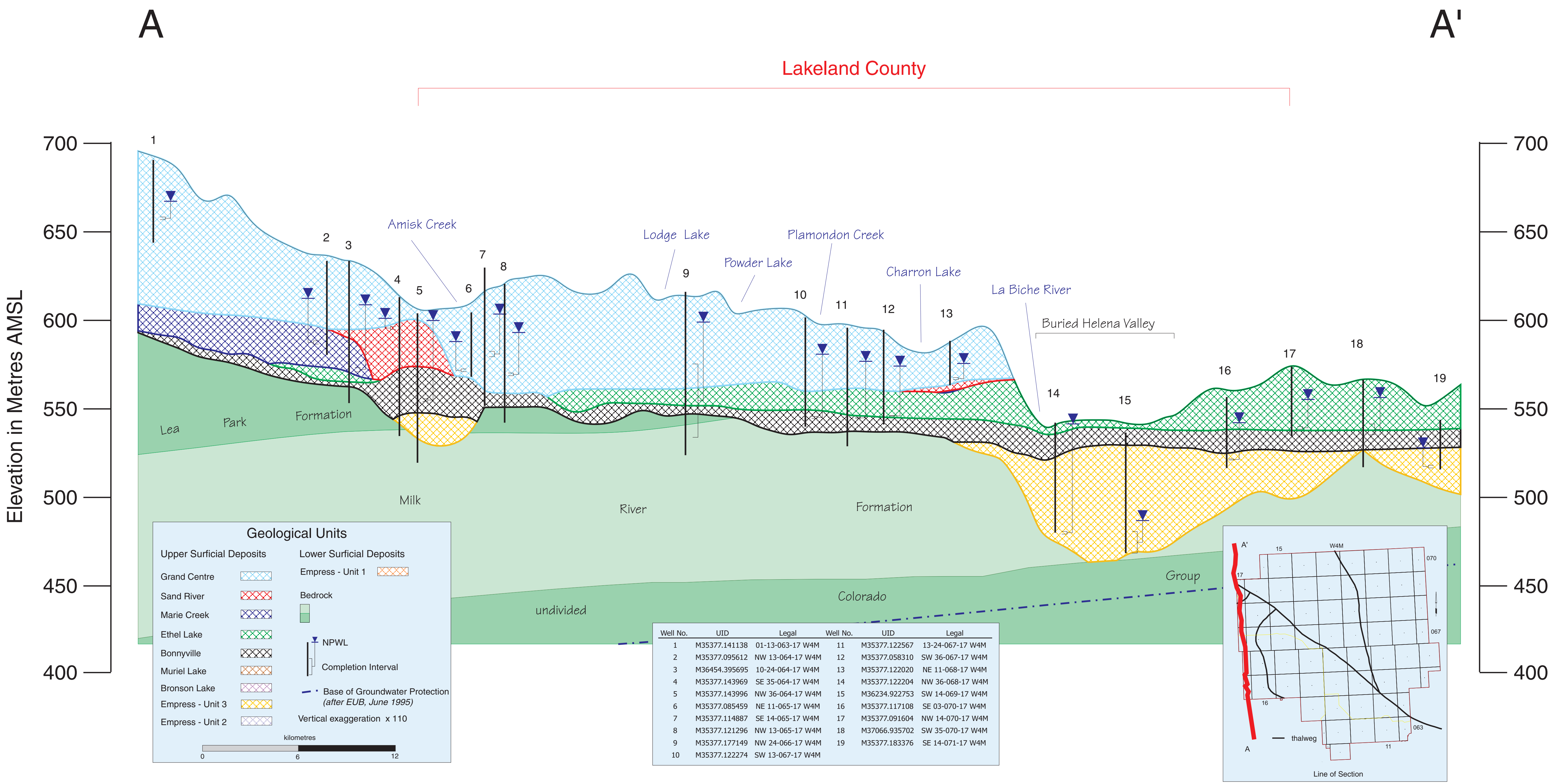
	Formation		Unit or Member		
Lithology Description	Average Thickness (m)	Designation	Average Thickness (m)	Designation	Lithology Description
diamicton	< 25	Grand Centre	< 20	Vilna Member	clayey diamicton
			< 30	Kehiwin Member	sandy diamicton
			< 10	Reita Lake Member	clayey sand diamicton
			< 10	Hilda Lake Member	clayey diamicton
sand and gravelly sand	< 25	Sand River			
diamicton	< 25	Marie Creek	10	Unit 2	sandy diamicton
			10	Unit 1	clayey diamicton
silt and clay with sand	2	Ethel Lake			
diamicton	50	Bonnyville	25	Unit 2	sandy clay diamicton
			25	Unit 1	clayey diamicton
sand and gravel	35	Muriel Lake			
clayey diamicton	5	Bronson Lake			
sand and gravel, silt and clay	70	Empress	25	Unit 3	sand and gravel
			25	Unit 2	silt and sand, minor sand and gravel
			25	Unit 1	preglacial sand and gravel (lower surficial deposits)
shale, siltstone	100-200	Lea Park Formation			
sandstone, siltstone, shale, coal	90-120	Milk River Formation			
shale, siltstone	200-1000	*undivided Colorado Group*			

Depth in Metres: 0, 20, 40, 60, 80, 100, 120, 140, 160, 180, 200, 220

Hydrogeological Map

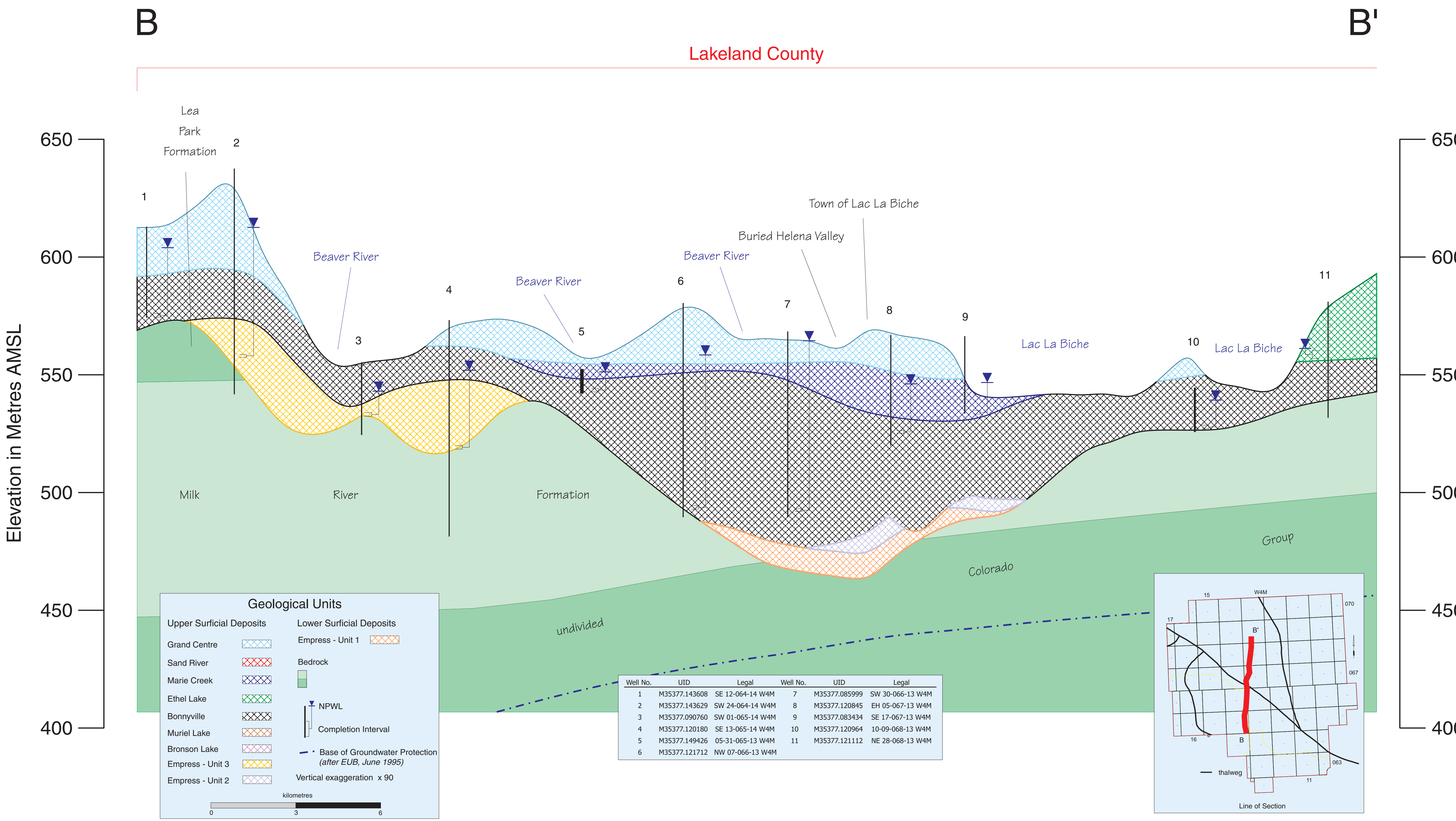


Cross-Section A - A'



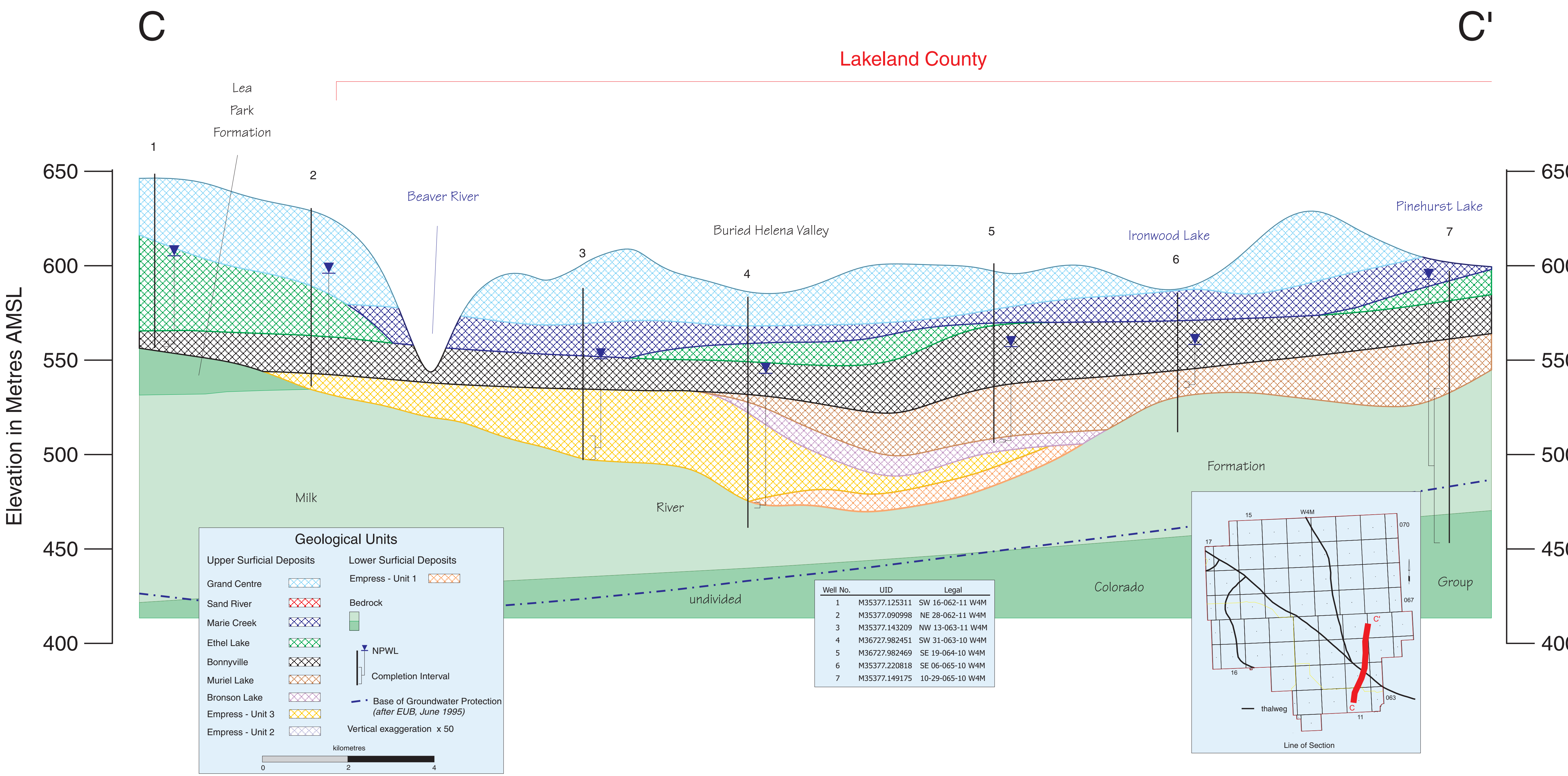
Well No.	UID	Legal	Well No.	UID	Legal
1	M35377.141138	01-13-063-17 W4M	11	M35377.122567	13-24-067-17 W4M
2	M35377.095612	NW 13-064-17 W4M	12	M35377.058310	SW 36-067-17 W4M
3	M36454.395695	10-24-064-17 W4M	13	M35377.122020	NE 11-068-17 W4M
4	M35377.143969	SE 35-064-17 W4M	14	M35377.122204	NW 36-068-17 W4M
5	M35377.143996	NW 36-064-17 W4M	15	M36234.922753	SW 14-069-17 W4M
6	M35377.085459	NE 11-065-17 W4M	16	M35377.117108	SE 03-070-17 W4M
7	M35377.114887	SE 14-065-17 W4M	17	M35377.091604	NW 14-070-17 W4M
8	M35377.121296	NW 13-065-17 W4M	18	M37066.935702	SW 35-070-17 W4M
9	M35377.177149	NW 24-066-17 W4M	19	M35377.183376	SE 14-071-17 W4M
10	M35377.122274	SW 13-067-17 W4M			

Cross-Section B - B'

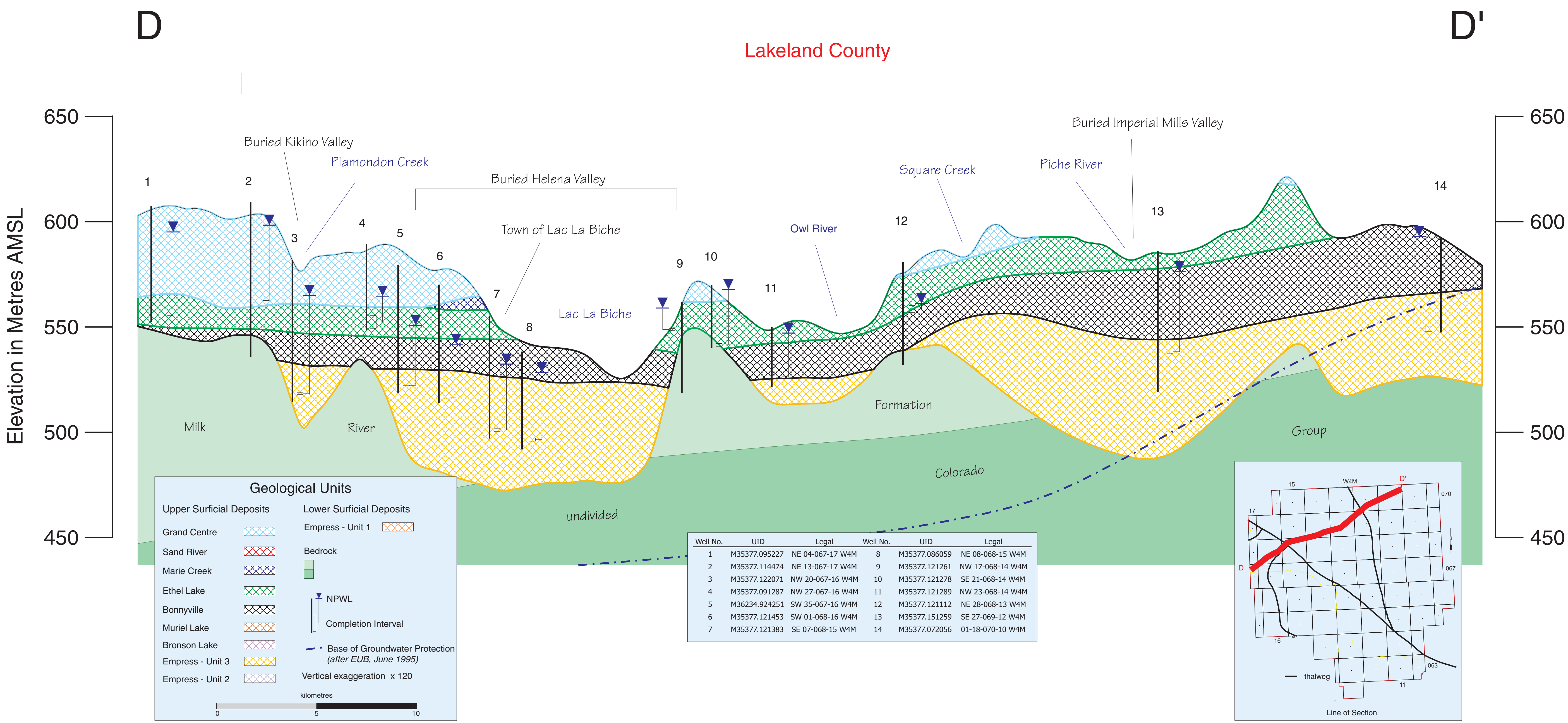


Well No.	UID	Legal	Well No.	UID	Legal
1	M35377.143608	SE 12-064-14 W4M	7	M35377.085999	SW 30-066-13 W4M
2	M35377.143629	SW 24-064-14 W4M	8	M35377.120845	EH 05-067-13 W4M
3	M35377.090760	SW 01-065-14 W4M	9	M35377.083434	SE 17-067-13 W4M
4	M35377.120180	SE 13-065-14 W4M	10	M35377.120964	10-09-068-13 W4M
5	M35377.149426	05-31-065-13 W4M	11	M35377.121112	NE 28-068-13 W4M
6	M35377.121712	NW 07-066-13 W4M			

Cross-Section C - C'

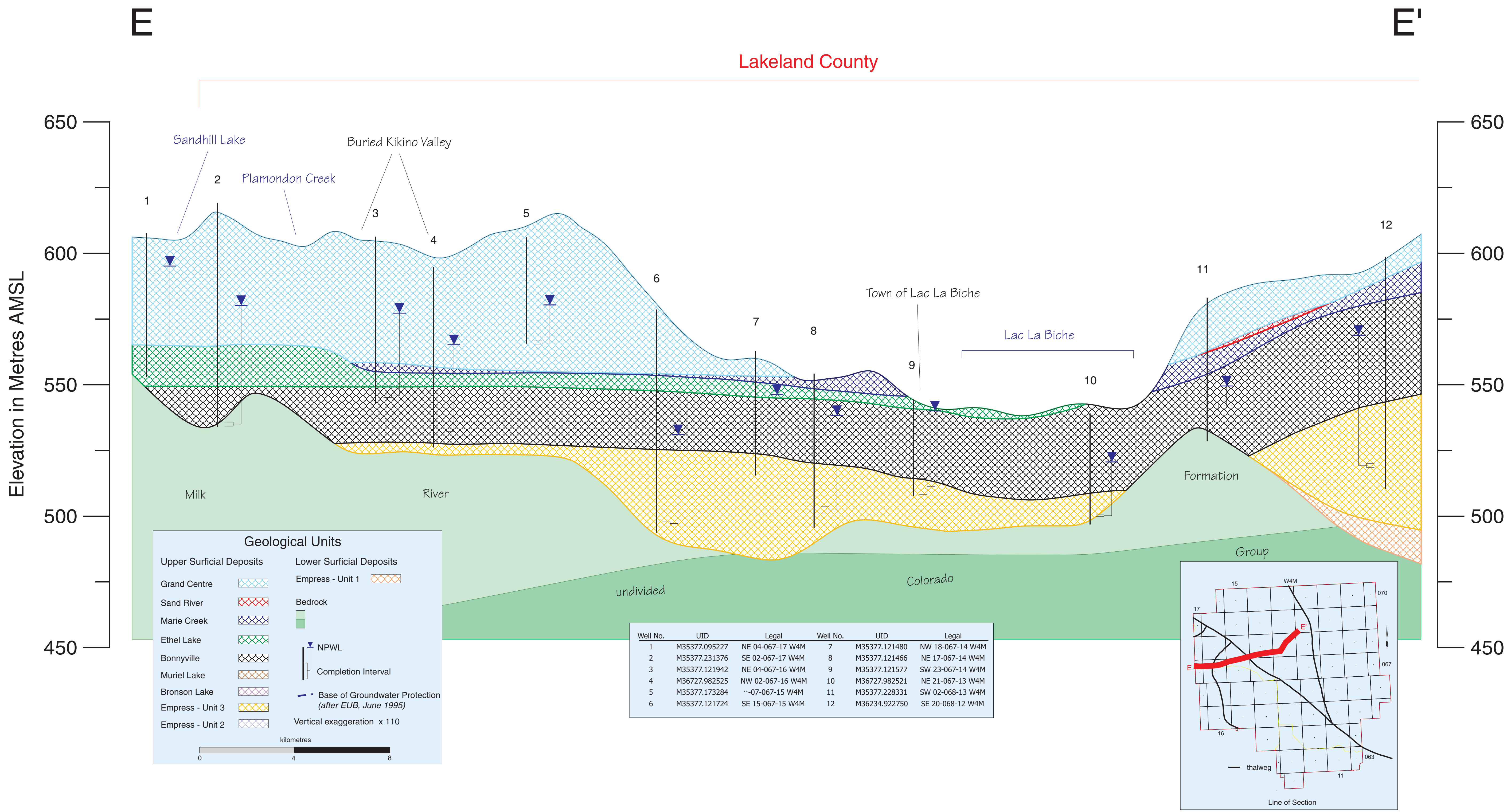


Cross-Section D - D'



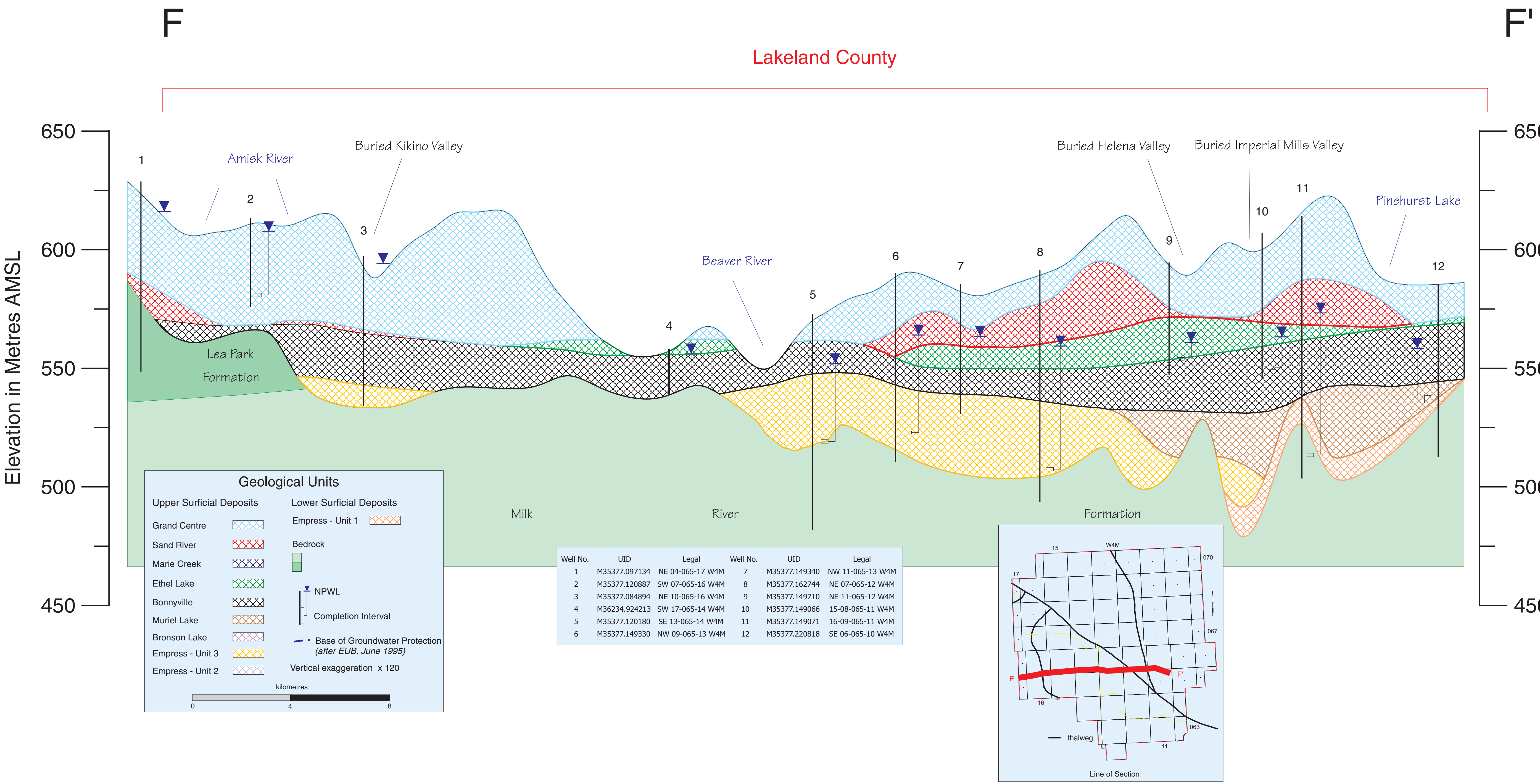
Well No.	UID	Legal	Well No.	UID	Legal
1	M35377.095227	NE 04-067-17 W4M	8	M35377.086059	NE 08-068-15 W4M
2	M35377.114474	NE 13-067-17 W4M	9	M35377.121261	NW 17-068-14 W4M
3	M35377.122071	NW 20-067-16 W4M	10	M35377.121278	SE 21-068-14 W4M
4	M35377.091287	NW 27-067-16 W4M	11	M35377.121289	NW 23-068-14 W4M
5	M36234.924251	SW 35-067-16 W4M	12	M35377.121112	NE 28-068-13 W4M
6	M35377.121453	SW 01-068-16 W4M	13	M35377.151259	SE 27-069-12 W4M
7	M35377.121383	SE 07-068-15 W4M	14	M35377.072056	01-18-070-10 W4M

Cross-Section E - E'



Well No.	UID	Legal	Well No.	UID	Legal
1	M35377.095227	NE 04-067-17 W4M	7	M35377.121480	NW 18-067-14 W4M
2	M35377.231376	SE 02-067-17 W4M	8	M35377.121466	NE 17-067-14 W4M
3	M35377.121942	NE 04-067-16 W4M	9	M35377.121577	SW 23-067-14 W4M
4	M36727.982525	NW 02-067-16 W4M	10	M36727.982521	NE 21-067-13 W4M
5	M35377.173284	··-07-067-15 W4M	11	M35377.228331	SW 02-068-13 W4M
6	M35377.121724	SE 15-067-15 W4M	12	M36234.922750	SE 20-068-12 W4M

Cross-Section F - F'



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2	M35377.120887	SW 07-065-16 W4M	8	M35377.162744	NE 07-065-12 W4M
3	M35377.084894	NE 10-065-16 W4M	9	M35377.149710	NE 11-065-12 W4M
4	M36234.924213	SW 17-065-14 W4M	10	M35377.149066	15-08-065-11 W4M
5	M35377.120180	SE 13-065-14 W4M	11	M35377.149071	16-09-065-11 W4M
6	M35377.149330	NW 09-065-13 W4M	12	M35377.220818	SE 06-065-10 W4M

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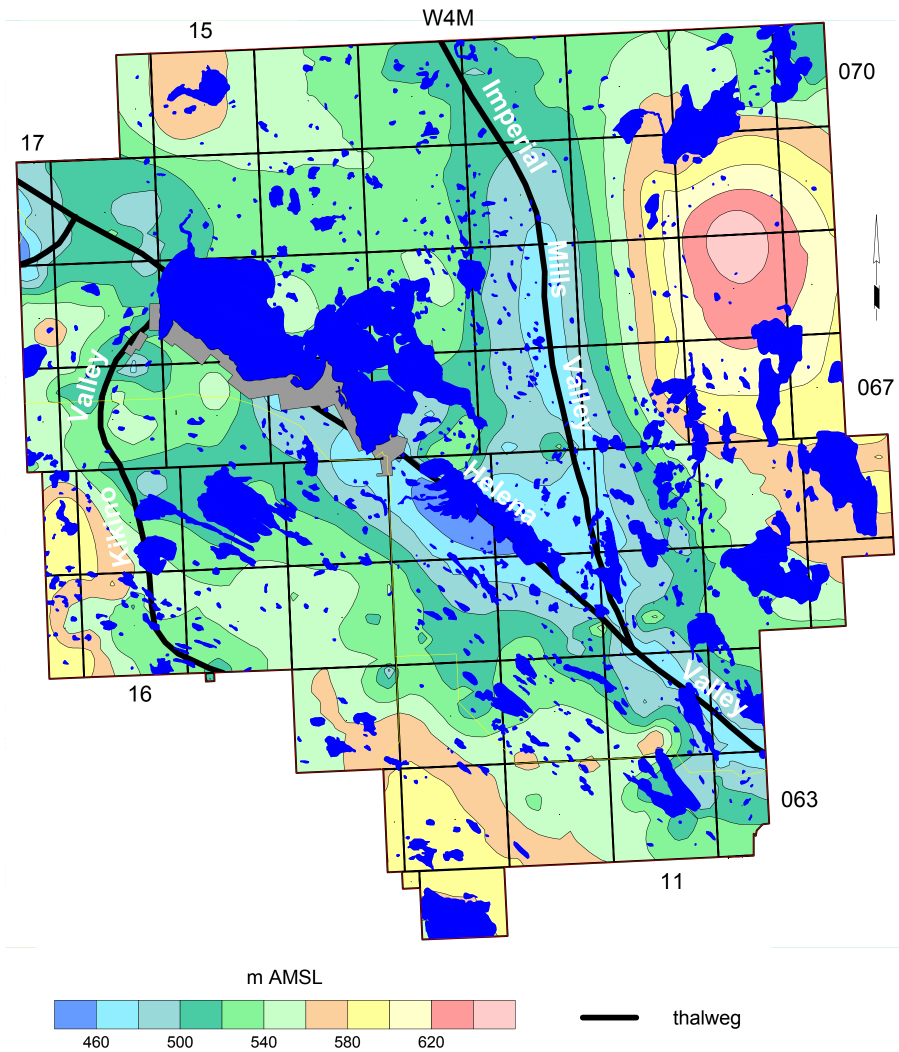
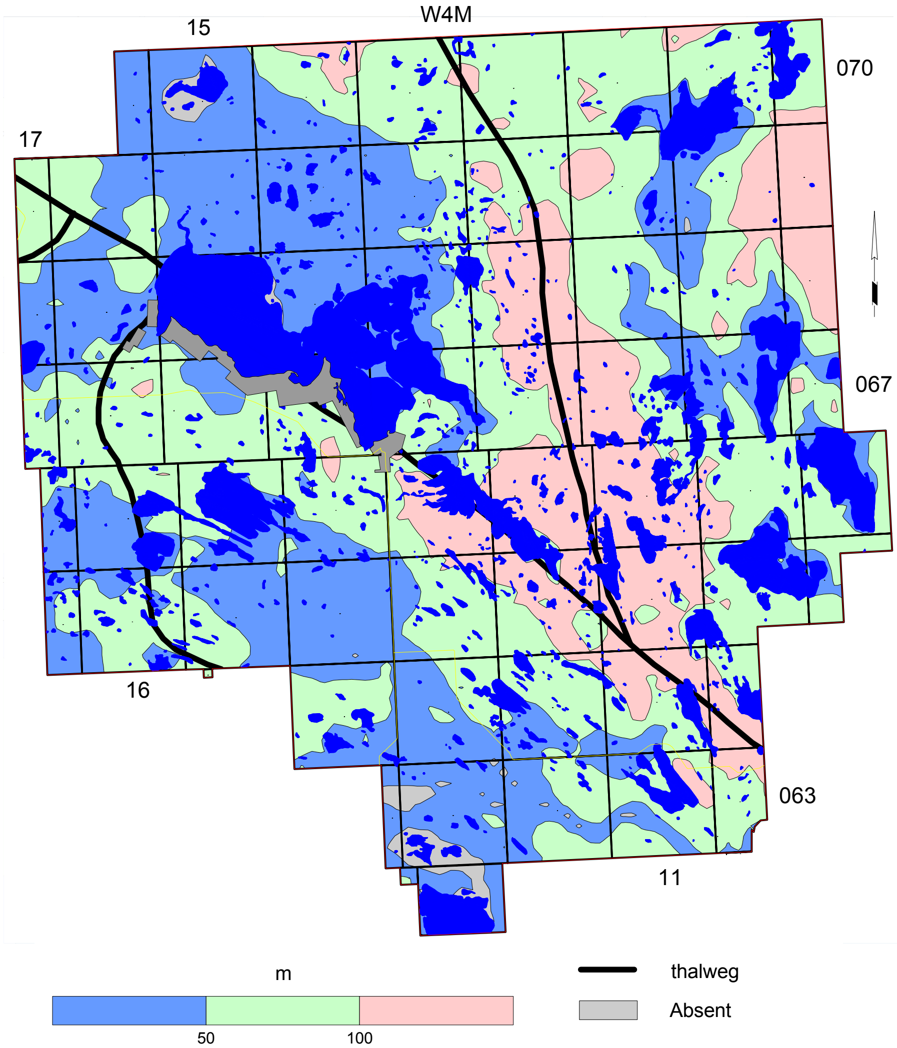
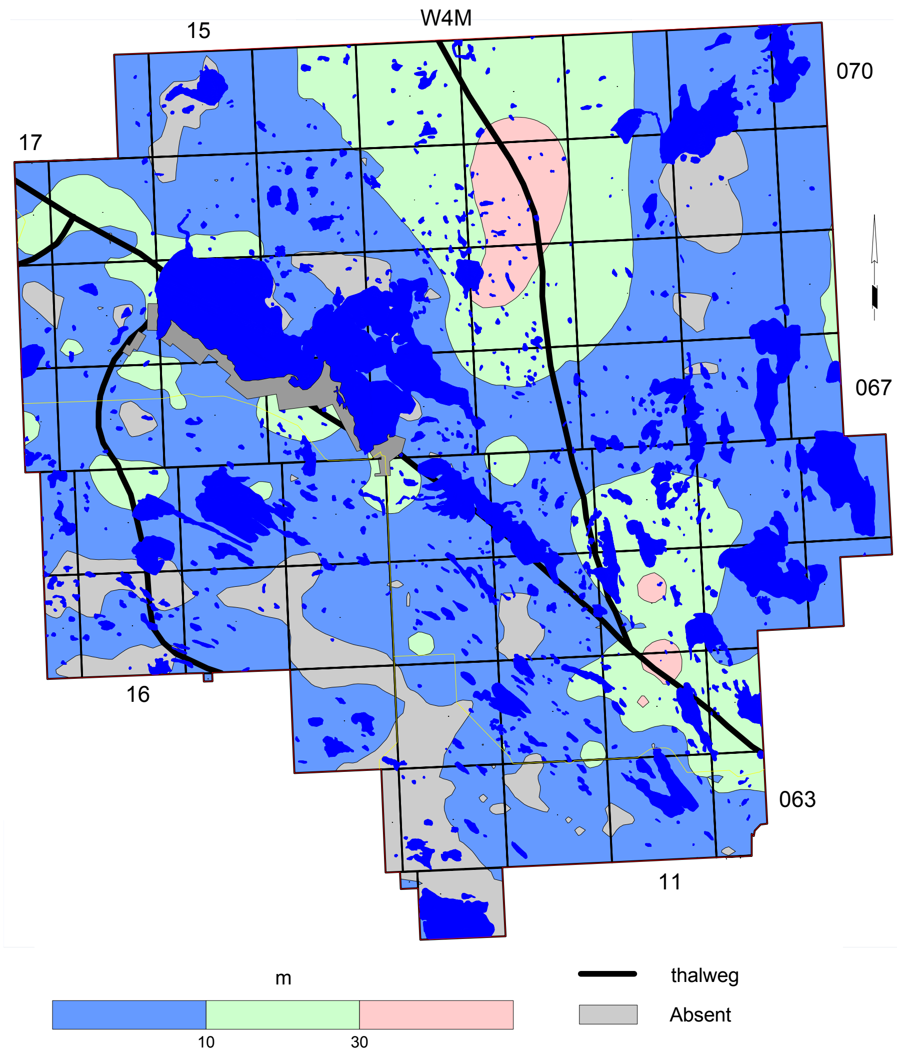
Bedrock Topography



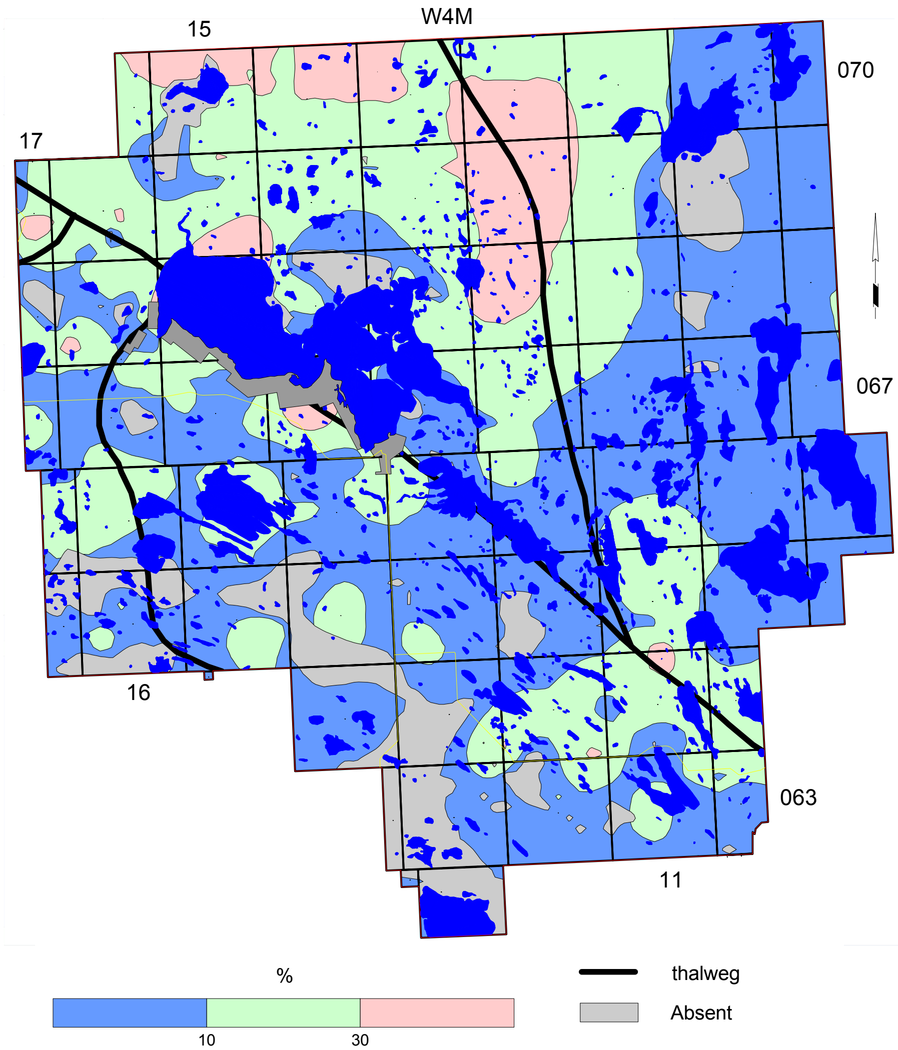
Thickness of Surficial Deposits



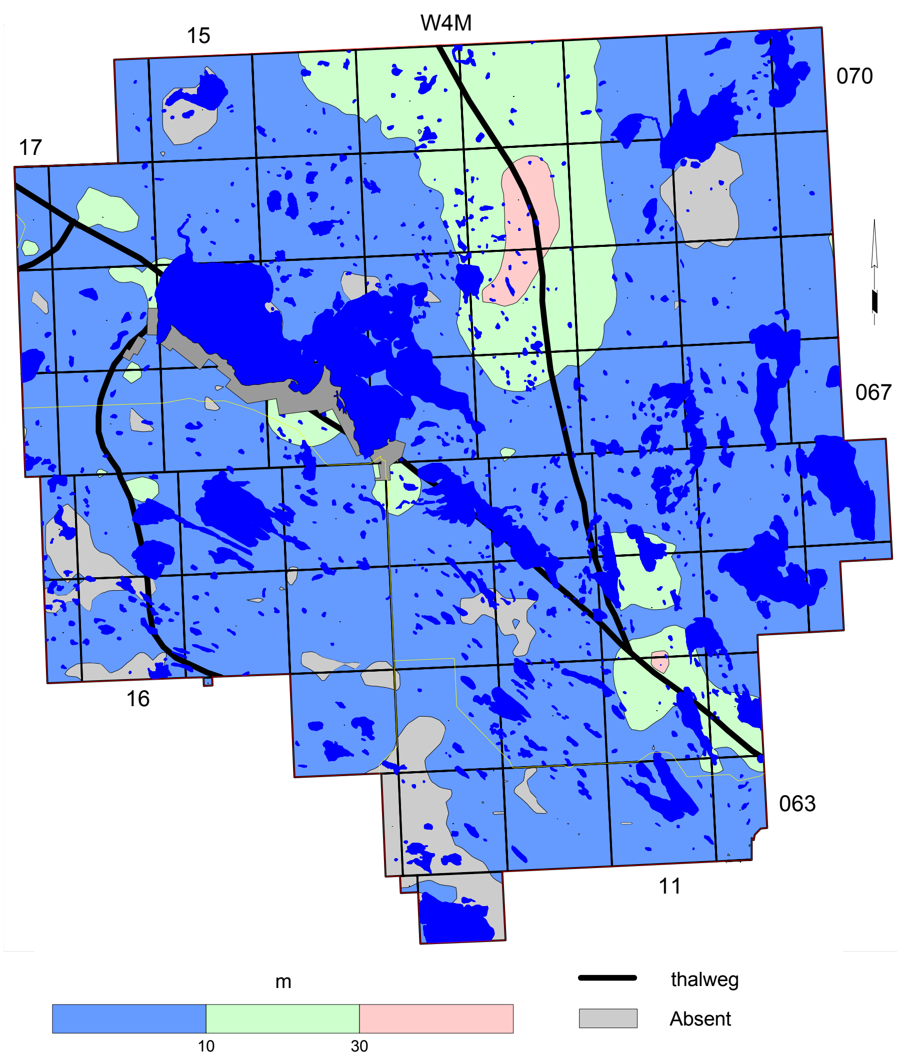
Thickness of Sand and Gravel Deposits



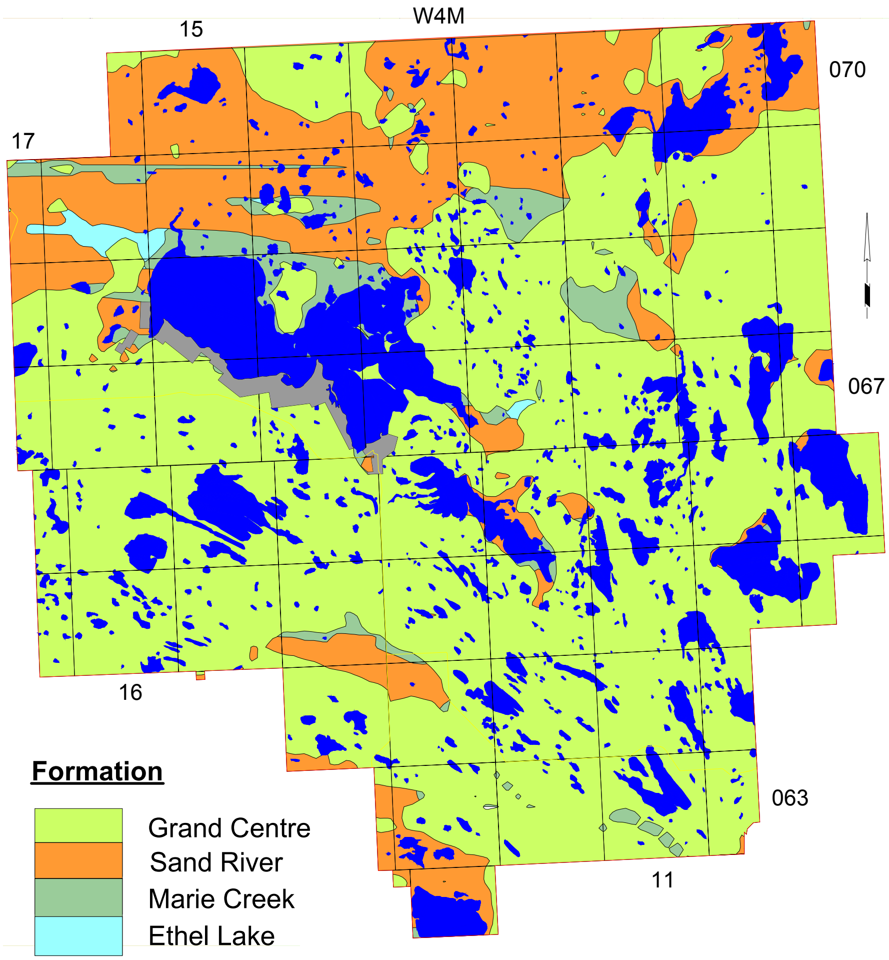
Amount of Sand and Gravel in Surficial Deposits



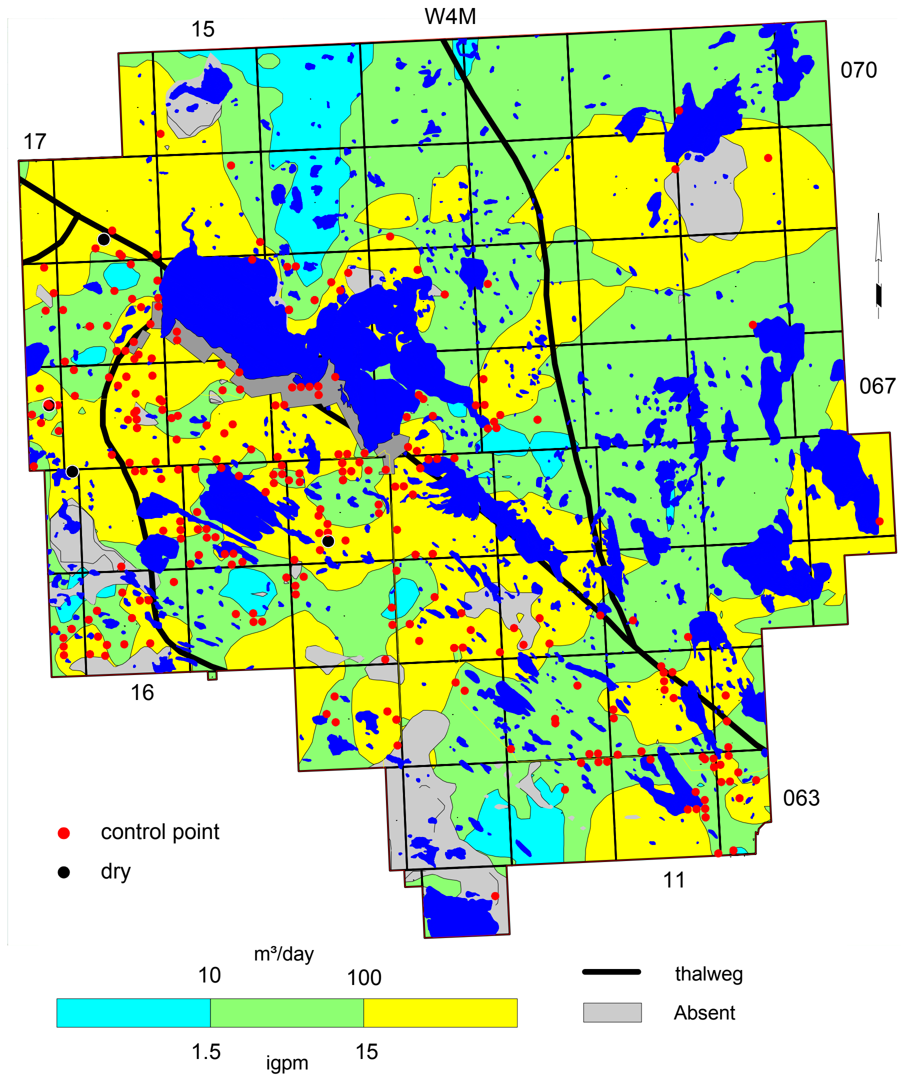
Thickness of Sand and Gravel Aquifer(s)



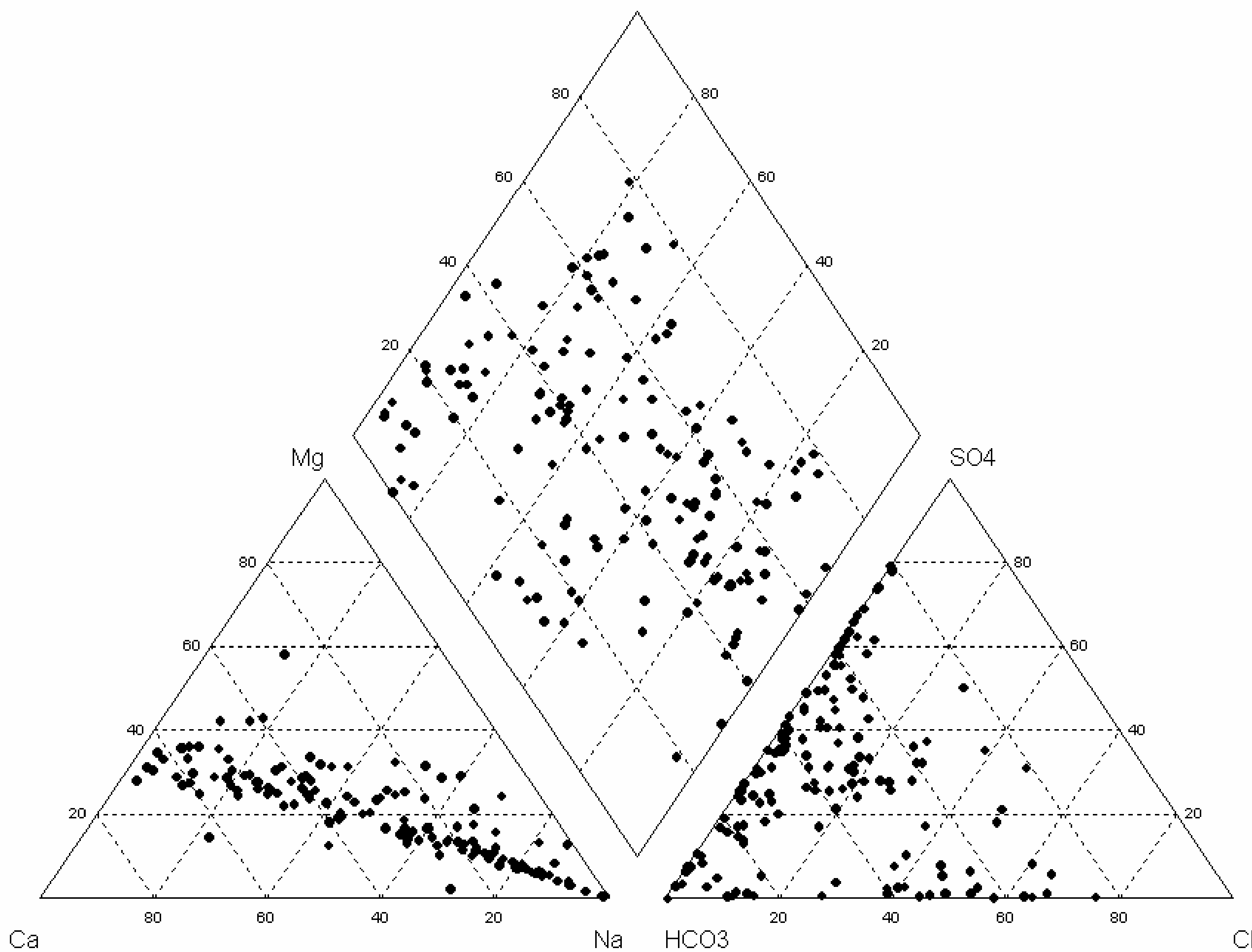
Surficial Geology



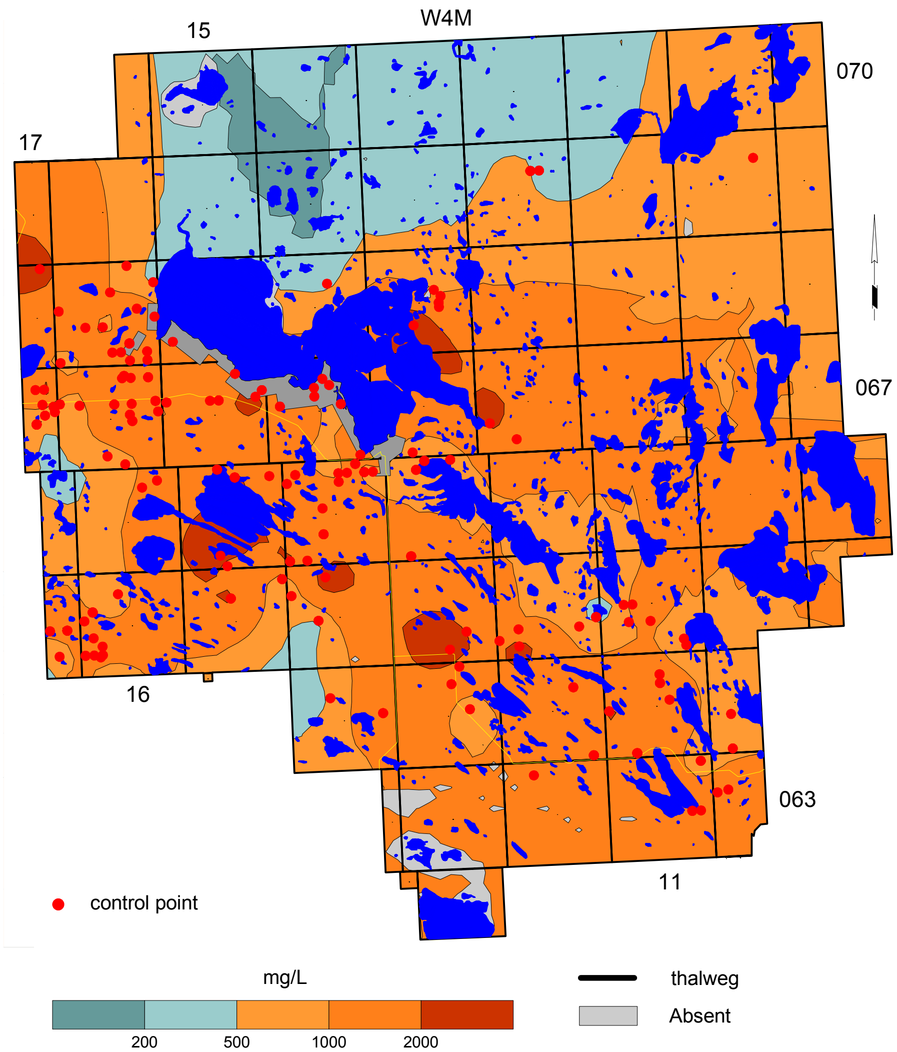
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)



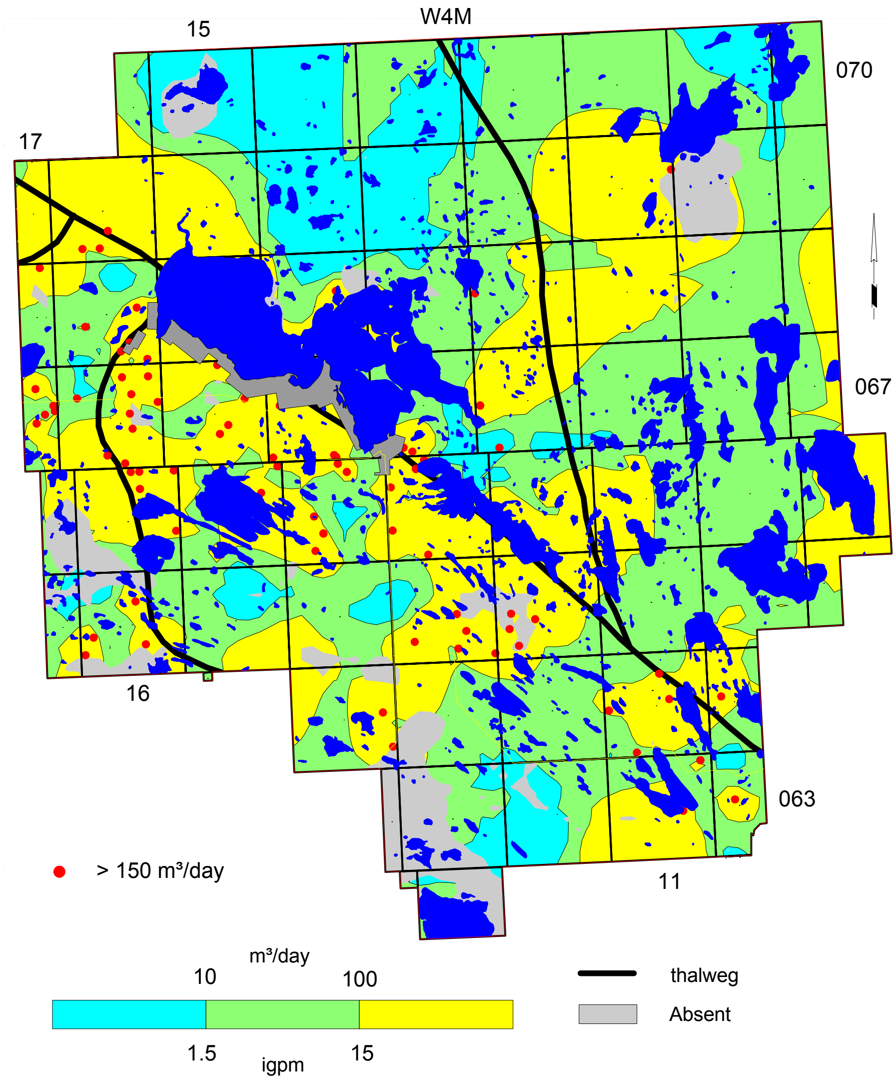
Piper Diagram – Surficial Deposits



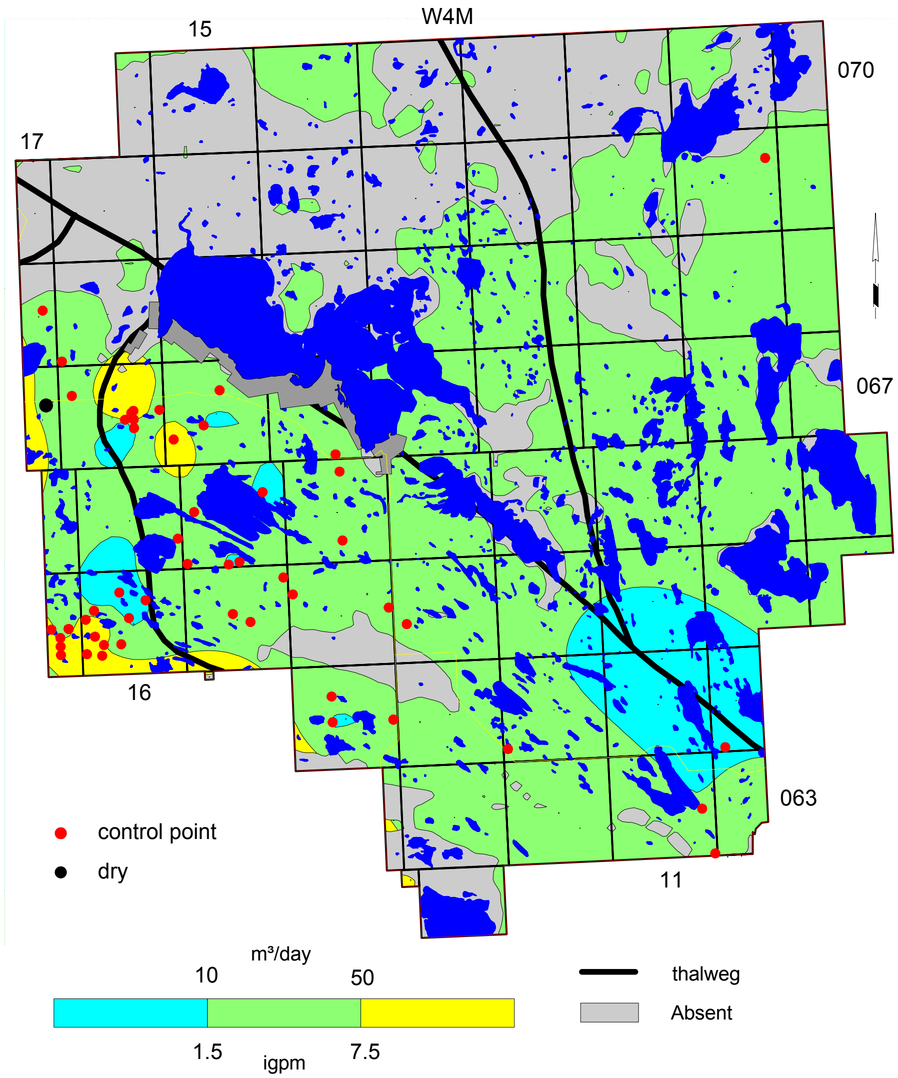
Total Dissolved Solids in Groundwater from Surficial Deposits



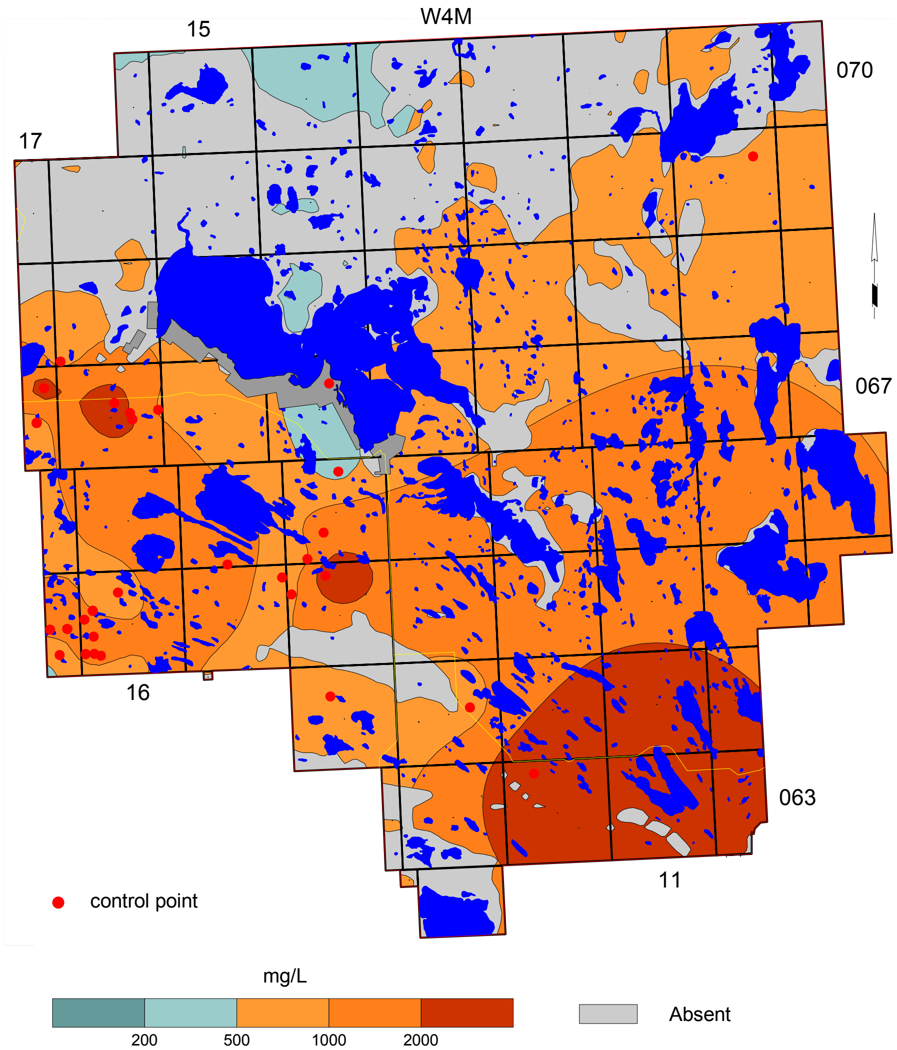
Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer



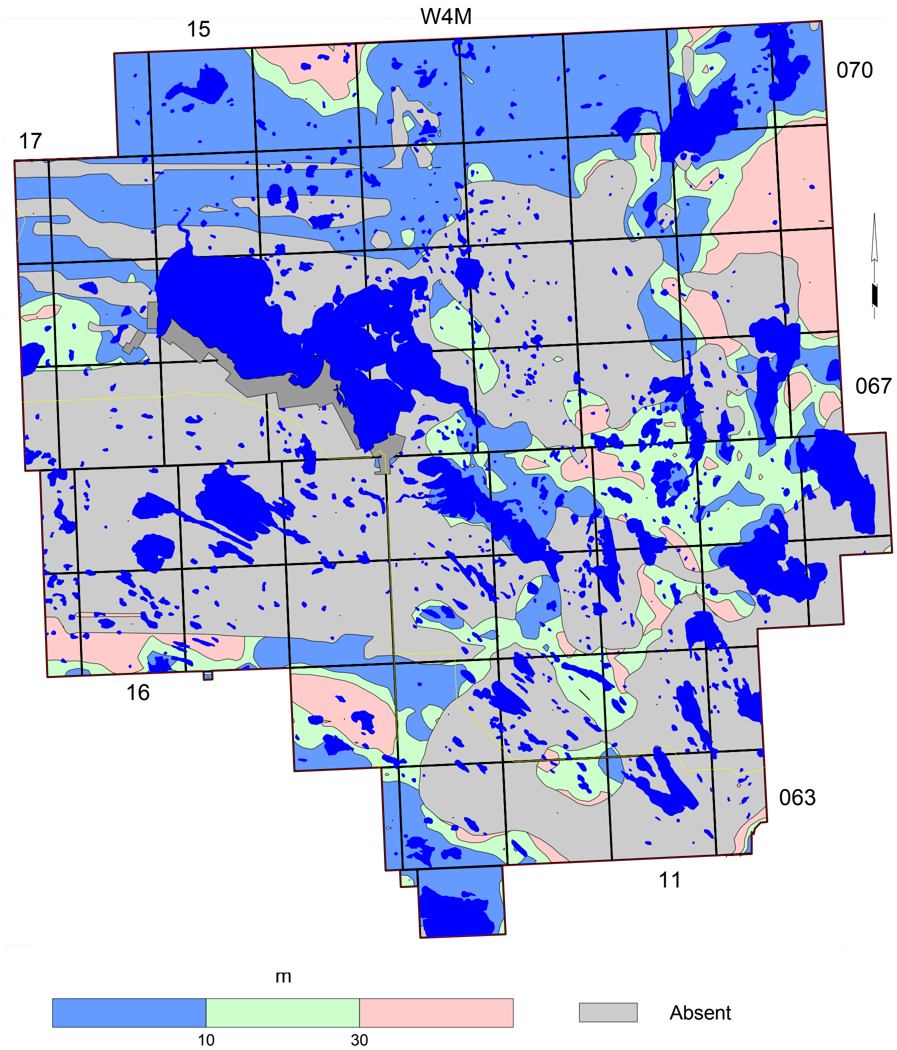
Apparent Yield for Water Wells Completed through Grand Centre Aquifer



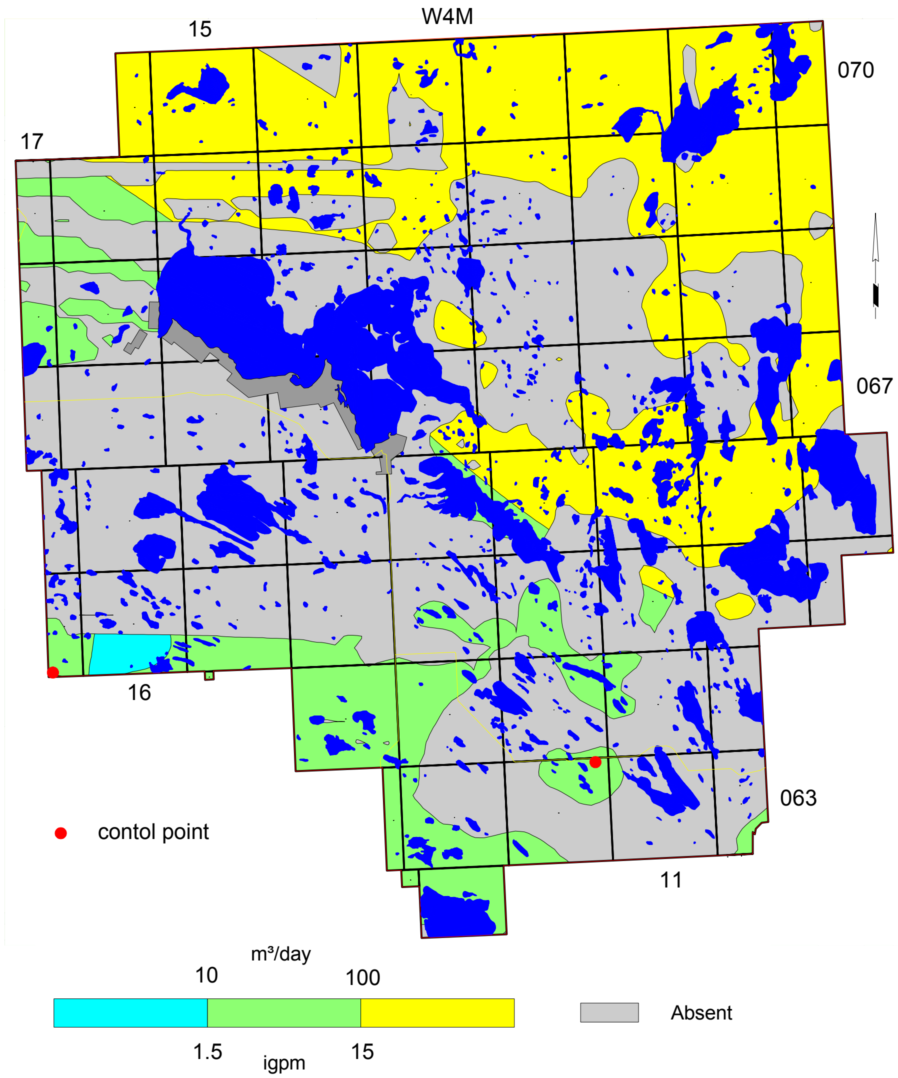
Total Dissolved Solids in Groundwater from Grand Centre Aquifer



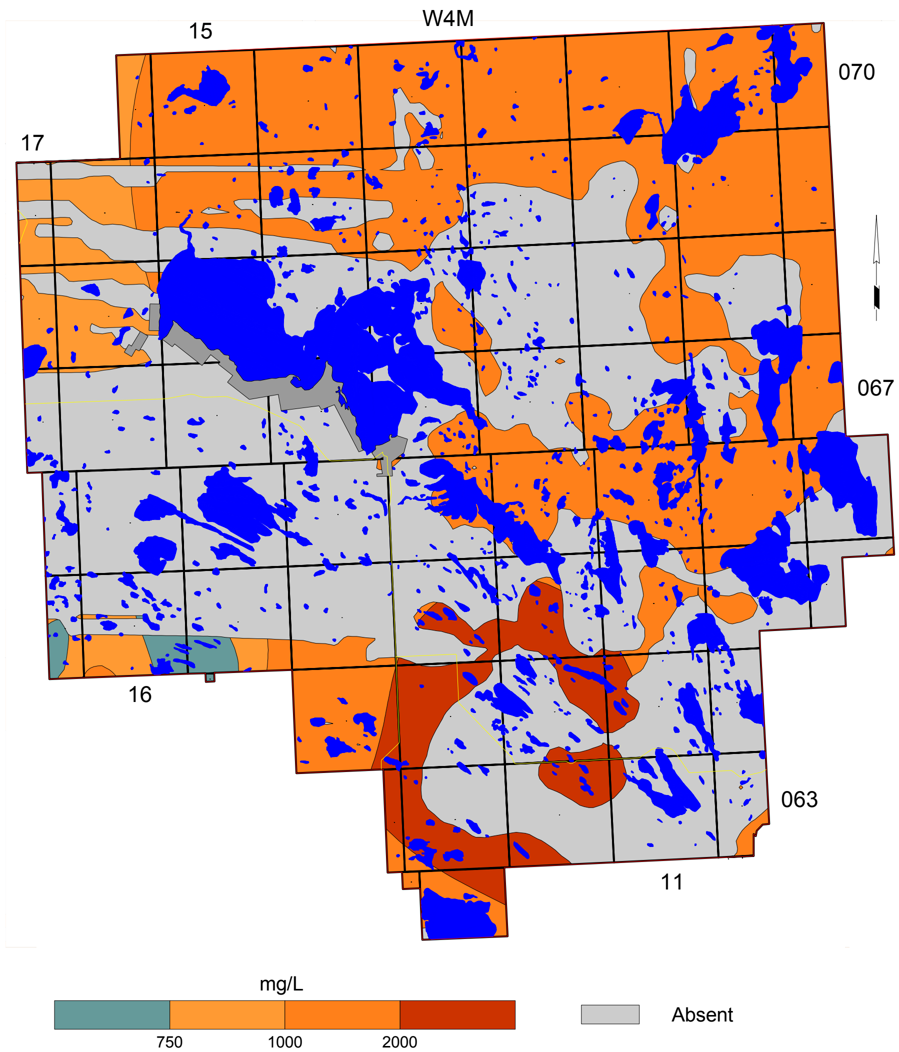
Depth to Top of Sand River Formation



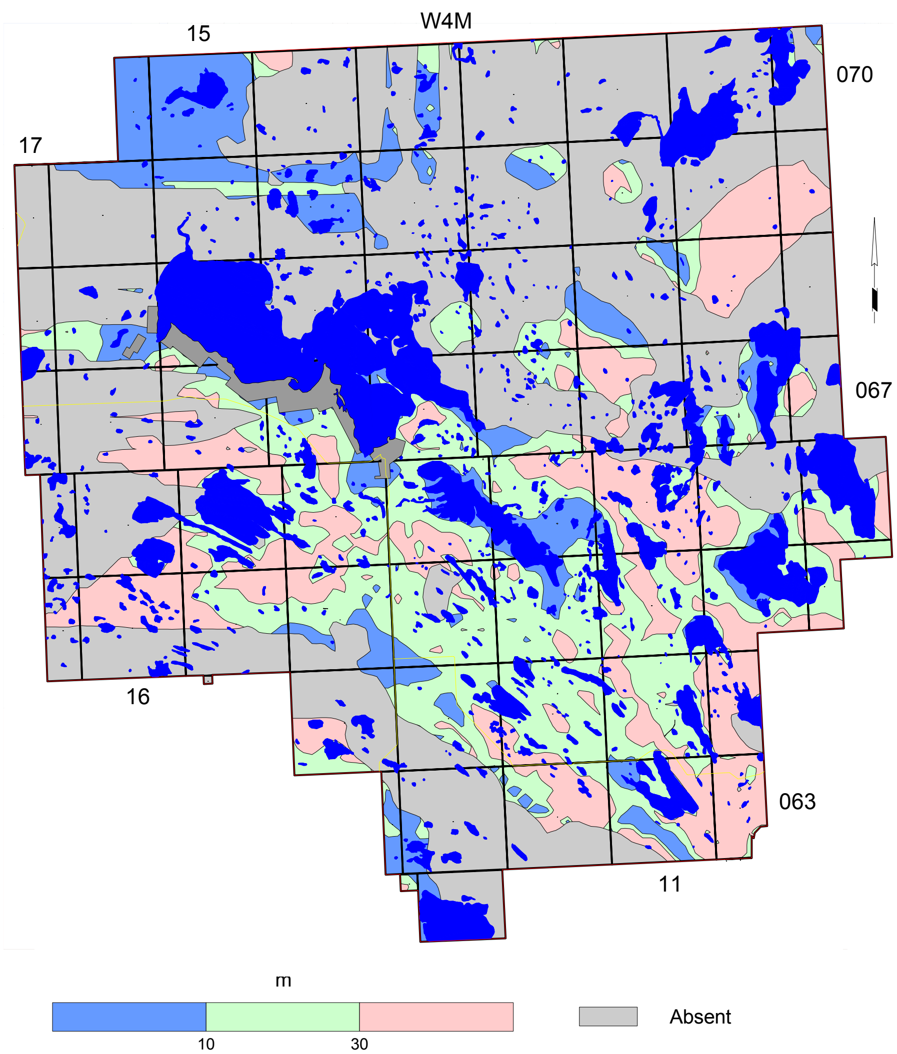
Apparent Yield for Water Wells Completed through Sand River Aquifer



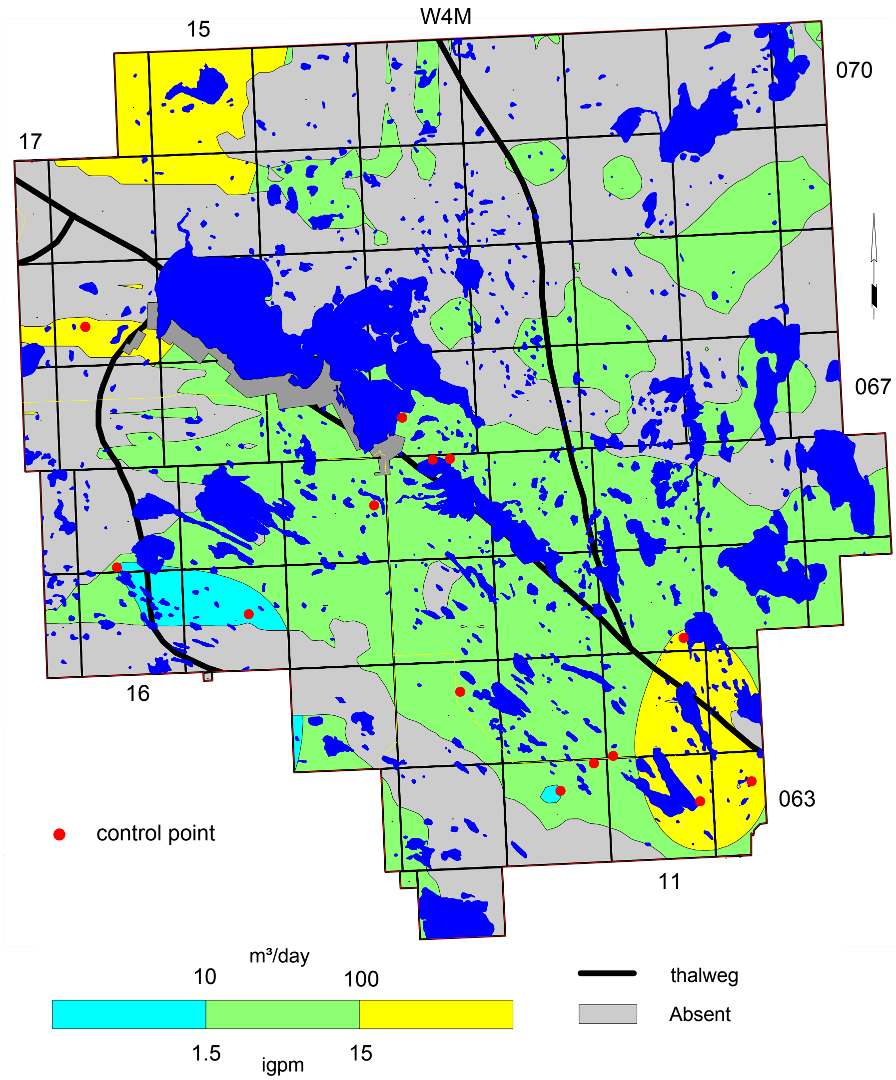
Total Dissolved Solids in Groundwater from Sand River Aquifer



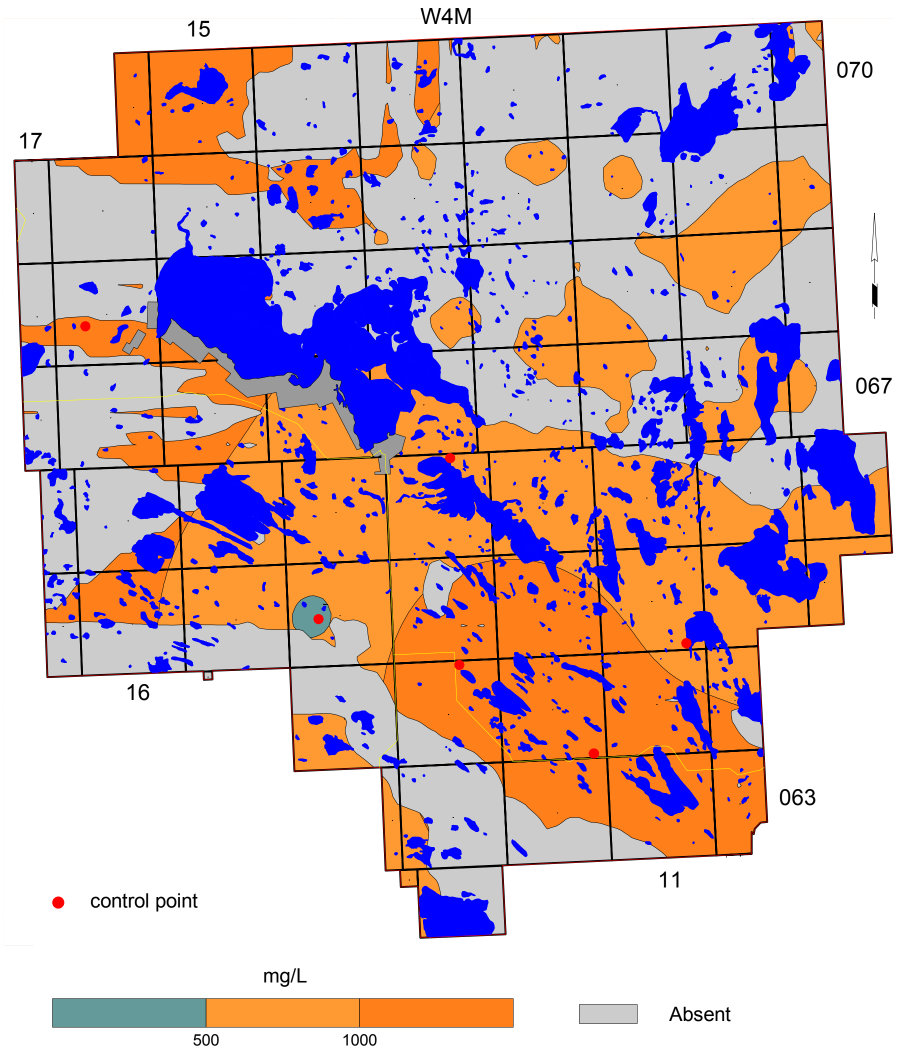
Depth to Top of Marie Creek Formation



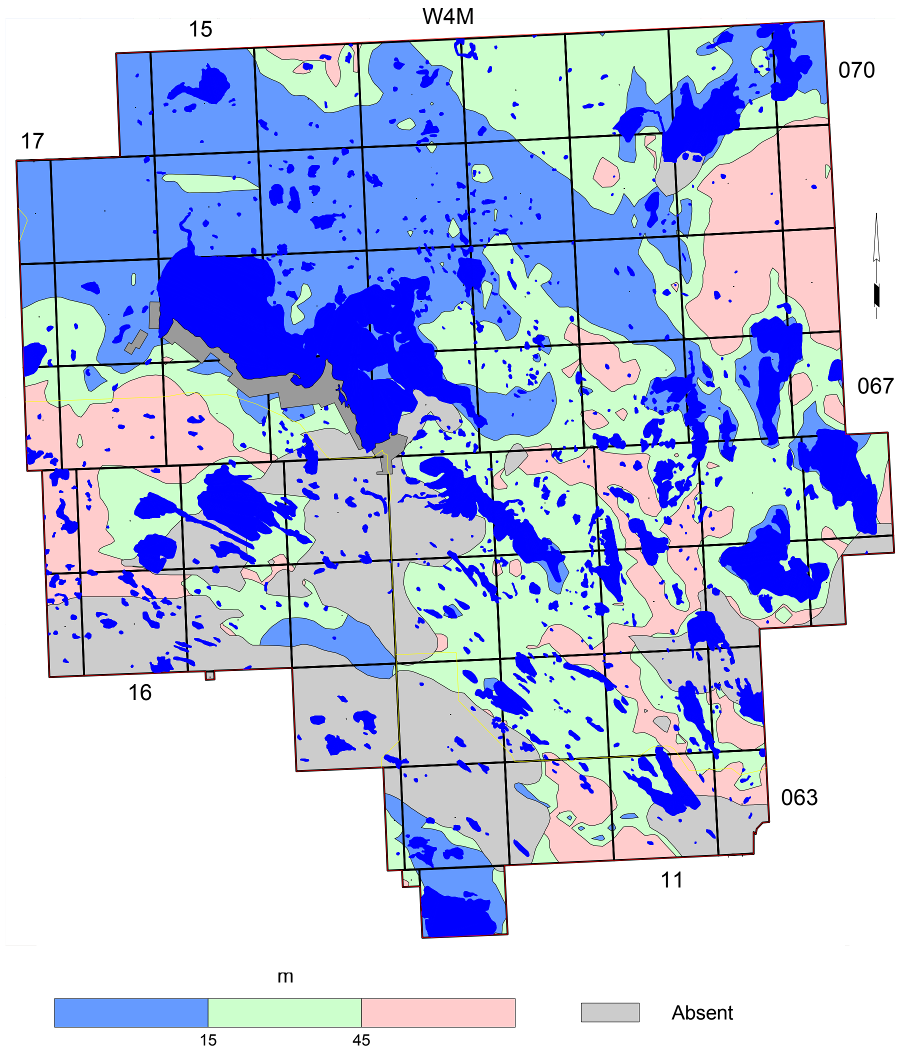
Apparent Yield for Water Wells Completed through Marie Creek Aquifer



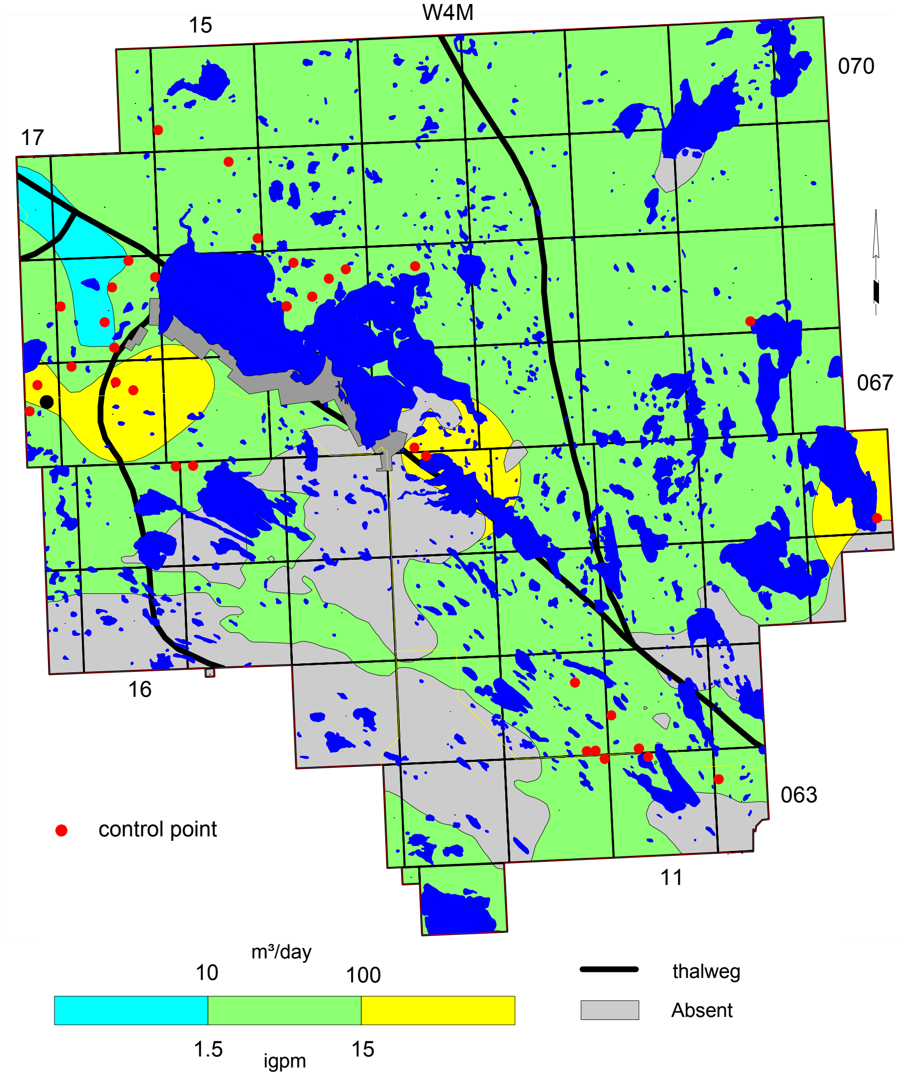
Total Dissolved Solids in Groundwater from Marie Creek Aquifer



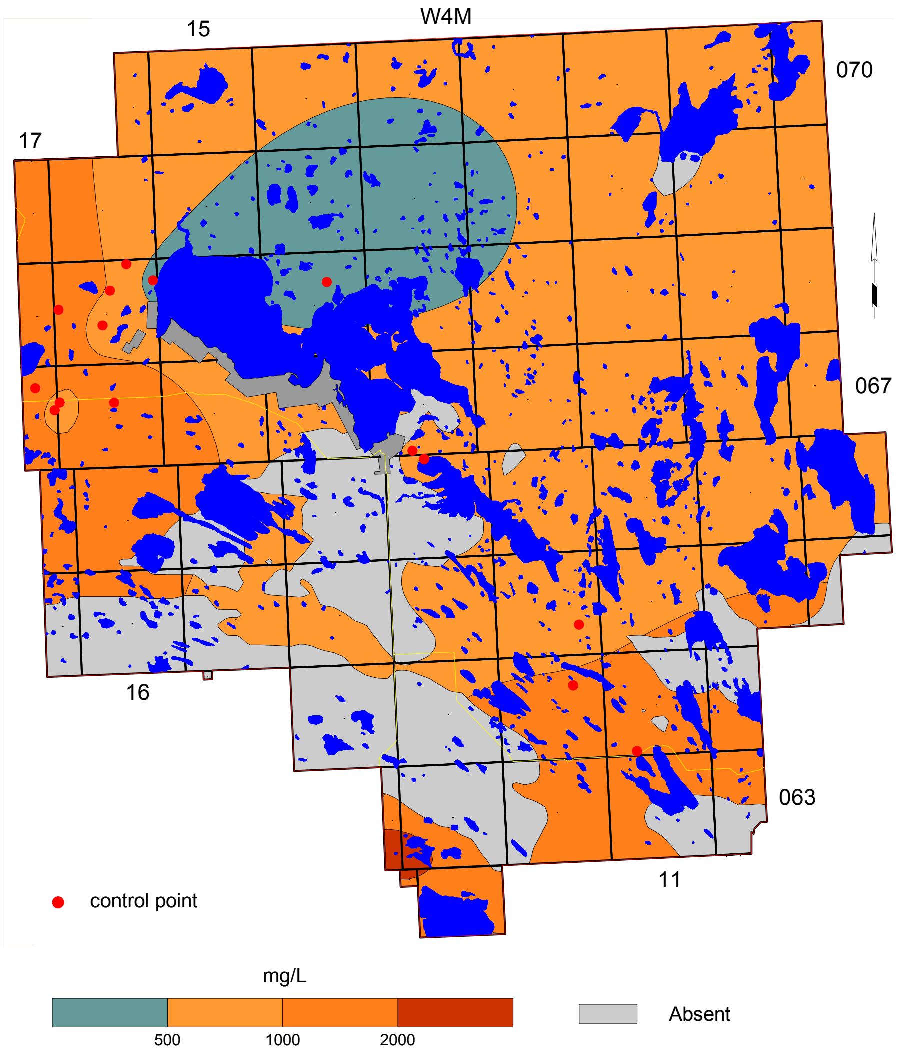
Depth to Top of Ethel Lake Formation



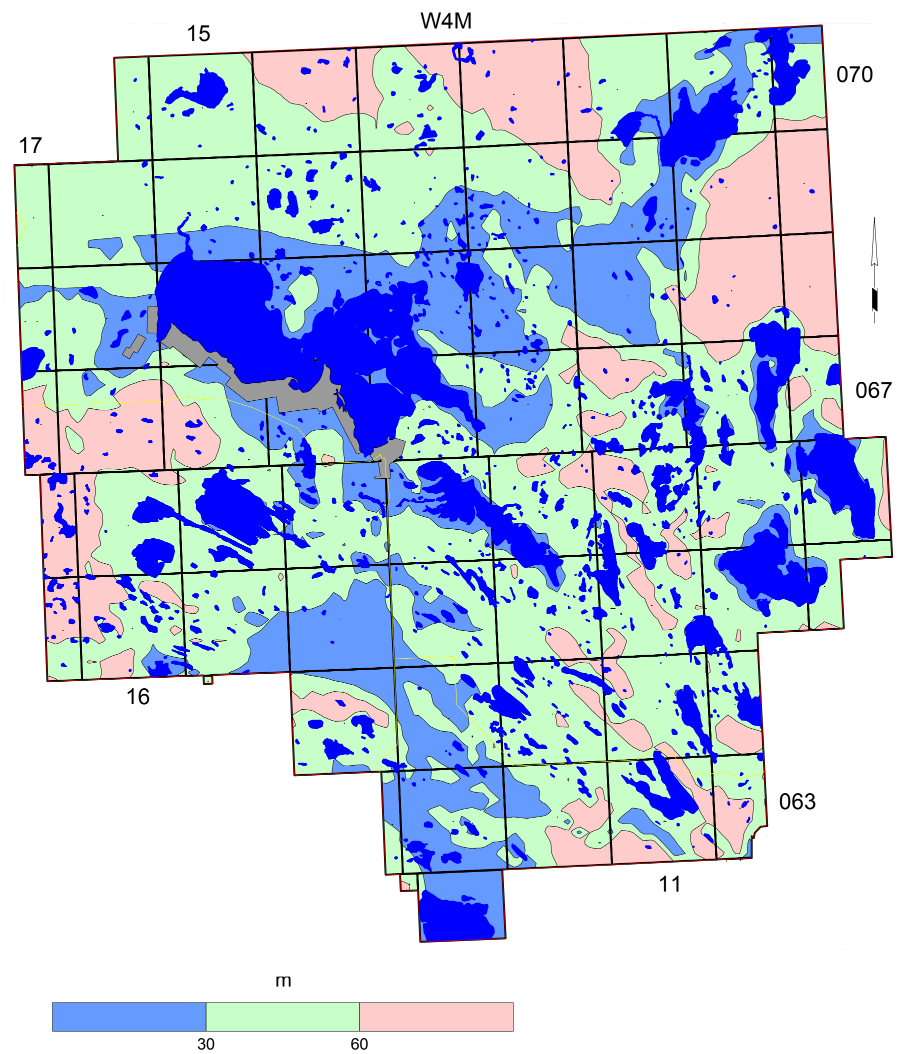
Apparent Yield for Water Wells Completed through Ethel Lake Aquifer



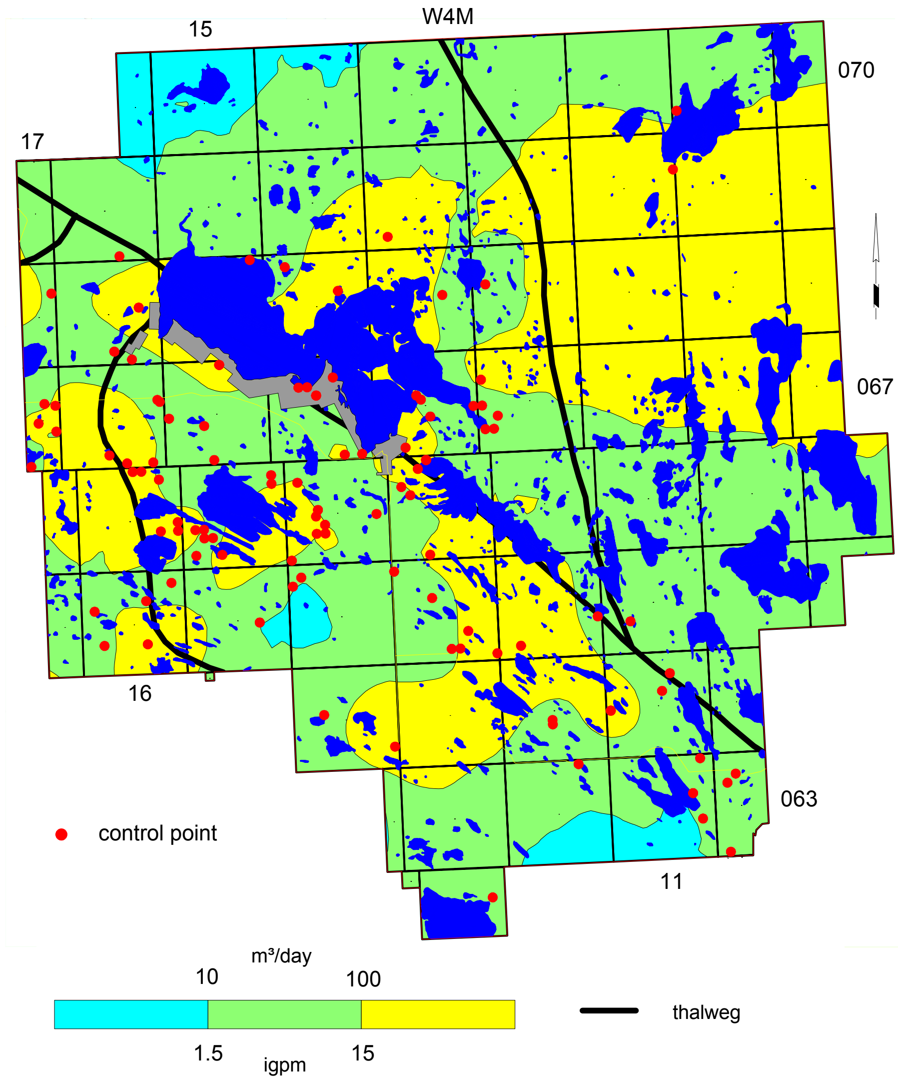
Total Dissolved Solids in Groundwater from Ethel Lake Aquifer



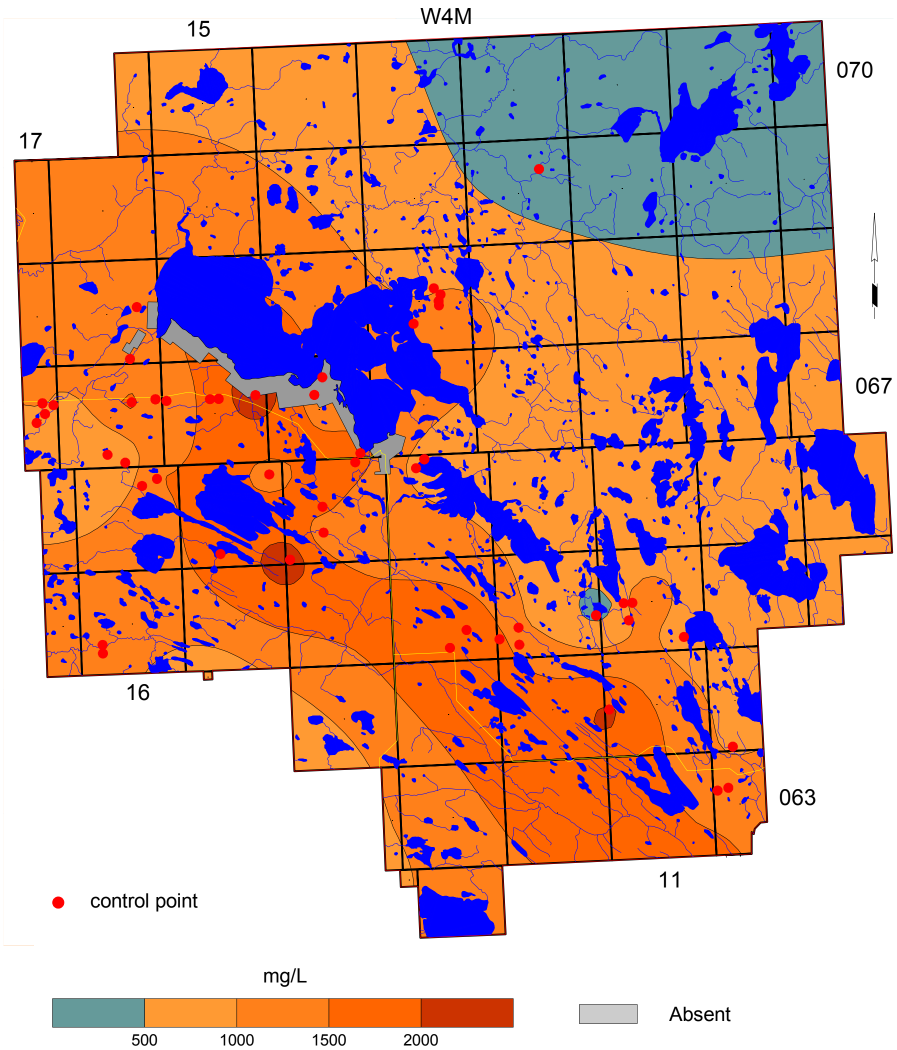
Depth to Top of Bonnyville Formation



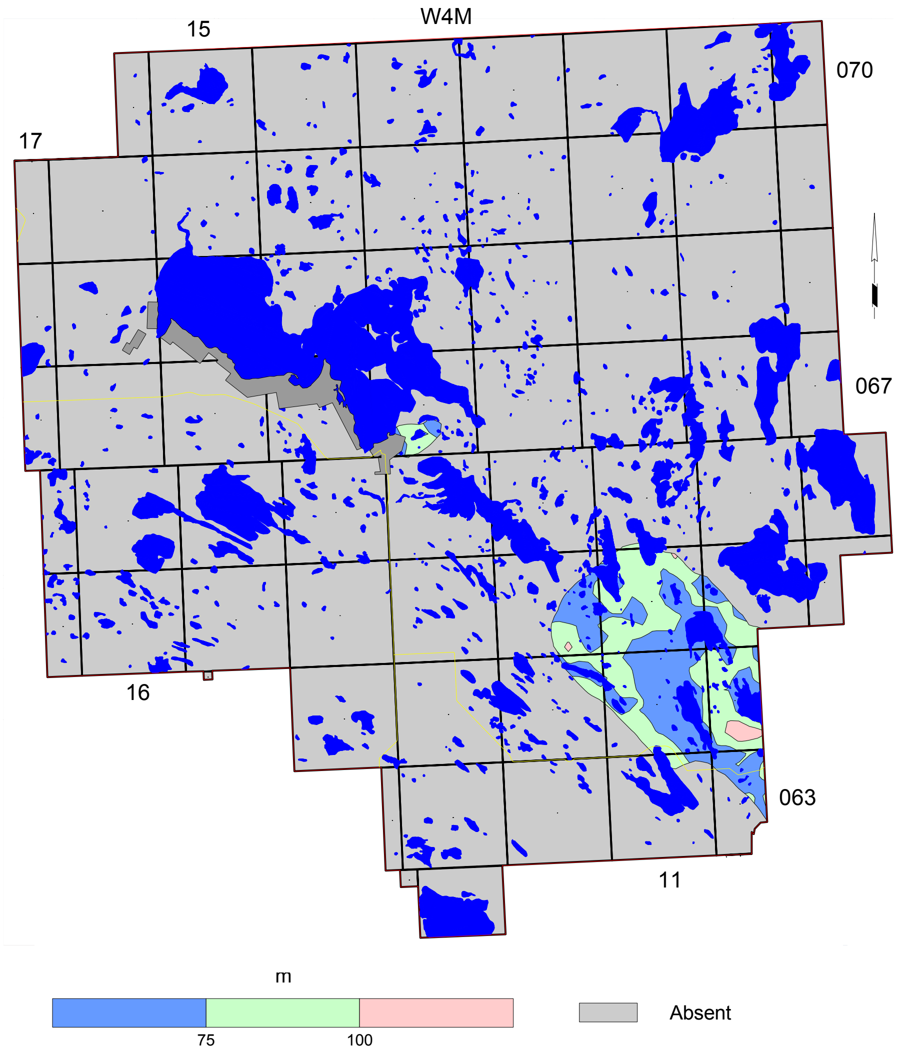
Apparent Yield for Water Wells Completed through Bonnyville Aquifer



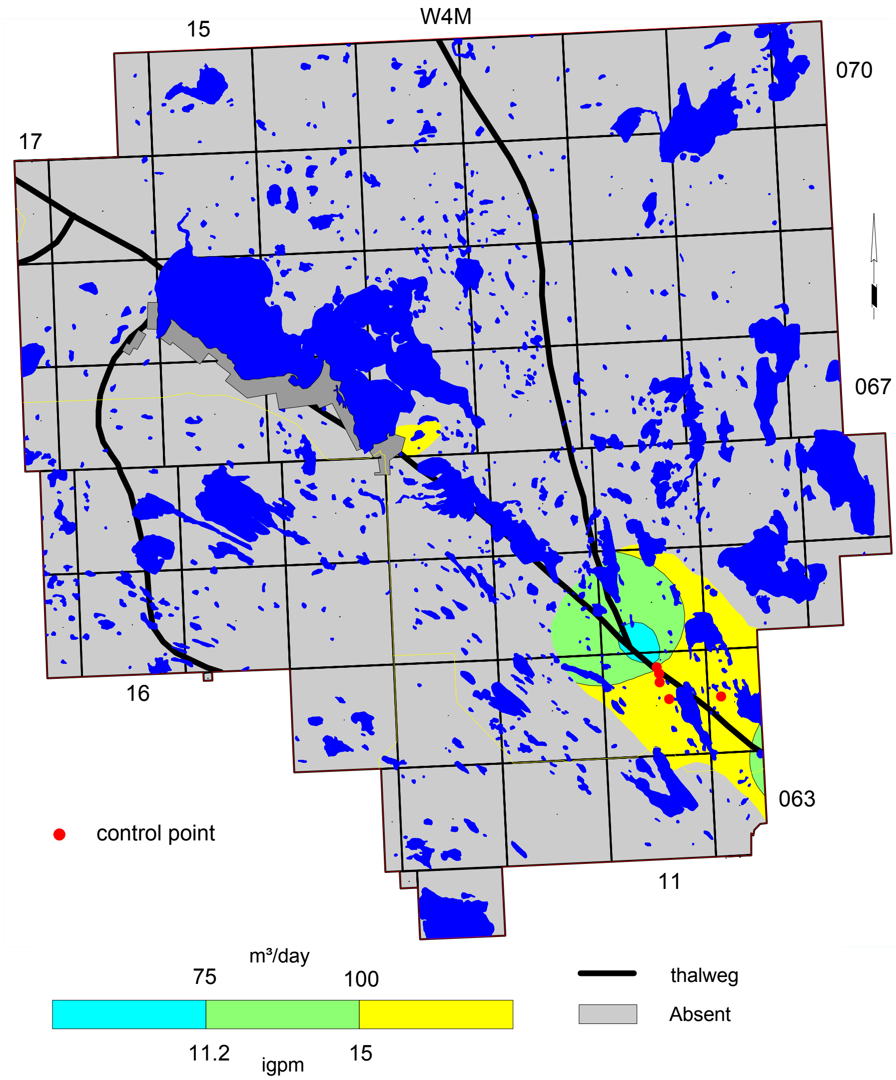
Total Dissolved Solids in Groundwater from Bonnyville Aquifer



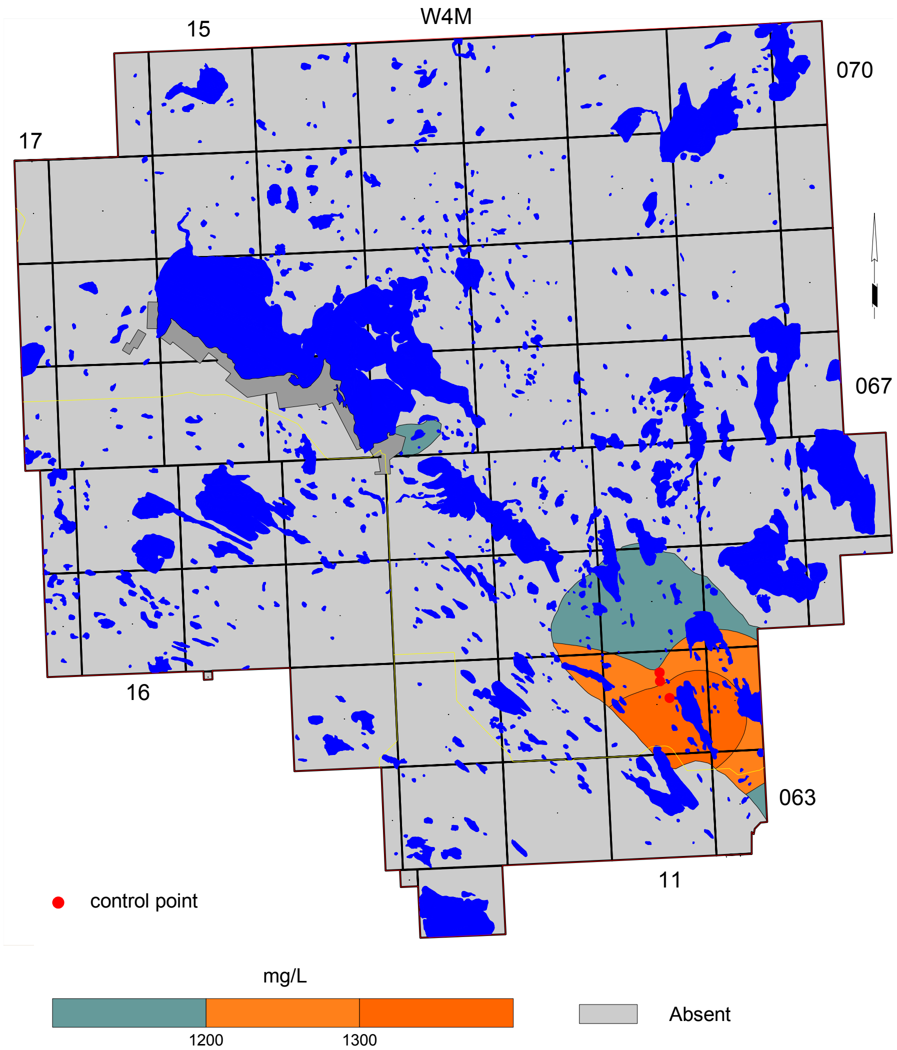
Depth to Top of Muriel Lake Aquifer



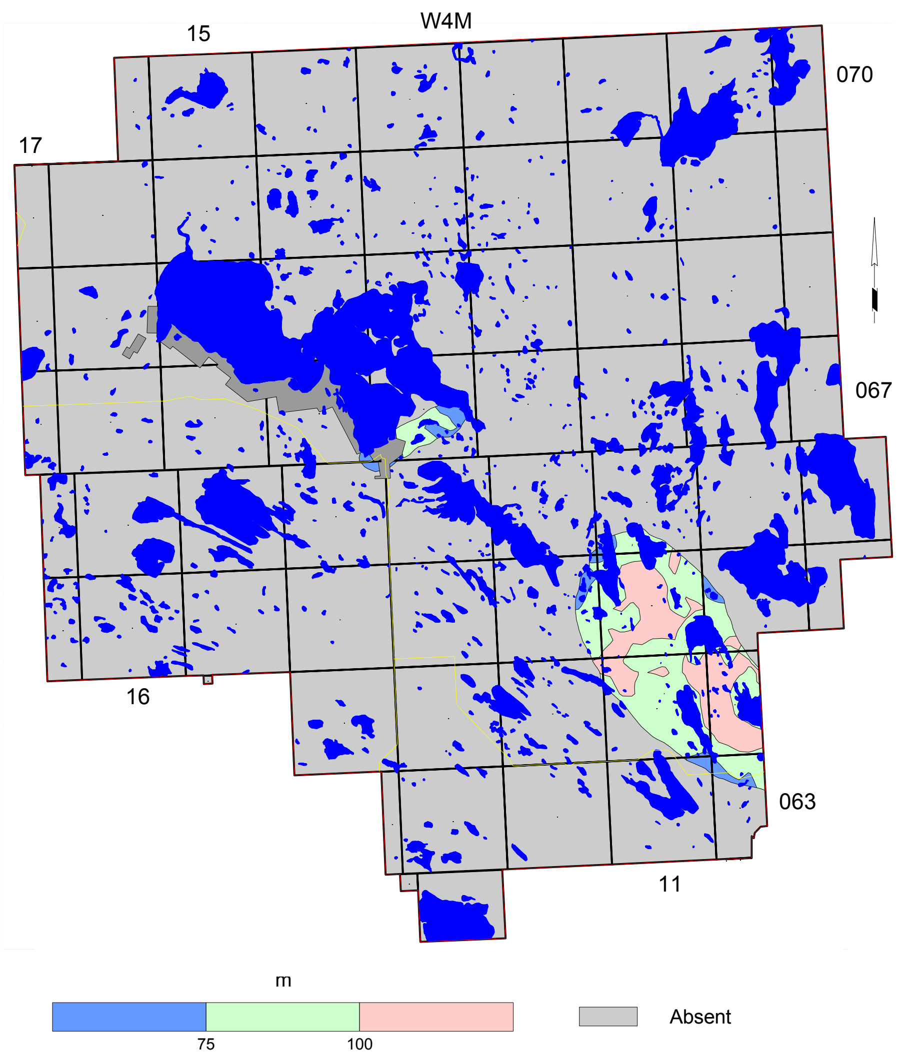
Apparent Yield for Water Wells Completed through Muriel Lake Aquifer



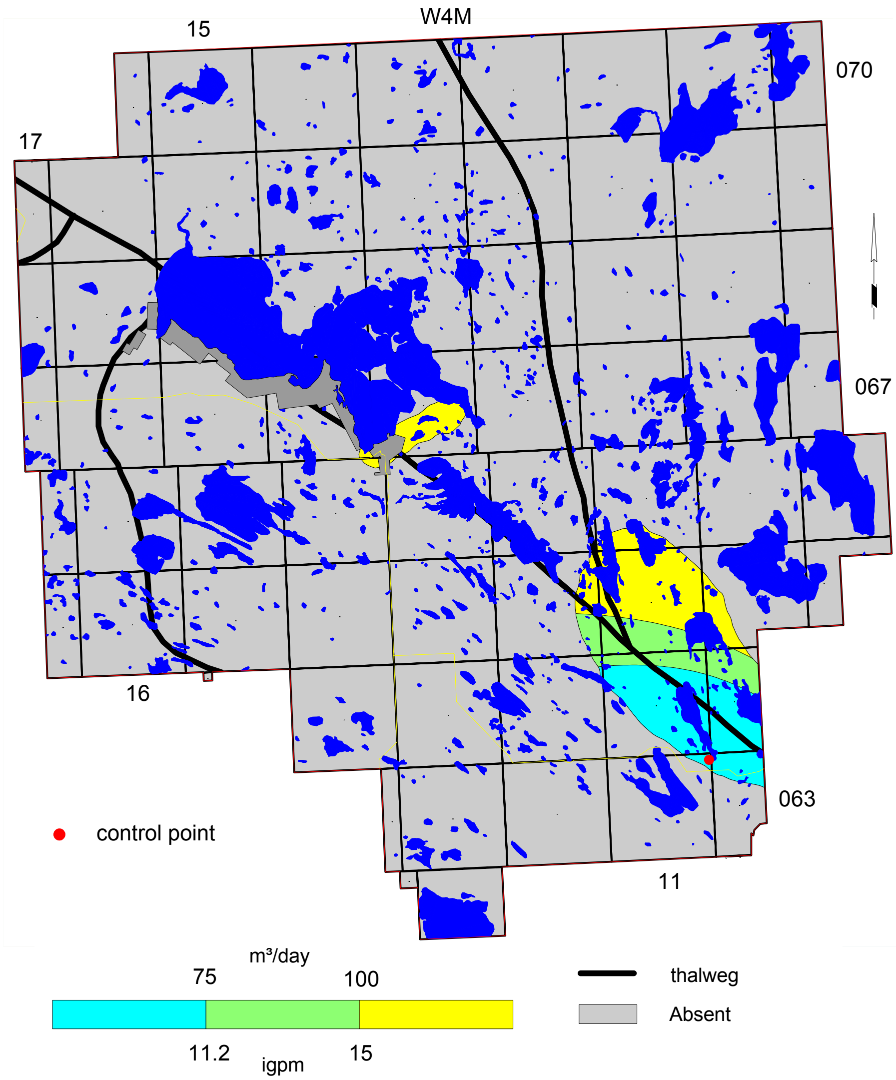
Total Dissolved Solids in Groundwater from Muriel Lake Aquifer



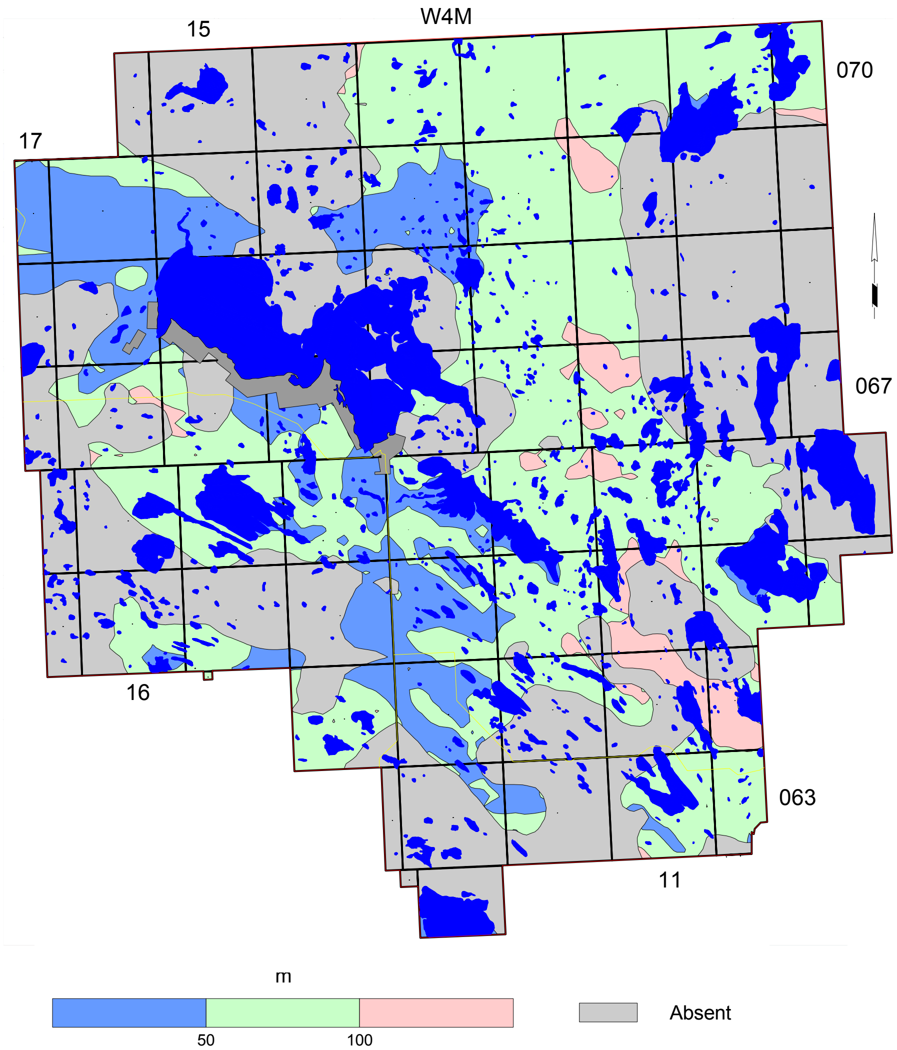
Depth to Top of Bronson Lake Formation



Apparent Yield for Water Wells Completed through Bronson Lake Aquifer



Depth to Top of Empress Formation – Unit 3



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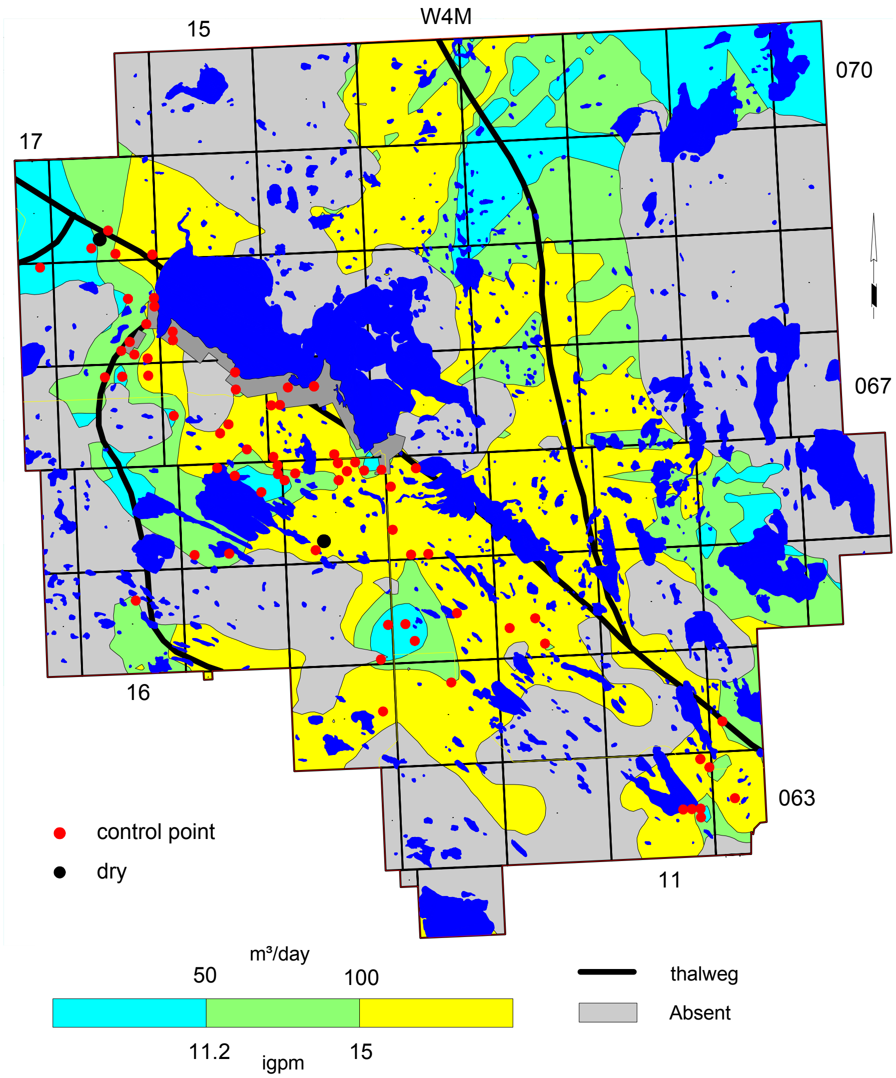

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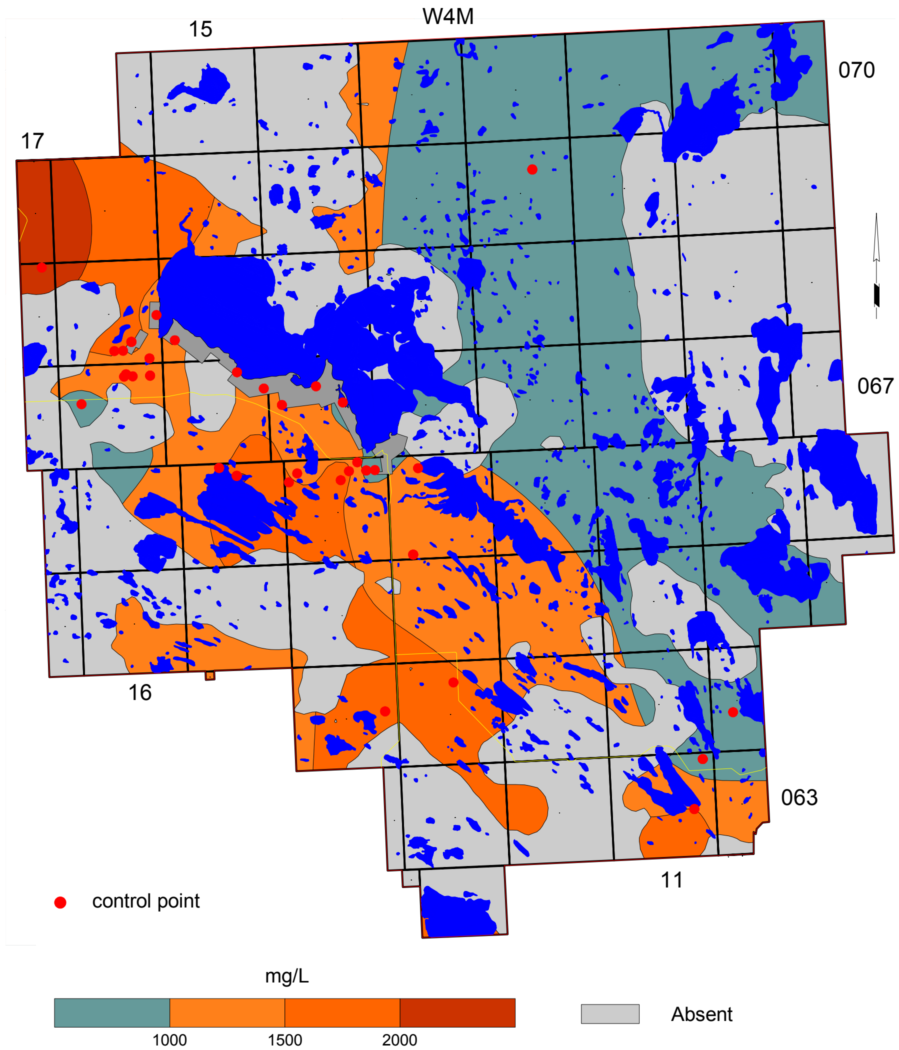
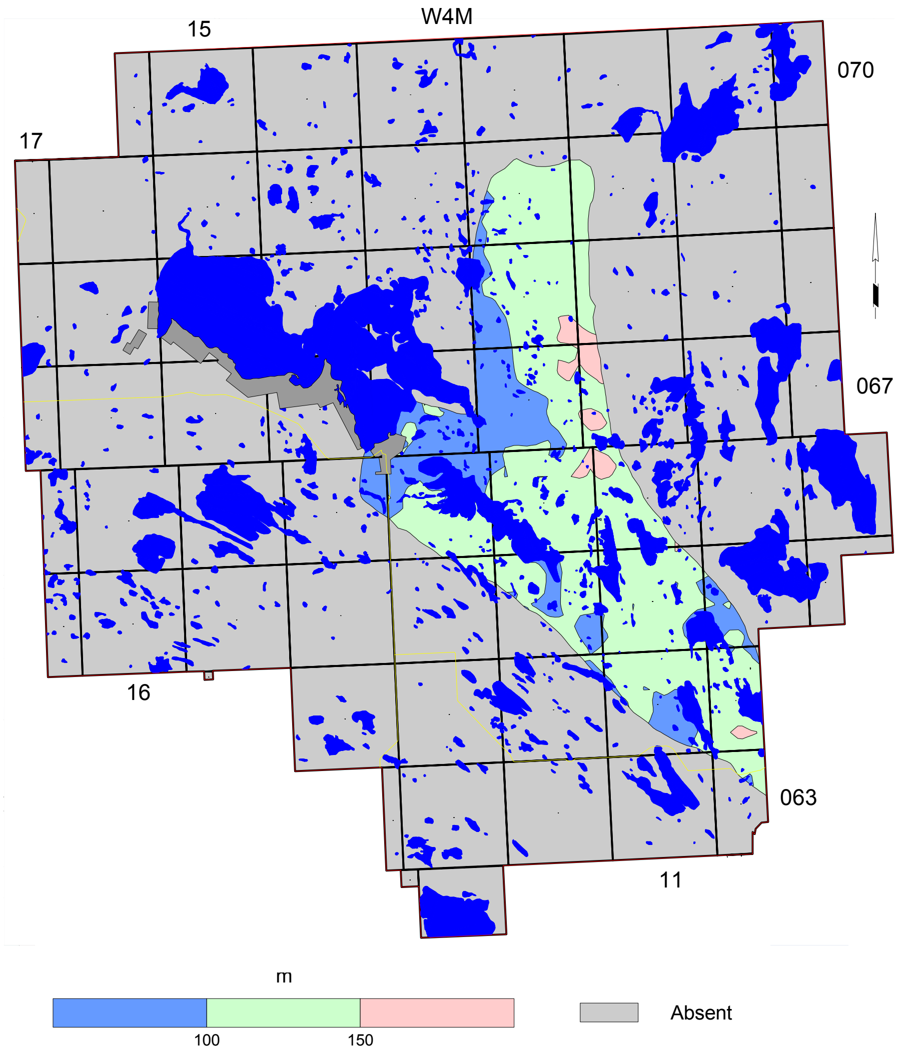
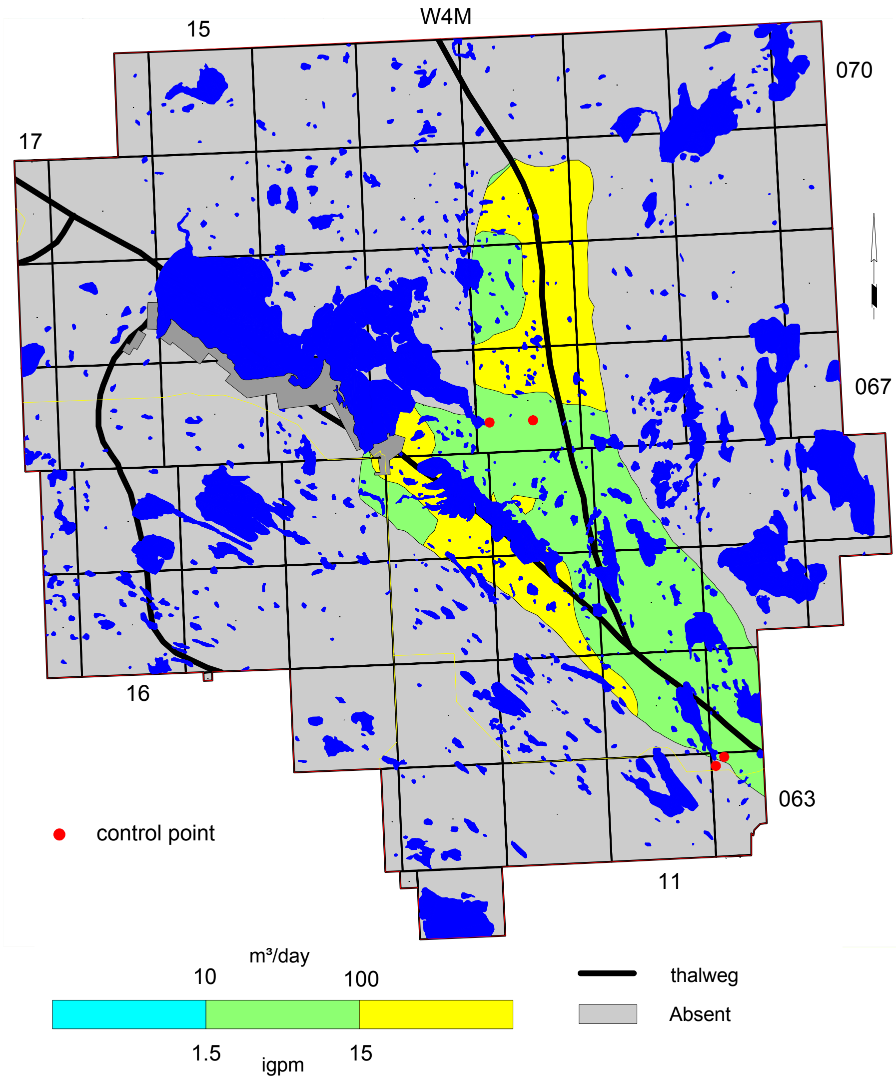


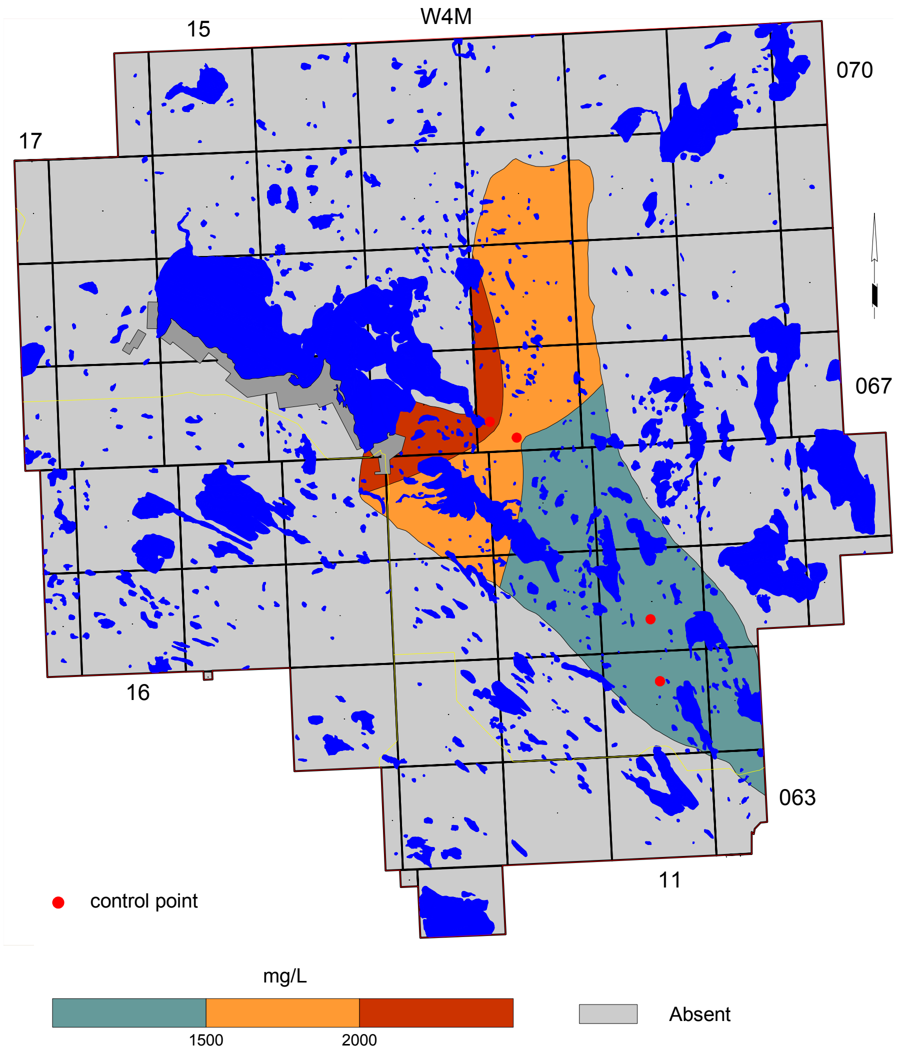
Depth to Top of Empress Formation – Unit 1



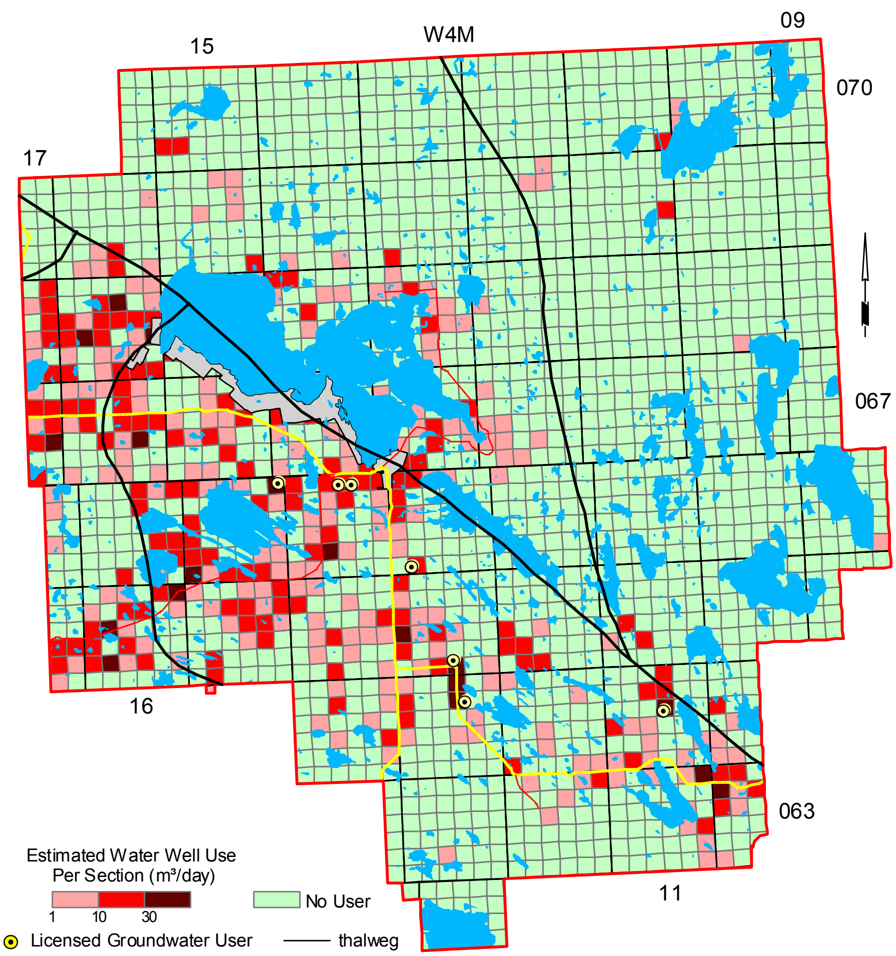
Apparent Yield for Water Wells Completed through Empress Aquifer – Unit 1



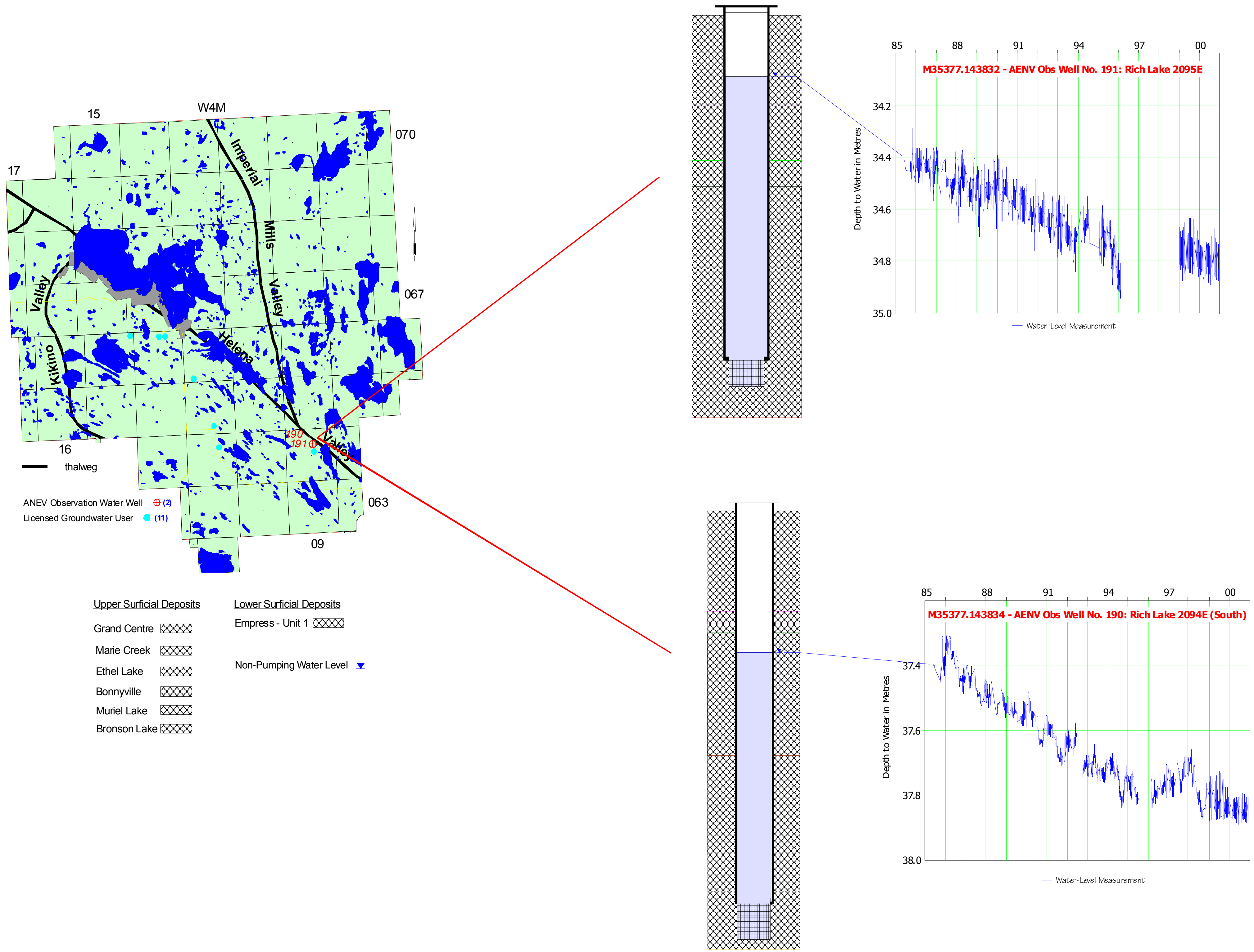
Total Dissolved Solids in Groundwater from Empress Aquifer – Unit 1



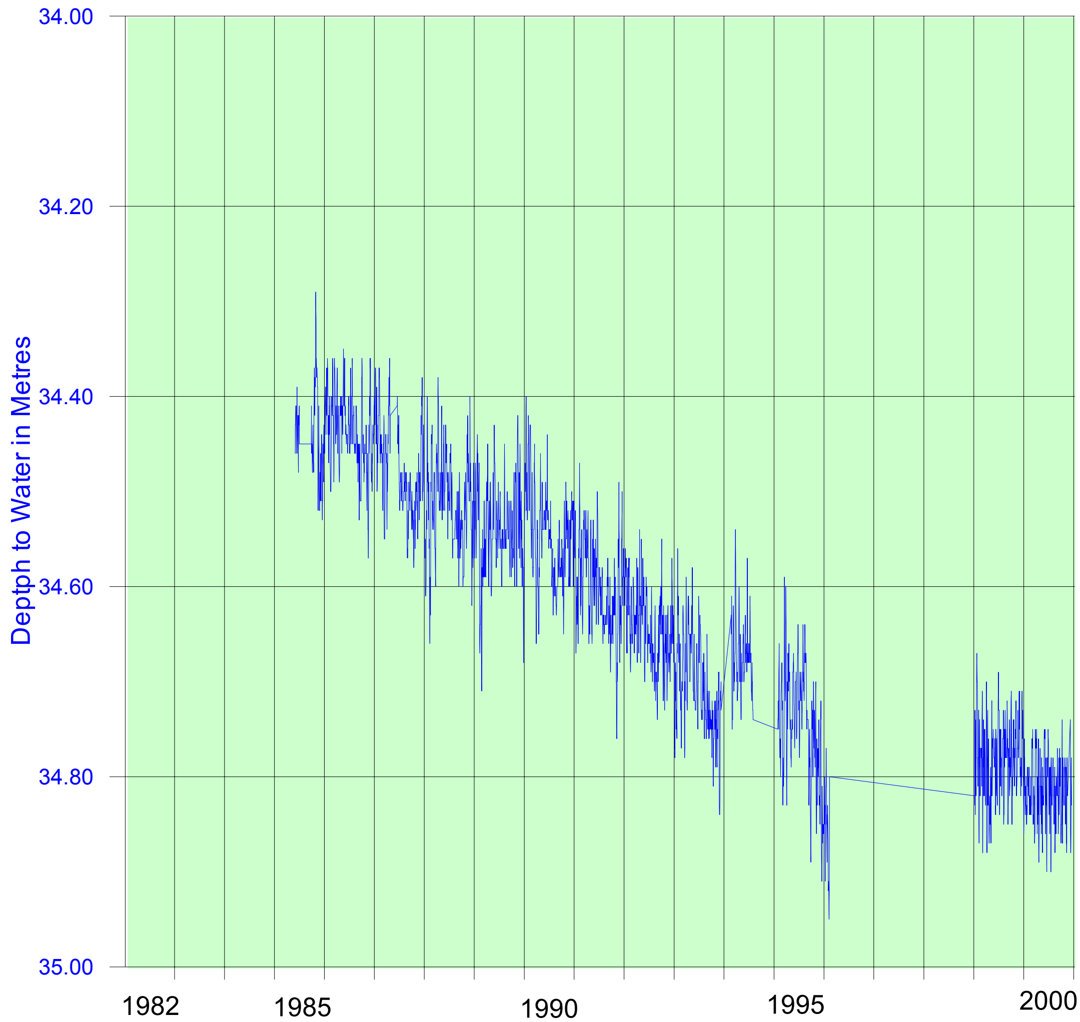
Estimated Water Well Use Per Section



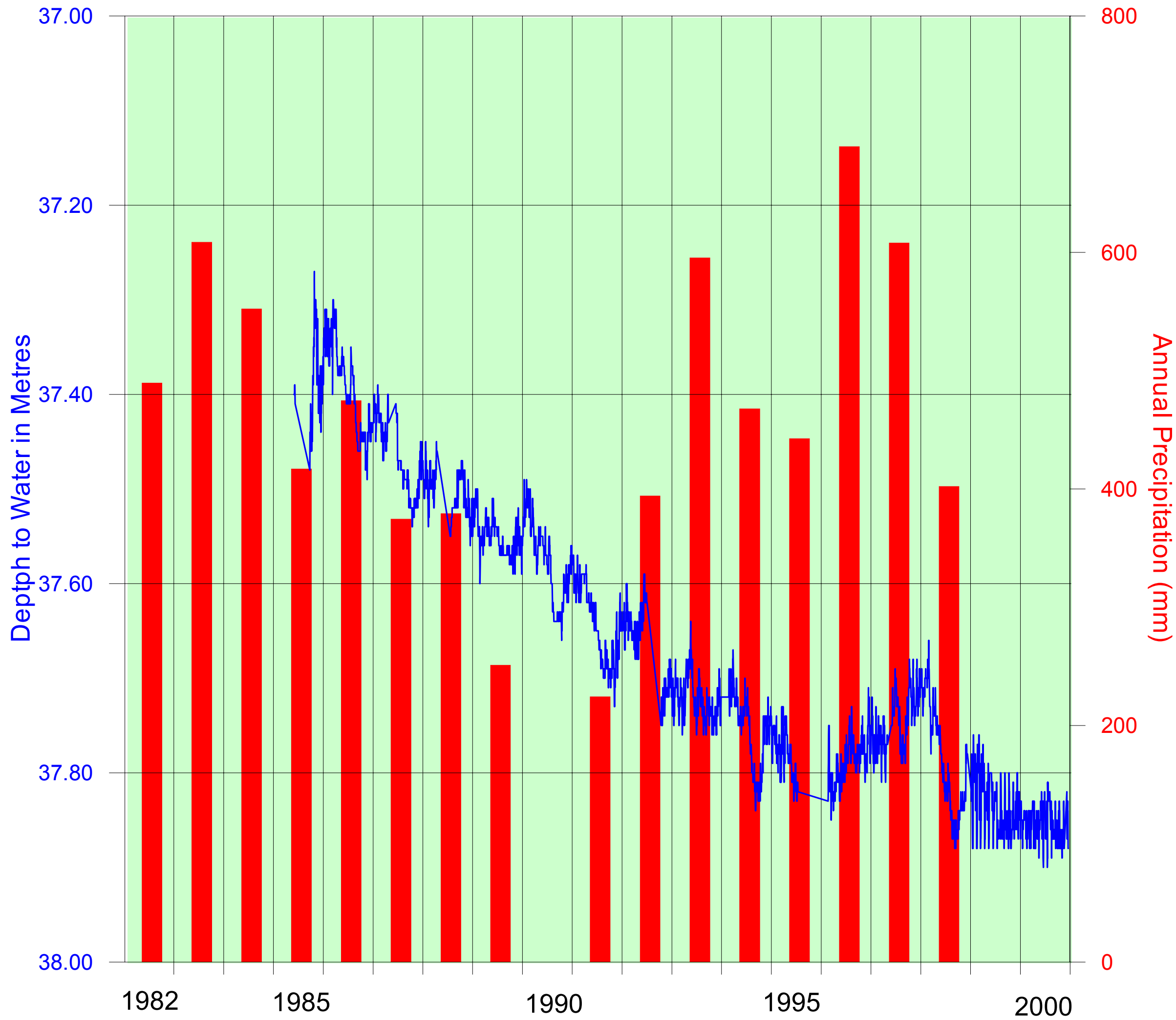
Hydrographs



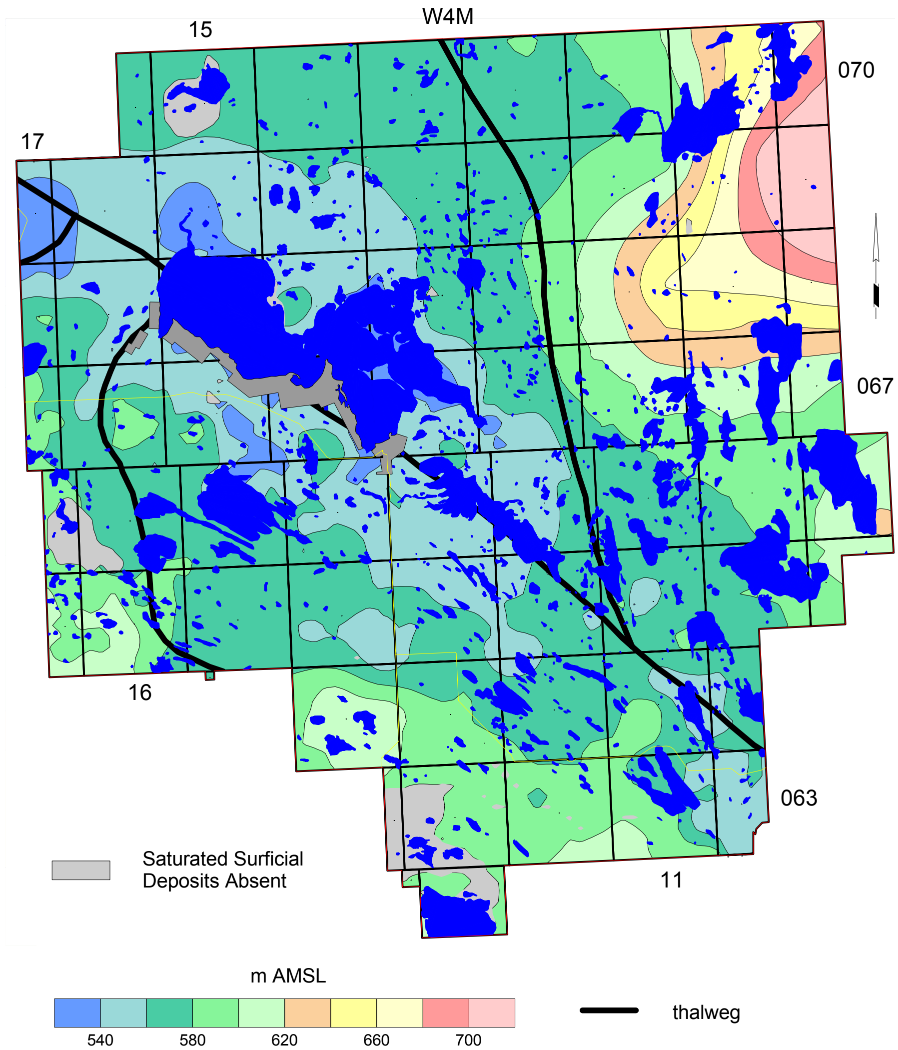
AENV Obs WW No. 191



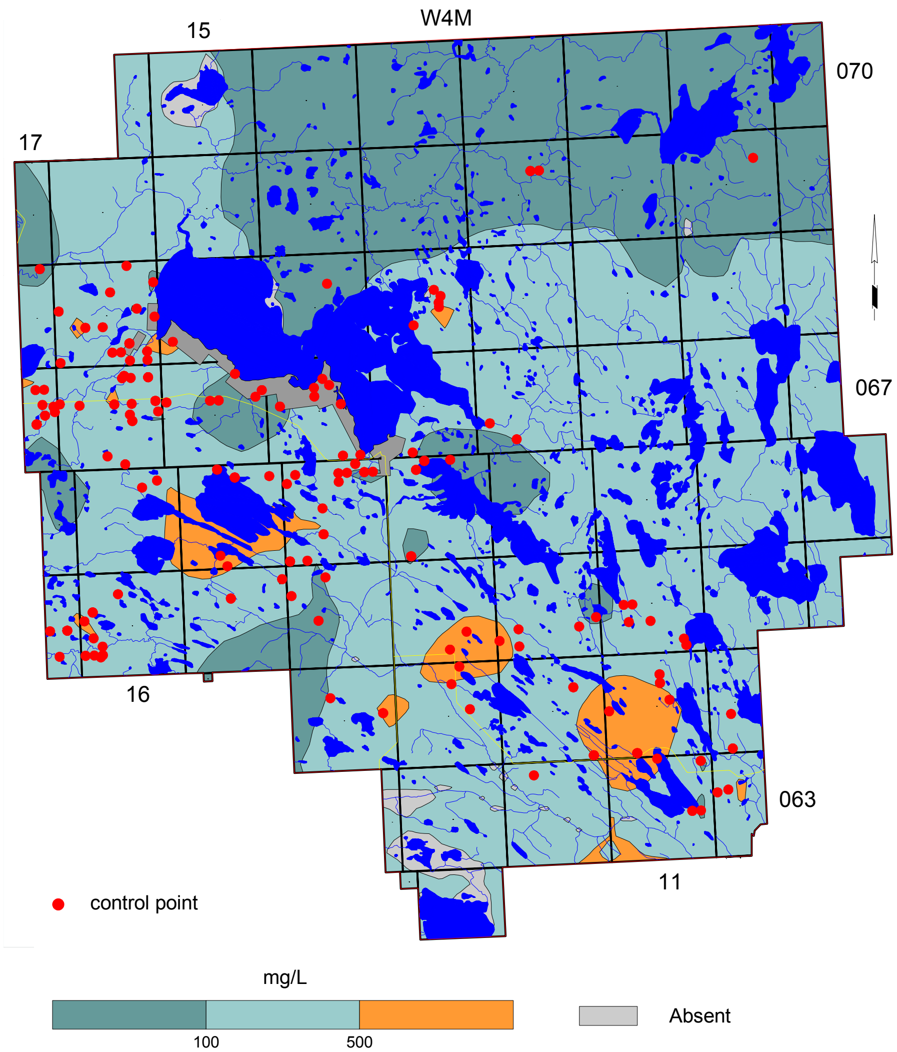
Annual Precipitation vs Water Levels in AENV Obs WW No. 190



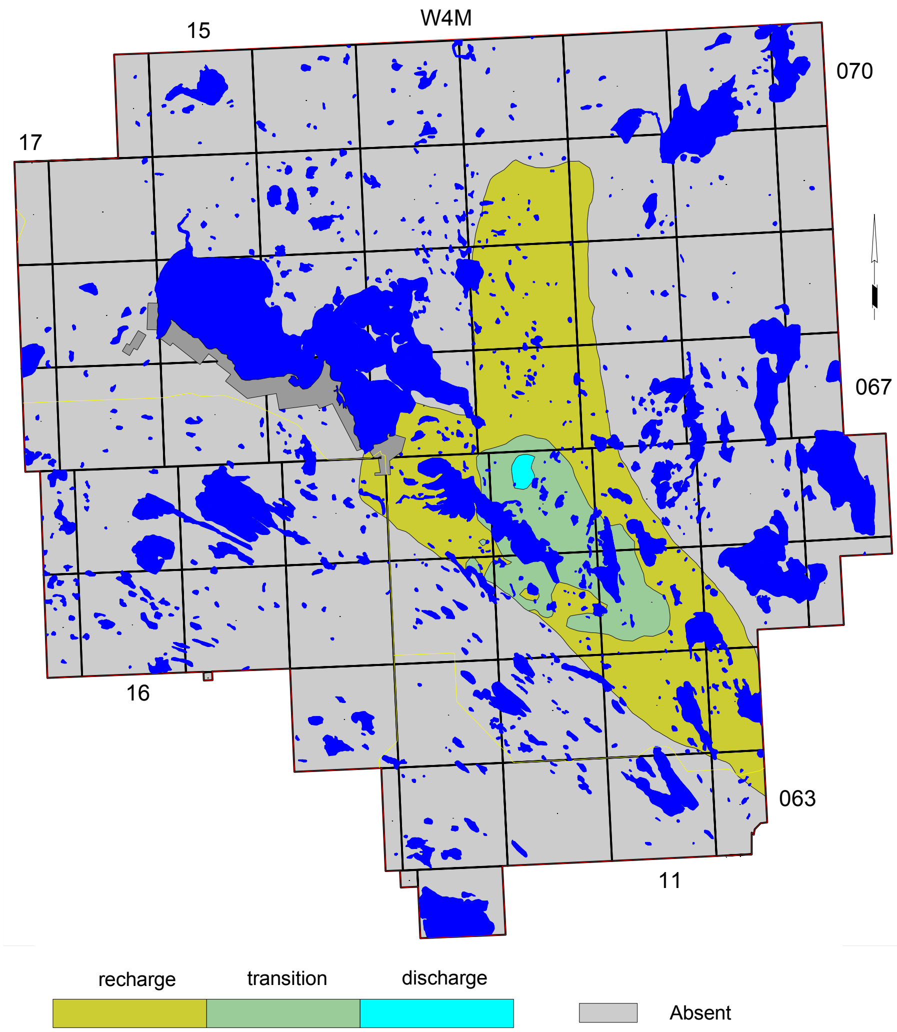
Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 metres Deep



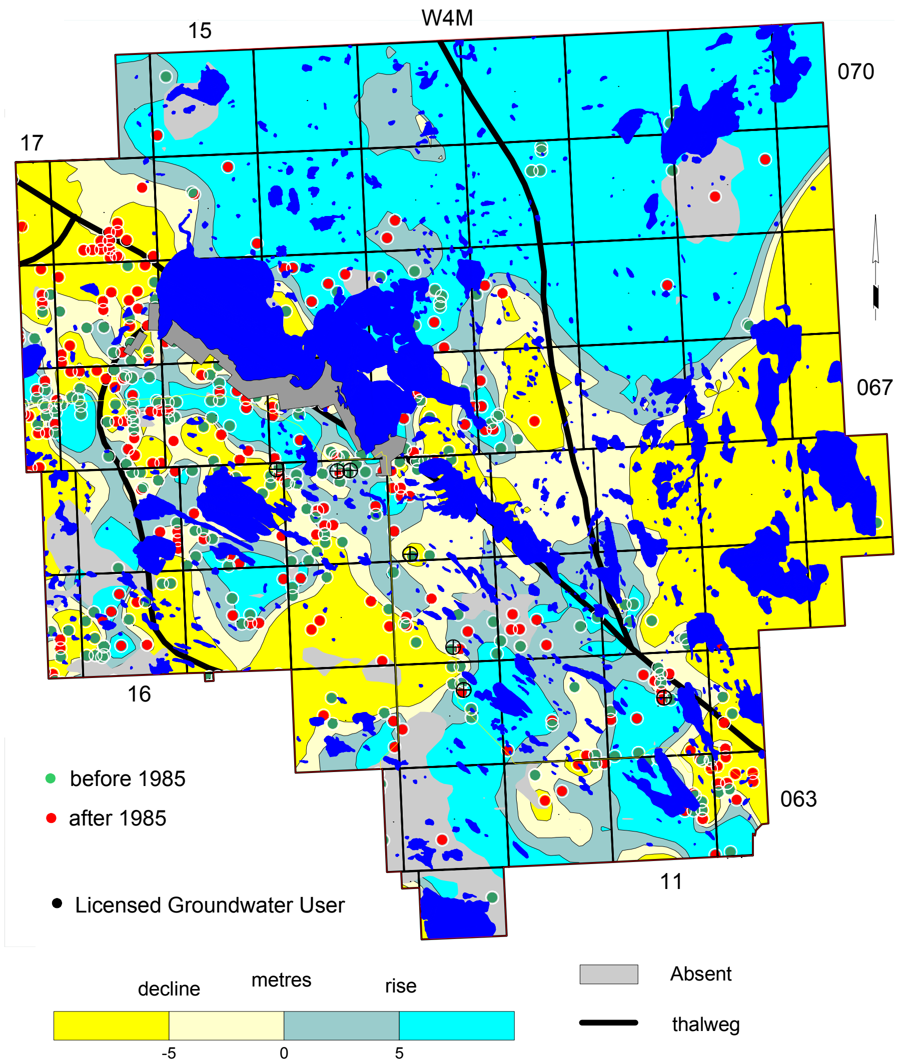
Sulfate in Groundwater from Surficial Deposits



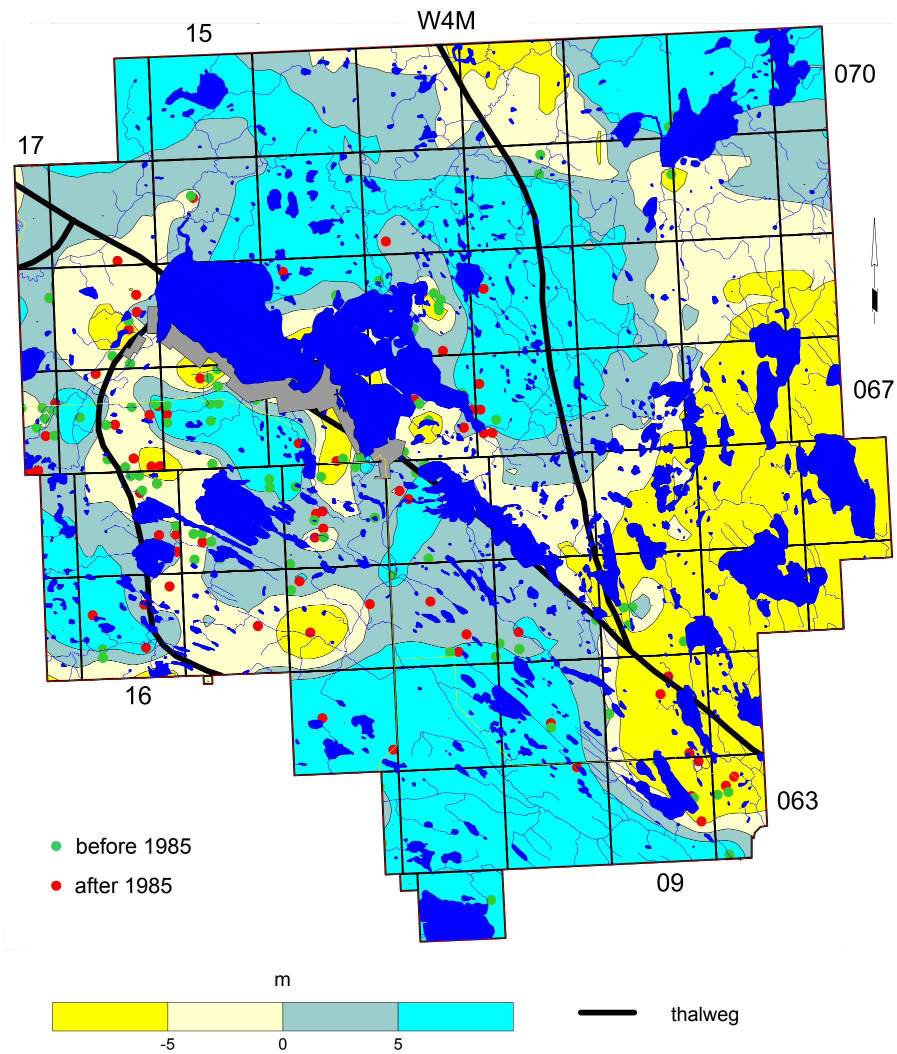
Recharge/Discharge Areas in Lower Sand and Gravel Aquifer (Empress – Unit 1)



Changes in Water Levels in Sand and Gravel Aquifer(s)



Changes in Water Levels in Bonnyville Aquifer



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Piper Diagram - Grand Centre Aquifer

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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.

Water Act - Water (Ministerial) Regulation

PROVINCE OF ALBERTA

WATER ACT

WATER (MINISTERIAL) REGULATION

Alberta Regulation 205/98

EXTRACT FROM THE ALBERTA GAZETTE

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ALBERTA REGULATION 205/98

Water Act

WATER (MINISTERIAL) REGULATION

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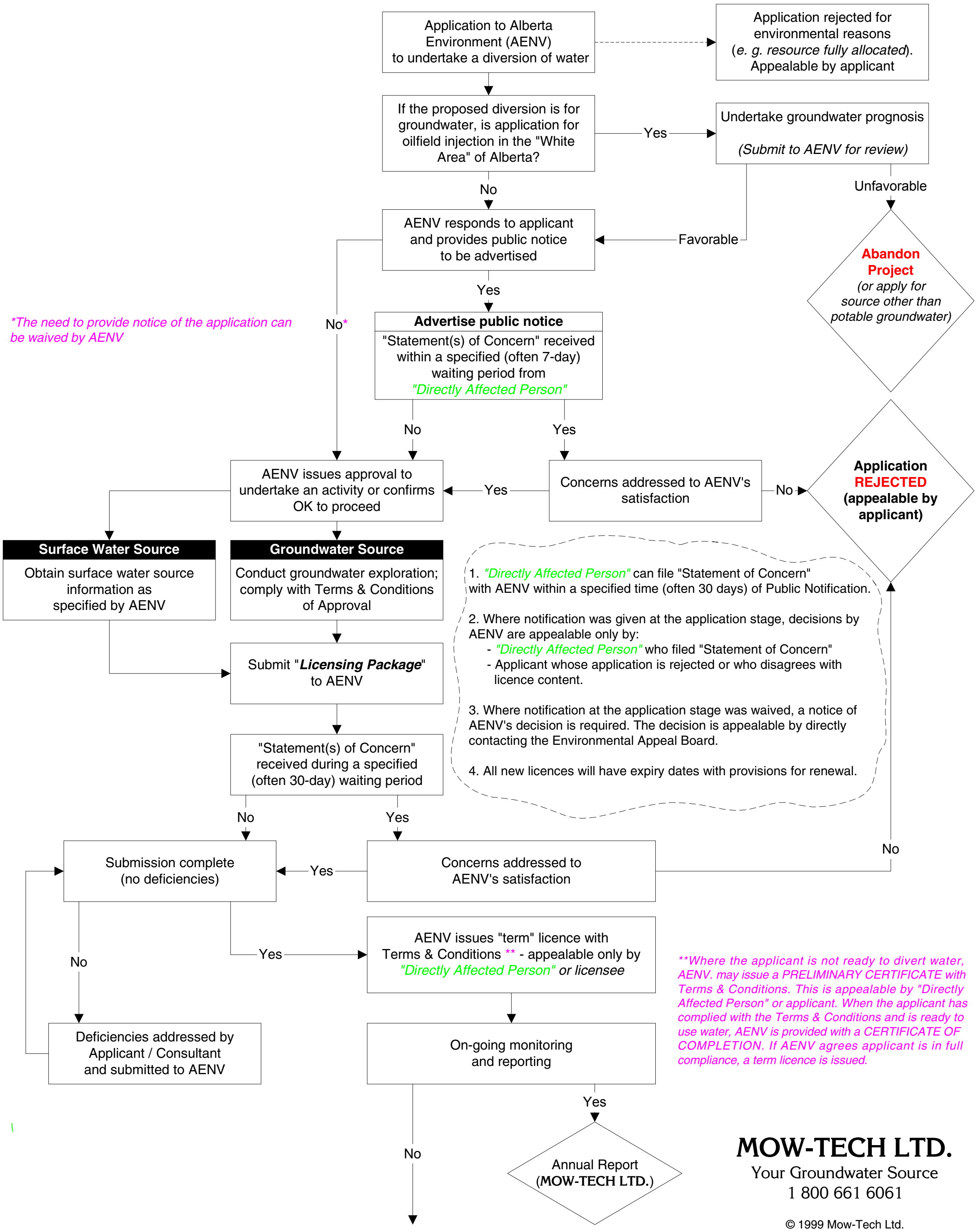
Water Act – Flowchart



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

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

Chemical Analysis of Farm Water Supplies

Adapted from Agdex 716 (D04) Published April 1991

A routine chemical analysis tests the water for 15 chemical parameters. It will reveal the hardness and iron concentration as well as the presence of other chemicals such as chlorides, sulphates, nitrates and nitrites. Chemicals, other than those listed below, can be tested but arrangements should be made with the lab before the sample is submitted. These special requests' must be clearly specified on the request form. Your farm water supply should be analyzed whenever a new water source is constructed, or when a change in water quality is noticed.

Your local health unit can provide you with the necessary water sample containers. Water samples specifically for human consumption must be submitted to the health unit.

The water sample you take should be representative. Choose an outlet as close to the source as possible. For most domestic samples, allow the water to run through the faucet for about five minutes and then fill the sample container.

Once you have obtained a good water sample, take it to your local health unit for forwarding to the appropriate laboratory. After the laboratory analysis is completed, the health inspector or technologist will receive a copy of the analysis and will be able to help you interpret the results.

Water Quality Criteria
It is not essential for private supplies to meet these guidelines. People have different reactions and tolerances to different minerals. If any chemical in your water exceeds drinking water limits consult you family doctor or local health unit.

All levels listed below (except pH) are listed in parts per million (ppm). 'Many labs report results in milligrams/Litre (mg/L), which is equivalent to ppm.

Sodium
Sodium is not considered a toxic metal, and 5,000 to 10,000 milligrams per day are consumed by normal adults without adverse effects. The average intake of sodium from water is only a small fraction of that consumed in a normal diet.

Persons suffering from certain medical conditions such as hypertension may require a sodium restricted diet, in which case the intake of sodium from drinking water could become significant. Sodium levels as low as 20 ppm are sometimes a concern to them. A maximum level of 300 (200*) ppm sodium has traditionally been used as a guideline but the "Guidelines for Canadian Drinking Water Quality" list no maximum acceptable concentration.

Sodium is a significant factor in assessing water for irrigation and plant watering. High sodium levels affect soil structure and a plant's ability to take up water.

Potassium
Potassium is usually only found in quantities of a few ppm in water. There is no recommended limit for potassium but levels over 2,000 ppm may be harmful to human nervous systems. Alberta water supplies rarely contain more than 20 ppm.

Calcium
Calcium is one cause of "hardness" in water. Calcium is not a hazard to health but is undesirable because it may be detrimental for domestic uses such as washing, bathing and laundering. It also tends to cause encrustations in kettles, coffee makers and water heaters. 200 ppm is often considered an acceptable limit.

Magnesium
Magnesium is another constituent causing "hardness" in water. A suggested limit of 150 ppm is used because of taste considerations.

Iron
Iron levels as low as 0.2 to 0.3 ppm will usually cause the staining of laundry and plumbing fixtures. The presence of iron bacteria in water supplies will often cause these symptoms at even lower levels. Iron gives water a metallic taste that may be objectionable to some persons at one to two ppm. Most water contains less that five ppm iron but occasionally levels over 30 ppm are found. Iron and iron bacteria are not considered a health concern.

Sulphate (SO4)
Sulphate concentrations over 500 ppm can be laxative to some humans and livestock. Sulphate levels over 500 ppm may be a concern for livestock on marginal intakes of certain trace minerals. Very high levels of sulphates have been associated with some brain disorders in cattle and pigs.

Chloride
Due to taste considerations the suggested maximum level for chloride is 250 ppm. Most water in Alberta contains less than 20 ppm chloride, although chloride in the 2,000 ppm range can be found.

NO2 Nitrogen (Nitrite)
Due to its toxicity, the maximum acceptable concentration of nitrite in drinking water is one ppm. Nitrite is usually an indicator of very direct contamination by sewage or manure because nitrites are unstable and quickly become nitrates.

The concentration in livestock water should not exceed 10 ppm.

NO3 Nitrogen (Nitrate)
Nitrates are also an indicator of contamination by human or livestock wastes, excessive fertilization or seepage from dump sites. The maximum acceptable concentration in drinking water is 10 ppm. The figure is based on the potential for the nitrate poisoning of infants. Adults can tolerate higher levels but high nitrate levels may cause irritation of the stomach and bladder. The suggested maximum for livestock use is 1,000 ppm.

Fluoride
Fluorides occur naturally in most well waters and are desirable since they help prevent dental cavities. Between one and 1.5 ppm is desirable. As fluoride levels increase above this amount there is an increase in the tendency to cause tooth mottling.

Fluoride levels less than four ppm are not considered a problem for livestock.

TDS Inorganic (Total Dissolved Solids)
This is a measure of the inorganic minerals dissolved in the water. As a general rule less than 1,000 (500*) ppm TDS is considered satisfactory. Levels higher than this are not necessarily a problem; it depends on the specific minerals present.

The suitability for livestock deteriorates as TDS exceeds the 2,000 to 3,000 ppm range.

Conductivity

Conductivity is measured in micro siemens per centimetre. It can be used to estimate the total dissolved solids in the water. Multiplying the conductivity by 0.65 will give a good approximation of the total dissolved solids. Conductivity tests are often used to assess water suitability for irrigation.

pH

pH is a measure of how acidic or basic the water is. The pH scale goes from zero (acidic) to 14 (basic) with seven being neutral. The generally accepted range for pH is 6.5 to 8.5 with an upper limit of 9.5.

Hardness

The harder the water is the greater its ability to neutralize soap suds. Hardness is caused primarily by calcium and magnesium, but is expressed as ppm equivalent of calcium carbonate. Hard water causes soap curd which makes bathroom fixtures difficult to keep clean and causes greying of laundry.

Hard water will also tend to form scale in hot water tanks, kettles, piping systems, etc.

Type of Water	**Amount of Hardness**	
	ppm	**grains per gallon**
Soft	0- 50	0-3
Moderately Soft	50 - 100	3-6
Moderately Hard	100 - 200	6-12
Hard	200 - 400	12- 23
Very Hard	400 - 600	23 - 35
Extremely Hard	Over 600	Over 35

Alkalinity

Alkalinity is not a specific substance but rather a combined effect of several substances. It is a measure of the resistance of a water to a change in pH. The alkalinity of most Alberta waters is in the range of 100 - 500 ppm, which is considered acceptable. Water with higher levels is often used. Alkalinity is a factor in corrosion or scale deposition and may affect some livestock when over 1,000 ppm.

Water Treatment

Water treatment equipment can often improve water quality significantly. Each type of water treatment equipment has its limitations and thus should be selected carefully. For more information on water treatment please refer to the Agdex 71 6 D series of fact sheets.

Helpful Conversions

1 ppm (part per million) = 1 mg/L (milligram per litre) 1 gpg (grain per gallon) = 17.1 ppm (parts per million)

References

Guidelines for Canadian Drinking Water Quality (1987) Health and Welfare Canada

*Federal-Provincial Subcommittee on Drinking Water of the Federal-Provincial-Territorial Committee on Environment and Occupational Health. March 2001. Summary of Guidelines for Canadian Drinking Water Quality.

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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WATER WELL LICENSING
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Dave Andrews (Irricana: 403-935-4478)

LOCAL HEALTH DEPARTMENTS

LAKELAND COUNTY STUDY AREA
Appendix D

Maps and Figures Included as Large Plots

Bedrock Topography 2
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s) 3
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Cross-Section B - B’ 8
Cross-Section C - C’ 9
Cross-Section D - D’ 10
Cross-Section E - E’ 11
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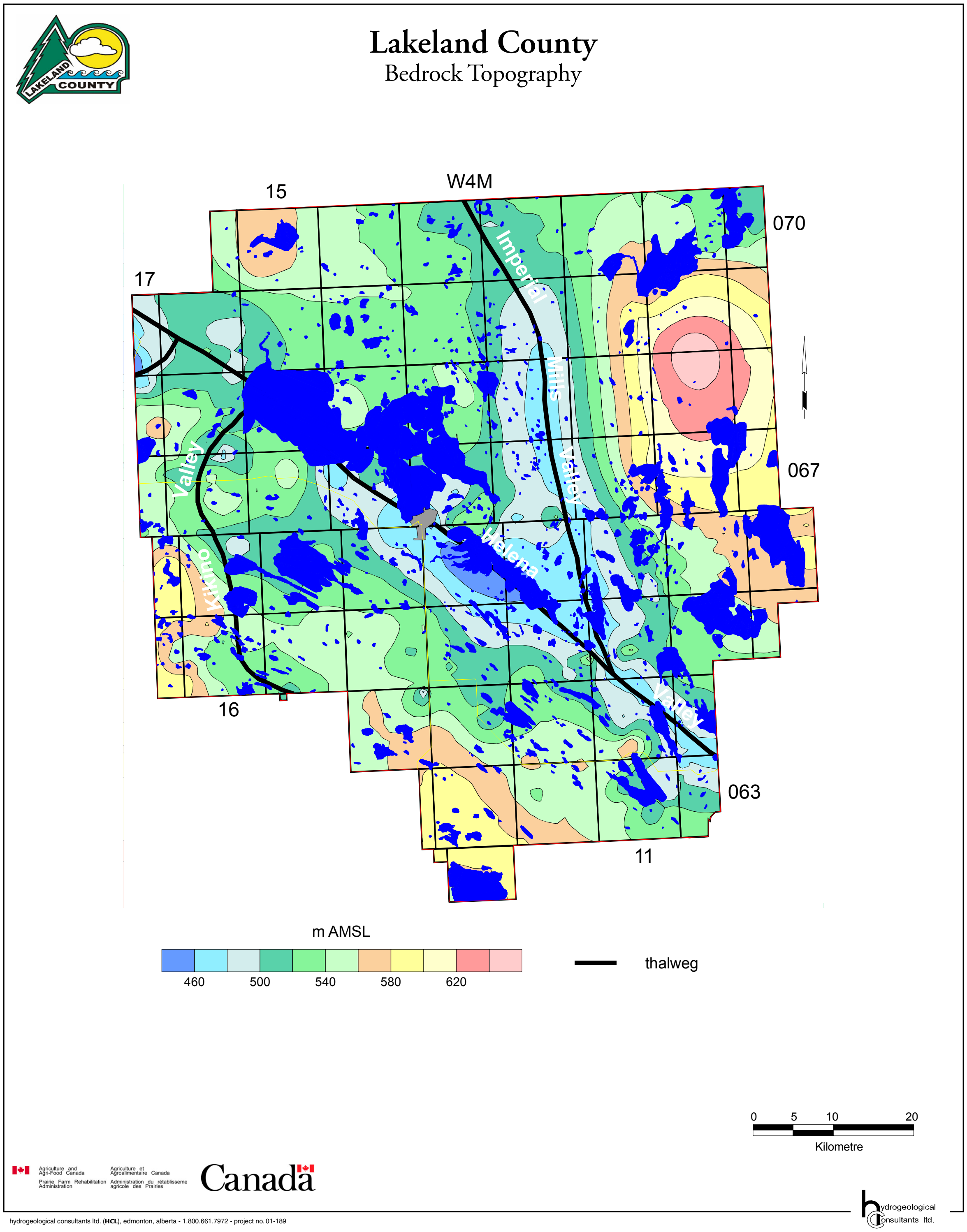
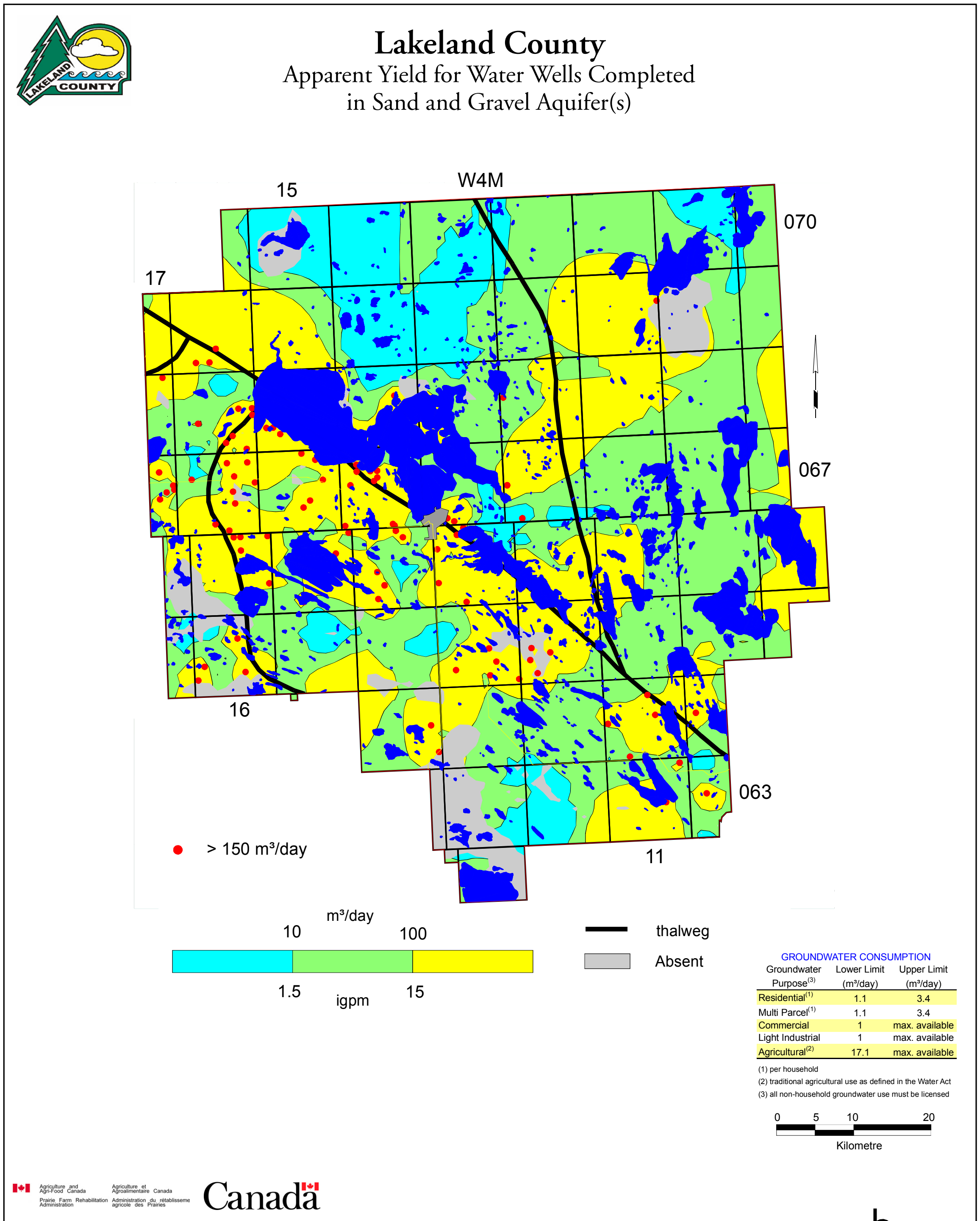
Bedrock Topography



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



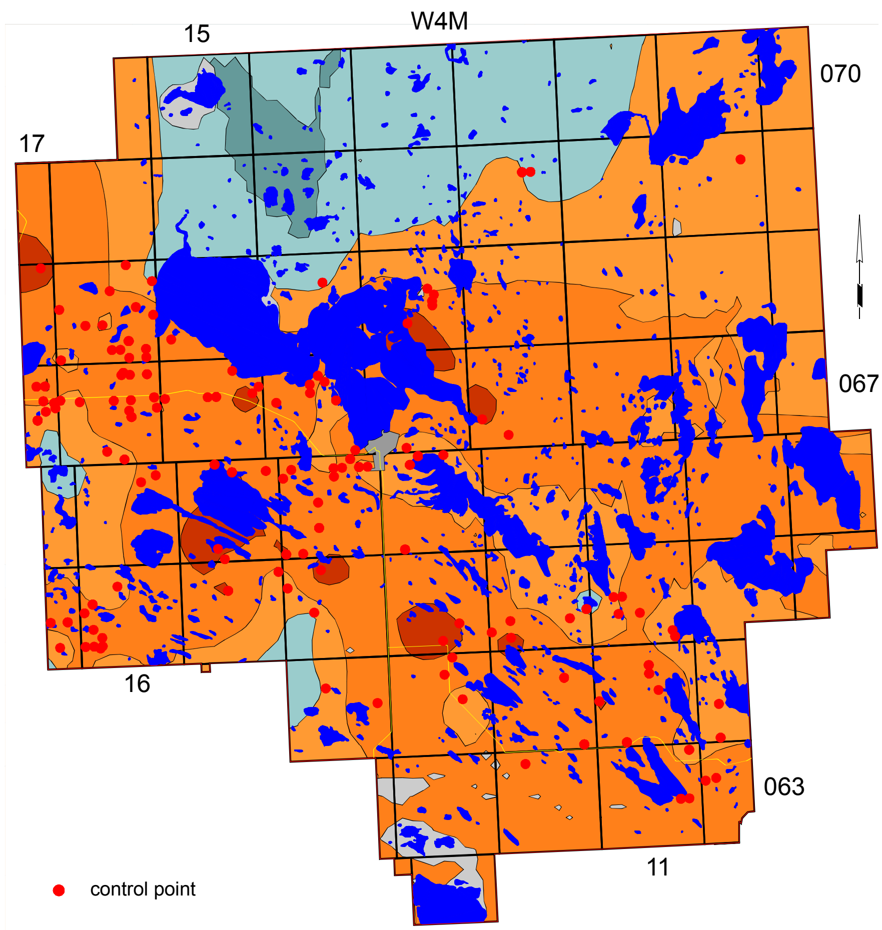
GROUNDWATER CONSUMPTION

Groundwater Purpose(3)	Lower Limit (m³/day)	Upper Limit (m³/day)
Residential(1)	1.1	3.4
Multi Parcel(1)	1.1	3.4
Commercial	1	max. available
Light Industrial	1	max. available
Agricultural(2)	17.1	max. available

(1) per household
(2) traditional agricultural use as defined in the Water Act
(3) all non-household groundwater use must be licensed

Total Dissolved Solids in Groundwater from Surficial Deposits

Lakeland County
Total Dissolved Solids in Groundwater from Surficial Deposits



MAXIMUM LIMIT
TOTAL DISSOLVED SOLIDS

Use	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

0 5 10 20
Kilometre

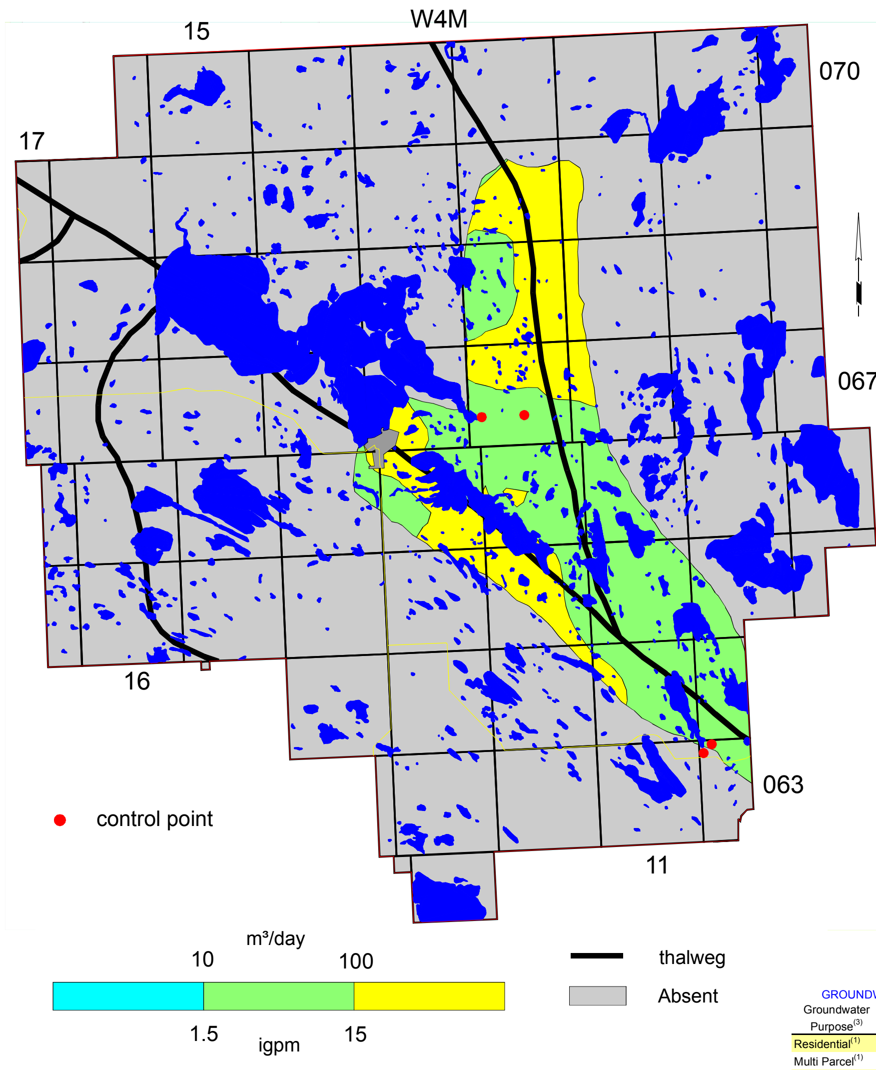
Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada
Prairie Farm Rehabilitation Administration / Administration du rétablissement agricole des Prairies

Canada

Apparent Yield for Water Wells Completed through Empress – Unit 1 Aquifer

Lakeland County

Apparent Yield for Water Wells Completed through Empress Aquifer - Unit 1



GROUNDWATER CONSUMPTION

Groundwater Purpose(3)	Lower Limit (m³/day)	Upper Limit (m³/day)
Residential(1)	1.1	3.4
Multi Parcel(1)	1.1	3.4
Commercial	1	max. available
Light Industrial	1	max. available
Agricultural(2)	17.1	max. available

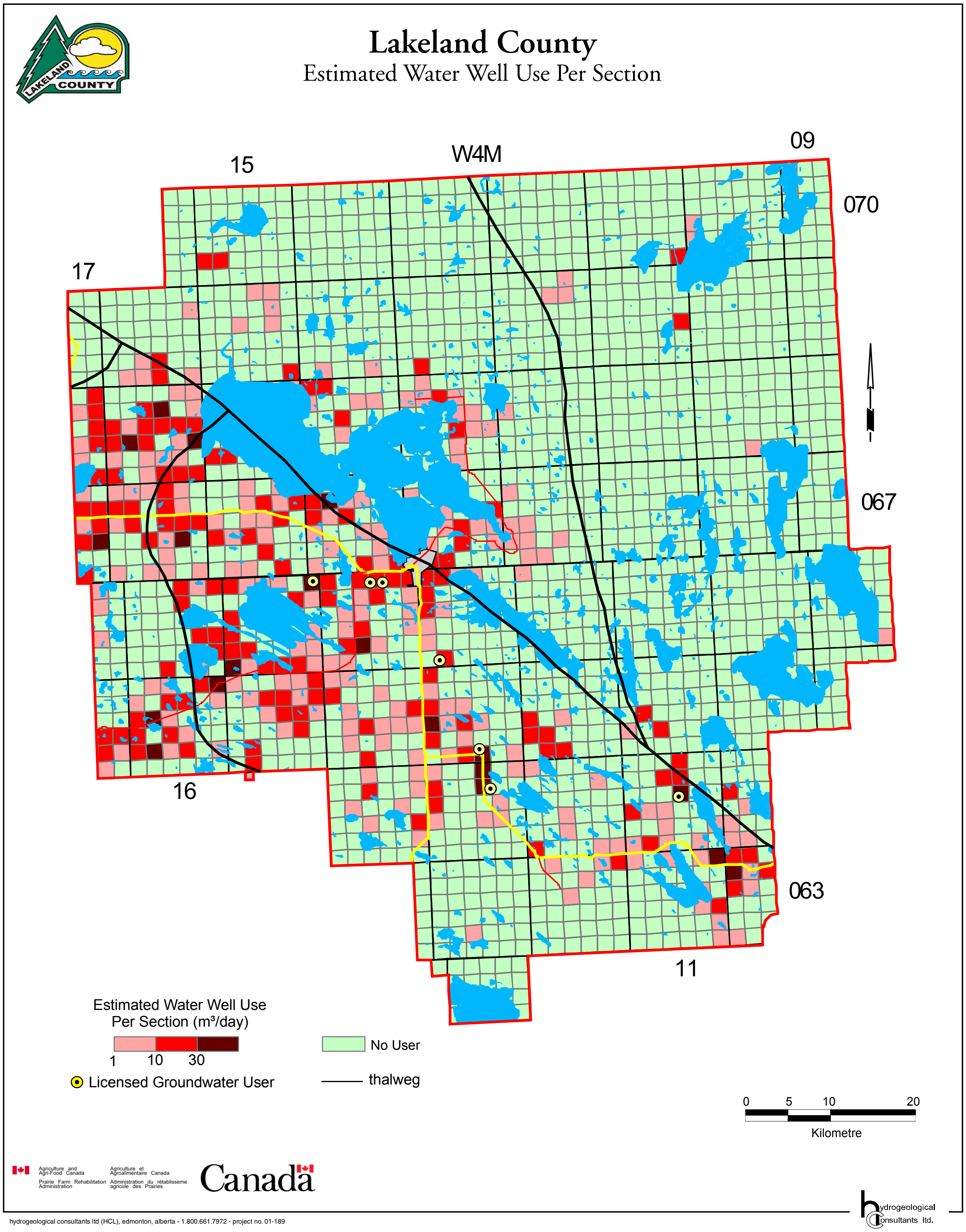
(1) per household
(2) traditional agricultural use as defined in the Water Act
(3) all non-household groundwater use must be licensed

0 5 10 20
Kilometre

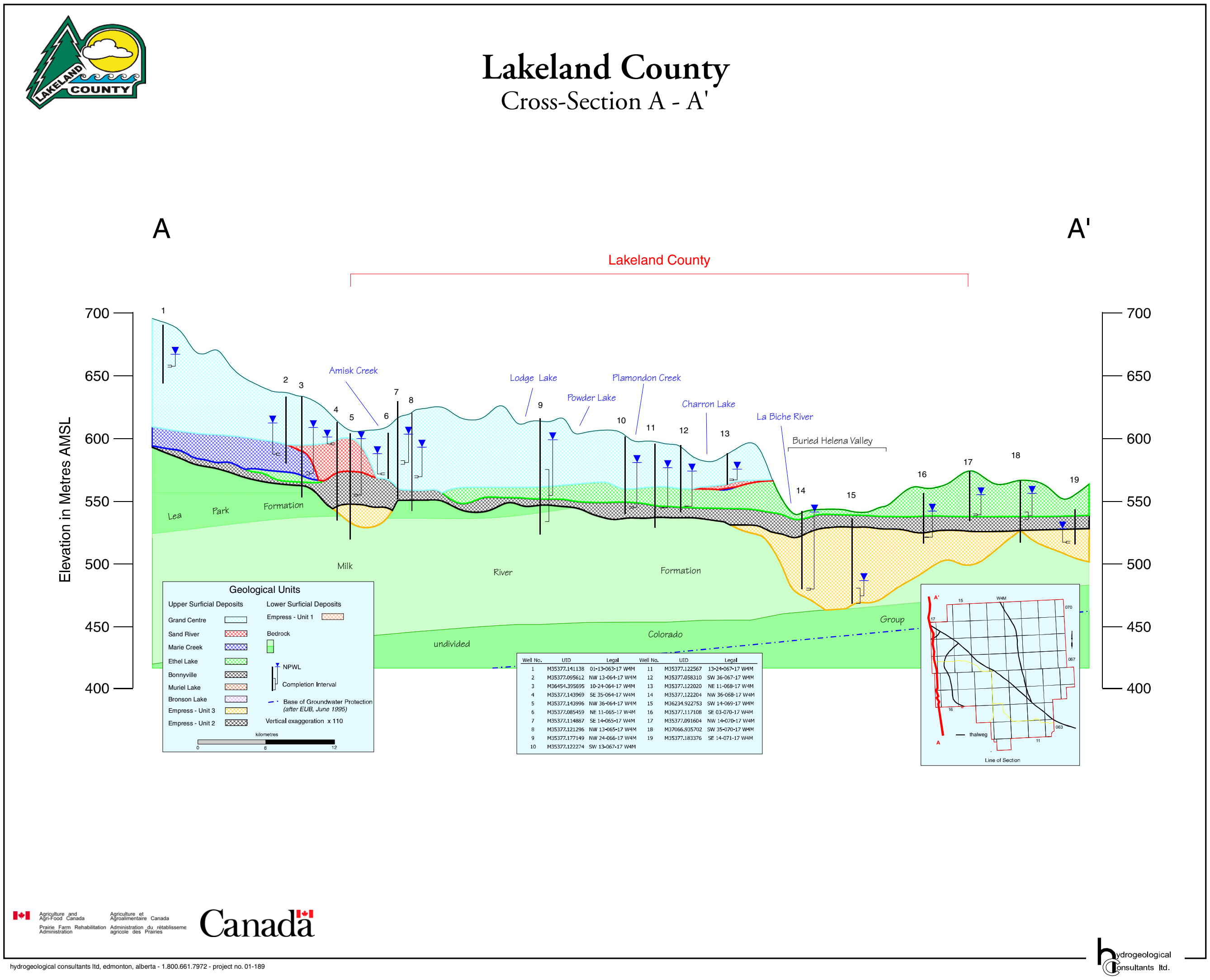
Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada
Prairie Farm Rehabilitation Administration / Administration du rétablissement agricole des Prairies
Canada

hydrogeological consultants ltd.

Estimated Water Well Use Per Section



Cross-Section A - A'



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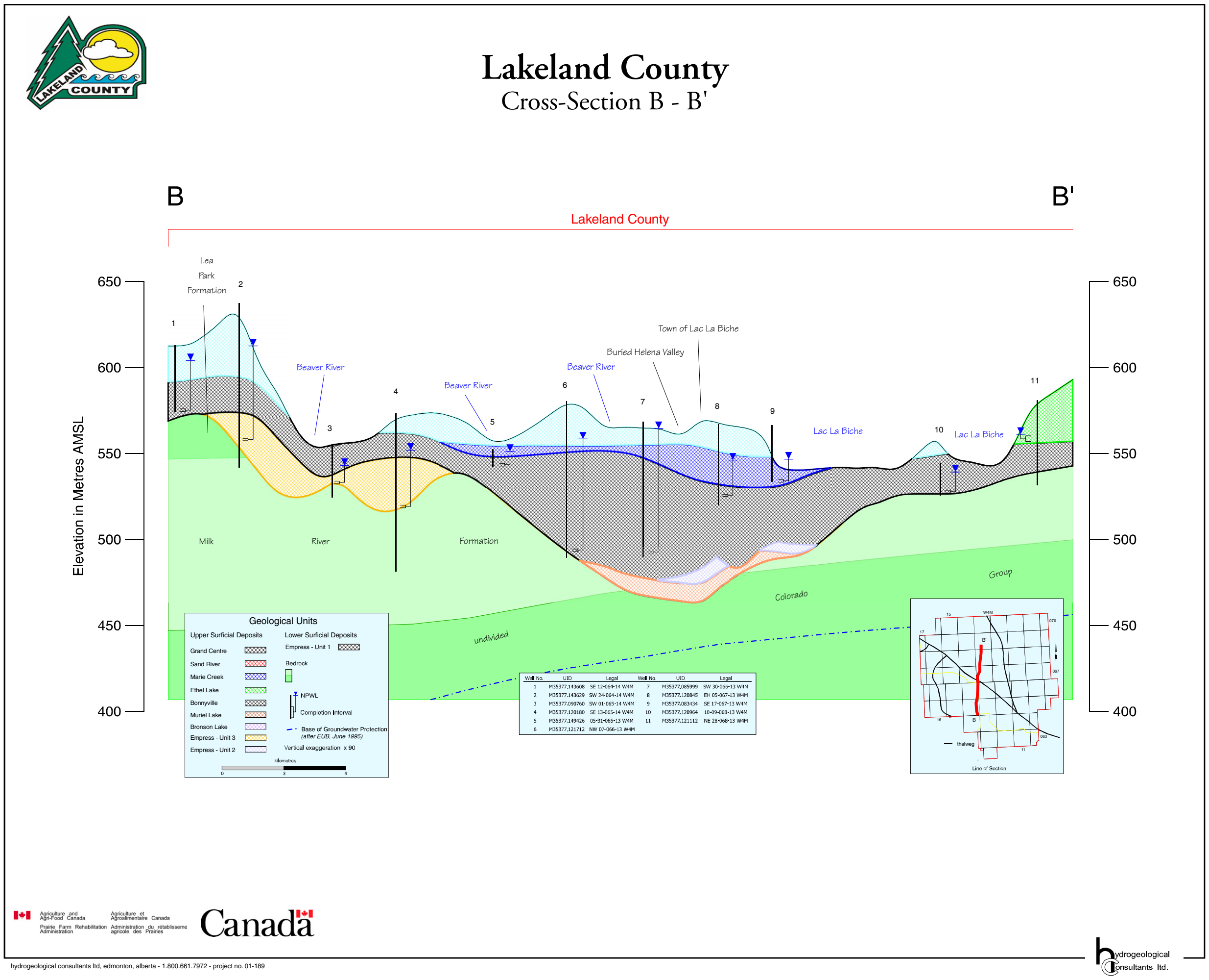
2	M35377.095612	NW 13-064-17 W4M	12	M35377.058310	SW 36-067-17 W4M
3	M36454.395695	10-24-064-17 W4M	13	M35377.122020	NE 11-068-17 W4M
4	M35377.143969	SE 35-064-17 W4M	14	M35377.122204	NW 36-068-17 W4M
5	M35377.143996	NW 36-064-17 W4M	15	M36234.922753	SW 14-069-17 W4M
6	M35377.085459	NE 11-065-17 W4M	16	M35377.117108	SE 03-070-17 W4M
7	M35377.114887	SE 14-065-17 W4M	17	M35377.091604	NW 14-070-17 W4M
8	M35377.121296	NW 13-065-17 W4M	18	M37066.935702	SW 35-070-17 W4M
9	M35377.177149	NW 24-066-17 W4M	19	M35377.183376	SE 14-071-17 W4M
10	M35377.122274	SW 13-067-17 W4M			

Cross-Section B - B'



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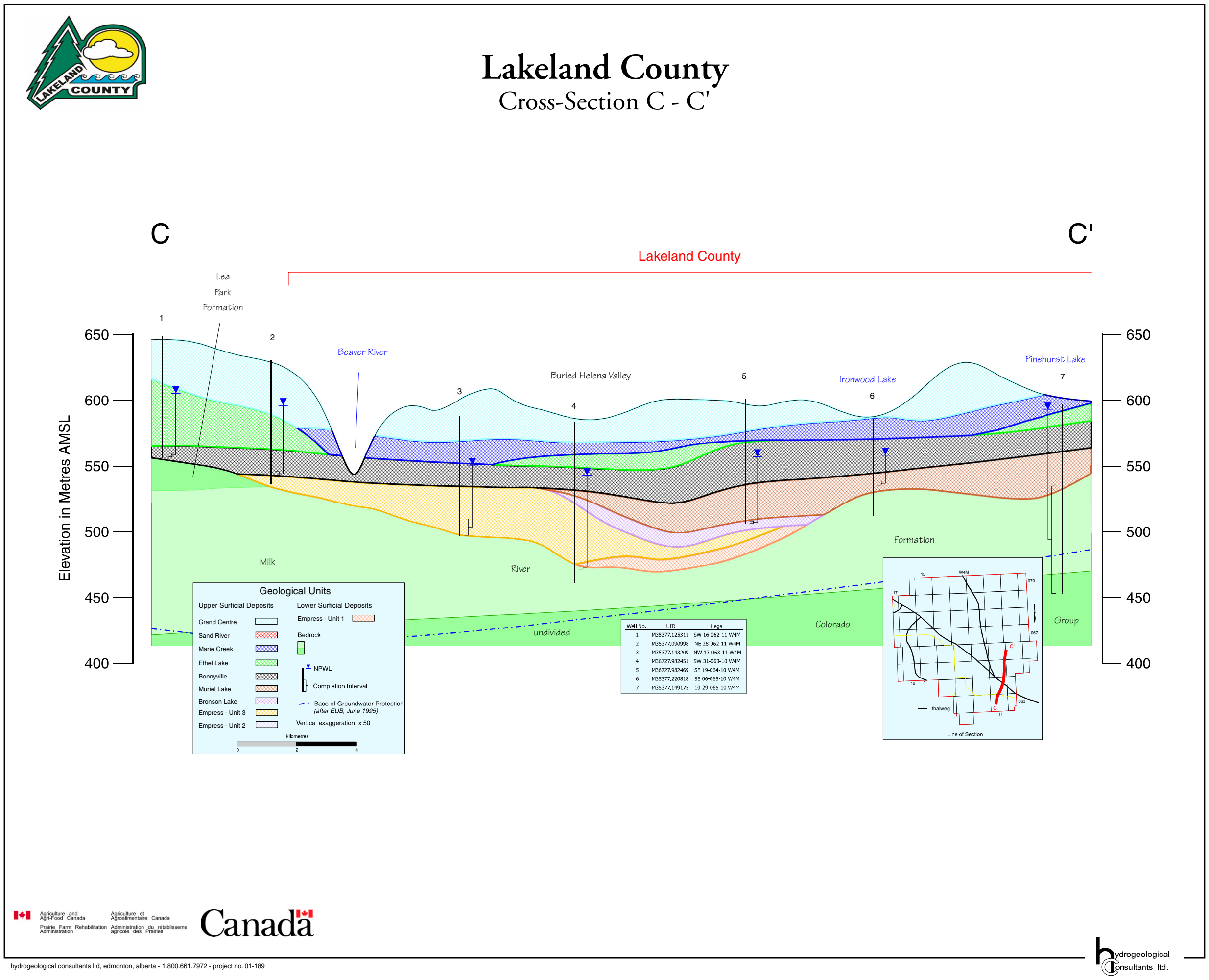
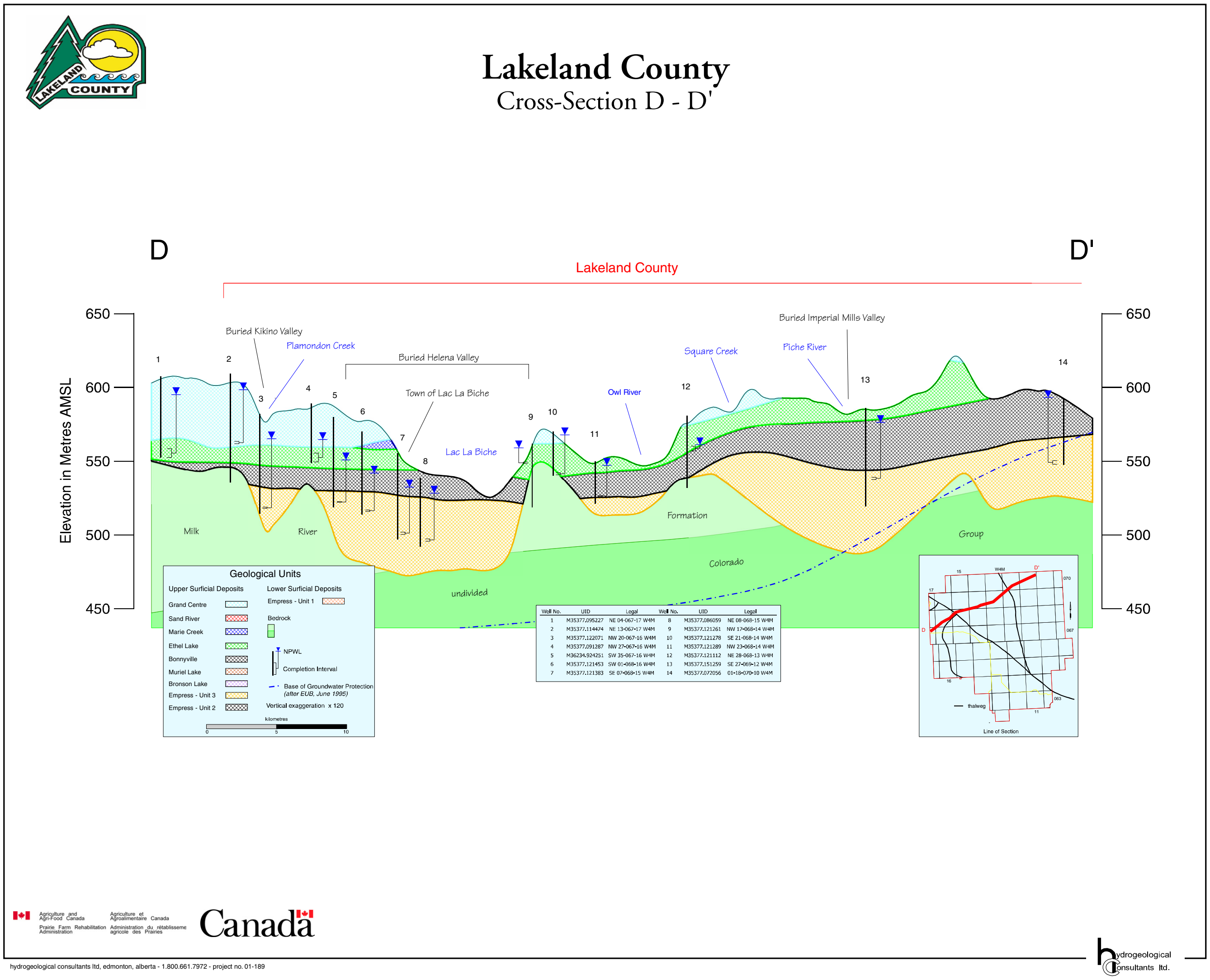


Cross-Section D - D'



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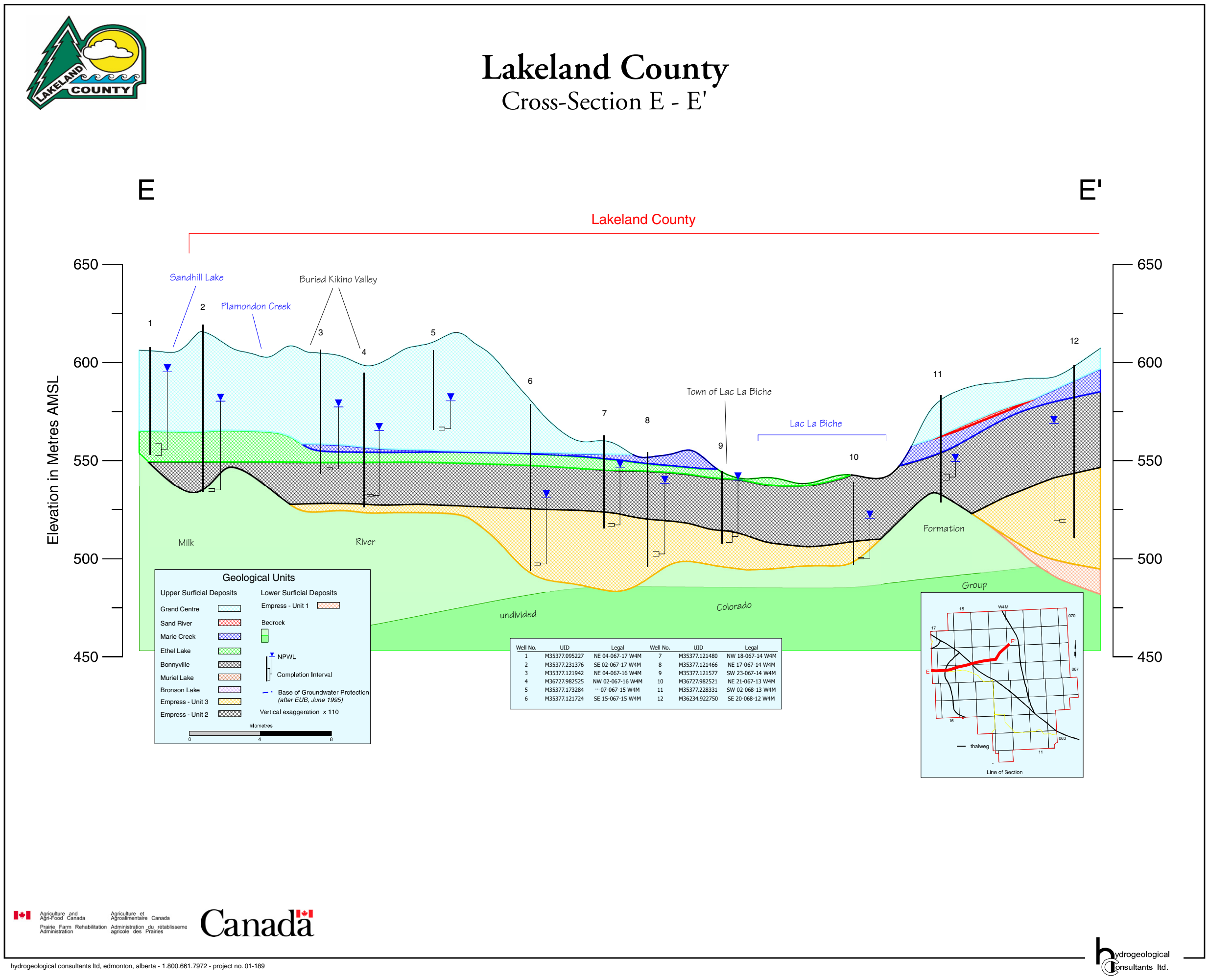
1	M35377.095227	NE 04-067-17 W4M	8	M35377.086059	NE 08-068-15 W4M
2	M35377.114474	NE 13-067-17 W4M	9	M35377.121261	NW 17-068-14 W4M
3	M35377.122071	NW 20-067-16 W4M	10	M35377.121278	SE 21-068-14 W4M
4	M35377.091287	NW 27-067-16 W4M	11	M35377.121289	NW 23-068-14 W4M
5	M36234.924251	SW 35-067-16 W4M	12	M35377.121112	NE 28-068-13 W4M
6	M35377.121453	SW 01-068-16 W4M	13	M35377.151259	SE 27-069-12 W4M
7	M35377.121383	SE 07-068-15 W4M	14	M35377.072056	01-18-070-10 W4M

Cross-Section E - E'



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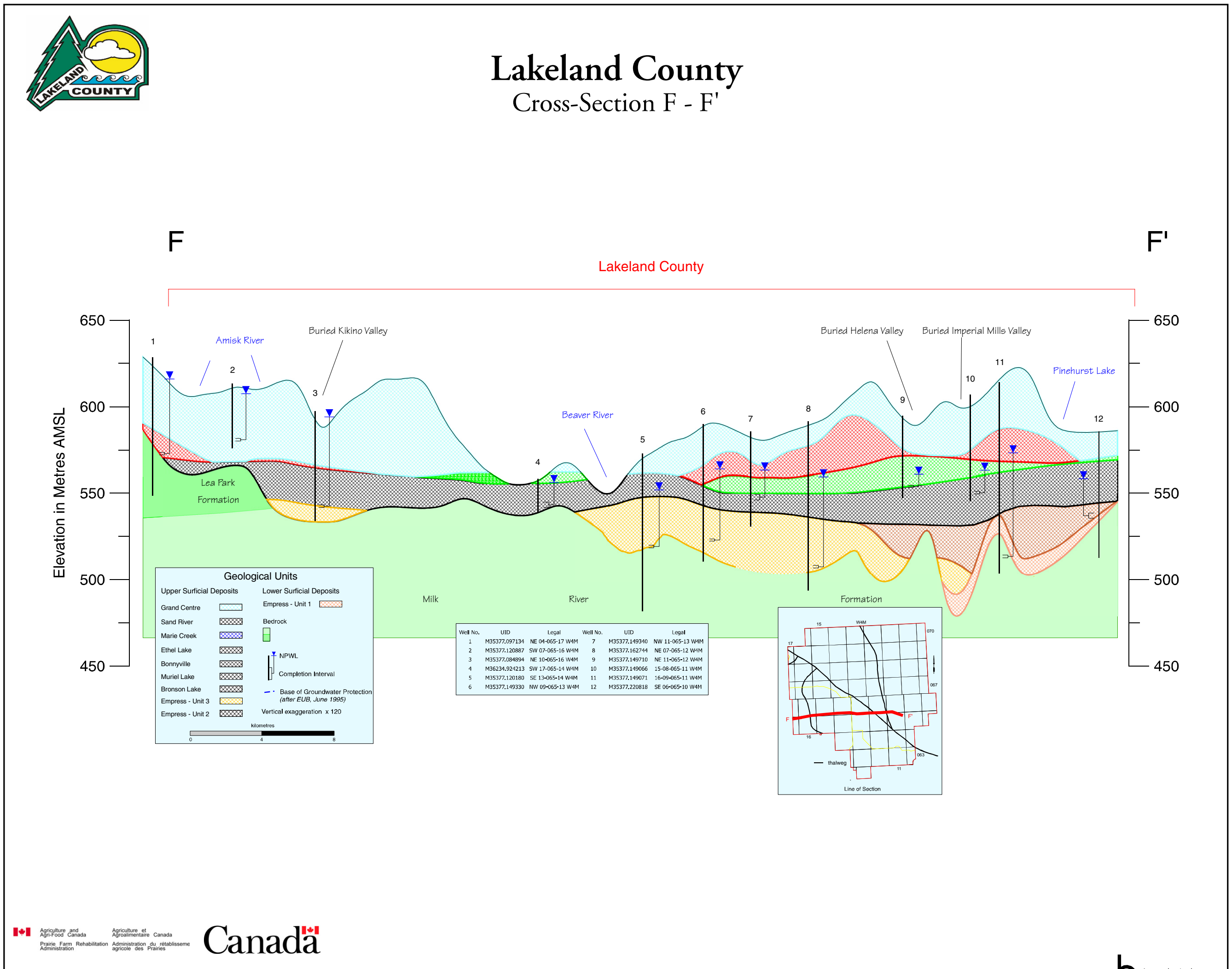
2	M35377.231376	SE 02-067-17 W4M	8	M35377.121466	NE 17-067-14 W4M
3	M35377.121942	NE 04-067-16 W4M	9	M35377.121577	SW 23-067-14 W4M
4	M36727.982525	NW 02-067-16 W4M	10	M36727.982521	NE 21-067-13 W4M
5	M35377.173284	··-07-067-15 W4M	11	M35377.228331	SW 02-068-13 W4M
6	M35377.121724	SE 15-067-15 W4M	12	M36234.922750	SE 20-068-12 W4M

Cross-Section F - F’



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2	M35377.120887	SW 07-065-16 W4M	8	M35377.162744	NE 07-065-12 W4M
3	M35377.084894	NE 10-065-16 W4M	9	M35377.149710	NE 11-065-12 W4M
4	M36234.924213	SW 17-065-14 W4M	10	M35377.149066	15-08-065-11 W4M
5	M35377.120180	SE 13-065-14 W4M	11	M35377.149071	16-09-065-11 W4M
6	M35377.149330	NW 09-065-13 W4M	12	M35377.220818	SE 06-065-10 W4M

hydrogeological consultants ltd, edmonton, alberta - 1.800.661.7972 - project no. 01-189

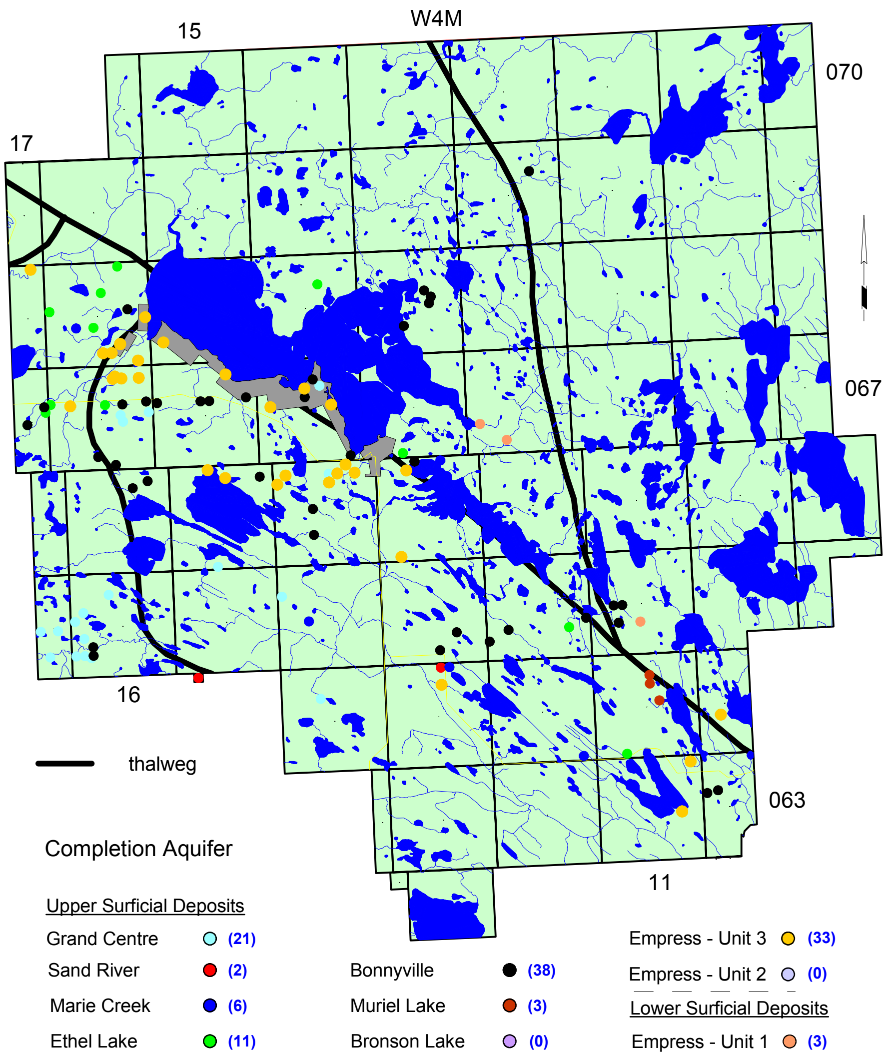
LAKELAND COUNTY STUDY AREA

Appendix E

Water Wells Recommended for Field Verification

Water Wells Recommended for Field Verification

(details on following pages)



WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
[unknown]	SW 26-069-12 W4M	Bonnyville		40.84	134.0	10.52	34.5	M35377.151242
Alberta Environment	SW 27-064-11 W4M	Muriel Lake	18-Aug-82	84.73	278.0	33.83	111.0	M35377.143833
Alberta Environment	09-22-068-13 W4M	Bonnyville	01-Nov-73	36.57	120.0	6.1	20.0	M35377.121040
Alberta Environment	10-09-068-13 W4M	Bonnyville	01-Nov-73	17.37	57.0	5.18	17.0	M35377.120964
Alberta Government Service	NE 34-066-13 W4M	Marie Creek	10-Jun-79	29.56	97.0	8.53	28.0	M35377.128716
Andrichuk, George	SE 22-064-11 W4M	Muriel Lake	09-Sep-75	69.49	228.0	28.35	93.0	M35377.143480
Bennett, Lloyd	NE 14-063-11 W4M	Empress - Unit 3	20-Apr-78	74.67	245.0	40.23	132.0	M35377.143240
Bergheim, Ken	NW 27-064-11 W4M	Muriel Lake	07-Nov-80	94.48	310.0	41.54	136.3	M35377.143835
Boucher, Fred	SE 35-066-14 W4M	Empress - Unit 3	27-Jun-74	24.38	80.0	9.75	32.0	M35377.122409
Bourassa, Ed	NW 20-067-16 W4M	Empress - Unit 3	01-May-78	64.00	210.0	16.85	55.3	M35377.122071
Bourassa, Laurier	NW 30-066-14 W4M	Empress - Unit 3	17-Jun-77	69.19	227.0	30.78	101.0	M35377.122288
Bourassa, Leo C.	SE 34-067-16 W4M	Empress - Unit 3	02-Jul-85	62.18	204.0	37.37	122.6	M35377.122218
Bourque, S., Isaac	NE 21-067-14 W4M	Bonnyville	07-Nov-85	37.79	124.0	8.84	29.0	M35377.121542
Bouvier, Dr.	NW 35-066-14 W4M	Empress - Unit 3	12-Mar-76	84.43	277.0	10.06	33.0	M35377.122422
Bouvier, Gabriel	NE 21-067-15 W4M	Bonnyville	09-Nov-81	77.11	253.0	42.67	140.0	M35377.121790
Broadbent, Alex	SW 21-066-14 W4M	Bonnyville	18-Sep-87	33.53	110.0	12.01	39.4	M35377.122247
Brockman, Alvin (Val Cote)	SW 35-067-15 W4M	Empress - Unit 3	13-Jul-88	63.09	207.0	17.07	56.0	M35377.121926
Bruce, Larry	SE 24-067-16 W4M	Grand Centre	13-Nov-86	59.74	196.0	25.91	85.0	M35377.122111
Buckton, Don	NW 22-067-15 W4M	Bonnyville	26-Jun-78	84.73	278.0	41.15	135.0	M35377.121794
Burdek, George	NW 27-064-13 W4M	Empress - Unit 3	07-Oct-85	62.48	205.0	19.2	63.0	M35377.143671
Burdek, Nick	NE 34-064-13 W4M	Marie Creek	05-Jul-69	21.94	72.0	3.08	10.1	M35377.143717
Cardinal, Gilbert	SE 27-068-14 W4M	Ethel Lake	05-Oct-87	14.63	48.0	7.62	25.0	M35377.121302
Cherniwochan, Nick	NW 14-065-17 W4M	Grand Centre	31-May-80	37.49	123.0	18.29	60.0	M35377.121301
Chevigny, Albert	NE 13-068-16 W4M	Empress - Unit 3	07-May-83	36.57	120.0	4.88	16.0	M35377.121780
Chevigny, George	08-34-067-16 W4M	Empress - Unit 3	02-Aug-79	54.56	179.0	26.21	86.0	M35377.122198
Cochrane, Ken	NW 36-068-17 W4M	Empress - Unit 3	18-Sep-85	62.79	206.0	0.61	2.0	M35377.122204
D. O. Environment	14-17-065-11 W4M	Bonnyville	22-Oct-73	53.64	176.0	21.94	72.0	M35377.149077
Davana Developments c/o Dave Power	NW 33-066-15 W4M	Empress - Unit 3	24-Jun-77	52.42	172.0	11.71	38.4	M35377.122689
Davana Developments c/o Dave Power	SW 34-066-15 W4M	Empress - Unit 3	28-Jun-77	74.67	245.0	18.01	59.1	M35377.122708
Davie, Wayne	SW 28-064-14 W4M	Grand Centre	08-Sep-82	17.68	58.0	7.62	25.0	M35377.143634
Department of Highways	08-02-065-11 W4M	Marie Creek	01-Jun-71	20.42	67.0	3.05	10.0	M35377.149056
Faulkner, Doug & Diane	SE 28-067-14 W4M	Empress - Unit 3	16-Jul-88	37.18	122.0	10.36	34.0	M35377.121599
Foley, Harry	SE 31-066-14 W4M	Empress - Unit 3	17-Jul-79	38.40	126.0	9.75	32.0	M35377.122322
Fortier, Eli	NE 07-067-12 W4M	Empress - Unit 1	20-Aug-79	60.35	198.0	31.09	102.0	M35377.150836
G & M Stock Farm (Cadieux)	SW 05-066-13 W4M	Empress - Unit 3	23-Sep-87	64.00	210.0	30.78	101.0	M35377.121697
Gaberel, Paul	SE 32-066-13 W4M	Empress - Unit 3	25-Sep-74	79.24	260.0	14.02	46.0	M35377.121819
Gange, Ed	SE 17-068-16 W4M	Marie Creek	17-Oct-79	29.87	98.0	15.24	50.0	M35377.121834
Gauthier, Cletus	SE 23-068-16 W4M	Bonnyville	06-Jul-87	33.22	109.0	3.96	13.0	M35377.121956
Gauthier, Jean Paul	NE 14-067-17 W4M	Bonnyville	01-Apr-83	77.11	253.0	27.43	90.0	M35377.122303
Gauthier, Roger	NW 35-068-16 W4M	Ethel Lake	19-May-82	15.54	51.0	7.01	23.0	M35377.121992
Gauthier, Roy	NW 19-067-15 W4M	Bonnyville	01-Oct-83	79.24	260.0	37.79	124.0	M35377.121778
Germain, J. P.	NW 03-068-16 W4M	Empress - Unit 3	15-Oct-82	47.24	155.0	24.38	80.0	M35377.121545
Gervais, Edgar	NW 03-065-13 W4M	Bonnyville	03-Sep-75	47.55	156.0	26.21	86.0	M35377.149178
Gladue, Joe	SE 13-065-12 W4M	Bonnyville	01-Oct-73	35.96	118.0	28.8	94.5	M35377.149713
Gordey, Alfred	SW 07-065-16 W4M	Grand Centre	03-Jun-80	33.22	109.0	5.79	19.0	M35377.120887
Gordey, John	SE 07-065-16 W4M	Grand Centre	08-Jun-80	41.45	136.0	10.97	36.0	M35377.120875
Hlewka, Rick	SW 36-067-16 W4M	Empress - Unit 3	07-Sep-83	91.74	301.0	60.04	197.0	M35377.122243
Holowachuk, John	NW 33-066-13 W4M	Bonnyville	21-Aug-78	65.53	215.0	6.4	21.0	M35377.122043
Hoye, Mark	NE 17-065-14 W4M	Marie Creek	21-Aug-89	14.63	48.0	9.75	32.0	M35377.120221
Hrynyh, Harold	SE 07-068-15 W4M	Empress - Unit 3	02-Jun-89	49.38	162.0	18.29	60.0	M35377.121391
Johnson, L.	SW 08-065-16 W4M	Bonnyville	29-May-80	42.67	140.0	11.28	37.0	M35377.120895
Kamke, Otto	13-14-068-13 W4M	Bonnyville	18-Sep-73	15.85	52.0	1.83	6.0	M35377.091066
Kinnunen, Seppo	16-17-065-11 W4M	Bonnyville	13-Sep-80	66.75	219.0	65.83	216.0	M35377.149079

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION (continued)

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
Krawchuk, Nickolos M.	SE 11-065-17 W4M	Grand Centre	14-Jul-82	10.97	36.0	10.36	34.0	M35377.121281
Labonte, Paul	SW 27-068-16 W4M	Ethel Lake	19-Sep-85	14.32	47.0	4.57	15.0	M35377.121985
Lac La Biche School Division Unit 51	SE 05-064-11 W4M	Ethel Lake	10-Dec-79	29.26	96.0	11.58	38.0	M35377.150051
Ladouceur, Fred	14-24-067-15 W4M	Bonnyville	22-Jun-76	11.58	38.0	9.45	31.0	M35377.076862
Lamoureux, Leo	04-07-065-12 W4M	Bonnyville	14-Nov-78	45.72	150.0	26.82	88.0	M35377.149665
Lansing, Rick	04-23-067-16 W4M	Grand Centre	02-Aug-79	45.72	150.0	21.64	71.0	M35377.122100
Lemay, George	16-27-066-16 W4M	Bonnyville	11-Sep-67	41.45	136.0	8.84	29.0	M35377.122923
Lemay, Marcel	SE 16-068-16 W4M	Ethel Lake	10-Nov-80	17.37	57.0	9.14	30.0	M35377.121814
L'Heureux, Albert	SW 34-066-14 W4M	Grand Centre	04-Nov-86	14.93	49.0	7.62	25.0	M35377.122376
Mac Millan	NW 22-067-16 W4M	Grand Centre	09-Jul-74	21.33	70.0	3.05	10.0	M35377.122080
Macdonald, Alex	NW 32-064-15 W4M	Sand River	01-Nov-73	12.19	40.0	4.57	15.0	M35377.143625
Macor, Art	SW 30-065-14 W4M	Grand Centre	24-Nov-78	21.64	71.0	3.66	12.0	M35377.120294
Malbeuf, Eli	SW 01-064-12 W4M	Marie Creek	11-May-72	14.63	48.0	10.06	33.0	M35377.143495
Mann, Lewis	NE 19-065-16 W4M	Grand Centre	29-Jul-74	9.75	32.0	6.1	20.0	M35377.121019
Mann, Lewis	SW 19-065-16 W4M	Grand Centre	06-Oct-78	17.68	58.0	10.97	36.0	M35377.121017
Marczak, Helmut	NW 27-066-14 W4M	Empress - Unit 3	20-Jun-77	58.52	192.0	34.14	112.0	M35377.122267
Mcfarland, Lenard	07-27-067-14 W4M	Grand Centre	22-Jun-76	12.50	41.0	7.92	26.0	M35377.076902
Mcmillan, Wayne	NW 22-067-16 W4M	Ethel Lake	26-Jul-80	45.41	149.0	13.72	45.0	M35377.122084
Menard, Andy	SE 03-067-16 W4M	Bonnyville	05-May-83	51.20	168.0	19.51	64.0	M35377.091058
Menard, Claude	SE 35-066-16 W4M	Bonnyville	22-Jul-81	46.63	153.0	21.33	70.0	M35377.122942
Menard, E. J.	NW 23-067-16 W4M	Bonnyville	19-Mar-76	82.90	272.0	54.56	179.0	M35377.122103
Menard, Maurice & Denis	SW 35-067-16 W4M	Empress - Unit 3	08-May-78	58.21	191.0	28.77	94.4	M35377.122229
Meyer, Glen	NW 13-065-17 W4M	Grand Centre	08-May-81	51.81	170.0	27.43	90.0	M35377.121296
Miller Glen	16-09-065-11 W4M	Empress - Unit 1	06-Aug-80	101.80	334.0	41.15	135.0	M35377.149071
Moville, Gary	NW 11-065-13 W4M	Bonnyville	24-Jul-86	39.32	129.0	21.94	72.0	M35377.149340
Onciul, Andrew	SW 17-064-10 W4M	Empress - Unit 3	25-Oct-73	110.33	362.0	31.39	103.0	M35377.143387
Onciul, Wilfred	16-19-063-10 W4M	Bonnyville	27-Sep-79	53.03	174.0	40.69	133.5	M35377.143183
Oncuil, William & Randy	NW 19-063-10 W4M	Bonnyville	09-Nov-74	58.52	192.0	38.95	127.8	M35377.143178
Panchuk, Stanley	NW 34-064-13 W4M	Sand River	16-Feb-77	14.93	49.0	7.62	25.0	M35377.143710
Paulson, Joyce	NW 08-065-16 W4M	Bonnyville	06-Oct-83	57.60	189.0	9.14	30.0	M35377.120916
Plamondom, Alex M.	NE 03-068-16 W4M	Empress - Unit 3	02-Jun-89	53.64	176.0	17.68	58.0	M35377.121572
Plamondon, Alcide	SW 11-068-16 W4M	Empress - Unit 3	05-Jul-82	52.42	172.0	12.19	40.0	M35377.121713
Plamondon, Gordon	SW 11-068-16 W4M	Empress - Unit 3	28-Jul-89	51.51	169.0	17.07	56.0	M35377.121721
Plamondon, Leonard	SW 01-068-16 W4M	Empress - Unit 3	30-Jun-87	54.25	178.0	28.35	93.0	M35377.121453
Poholski, Kate	02-04-066-15 W4M	Grand Centre	22-Sep-80	26.82	88.0	15.24	50.0	M35377.119929
Polonuk, J. N. Development, Planning & Research	SW 23-067-14 W4M	Empress - Unit 3	30-Jun-79	36.57	120.0	4.69	15.4	M35377.121577
Polylyk, John	SE 18-065-16 W4M	Grand Centre	08-Jun-80	36.57	120.0	12.19	40.0	M35377.120994
Postill, Frank	NE 04-067-16 W4M	Bonnyville	05-May-83	61.26	201.0	29.17	95.7	M35377.121942
Redhead, Ron	SW 36-066-15 W4M	Bonnyville	05-Jun-83	63.09	207.0	42.67	140.0	M35377.122793
Redinger, John & Norma	04-08-065-16 W4M	Grand Centre	25-May-82	39.01	128.0	9.14	30.0	M35377.120898
Rizzoli, Ray	SW 04-067-13 W4M	Ethel Lake	17-Oct-85	37.79	124.0	16.7	54.8	M35377.120794
Schaub, Andy	15-24-067-16 W4M	Bonnyville	27-May-80	75.89	249.0	57.91	190.0	M35377.122121
Schauer, Morris	NW 28-065-16 W4M	Grand Centre	29-Mar-88	24.38	80.0	5.49	18.0	M35377.121108
Stapka, Peter	SW 19-068-16 W4M	Ethel Lake	01-Jun-70	40.54	133.0	24.69	81.0	M35377.121889
Stefanyk, Jerry	SW 11-068-16 W4M	Empress - Unit 3	17-Aug-79	36.27	119.0	10.97	36.0	M35377.121704
Steiner, Nevin	SE 19-067-14 W4M	Empress - Unit 3	15-Aug-84	40.84	134.0	12.16	39.9	M35377.121482
Suhan, John	11-36-063-11 W4M	Empress - Unit 3	18-Apr-78	71.01	233.0	30.48	100.0	M35377.143458
Swan, George	15-08-065-11 W4M	Bonnyville	01-Oct-73	57.91	190.0	44.19	145.0	M35377.149066
Tarrabain, J.	SW 01-067-14 W4M	Bonnyville	06-Jul-81	13.41	44.0	6.71	22.0	M35377.121277
Tchir, Dennis	NW 33-066-13 W4M	Bonnyville	14-Nov-82	31.09	102.0	13.41	44.0	M35377.121924
Tournier, Don J.	SW 23-068-13 W4M	Bonnyville	28-Jun-77	46.63	153.0	25.3	83.0	M35377.121061
Turgeon, Paul	NW 08-065-12 W4M	Bonnyville	26-Jun-86	56.39	185.0	26.82	88.0	M35377.149704
Two Thousand & One Drive In	SE 34-066-14 W4M	Empress - Unit 3	19-May-81	69.19	227.0	21.94	72.0	M35377.122347
Uganecz, Eugene	NW 09-066-14 W4M	Grand Centre	26-Oct-86	7.92	26.0	6.4	21.0	M35377.122176
Uganecz, Eugene	NW 09-066-14 W4M	Bonnyville	27-Aug-79	30.78	101.0	8.17	26.8	M35377.122170
Ulliac, Emile	13-19-067-16 W4M	Ethel Lake	29-Jun-77	38.10	125.0	3.66	12.0	M35377.122063
Ulliac, Laurence	SE 24-067-17 W4M	Ethel Lake	05-May-81	49.38	162.0	10.48	34.4	M35377.122500
Ulliac, Raymond	NE 24-067-17 W4M	Bonnyville	18-Jul-82	43.89	144.0	11.52	37.8	M35377.122584
Vistula Dev Co. Ltd.	NE 14-063-11 W4M	Empress - Unit 3	02-Oct-83	53.95	177.0	41.15	135.0	M35377.143259
Wheele, Ron	NW 04-067-12 W4M	Empress - Unit 1	15-Jun-82	75.89	249.0	6.1	20.0	M35377.150828
Wickberg, Art	NW 14-067-16 W4M	Grand Centre	10-Aug-83	56.69	186.0	21.33	70.0	M35377.122036
Wickberg, Arthur, J.	NW 14-067-16 W4M	Grand Centre	26-Oct-77	31.09	102.0	18.29	60.0	M35377.122033
Widford, W.	NE 11-065-12 W4M	Ethel Lake	12-Oct-73	40.84	134.0	33.22	109.0	M35377.149710
Young, Jack	NW 27-067-14 W4M	Bonnyville	01-Apr-68	36.57	120.0	9.75	32.0	M35377.121591

LAKELAND COUNTY AND M.D. OF BONNYVILLE STUDY AREAS
Appendix F

Hydrogeological Maps and Figures

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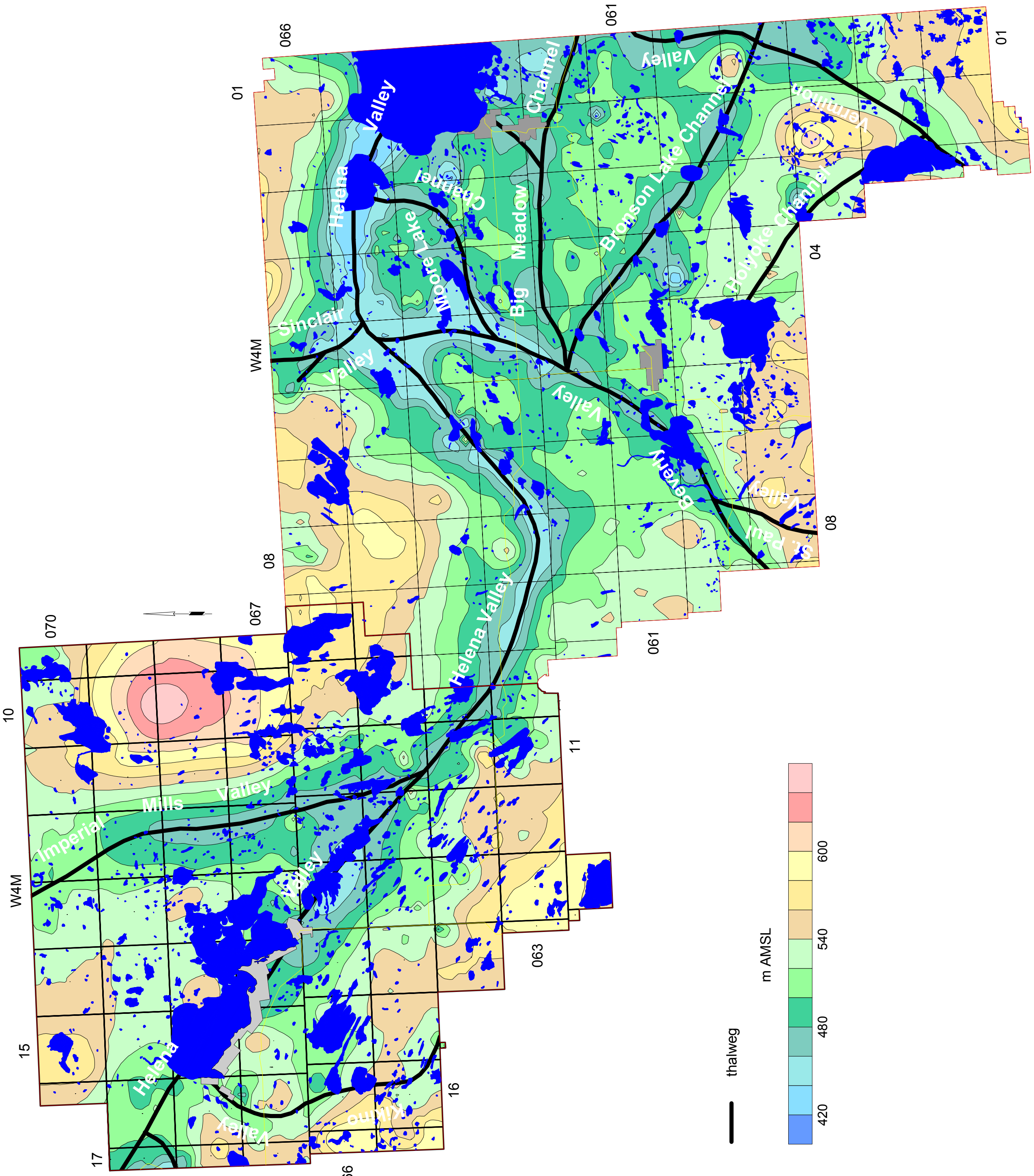
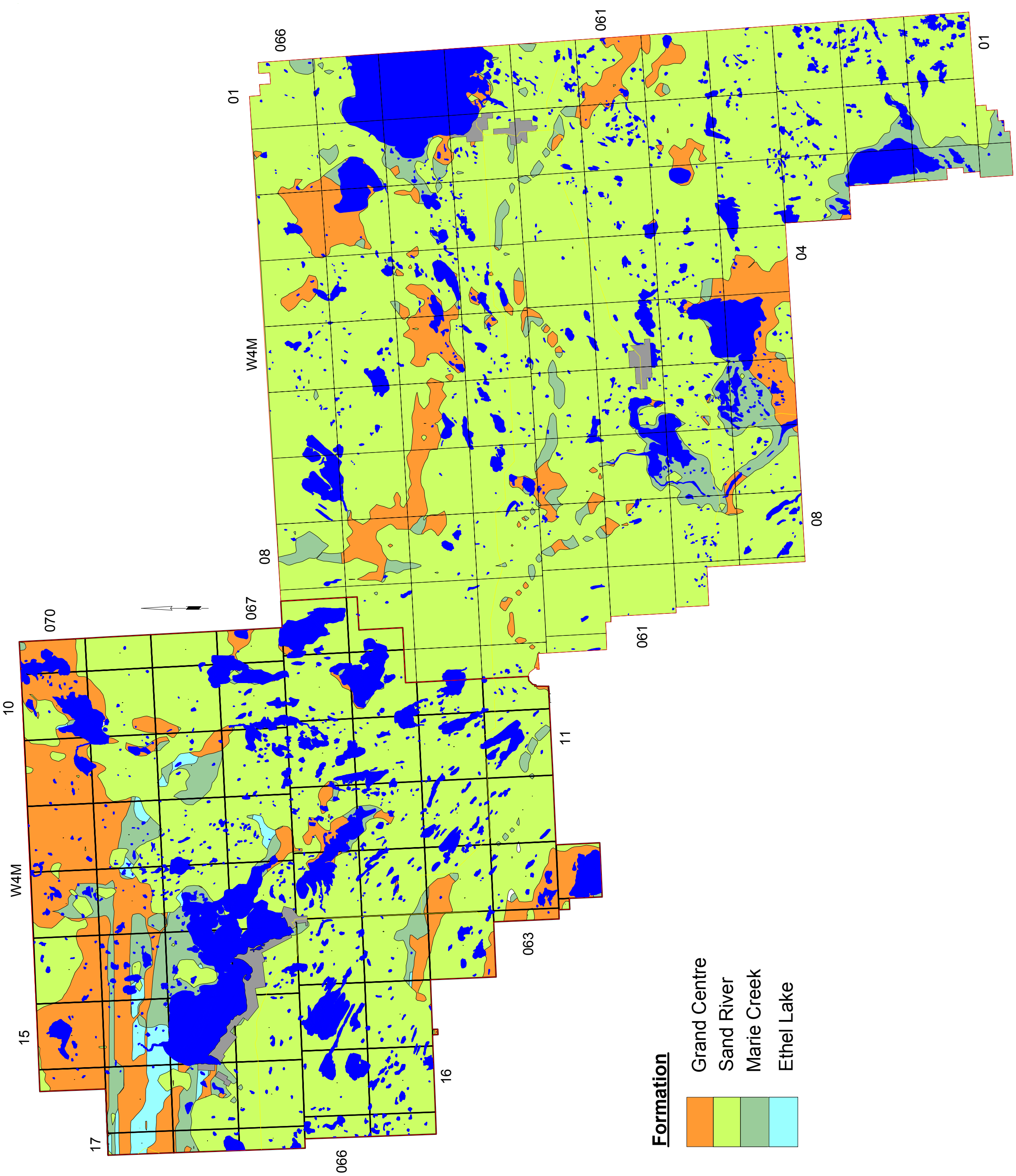
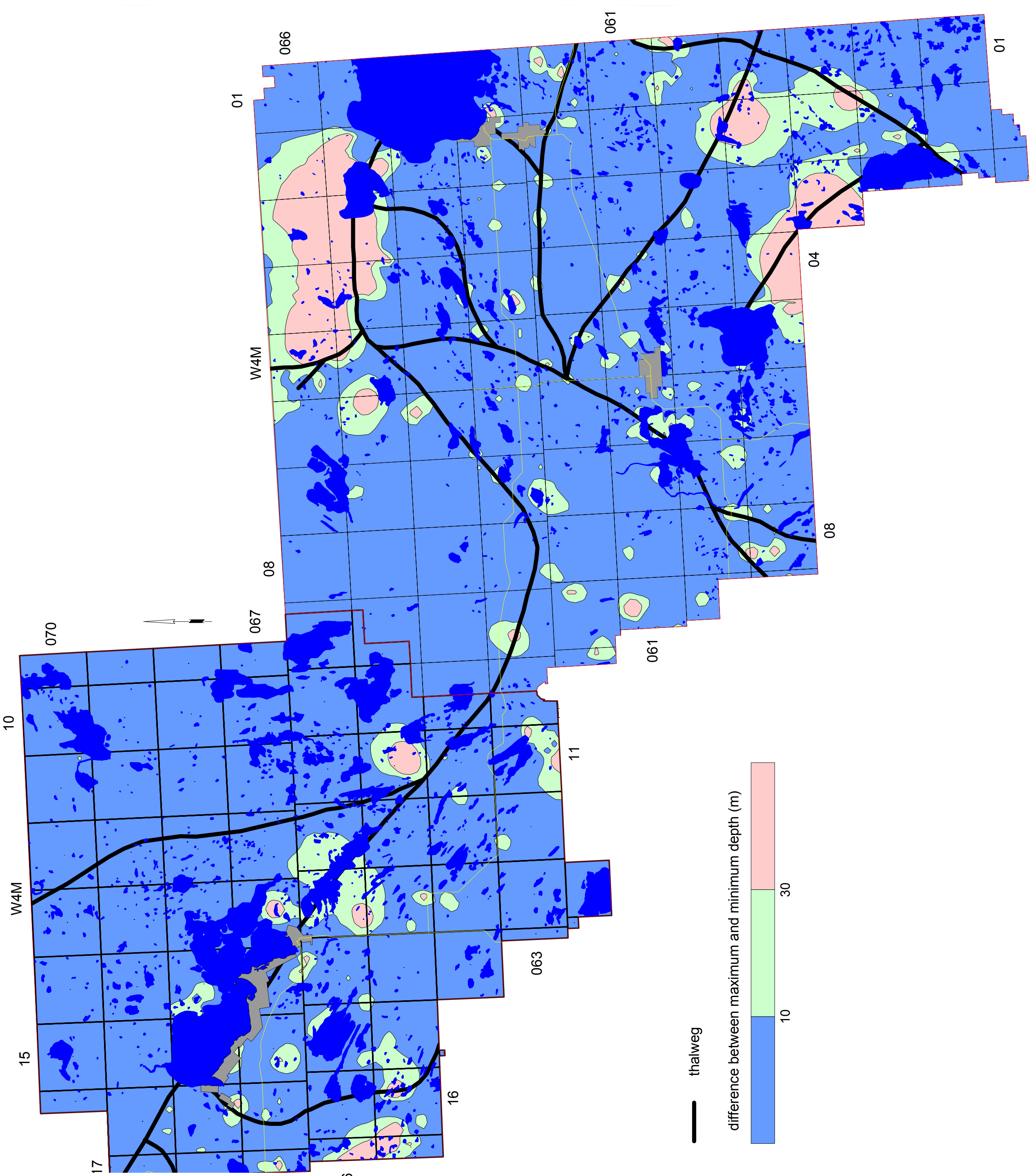
Bedrock Topography Map



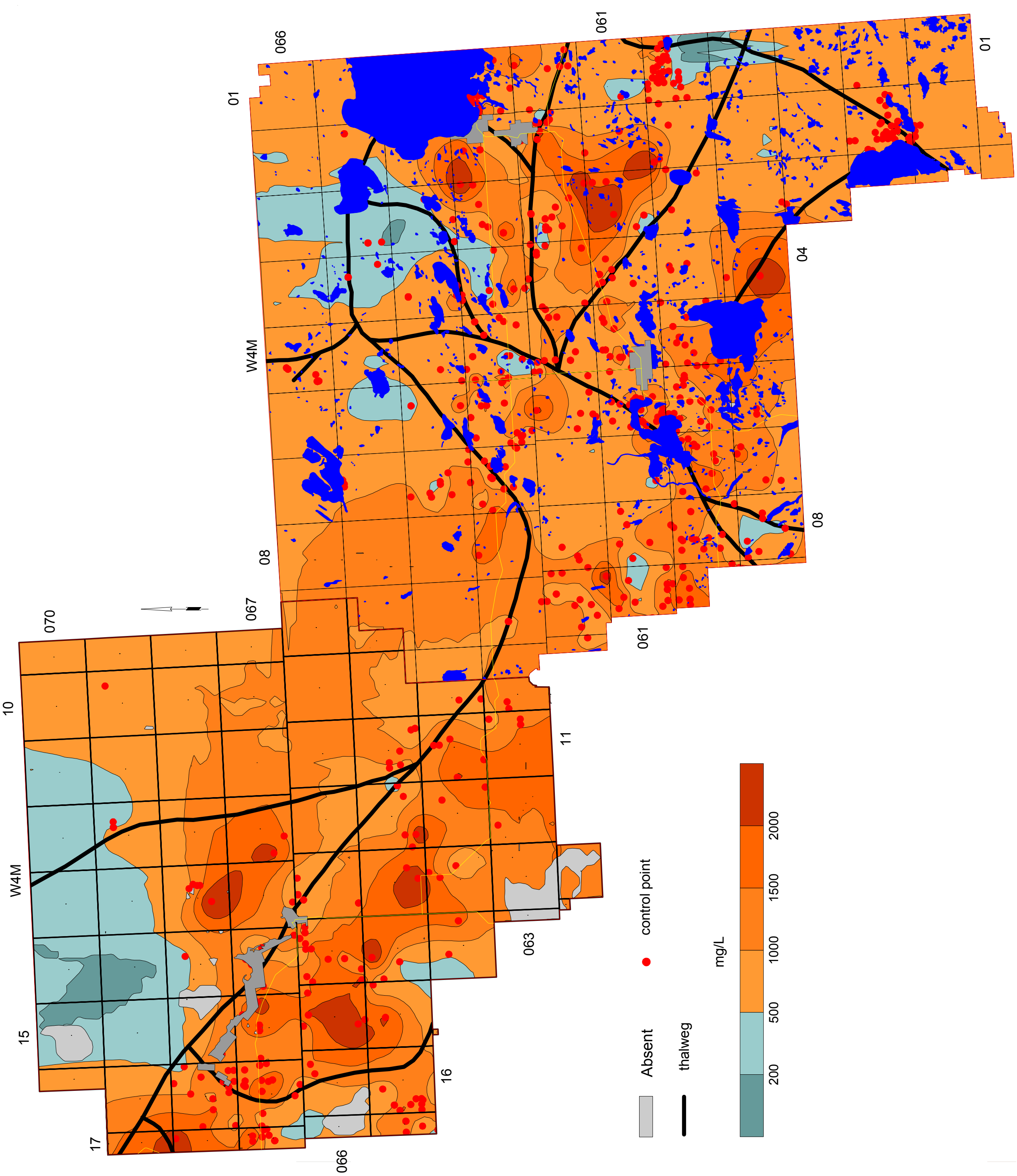
Surficial Geology Map



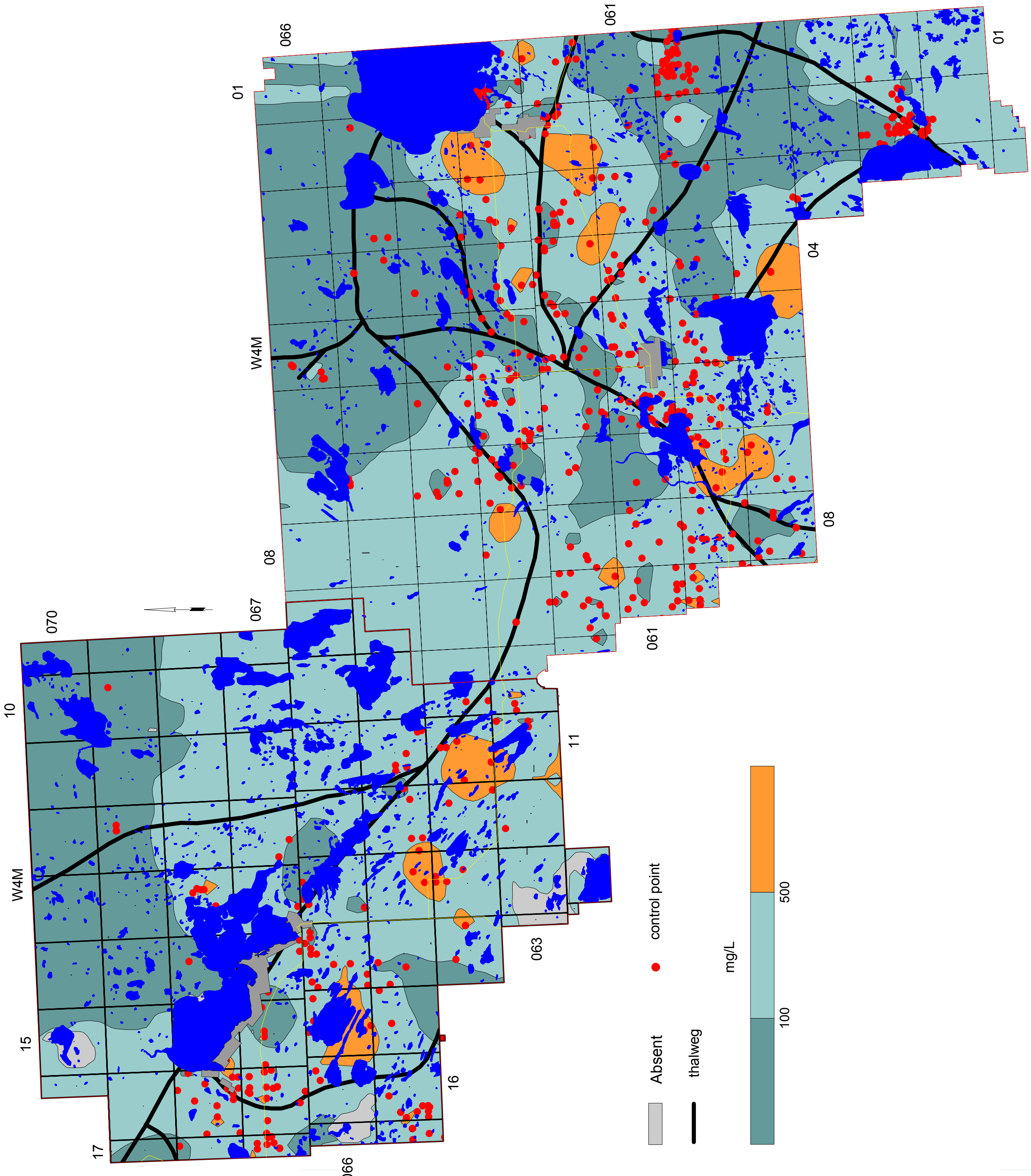
Depth of Existing Water Wells



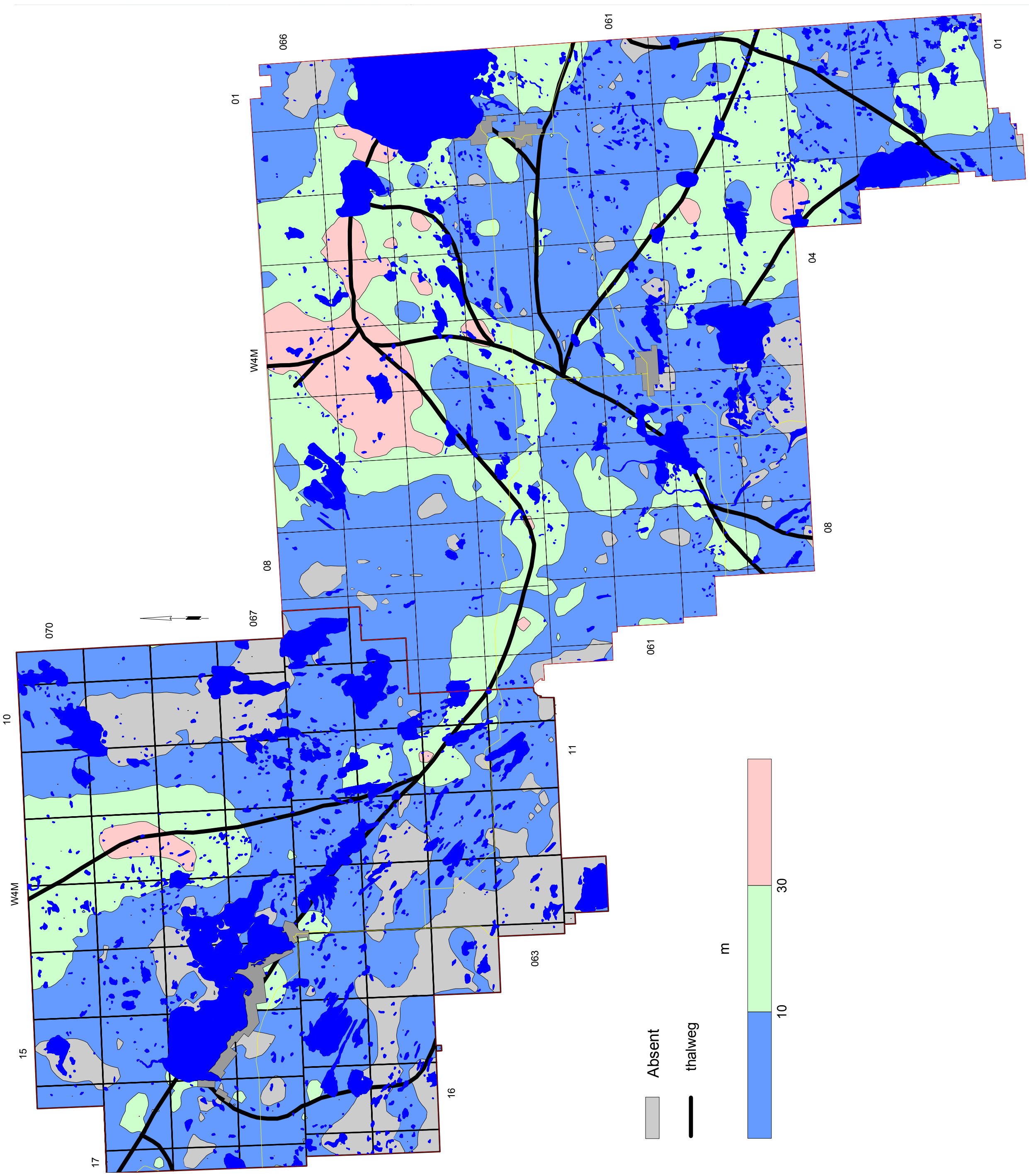
Total Dissolved Solids in Groundwater from Surficial Deposits



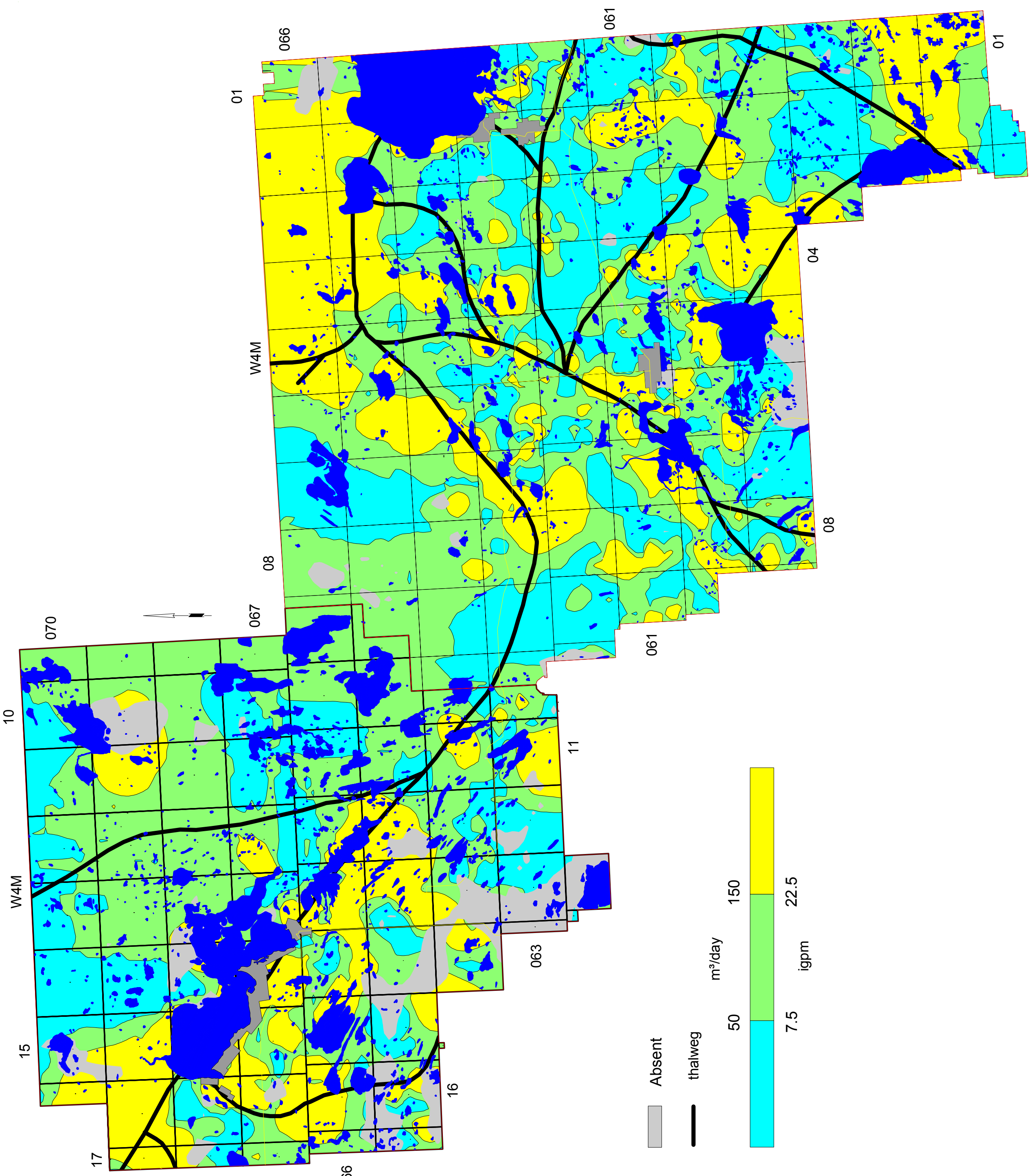
Sulfate in Groundwater from Surficial Deposits



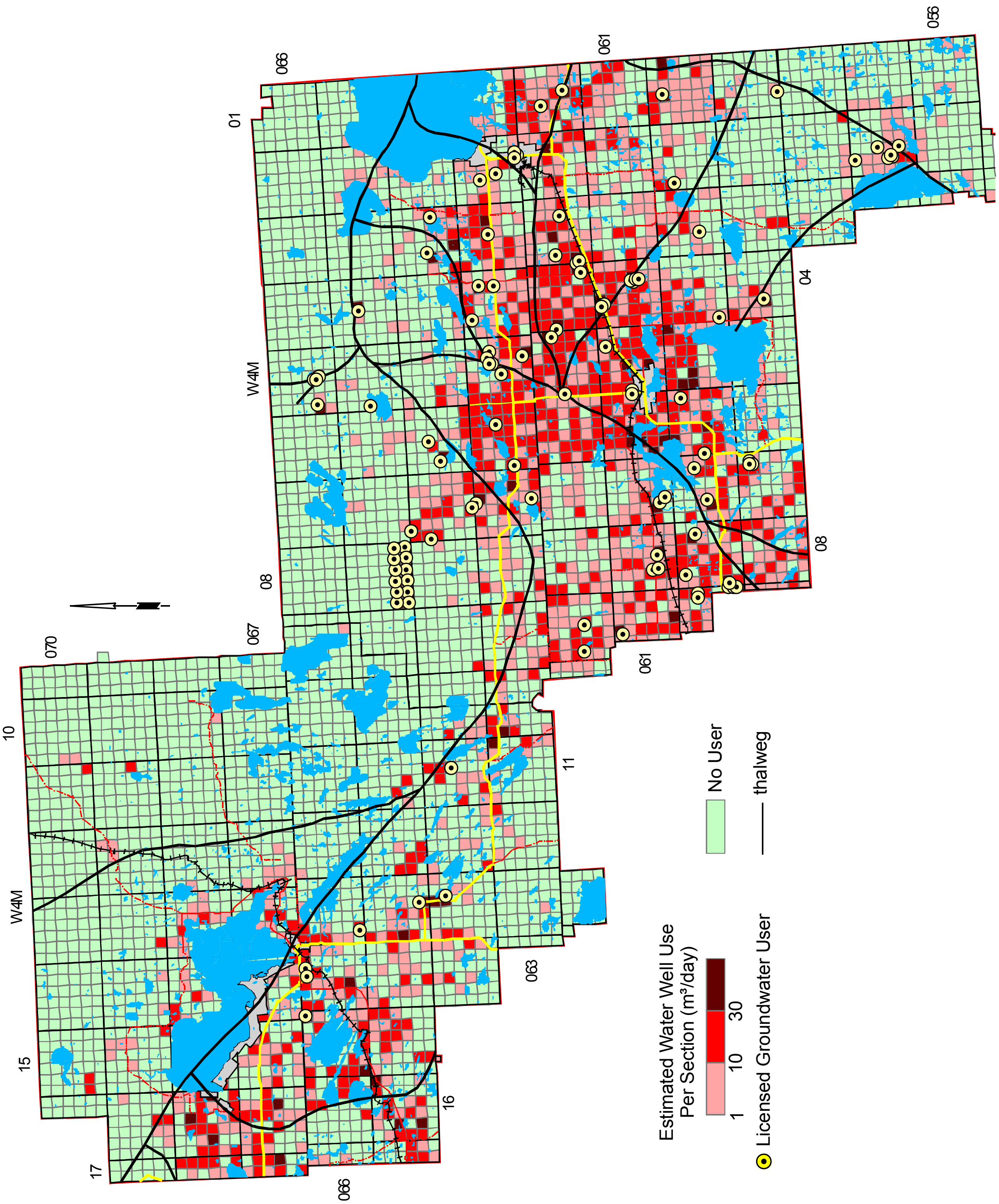
Thickness of Sand and Gravel Aquifer(s)



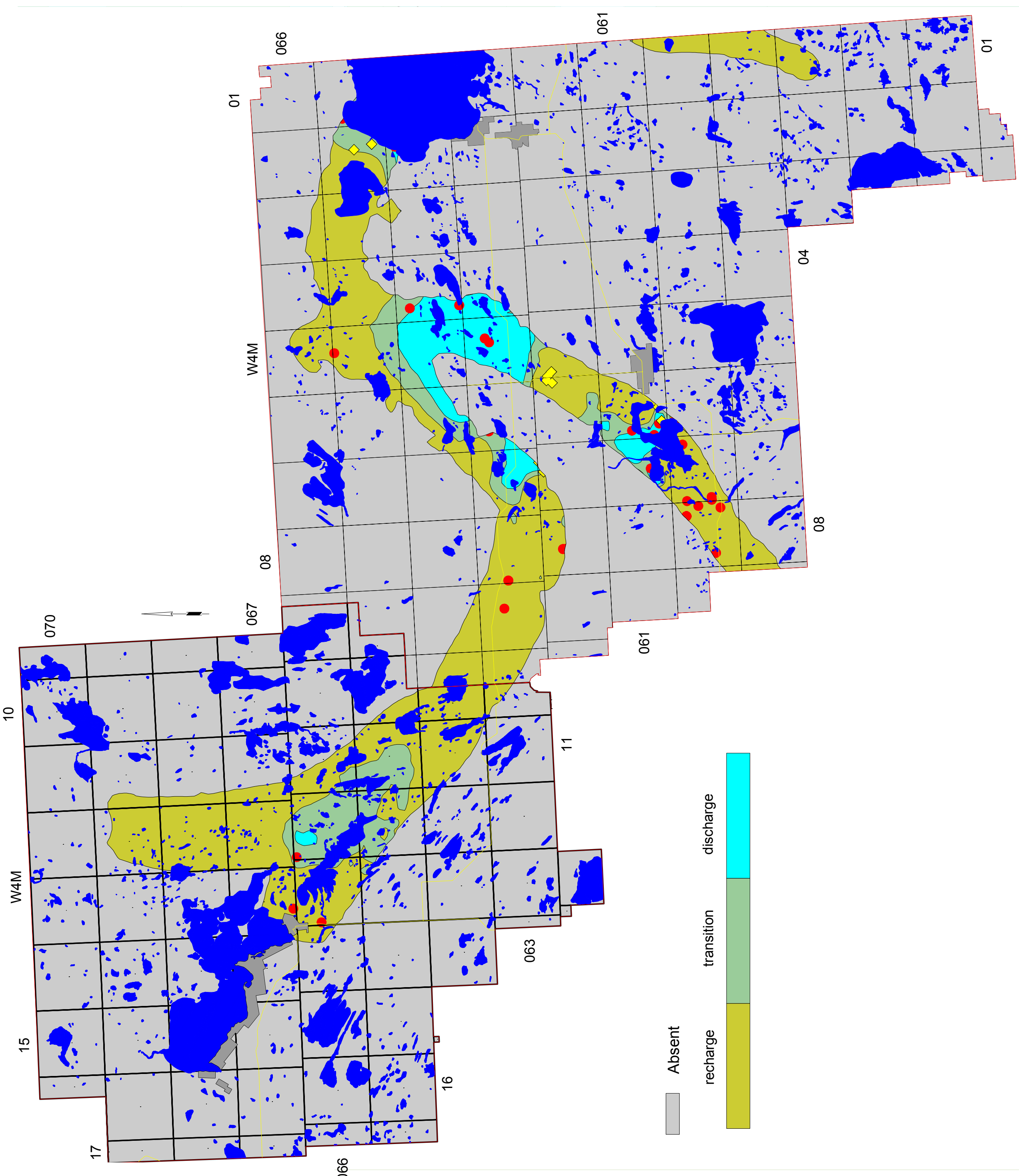
Apparent Yield in Sand and Gravel Aquifer(s)



Estimated Water Well Use Per Section



Recharge/Discharge Areas in Empress Aquifer – Unit 1



Changes in Water Levels in Sand and Gravel Aquifer