Cypress County

Part of the Missouri and South Saskatchewan River Basins
Parts of Tp 001 to 021, R 01 to 13, W4M
Regional Groundwater Assessment

Prepared for Cypress 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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The Association of Professional Engineers, Geologists and Geophysicists of Alberta

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Table of Contents

List of Figures

List of Tables

Appendices

Acknowledgements

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Mr. Terry Dash – PFRA

Mr. Ryan Davison – PFRA

Mr. Brian Whitson – Cypress County

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 Cypress 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 Cypress County prepared by Hydrogeological Consultants Ltd. (HCL) with financial and technical assistance from Prairie Farm Rehabilitation Administration (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] and the upper bedrock
- spatially identify the main aquifers
- describe the quantity and quality of the groundwater associated with each aquifer
- identify the hydraulic relationship between aquifers
- identify possible groundwater depletion areas associated with each upper bedrock 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 Cypress 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 Cypress 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.

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.

[3] See glossary

2. Introduction

2.1 Setting

Cypress County is situated in southeastern Alberta. The County is within the Missouri and South Saskatchewan River basins; the Bow River and the South Saskatchewan River form part of the County's western boundary and a part of the County's northern boundary is the South Saskatchewan River. The other County boundaries follow township or section lines. The area includes parts of the area bounded by township 001, range 13, W4M in the southwest and township 021, range 01, W4M in the northeast.

Regionally, the topographic surface varies between 550 and 1,500 metres above mean sea level (AMSL). The lowest elevations occur in the north central part of the County along the South Saskatchewan River Valley and the highest are in the Cypress Hills Provincial Park as shown on Figure 1 and page A-3.

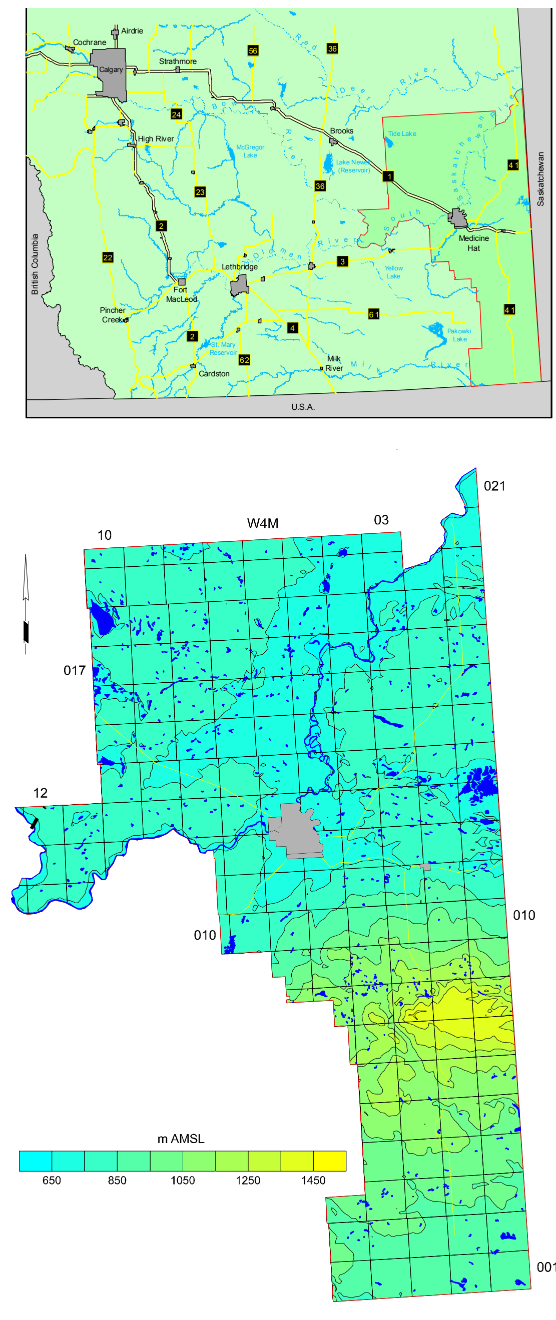

Figure 1. Index Map

2.2 Climate

Cypress County lies within the Bsk climate boundary. This classification is based on potential evapotranspiration[4] 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 Dry Mixed Grass and Mixed Grass region. At higher elevations in the Cypress Hills Provincial Park, the Montane Region[5] is present.

A Bsk climate is characterized by its moisture deficiency, where mean annual potential evapotranspiration exceeds the mean annual precipitation.

The mean annual precipitation averaged from four meteorological stations within the County measured 332 millimetres (mm), based on data from 1961 to 1993. The mean annual temperature averaged 4.6° C, with the mean monthly temperature reaching a high of 19.4° C in July, and dropping to a low of –11.9° C in January. The calculated annual potential evapotranspiration is 559 millimetres.

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4 See glossary
5 See glossary

2.3 Background Information

2.3.1 Number, Type and Depth of Water Wells

There are currently records for 3,348 water wells in the groundwater database for the County. Of the 3,348 water wells, 2,686 are for domestic/stock purposes. The remaining 662 water wells were completed for a variety of uses, including municipal, industrial, observation, irrigation, investigation, monitoring and dewatering. Based on a rural population of 5,683 (Phinney, 2001), there are 1.9 domestic/stock water wells per family of four. It is unknown how many of these water wells may still be active. Of the 2,598 domestic or stock water wells with a completed depth, 2,413 are completed at depths of less than 100 metres below ground level. Details for lithology[6] are available for 1,593 water wells.

2.3.2 Number of Water Wells in Surficial and Bedrock Aquifers

There are 891 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 891 water wells for which aquifers could be defined, 617 are completed in surficial aquifers, with 331 (54%) having a completion depth of less than 20 metres below ground level. Nearly 80% of the 331 water wells completed in surficial aquifers are bored water wells. The adjacent map shows that the water wells completed in the surficial deposits occur throughout the County, but mainly in the vicinity of linear bedrock lows and in the northeastern part of the County.

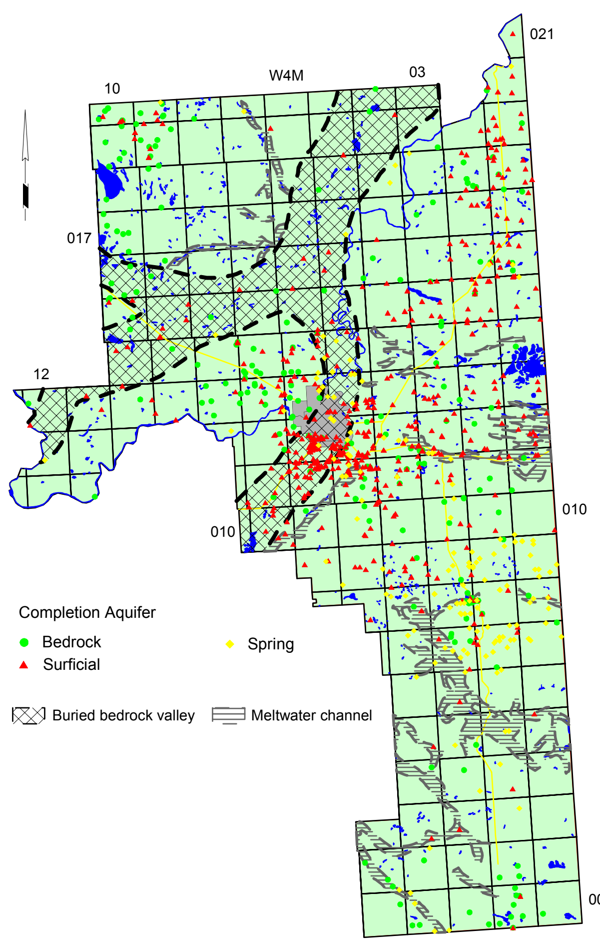

Figure 2. Location of Water Wells and Springs

The data for 274 water wells show that the top of the water well completion interval is below the bedrock surface, indicating that the bedrock water wells are completed in at least one bedrock aquifer. From Figure 2, it can be seen that water wells completed in bedrock aquifers occur throughout the County. Within the County, casing-diameter information is available for 264 of the 274 water wells completed below the top of bedrock. Of these 264 water wells, 98% have surface-casing diameters of less than 275 mm and these bedrock water wells have been mainly completed with either a perforated liner or as open hole; there are 55 bedrock water wells completed with a water well screen.

There are currently records for 167 springs in the groundwater database, including eight springs that were identified by Borneuf (1983). In the County, the spring locations appear to be mainly concentrated from townships 007 to 009 in the Cypress Hills area, and in the linear bedrock lows near Medicine Hat. Of the 106 available total dissolved solids (TDS) values for springs, 70% have TDS concentrations of more than 500

6 See glossary

milligrams per litre (mg/L). The remaining 30% having a TDS concentration of less than 500 mg/L are mainly on the north flank of the Cypress Hills (see CD-ROM). Of the 106 available total hardness values, 85% have total hardness concentrations of less than 500 mg/L. The 12 available flow rates for springs within the County range from 4.8 to 228 litres per minute (lpm). The one available flow rate for a spring in the Cypress Hills is 228 lpm (Borneuf, 1983).

2.3.3 Casing Diameter and Type

Data for casing diameters are available for 1,275 water wells, with 706 (55%) indicated as having a diameter of less than 275 mm and 569 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 1,275 water wells that have been designated as either bored or drilled water wells based on casing diameter, another 860 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 860 water wells having no casing size, 417 are drilled water wells and 443 are bored water wells. The locations of the 1,123 drilled water wells and the 1,012 bored or dug water wells are shown on Figure 3. One area in particular where data are limited is within the Canadian Forces Base (CFB) Suffield borders (see overlay in back of report).

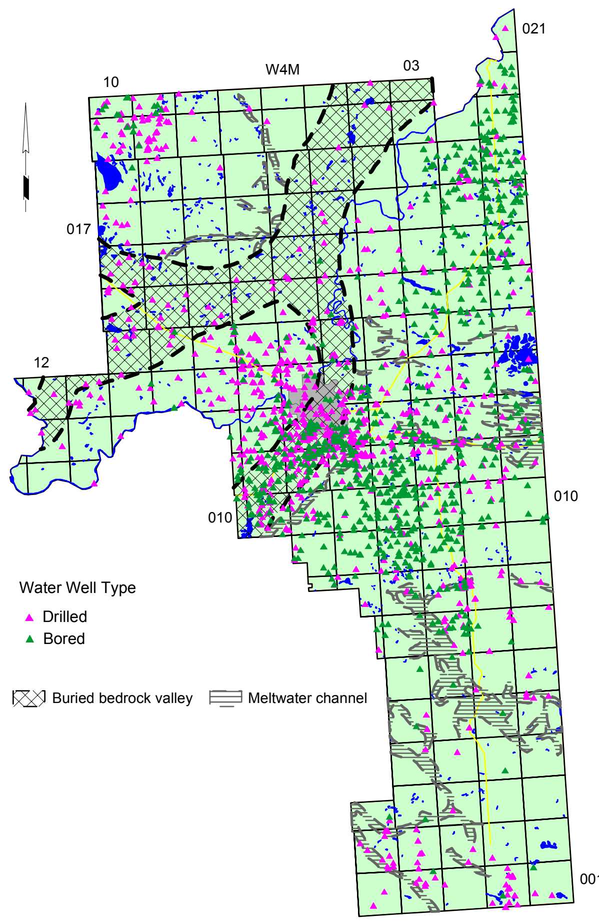

Figure 3. Location of Water Well Type

Figure 3 shows that bored water wells occur in groupings in the same areas as drilled water wells, with the exception being the buried bedrock valleys north and west of Medicine Hat and in the southern part of the County. Bored water well locations appear to be mainly focused in the buried bedrock valley south of Medicine Hat, and in the area southeast of Medicine Hat and in the northeastern part of the County. Most of the bored water wells are located in areas of generally lower groundwater development potential (see Figure 8).

In the area southeast of Medicine Hat, from townships 009 to 011, ranges 03 to 04, W4M, there are 61 drilled water wells and 219 bored water wells with a drilled depth. The average drilled depth for the 61 drilled water wells is 70 metres and for the 219 bored water wells is 10 metres.

Before 1975, an average of 46% of all water wells completed in the County were bored, with the remainder being drilled water wells. After 1975, an average of only 10% of all water wells completed in the County were bored.

In the County, steel, galvanized steel and plastic surface casing materials have been used in 99% of the drilled water wells over the last 40 years. Until the early 1970s, the type of surface casing used in drilled water wells was mainly undocumented. Steel casing was in use in the 1950s and is still used in 34% of the water wells being drilled in the County in the late 1990s.

Unlike in other areas of Alberta, galvanized steel surface casing was only in use in the County prior to 1955 and only in 4% of the drilled water wells. Plastic casing was first used in April 1973. The percentage of water wells with plastic casing has increased and by the late 1990s, plastic casing was used in 65% of the drilled water wells in the County.

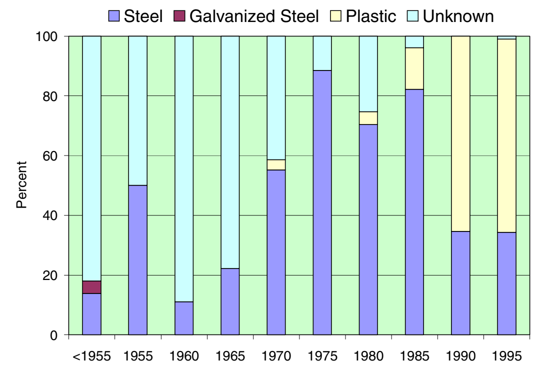

Figure 4. Surface Casing Types Used in Drilled Water Wells

2.3.4 Dry Water Test Holes

In the County, there are 4,609 records in the groundwater database. Of these 4,609 records, 215 (less than 5% of the total number of test holes drilled) are indicated as being dry or abandoned with “insufficient water”. Of the 215 “dry” test hole records, 127 were drilled or completed in the surficial deposits and 88 were in the bedrock. Also included in these dry test holes is any record that includes comments that state the water well goes dry in dry years.

2.3.5 Requirements for Licensing

Water wells used for household needs in excess of 1,250 cubic metres per year and all other groundwater use must be licensed. The only groundwater users that do not need licensing are (1) household use of up to 1,250 m^3/year and (2) groundwater with total dissolved solids in excess of 4,000 mg/L. At the end of 1999, 78 groundwater allocations were licensed in the County. Of the 78 licensed groundwater users, 41 could be linked to the Alberta Environment (AENV) groundwater database. Of the 78 licensed groundwater users, 36 are for agricultural purposes, 21 are for municipal purposes, 14 are for commercial purposes, and the remaining seven are for recreation, irrigation, industrial or exploration purposes. The total maximum authorized diversion from the water wells associated with these licences is 20,389 cubic metres per day (m^3/day), although actual use could be less. Of the 20,389 m^3/day, 13,749 m^3/day (67%) is authorized for commercial purposes from 13 water wells, as shown below in Table 1. Eighty percent of the 13,749 m^3/day is licensed to the City of Medicine Hat. Of the remaining 6,640 m^3/day, 27% is allotted for municipal use, and 6% is allotted for agricultural, irrigation and recreation use. A figure showing the locations of the licensed users is in Appendix A (page A-7) and on the CD-ROM.

Table 1 on the following page shows a breakdown of the 78 licensed groundwater allocations by the aquifer in which the water well is completed. The largest total licensed allocations are in the Lower Sand and Gravel Aquifer. Of the 18,944 m^3/day licensed groundwater use in the Lower Sand and Gravel Aquifer, 70% of the groundwater use is from water wells located at Police Point in townships 012 and 013, range 05, W4M along the South Saskatchewan River.

Aquifer **	No. of Diversions	Licensed Groundwater Users* (m³/day) Agricultural	Municipal	Commercial	Irrigation	Recreation	Industrial	Exploration	Total	Percentage
Upper Sand and Gravel	8	17	118	34	34	0	3.4	0.2	206	1
Lower Sand and Gravel	32	200	4,576	13,593	385	189	0	0	18,944	93
Horseshoe Canyon	3	0	328	0	0	0	0	0	328	2
Bearpaw	1	0	0	0	0	0	0	0	0	0
Oldman	11	68	85	0	0	0	0	0	152	1
Foremost	2	20	0	54	0	0	0	0	74	0
Milk River	4	81	0	0	0	0	0	0	81	0
Unknown	17	180	356	68	0	0	0	0	604	3
Total	78	566	5,463	13,749	419	189	3.4	0.2	20,389	100
Percentage		3	27	67	2	1	0	0	100	

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

Table 1. Licensed Groundwater Diversions

Based on the 1996 Agriculture Census, the calculated water requirement for livestock for the County is in the order of 13,767 m³/day. Of the 13,767 m³/day average calculated livestock use, AENV has licensed a groundwater diversion of 566 m³/day (4%) and a surface-water consumptive diversion of 5,504 m³/day (40%). The remaining 56% of the calculated livestock use would have to be from unlicensed sources.

2.3.6 Groundwater Chemistry and Base of Groundwater Protection

Groundwaters from the surficial deposits can be expected to be chemically hard, with a high dissolved iron content. High nitrate + nitrite (as N) concentrations were evident in 7% of the available chemical data for the surficial aquifers and 2% of the available chemical data for the upper bedrock aquifer(s); a plot of nitrate + nitrite (as N) in surficial aquifers is on the accompanying CD-ROM. The TDS concentrations in the groundwaters from the upper bedrock in the County range from less than 500 to more than 3,000 mg/L (page A-34). Groundwaters from the bedrock aquifers frequently are chemically soft, with generally low concentrations of dissolved iron. The chemically soft groundwater is high in concentrations of sodium. Less than ten percent of the chemical analyses indicate a fluoride concentration above 1.5 mg/L, with most of the exceedances occurring in the southern and east-central part of the County (see CD-ROM).

The minimum, maximum and median[7] concentrations of TDS, sodium, sulfate, chloride and fluoride in the groundwaters from water wells completed in the upper bedrock in the County have been compared to the Guidelines for Canadian Drinking Water Quality (GCDWQ) in Table 2. Of the five constituents compared to the GCDWQ, median values of TDS and sodium concentrations exceed the guidelines; maximum values of all five constituents exceed the guidelines.

Constituent	Range for County in mg/L Minimum	Maximum	Median	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	26	26,646	1514	500
Sodium	1	5,761	380	200
Sulfate	0	11,861	426	500
Chloride	0	9,615	26	250
Fluoride	0	6	0.4	1.5

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Fluoride, which is for Maximum Acceptable Concentration (MAC)

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

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

The maximum TDS and sulfate values shown in the adjacent table are from an industrial water well drilled in NE 17-012-05 W4M to a depth of 121 metres and completed in the Foremost Aquifer below the Base of Groundwater Protection.

[7] see glossary

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[8] 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 100 metres to more than 800 metres below ground level, as shown on Figure 5 and on each cross-section presented in Appendix A and on the CD-ROM. The main area where the depth to Base of Groundwater Protection is less than 100 metres is in the Buried Medicine Hat Valley north of Medicine Hat.

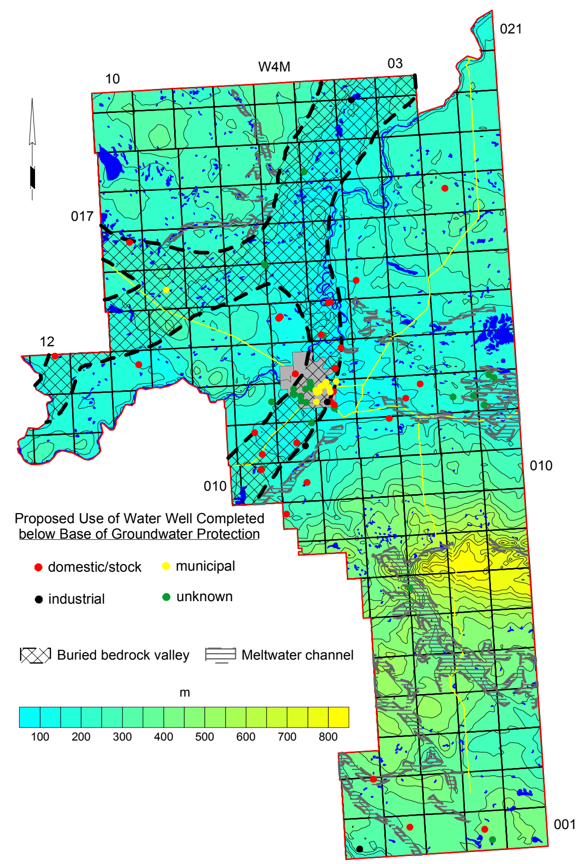

Figure 5. Depth to Base of Groundwater Protection (after EUB, 1995)

Of the 3,476 water wells with completed depth data, 68 are completed below the Base of Groundwater Protection. These 68 water wells identified on the CD-ROM have been posted on the adjacent figure and show that they are mainly completed in linear bedrock lows. Of the 11 water wells that were completed for municipal purposes, ten were for the City of Medicine Hat drilled to a depth of approximately 300 metres below ground surface in the early 1900s; none are currently licensed for groundwater diversion by AENV.

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 16 AENV-operated observation water wells within the County. Of the 16 AENV-operated observation water wells, only five are currently active. 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.

However, even with the available sources of data, the number of water-level data points relative to the size of the County is too few to provide a reliable groundwater budget (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.

8 See glossary

3. Terms

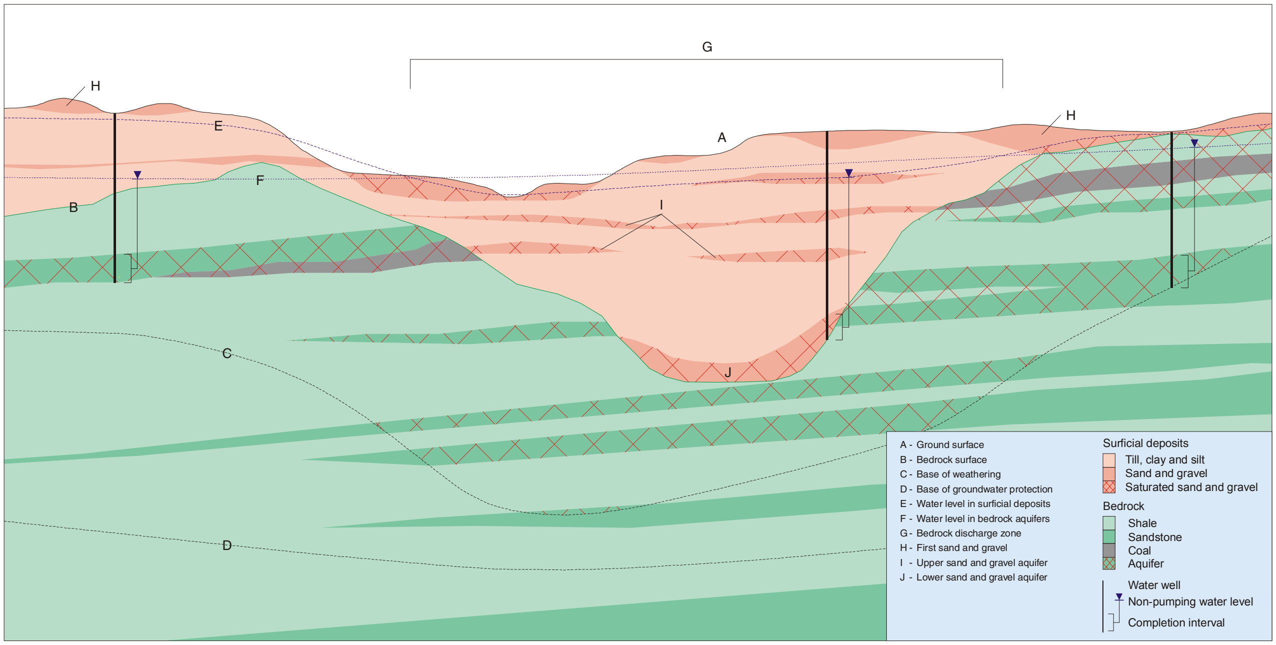

Figure 6. Generalized Cross-Section (for terminology only)

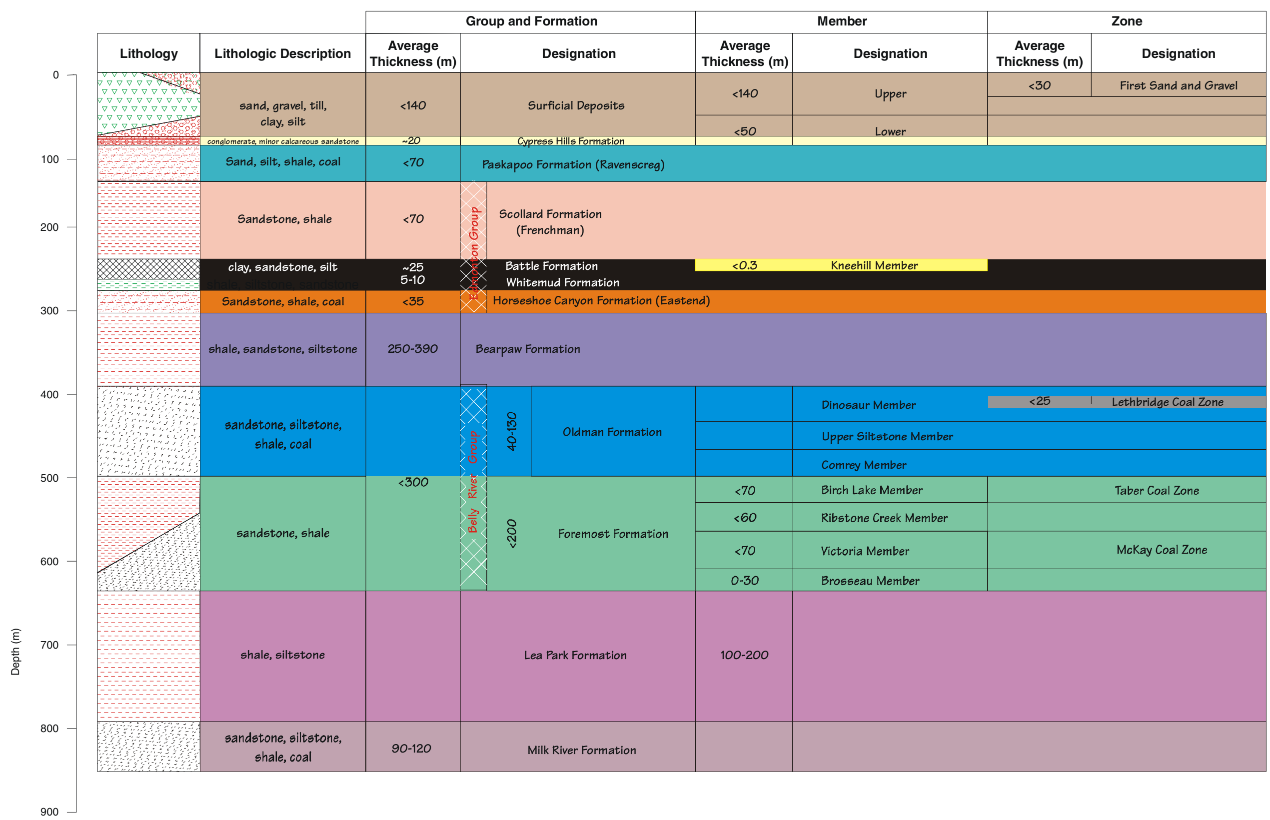

Figure 7. Geologic Column

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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. This means that a record for the SW ¼ of section 34, township 014, range 09, W4M, would have a horizontal coordinate with an Easting of 273,760 metres and a Northing of 5,566,452 metres, the centre of the quarter section. If the water well has been repositioned by 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 possible, determinations are made from individual records for the following:

1) depth to bedrock
2) total thickness of sand and gravel below 15 metres
3) total thickness of saturated sand and gravel
4) depth to the top and bottom of completion intervals.

Also, where sufficient information is available, values for apparent transmissivity[9] and apparent yield[10] 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 maps covering the County were published in 1976 (Borneuf, 1976) and 1977 (Stevenson and Borneuf, 1977), 864 values for apparent transmissivity and 485 values for apparent yield have been added to the groundwater database. With the addition of the apparent yield values, a hydrogeological map has been prepared (Figure 8) to help illustrate the general groundwater availability across the County. 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.

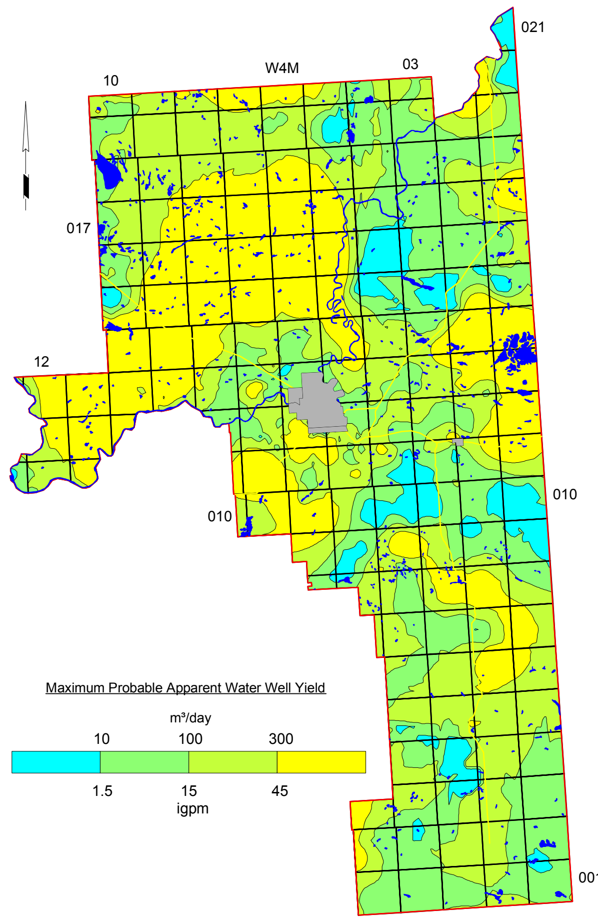

Figure 8. Hydrogeological Map

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

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9 For definitions of Transmissivity, see glossary
10 For definitions of Yield, see glossary

4.2 Spatial Distribution of Aquifers

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

1) lithologs provided by the water well drillers
2) geophysical logs from structure test holes
3) geophysical logs for wells drilled by the oil and gas industry
4) 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. One area in particular where data are limited is within the Canadian Forces Base (CFB) Suffield borders (see overlay in back of report).

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 if neither aquifer nor effective transmissivity values are available. The total dissolved solids, sulfate and chloride concentrations from the chemical analysis of the groundwater are also assigned to applicable aquifers. In addition, chemical parameters of nitrate + nitrite (as N) are assigned to surficial aquifers and fluoride is assigned to upper bedrock aquifer(s). 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 001 to 021, ranges 01 to 13, 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. Eight cross-sections are presented in Appendix A of this report and as poster-size drawings forwarded with this report; only two (D-D’ and G-G’) 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 XP Professional
- Surfer 7.0

5. Aquifers

5.1 Background

An aquifer is a permeable rock that is saturated. If the non-pumping water level is above the top of the rock unit, this type of aquifer is an artesian aquifer. If the rock unit is not entirely saturated and the water level is below the top of the unit, this type of aquifer is a water-table aquifer. These types of aquifers occur in one of two general geological settings in the County. The first geological setting includes the sediments that overlie the bedrock surface. In this report, these 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 50 metres thick, except in areas of linear bedrock lows where the thickness of the surficial deposits can exceed 100 metres. The Buried Lethbridge Valley and the Buried Medicine Hat Valley are the main linear bedrock lows in the County. The west-east cross-section D-D', Figure 9 shown below, passes across the Buried Medicine Hat Valley and shows the surficial deposits being less than 80 metres thick. Surficial deposits are mainly absent on top of the Cypress Hills because this area escaped glaciation by both Laurentide and Cordilleran ice. The Cypress Hills were subject to permafrost and elevated groundwater tables during some of the glaciations and to wind action and loess deposition during glacier retreat. As a result, their original surfaces and soils have been strongly modified and contorted (Stalker and Vincent, 1993).

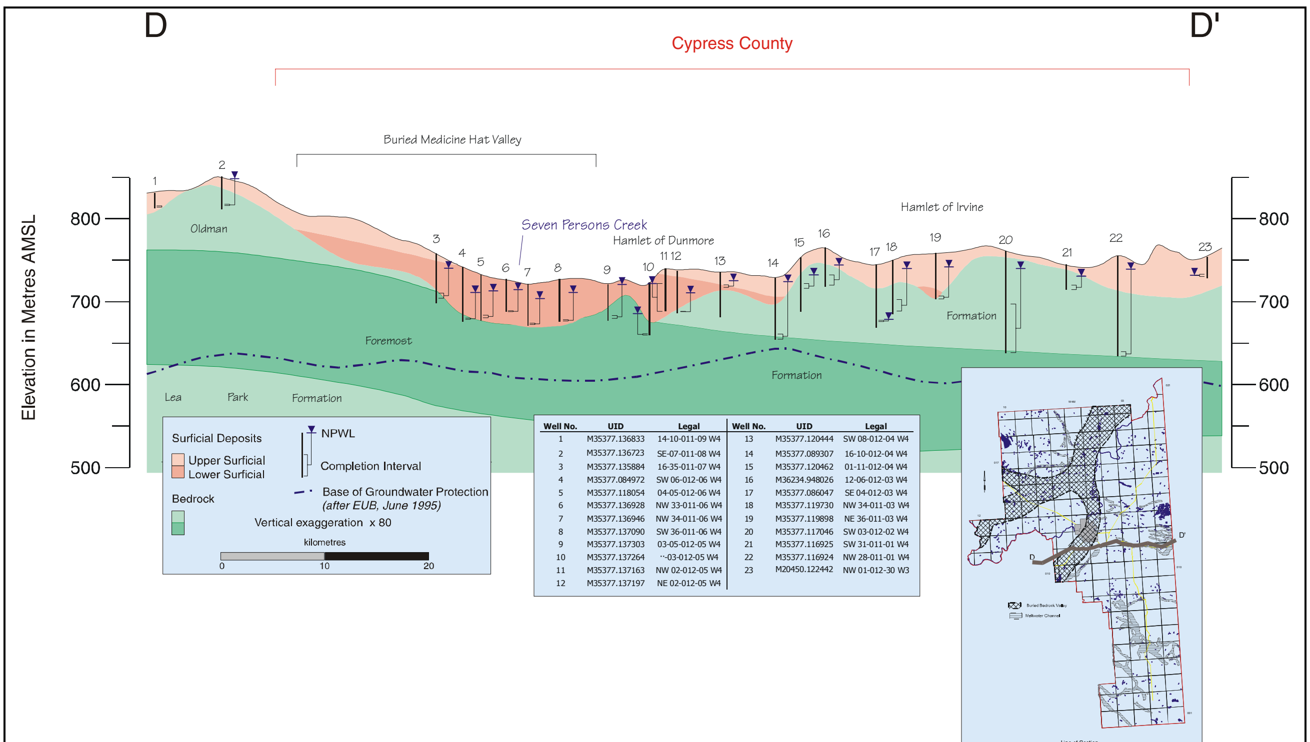


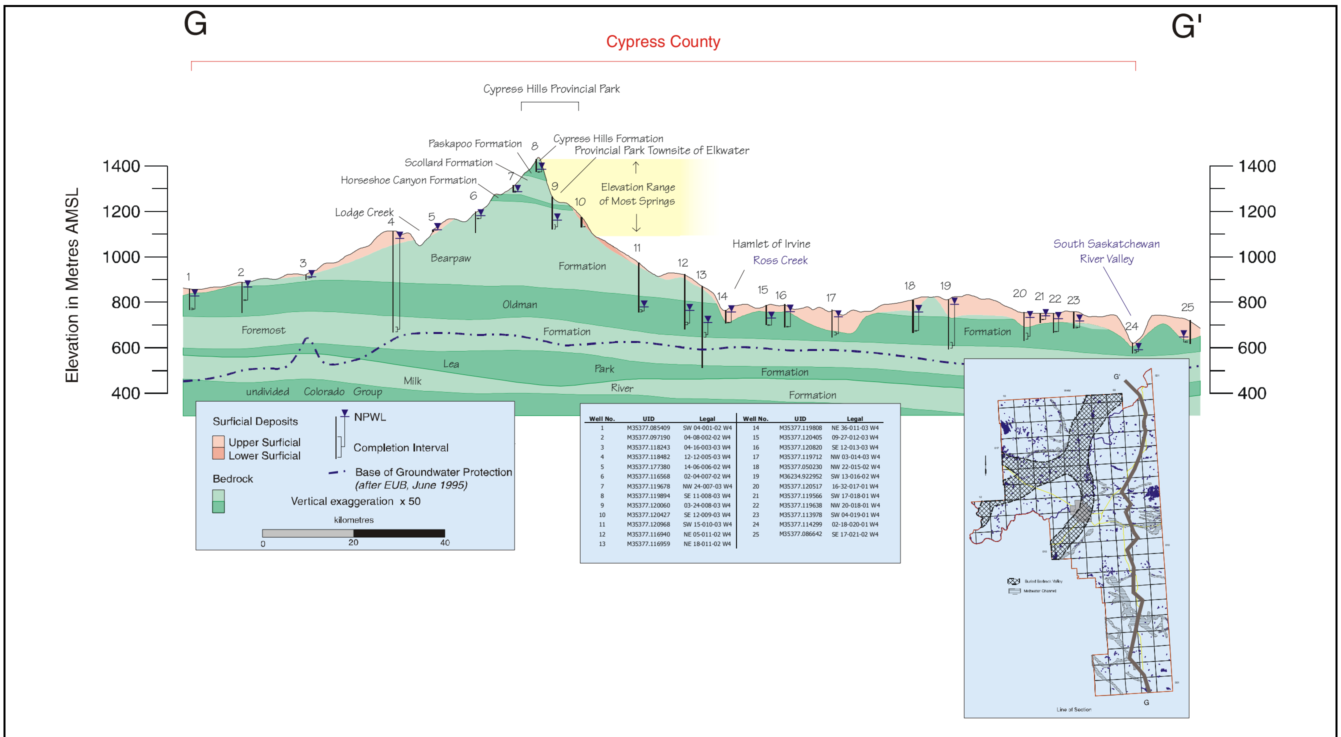
Figure 9. Cross-Section D - D'

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 592 of the 617 water wells completed in the surficial deposits; 50 percent of these 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 Cypress Hills, Paskapoo, Scollard, Battle/Whitemud, Horseshoe Canyon, Bearpaw, Oldman and Foremost formations. Cross-section G-G' (Figure 10) shows that the aquifers in which water wells are completed are mainly within 200 metres of the ground surface. Some of this bedrock contains saturated rocks that are permeable enough to transmit groundwater for a specific need. Water wells completed in bedrock aquifers usually do not require water well screens, although some of the sandstones may be friable[11] and water well screens are a necessity. The groundwater from the bedrock aquifers is usually chemically soft.



Well No.	UID	Legal	Well No.	UID	Legal
1	M35377.085409	SW 04-001-02 W4	14	M35377.119808	NE 36-011-03 W4
2	M35377.097190	04-08-002-02 W4	15	M35377.120405	09-27-012-03 W4
3	M35377.118243	04-16-003-03 W4	16	M35377.120820	SE 12-013-03 W4
4	M35377.118482	12-12-005-03 W4	17	M35377.119712	NW 03-014-03 W4
5	M35377.177380	14-06-006-02 W4	18	M35377.050230	NW 22-015-02 W4
6	M35377.116568	02-04-007-02 W4	19	M36234.922952	SW 13-016-02 W4
7	M35377.119678	NW 24-007-03 W4	20	M35377.120517	16-32-017-01 W4
8	M35377.119894	SE 11-008-03 W4	21	M35377.119566	SW 17-018-01 W4
9	M35377.120060	03-24-008-03 W4	22	M35377.119638	NW 20-018-01 W4
10	M35377.120427	SE 12-009-03 W4	23	M35377.113978	SW 04-019-01 W4
11	M35377.120968	SW 15-010-03 W4	24	M35377.114299	02-18-020-01 W4
12	M35377.116940	NE 05-011-02 W4	25	M35377.086642	SE 17-021-02 W4
13	M35377.116959	NE 18-011-02 W4			

Figure 10. Cross-Section G - G'

In most of the area, the middle of the Foremost Formation coincides with the Base of Groundwater Protection. In some areas, the Base of Groundwater Protection extends below the Milk River Formation. A map showing the depth to the Base of Groundwater Protection is given on page 8 of this report, in Appendix A, and on the CD-ROM.

[11] See glossary

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[12] and lacustrine[13] deposits. The lacustrine deposits include clay, silt and fine-grained sand. The *upper surficial deposits* include the more traditional glacial deposits of till[14] and meltwater deposits. In the County, pre-glacial materials are expected to be mainly present in association with the buried bedrock valleys. The numerous glacial meltwater channels are primarily in the southern half of the County.

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 mainly 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 9. 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.

Over the majority of the County, the surficial deposits are less than 50 metres thick, and on Cypress Hills are nearly absent (page A-21). 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 100 metres. The main linear bedrock lows in the County are southwest-northeast-trending that have been designated as the Buried Lethbridge Valley and the Buried Medicine Hat Valley. The Buried Medicine Hat Valley is a tributary valley to the Buried Lethbridge Valley, as shown on Figure 11.

The Buried Lethbridge Valley is present in the northwestern part of the County, and mainly parallels the present-day South Saskatchewan River, north of the City of Medicine Hat. The Valley is nine to twelve kilometres wide within the County, with local bedrock relief being up to 100 metres. Sand and gravel deposits can be expected in association with this bedrock low, with the thickness of the sand and gravel deposits expected to be mainly less than 30 metres.

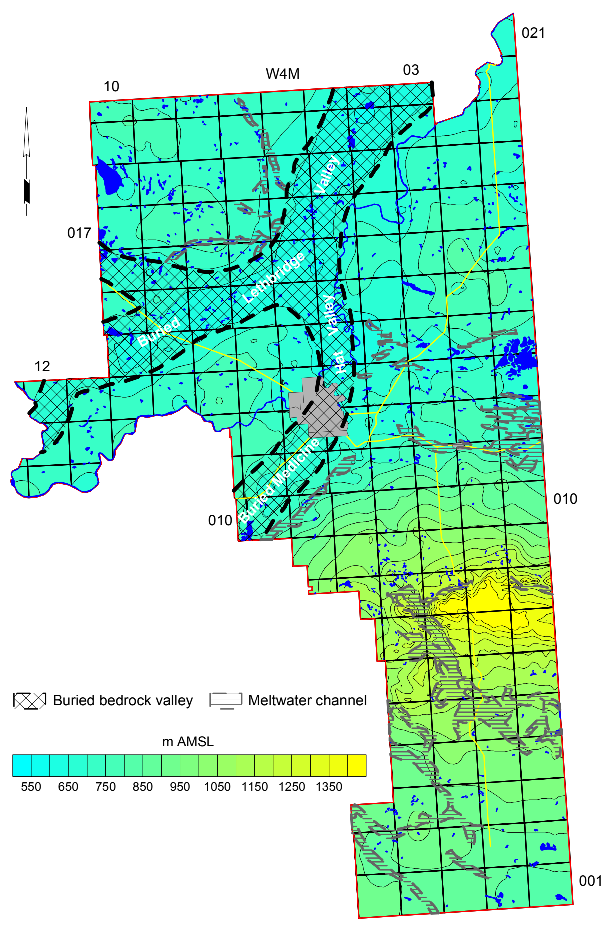


Figure 11. Bedrock Topography

12 See glossary
13 See glossary
14 See glossary

The Buried Medicine Hat Valley is present in the north-central part of the County, and mainly parallels the stretch of present-day Seven Persons Creek between Seven Persons and Medicine Hat. The Valley is mainly less than nine 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 thickness of the sand and gravel deposits being mainly less than ten metres.

The lower surficial deposits are composed mostly of fluvial and lacustrine deposits. Lower surficial deposits occur mainly in the linear bedrock lows and in the southern part of the County. The total thickness of the lower surficial deposits is mainly less than 30 metres, but can be more than 50 metres in the buried bedrock valleys and in the southwestern part of the County. The lowest part of the lower surficial deposits includes pre-glacial sand and gravel deposits. These deposits would generally be expected to directly overlie the bedrock surface in the buried bedrock valleys. The lowest sand and gravel deposits are of fluvial origin, are usually less than five metres thick and may be discontinuous.

In the County, there are a number of linear bedrock lows that trend mainly northwest to southeast and are indicated as being of meltwater origin. Because sediments associated with the lower surficial deposits are indicated as being present in many of these linear bedrock lows, it is possible that the bedrock lows were originally tributaries to the buried bedrock valleys as shown in the bedrock topography map on Figure 11.

The upper surficial deposits are either directly or indirectly a result of glacial activity. The deposits include till, with minor sand and gravel deposits of meltwater origin, which are expected to occur mainly as isolated pockets. 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 major meltwater channels in the County have been outlined by Shetsen (1987). The thickness of the upper surficial deposits is mainly less than ten metres, but can be more than 30 metres in the Buried Lethridge Valley and in association with some meltwater channels. Upper surficial deposits are mainly absent from the Buried Medicine Hat Valley (see CD-ROM).

Sand and gravel deposits can occur throughout the surficial deposits. The total thickness of sand and gravel deposits is generally less than ten metres but can be more than 30 metres in association with the Buried Lethbridge Valley.

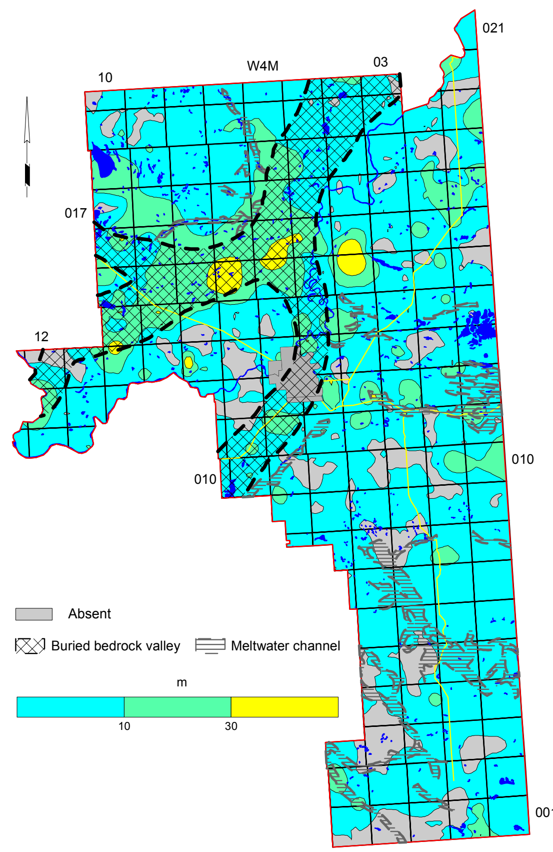


Figure 12. Thickness of Sand and Gravel Deposits

The combined thickness of all sand and gravel deposits has been determined as a function of the total thickness of the surficial deposits (Figure 12). Over approximately 20% of the County where sand and gravel deposits are present, the sand and gravel deposits are more than 30% of the total thickness of the surficial deposits (page A-24). 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 the buried bedrock valleys and meltwater channels and in the northeastern part of the County.

5.2.2 Sand and Gravel Aquifer(s)

One source of groundwater in the County includes aquifers in the surficial deposits. Since the sand and gravel aquifer(s) are not everywhere, the actual aquifer that is developed at a given location is usually dictated by the aquifer that is present. In the County, the thickness of the sand and gravel aquifer(s) is generally less than five metres, but can be more than 30 metres in the vicinity of the buried bedrock lows (page A-25).

From the present hydrogeological analysis, 2,053 water wells are completed in aquifers in the surficial deposits. Of the 2,053 water wells, 1,154 are completed in aquifers in the upper surficial deposits and 899 are completed in aquifers in the lower surficial deposits. This number of water wells is more than three times the number (617) determined to be completed in aquifers in the surficial deposits, based on lithologies given on the water well drilling reports. The larger number is obtained by comparing the elevation of the reported depth of a water well to the elevation of the bedrock surface at the same location. For example, if only the depth of a water well is known, the elevation of the completed depth can be calculated. If the elevation of the completed depth is above the elevation of the bedrock surface determined from the gridded bedrock topographic surface at the same location, then the water well is considered to be completed in an aquifer in the surficial deposits.

Water wells completed in the upper surficial deposits occur mainly in the northern half of the County. Eighty percent of the water wells completed in the lower surfical deposits are in the area underlain by the Buried Medicine Hat Valley, south of Medicine Hat (Figure 13).

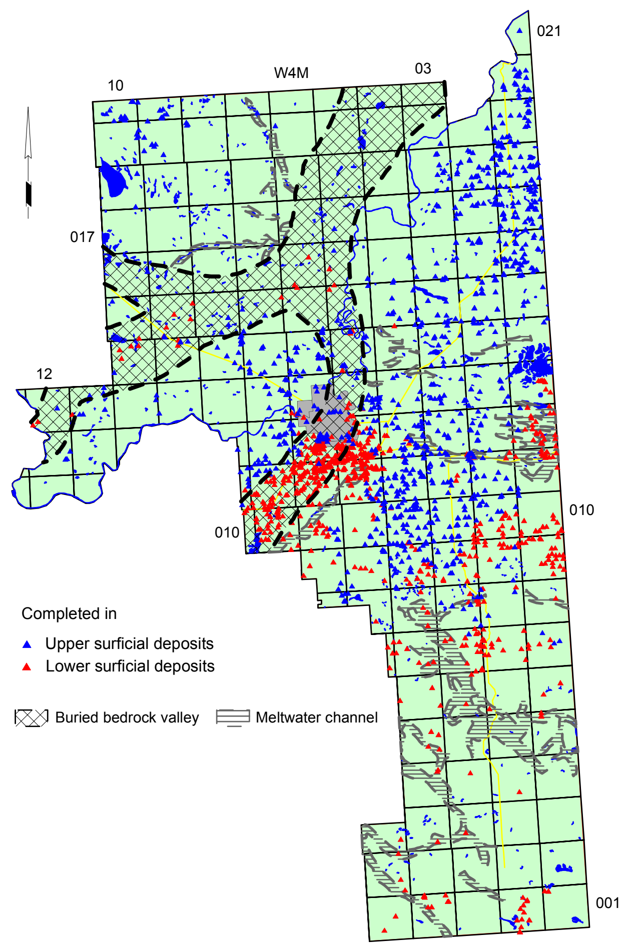


Figure 13. Water Wells Completed in Surficial Deposits

The map below shows expected yields for water wells completed in sand and gravel aquifers(s). Over approximately 30% 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 map.

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 several areas of the County. The most notable areas where yields of more than 100 m³/day are expected are mainly in association with the Buried Lethbridge Valley, but can also occur in the Buried Medicine Hat Valley and in the meltwater channels east of Medicine Hat. The yields present within the northwestern part of CFB Suffield could be a result of the gridding procedure used to process a limited number of data points. In the County, there are 381 records for surficial water wells with apparent yield data.

In addition to the 381 apparent yield values, there are 122 records that indicate dry or abandoned with “insufficient water”. Of the 122 records, 88 were drilled or completed in the upper surficial deposits and 34 were in the lower surficial deposits. The locations of these dry holes have been posted on the adjacent map. Also included in these postings is any record that includes comments that state the water well goes dry in dry years. In order to depict a more accurate yield map, an apparent yield of 0.1 m³/day was assigned to the 122 dry holes prior to gridding. The two main areas with the largest number of dry holes and lowest yields are in townships 009 and 010, ranges 01 to 04, W4M, and in townships 015 and 016, ranges 03 and 04, W4M as shown on Figure 14.

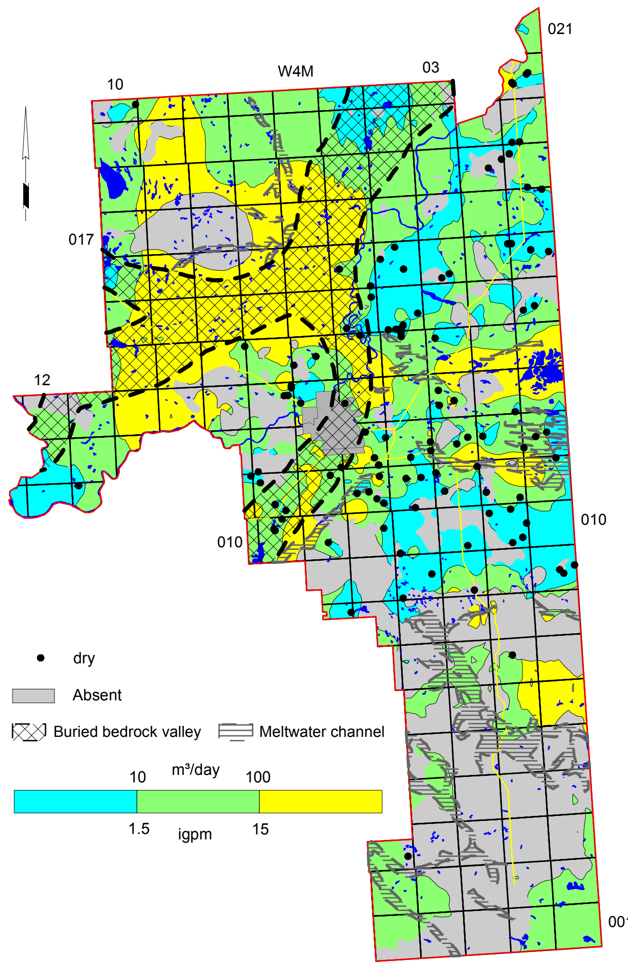


Figure 14. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)

5.2.2.1 Chemical Quality of Groundwater from Surficial Deposits

The chemical analysis results of groundwaters from the sand and gravel aquifers in the surficial deposits indicate the groundwaters are generally chemically hard and high in dissolved iron. In Cypress County, groundwaters from the surficial aquifers mainly have a chemical hardness of greater than 200 mg/L (see CD-ROM).

The Piper tri-linear diagram[15] (page A-32) for surficial deposits shows the groundwaters are mainly calcium-magnesium-bicarbonate or calcium-magnesium-sulfate type waters. The records with sodium-bicarbonate waters were individually checked in the database to confirm the completion aquifer. Nearly 90% of the groundwaters from the surficial deposits have a TDS concentration of more than 500 mg/L. Of the groundwaters having TDS concentrations of more than 3,000 mg/L, nearly 60% are from bored water wells that have a completion depth of less than ten metres. Eighty-two percent of the groundwaters from the surficial deposits are reported to have dissolved iron concentrations of less than one mg/L. However, many iron analysis results are questionable due to varying sampling and analytical methodologies.

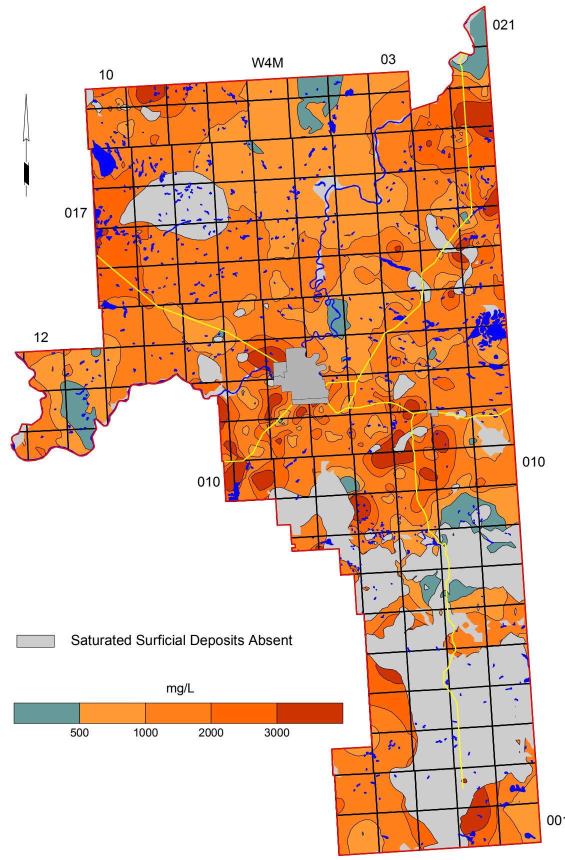


Figure 15. Total Dissolved Solids in Groundwater from Surficial Deposits

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 91% of the samples analyzed in the County, the chloride ion concentration is less than 100 mg/L (see CD-ROM).

Constituent	Range for County in mg/L Minimum	Maximum	Median	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	84	12610	1302	500
Sodium	2	2820	166	200
Sulfate	0	8533	460	500
Chloride	0	3200	21	250
Nitrate + Nitrite (as N)	0	131	0.1	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)
GCDWQ - Guidelines for Canadian Drinking Water Quality, Sixth Edition Minister of Supply and Services Canada, 1996

Table 3. Concentrations of Constituents in Groundwaters from Surficial Aquifers

In the County, the nitrate + nitrite (as N) concentrations in the groundwaters from the surficial deposits exceed the maximum acceptable concentrations (MAC) of ten mg/L in 8% of the samples. Groundwaters with a nitrate + nitrite (as N) concentration exceeding the MAC (10 mg/L) have been posted on the nitrate + nitrite (as N) map (see CD-ROM). The map shows the exceedances are mainly in the vicinity of Medicine Hat.

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 GCDWQ in the adjacent table. Of the five constituents that have been compared to the GCDWQ, the median value of TDS concentrations exceeds the guidelines.

[15] See glossary

5.2.3 Upper Sand and Gravel Aquifer

The Upper Sand and Gravel Aquifer includes saturated sand and gravel deposits in the upper surficial deposits. 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 but are expected over approximately 35% of the County.

5.2.3.1 Aquifer Thickness

The thickness of the Upper Sand and Gravel Aquifer is a function of two parameters: (1) the elevation of the non-pumping water-level surface associated with the surficial deposits; and (2) the depth to the bedrock surface or depth to top of 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 vicinity of the linear bedrock lows (see CD-ROM).

5.2.3.2 Apparent Yield

The permeability of the Upper Sand and Gravel Aquifer can be high. The high permeability combined with significant thickness leads to an extrapolation of high yields for water wells; however, because the sand and gravel deposits occur mainly as hydraulically discontinuous pockets, the apparent yields of the water wells are limited. The apparent yields for water wells completed through this Aquifer are expected to be mainly less than 100 m³/day. Apparent yields of greater than 100 m³/day may be encountered in the northwestern part of the County, and in the linear bedrock lows north and east of Medicine Hat, as shown on Figure 16. In addition to the 173 water well records with apparent yield data, there are 88 records that indicate dry or abandoned surficial water wells with “insufficient water”. In order to depict a more accurate yield map, an apparent yield of 0.1 m³/day was assigned to the dry holes prior to gridding.

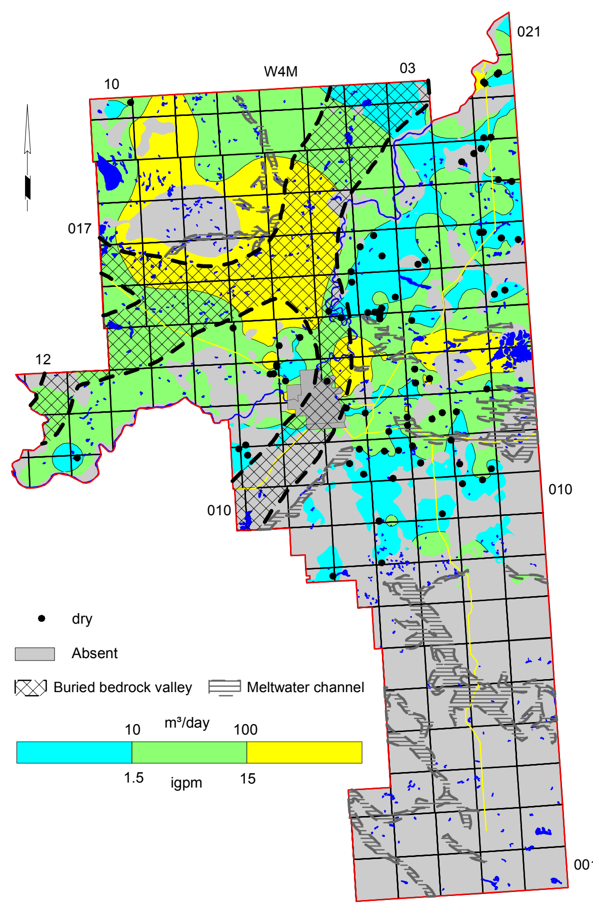


Figure 16. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

Where the Upper Sand and Gravel Aquifer is absent and where the yields are low, the development of water wells for the domestic needs of single families may not be possible from this Aquifer, and construction of a water supply well into the underlying bedrock may be the only alternative, provided that yields and quality of groundwater from the bedrock aquifer(s) are suitable.

In the County, there are eight licensed water wells that are completed through the Upper Sand and Gravel Aquifer, with a total authorized diversion of 206 m³/day. The two highest allocations, totalling 118.3 m³/day, are for two Cypress County water wells used for municipal purposes, in 04-36-017-01 W4M and 06-12-016-04 W4M. Three of the eight licensed water wells completed through the Upper Sand and Gravel Aquifer could be linked to a water well in the AENV groundwater database.

5.2.4 Lower Sand and Gravel Aquifer

The Lower Sand and Gravel Aquifer is a saturated sand and gravel deposit that occurs at or near the base of the surficial deposits in the deeper part of the linear bedrock lows. The top of the lower surficial deposits is based on more than 1,000 control points across Alberta; 51 are in the County, including 15 that are provided by Allong (1967), Edwards (1984), Leckie et al (1989), Lorberg (1973), Stalker (1969), and Westgate (1968).

5.2.4.1 Aquifer Thickness

The thickness of the Lower Sand and Gravel Aquifer is mainly less than five metres, but can be more than 15 metres in the buried bedrock valleys and meltwater channels (see CD-ROM).

5.2.4.2 Apparent Yield

Apparent yields for water wells completed in the Lower Sand and Gravel Aquifer range from less than 10 m³/day to more than 100 m³/day. Yields of more than 100 m³/day are consistently expected in the Lower Sand and Gravel Aquifer associated with the Buried Lethbridge Valley, with the Buried Medicine Hat Valley south of Medicine Hat and in the meltwater channels near Irvine. In addition to the 208 water well records for the Lower Sand and Gravel Aquifer water wells with apparent yield data, there are 34 records that indicate dry, or abandoned with “insufficient water”. In order to depict a more accurate yield map, an apparent yield of 0.1 m³/day was assigned to the 34 dry holes prior to gridding.

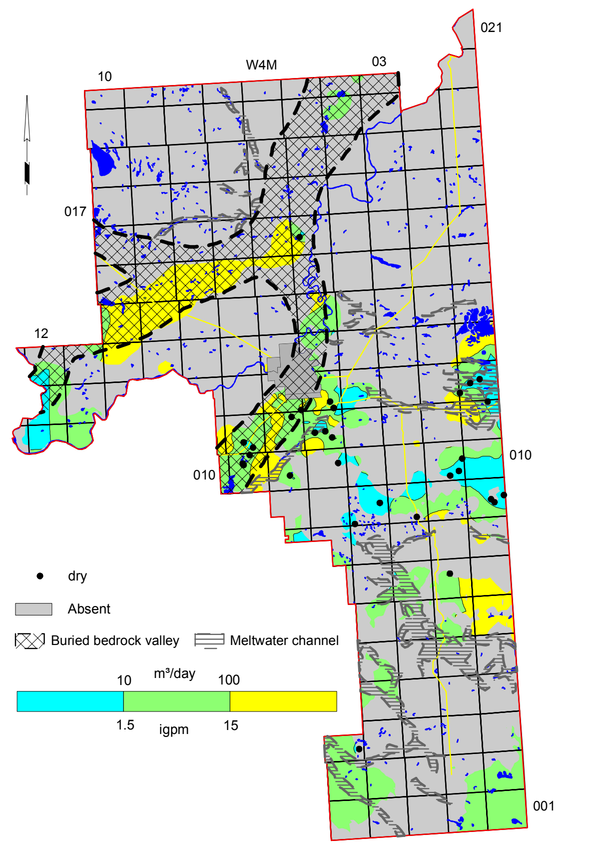


Figure 17. Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer

In the County, there are 32 licensed water wells that are completed through the Lower Sand and Gravel Aquifer, for a total authorized diversion of 18,944 m^3/day, of which 72% is used for commercial purposes.

Twenty-one of the 32 licensed water wells completed through the Lower Sand and Gravel Aquifer could be linked to a water well in the AENV groundwater database.

Alberta Energy Company Ltd. (AECL) have a water source well (WSW No. 3-98) completed in the depth interval from 97 to 104 metres below ground surface in the Lower Sand and Gravel Aquifer associated with the Buried Lethbridge Valley in 04-04-016-06 W4M. An extended aquifer test conducted with WSW No. 3-98, using the PFRA Windmill Water Supply Well in 13-04-016-06 W4M as an observation water well, indicated a theoretical long-term yield of 900 m³/day based on an aquifer transmissivity of 65 m²/day (HCL, 1999). The water source well is currently licensed to divert 200 m³/day. The PFRA Windmill Water Supply Well is also completed in the Lower Sand and Gravel Aquifer and is licensed to divert 6.7 m³/day for stock purposes.

The groundwater from the AECL water source well in 04-04-016-06 W4M had a TDS concentration of 970 mg/L, a sulfate concentration of 238 mg/L, a chloride concentration of 29.1 mg/L, and a total hardness of 100 mg/L.

5.3 Bedrock

5.3.1 Geological Characteristics

The upper bedrock in the County includes the Cypress Hills Formation, the Paskapoo Formation, the Edmonton Group, the Bearpaw Formation, and the Belly River Group. The adjacent bedrock geology map, showing the subcrop of different geological units, has been prepared in part from the interpretation of geophysical logs related to oil and gas activity and in part based on Tokarsky (1985). In order to obtain a reasonable bedrock surface and, therefore, bedrock geology map in the area of the Cypress Hills, an average surficial thickness of three metres was subtracted from 7,500 DEM-determined topographic points. A generalized geologic column is illustrated in Figure 7, in Appendix A and on the CD-ROM.

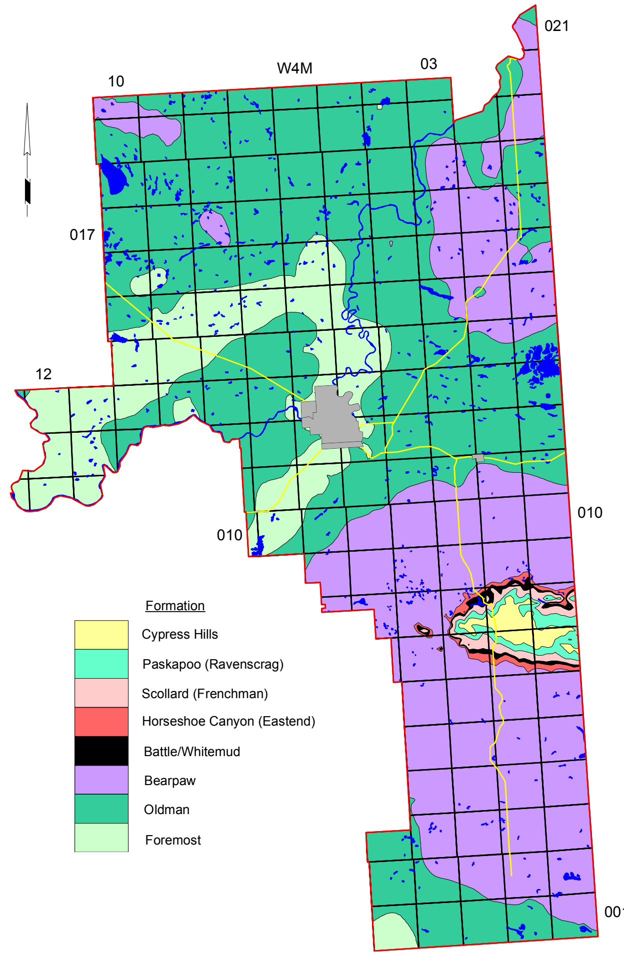


Figure 18. Bedrock Geology

The upper bedrock that underlies the Cypress Hills are the Ravenscrag, the Frenchman, the Battle and Whitemud, and the Eastend formations. Carrigy (1970) has suggested that the term Frenchman be restricted to the Saskatchewan side and on the Alberta side be included in the lower part of the Ravenscrag Formation. Westgate (1968) and Tokarsky (1985) refer to the Frenchman Formation as a separate geologic unit. For continuity with other regional studies, HCL will use the equivalent terms Paskapoo, Scollard and Horseshoe Canyon formations, as shown on the adjacent figure.

The Cypress Hills Formation underlies the summit region of the Cypress Hills. It is composed of conglomerate with minor lenses of sand and thin bentonite beds (Westgate, 1968). The Cypress Hills Formation is less than 20 metres thick. The contact between the underlying Paskapoo Formation and the Cypress Hills Formation is a source for many freshwater springs. The saturated thickness of the Cypress Hills Formation is usually minimal.

The Paskapoo Formation is exposed along the escarpment of the Cypress Hills. It is a non-marine sequence of thinly bedded, fine-grained sands, silts, and shales with numerous coal beds and lignitic laminae. The upper limit of the Formation is an erosional surface, so thicknesses are variable, but exceed 30 metres in the County (Westgate, 1968). Tokarsky (1985) shows the Ravenscrag (Paskapoo) Formation thickness to be in the order of 70 metres.

The Edmonton Group includes the Scollard Formation, the Battle and Whitemud formations, and the Horseshoe Canyon Formation. Westgate describes the Frenchman (Scollard) Formation as consisting essentially of thick, massive or coarsely cross-bedded, medium-grained sandstone with rare coaly beds. Tokarsky (1985) shows the Frenchman (Scollard) Formation to be approximately 60 metres thick.

There will be no direct review of either the Cypress Hills Formation or the Paskapoo Formation and only a limited review of the Scollard Formation. Because of the limited amount of hydrogeological information in the County, a complete detailed map set has not been prepared; the only maps associated with the Cypress Hills or the Paskapoo formations to be included on the CD-ROM will be structure-contour maps.

The Horseshoe Canyon Formation is the lower part of the Edmonton Group. In Cypress County, the Horseshoe Canyon (Eastend) Formation has an approximate thickness of 35 metres (Tokarsky, 1985). Westgate describes the Horseshoe Canyon (Eastend) Formation as being confined to the Cypress Hills area, where it occupies a belt at the foot of the main escarpment. It is made up of massive, medium-grained sandstone and dark shales.

The Bearpaw Formation underlies the Horseshoe Canyon (Eastend) Formation and borders the Cypress Hills on all sides. In Cypress County, the Bearpaw Formation has an approximate thickness of 370 metres (Tokarsky, 1985), and is also the upper bedrock in parts of the northeastern and extreme northwestern parts of the County. The Bearpaw Formation includes transgressive, shallow marine (shoreface) and open marine facies[16] deposits. In Cypress County, the Bearpaw Formation is composed mainly of shale with occasional sandstone beds.

The Belly River Group includes the Oldman and Foremost formations. The Oldman Formation is present as the upper bedrock in most of the northern part and in the southwestern part of the County, and is mainly less than 130 metres thick. The Oldman Formation is composed of continental deposits, sandstone, siltstone, shale and coal. The Oldman Formation is the upper part of the Belly River Group.

The Foremost Formation has been eroded in most of the County and subcrops mainly along the Bow River Valley and the South Saskatchewan River Valley in the west-central part of the County. The Foremost Formation is less than 150 metres thick and is between the overlying Oldman Formation and the underlying Lea Park Formation. The Foremost Formation includes both sandstone and shale units. Coal zones occur within the Foremost Formation, with the main ones referred to as the McKay and the Taber Coal zones. There are also minor amounts of ironstone, a chemical deposit.

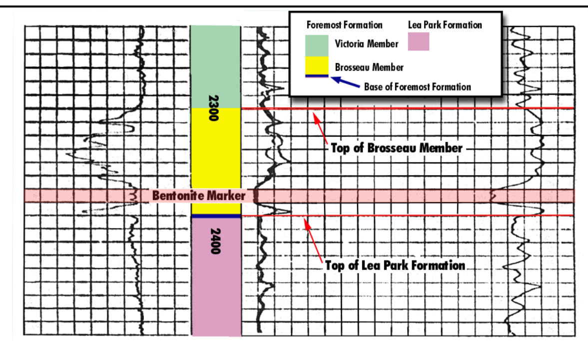


Figure 19. E-Log showing Base of Foremost Formation

The present identification of the Foremost Formation would not be possible without identifying a continuous top for the Lea Park Formation. The top of the Lea Park Formation represents a geologic time border between the marine environment of the Lea Park Formation and the mostly continental environment of the Foremost Formation. The top of the Lea Park Formation is the bottom of the higher resistivity layer that occurs within a few metres below a regionally identifiable bentonite marker, as shown in the adjacent e-log. This marker occurs approximately 100 metres above the Milk River Shoulder. The Lea Park Formation is mostly composed of shale, with only minor amounts of bentonitic sandstone present in some areas. Regionally, the Lea Park Formation is an aquitard[17]. Because the Lea Park Formation is an aquitard, there will be no direct review in this report. Structure-contour maps associated with the Lea Park Formation are included in Appendix A and on the CD-ROM.

The Colorado Group includes the Milk River Formation, the *undivided* Colorado Group and the Viking Formation. The Milk River Formation is present under the County but does not subcrop in the County. The Milk River Formation is composed mostly of thick-bedded sandstone with shale, and in southern Alberta can be an important source of groundwater and is an important supply of natural gas.

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16 See glossary
17 See glossary

5.3.2 Aquifers

Of the 3,348 water wells in the database, 274 were defined as being completed below the top of bedrock and 617 completed in surficial aquifers, based on lithologic information and water well completion details. However, at least a reported completion depth is available for the majority of the remaining 2,545 water wells. Assigning the water well to specific geologic units is possible only if the completion interval is identified. In order to make use of additional information within the groundwater database, it was assumed that if the total drilled depth of a water well was more than ten metres below the top of a particular geologic unit, the water well was assigned to the particular geologic unit. With this assumption, it has been possible to designate the specific bedrock aquifer of completion for 1,063 water wells. The remaining 86 of the total 1,149 bedrock water wells are identified as being completed in more than one bedrock aquifer. The bedrock water wells are mainly completed in the Bearpaw, Oldman and Foremost aquifers, as shown in the table above.

Geologic Unit	No. of Bedrock Water Wells
Cypress Hills	0
Paskapoo (Ravenscrag)	3
Scollard (Frenchman)	6
Horseshoe Canyon (Eastend)	22
Bearpaw	277
Oldman	495
Foremost	249
Lea Park	0
Milk River	11
Saline	13
Multiple Completions	73
Total	1,149

Table 4. Completion Aquifer

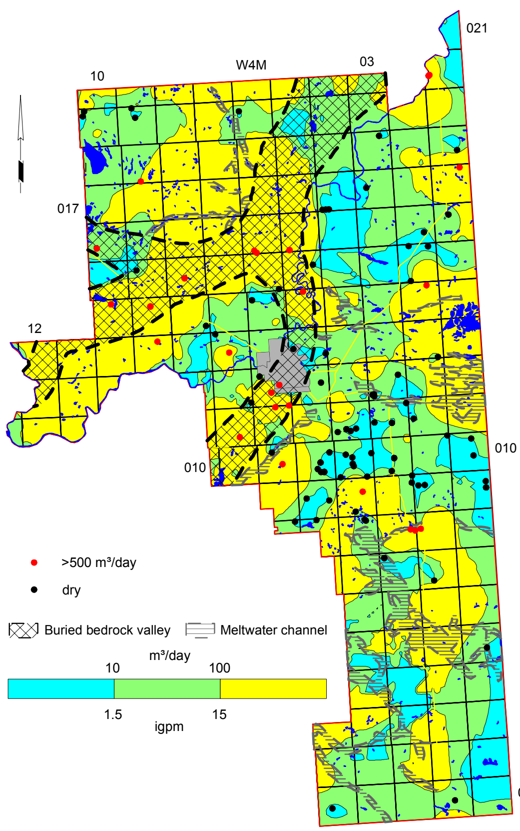


Figure 20. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

There are 360 records for bedrock water wells that have apparent yield values, which is 31% of the 1,149 bedrock water wells. In the County, yields for water wells completed in the upper bedrock aquifer(s) are mainly between 10 and 100 m³/day. Many of the areas with yields of more than 100 m³/day are in association with buried bedrock valleys, as shown on the adjacent figure. These higher yield areas may identify areas of increased permeability resulting from the weathering process. In addition to the 360 records for bedrock water wells, there are 88 records that indicate that the water well is dry, or abandoned with "insufficient water". In order to depict a more accurate yield map, an apparent yield of 0.1 m³/day was assigned to the 88 dry holes prior to gridding. A similar value has been assigned to all dry holes in bedrock aquifers.

Aquifer	No. of Water Wells with Values for Apparent Yield	Number of Water Wells with Apparent Yields			Dry Test Holes	% of Total
		<10 m³/day	10 to 100 m³/day	>100 m³/day		
Cypress Hills	0	0	0	0	0	0
Paskapoo	1	0	1	0	0	0
Scollard	2	0	2	0	0	0
Horseshoe Canyon	12	1	4	7	0	0
Bearpaw	34	10	16	8	52	60
Oldman	199	34	129	36	29	13
Foremost	106	3	61	42	4	4
Lea Park	0	0	0	0	0	0
Milk River	3	0	1	2	0	0
Multiple Completions	3	0	3	0	3	50
Totals	360	48	217	95	88	20

Table 5. Apparent Yields of Bedrock Aquifers

Of the 360 water well records with apparent yield values, 357 have been assigned to aquifers associated with specific geologic units. Thirteen percent (48) of the 360 water wells completed in the bedrock aquifers have apparent yields that are less than 10 m³/day, 60% (217) have apparent yield values that range from 10 to 100 m³/day, and 27% (95) have apparent yields that are greater than 100 m³/day, as shown in Table 5.

5.3.3 Chemical Quality of Groundwater

The TDS concentrations in the groundwaters from the upper bedrock aquifer(s) range from less than 500 to more than 3,000 mg/L. In approximately 90% of the area, TDS values are more than 1,000 mg/L, with only a few small areas having a TDS concentration of less than 500 mg/L. The two main areas where TDS concentrations are less than 500 mg/L are along the flanks of the Cypress Hills and along the South Saskatchewan River in the western part of the County.

The lower TDS concentrations in the Cypress Hills area may be a result of more active flow systems and shorter flow paths due to the pronounced local relief.

The relationship between TDS and sulfate concentrations shows that when TDS values in the groundwaters from the upper bedrock aquifer(s) exceed 1,200 mg/L, the sulfate concentrations exceed 400 mg/L.

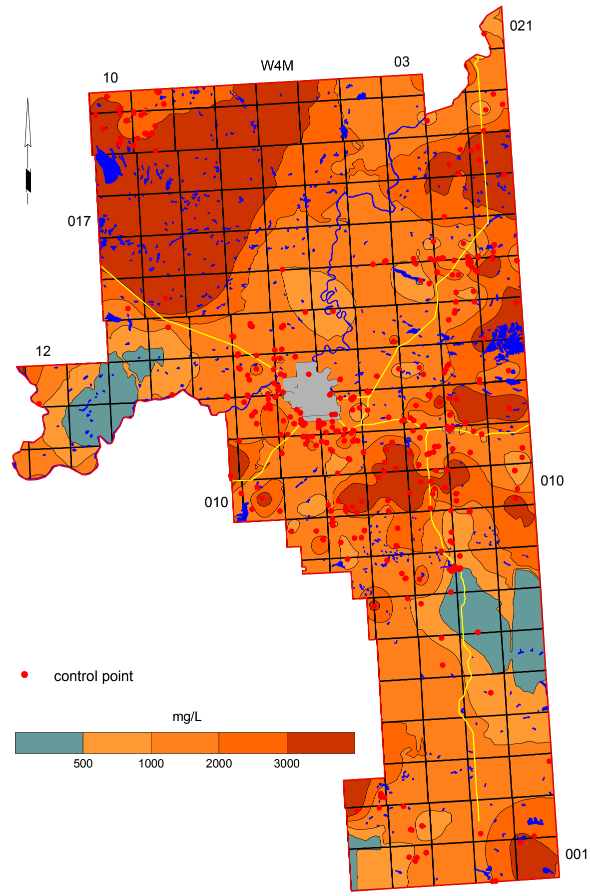


Figure 21. Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

The chloride concentrations in the groundwaters from the upper bedrock aquifer(s) are less than 100 mg/L in approximately 80% of the County. Chloride values of greater than the GCDWQ of 250 mg/L are mainly in the CFB Suffield area and are a result of gridding only a few points. The nitrate + nitrite (as N) concentrations are less than 0.1 mg/L in 65% of the chemical analyses for bedrock water wells. Unlike other areas in Alberta, total hardness values in the groundwaters from the upper bedrock aquifer(s) are mainly greater than 200 mg/L. The higher values of total hardness occur mainly from townships 008 to 011, ranges 01 to 08, W4M (see CD-ROM).

In the County, approximately 62% of the groundwater samples from upper bedrock aquifer(s) have fluoride concentrations that are too low (less than 0.5 mg/L) to meet the recommended daily needs of people. Approximately 29% of the groundwater samples from the entire County are between 0.5 and 1.5 mg/L and approximately 9% exceed the maximum acceptable concentration for fluoride of 1.5 mg/L. The fluoride values of greater than 1.5 mg/L occur mainly in the Oldman Aquifer where the Oldman Formation is the upper bedrock (page A-35).

The Piper tri-linear diagram for bedrock aquifers (page A-32) shows that all chemical types of groundwater occur in the bedrock aquifers. However, the majority of the groundwaters are sodium-bicarbonate or sodium-sulfate types.

5.3.4 Horseshoe Canyon (Eastend) Aquifer

The Horseshoe Canyon Aquifer comprises the permeable parts of the Horseshoe Canyon Formation that occupies the base of the main escarpment of the Cypress Hills in south-central Cypress County. The thickness of the Horseshoe Canyon Formation is approximately 35 metres (Tokarsky, 1985); outside the Cypress Hills area, the Horseshoe Canyon Formation has been eroded. The groundwater flow direction in the Horseshoe Canyon Aquifer is to the northwest (see CD-ROM).

5.3.4.1 Depth to Top

The depth to top of the Horseshoe Canyon Formation ranges from less than 50 to more than 150 metres below ground level at the Cypress Hills summit (page A-39).

5.3.4.2 Apparent Yield

The apparent yields for individual water wells completed through the Horseshoe Canyon Aquifer are mainly greater than 100 m³/day. There are 12 water well records with apparent yield values, of which seven have apparent yields of more than 100 m³/day. The areas where apparent yields are greater than 100 m³/day are in the Elkwater area.

In the County, Alberta Recreation and Parks operates three water supply wells completed in the Horseshoe Canyon Aquifer that are licensed to divert a total of 330 m³/day for municipal purposes. Aquifer testing within the Cypress Hills Provincial Park was conducted by HCL in 1972, 1974 and 1981. Based on the results of extended aquifer tests conducted with the three water supply wells, it was recommended that the three water supply wells completed in the Horseshoe Canyon Aquifer not exceed a total maximum pumping rate of 550 m³/day (HCL, 1982).

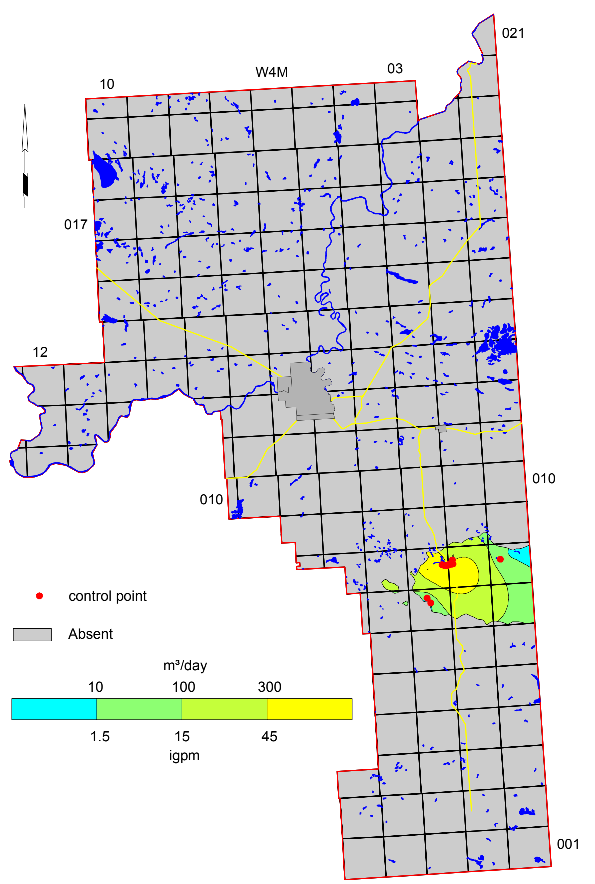


Figure 22. Apparent Yield for Water Wells Completed through Horseshoe Canyon Aquifer

5.3.4.3 Quality

The groundwaters from the Horseshoe Canyon Aquifer are a bicarbonate-type with no dominant cation (see Piper diagram on CD-ROM), with 60% of the groundwater samples having TDS concentrations of less than 500 mg/L. The sulfate concentrations are less than 100 mg/L. Chloride concentrations from the Horseshoe Canyon Aquifer are less than ten mg/L. There are no analyses where fluoride concentrations exceed 0.5 mg/L.

5.3.5 Other Cypress Hills Area Aquifers

The formations that overlie the Horseshoe Canyon Formation in the Cypress Hills area are the Scollard, the Paskapoo and the Cypress Hills formations; however, the only hydrogeological information available in the database for these aquifers are three samples of chemistry data for water wells completed in the Scollard Aquifer. The TDS concentrations from these three groundwater samples are below 500 mg/L, the sulfate concentrations are less than or equal to ten mg/L, the chloride concentrations are one mg/L and the fluoride concentrations are less than 0.5 mg/L.

5.3.6 Bearpaw Aquifer

The Bearpaw Aquifer comprises the permeable parts of the Bearpaw Formation. The Bearpaw Formation borders the Cypress Hills and forms the upper bedrock unit for some distance on all sides of the Cypress Hills. In Cypress County, the Bearpaw Formation has an approximate maximum thickness of 370 metres (Tokarsky, 1985), and is the upper bedrock in parts of the northeastern and extreme northwestern parts of the County.

5.3.6.1 Depth to Top

The depth to the top of the Bearpaw Formation is mainly less than 50 metres below ground level; however, the top of the Formation can be more than 200 metres below ground level where the Formation underlies the Cypress Hills (page A-42).

5.3.6.2 Apparent Yield

The apparent yields for individual water wells completed through the Bearpaw Aquifer are mainly in the range of 10 to 100 m³/day. There are 34 water well records with apparent yield values, of which 26 have apparent yields that are less than 100 m³/day. In addition to the 34 water well records with apparent yields, there are 52 records that indicate dry, or abandoned with “insufficient water”.

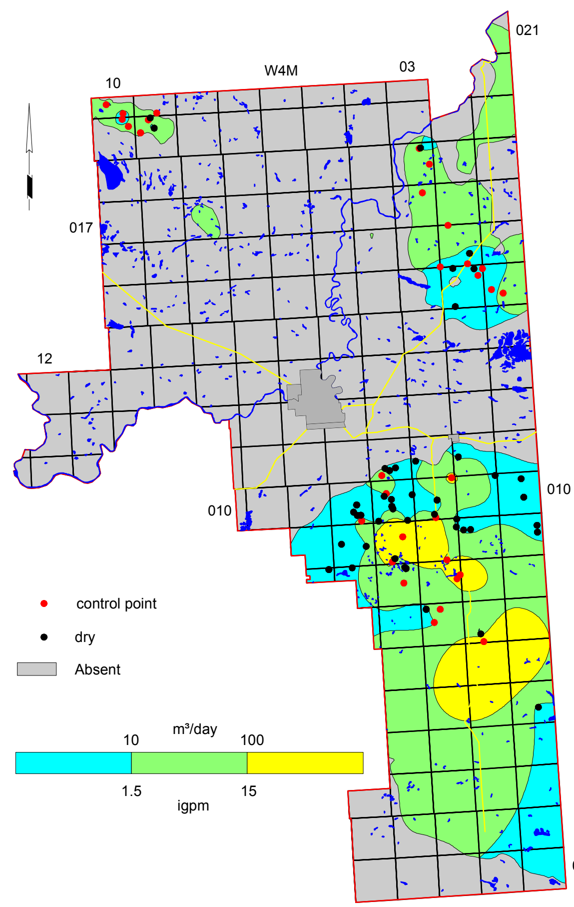


Figure 23. Apparent Yield for Water Wells Completed through Bearpaw Aquifer

In the County, there is one licensed water well that is completed in the Bearpaw Aquifer. This is presumably a standby water supply well for Alberta Recreation and Parks because there is a licensed diversion of 0 m³/day. This water supply well (WTH No. 1-81) in 03-24-008-03 W4M was part of a drilling and aquifer testing program conducted by HCL (HCL, 1982).

The results of an extended aquifer test conducted with WTH No. 1-81 indicated a long-term yield of 98 m³/day based on an effective transmissivity of 7.8 m²/day (HCL, 1982).

5.3.6.3 Quality

The groundwaters from the Bearpaw Aquifer are mainly a bicarbonate-to-sulfate type, with calcium-magnesium or sodium as the main cation (see Piper diagram on CD-ROM). TDS concentrations range from less than 500 to more than 3,000 mg/L, with lower values being next to the Cypress Hills and higher values being further from the Cypress Hills as a result of longer groundwater flow paths (see CD-ROM). The sulfate concentrations are mainly below 1,000 mg/L and the chloride concentrations are mainly less than 100 mg/L. There are only two out of 124 analyses where fluoride concentrations exceed 1.5 mg/L.

The groundwater from WTH No. 1-81 has TDS concentrations from three samples that range from 600 to 800 mg/L, sulfate concentrations that range from 100 to 200 mg/L, and chloride concentrations of <10 mg/L. The iron concentrations ranged from 0.3 to 0.5 mg/L. The groundwater from WTH No. 1-81 is a sodium-bicarbonate type.

5.3.7 Oldman Aquifer

The Oldman Aquifer comprises the permeable parts of the Oldman Formation. The Oldman Formation is present under most of the County, being absent only in parts of the Buried Lethbridge and Medicine Hat valleys and in the extreme southwestern corner of the County. The maximum thickness of the Oldman Formation is in the order of 130 metres in most of the County. The regional groundwater flow in the Oldman Aquifer is downdip to the east and northeast in the County.

5.3.7.1 Depth to Top

The depth to the top of the Oldman Formation (page A-45) is mainly less than 100 metres in the County except where the surface elevation is greater than 900 metres AMSL. Where the Oldman is below the Cypress Hills, the depth to the top of the Oldman Formation can be more than 600 metres. Even at a depth at over 600 metres below ground surface, the Oldman Formation is generally above the Base of Groundwater Protection (Fig. 10).

5.3.7.2 Apparent Yield

The apparent yields for individual water wells completed through the Oldman Aquifer are mainly between 10 and 100 m³/day. There are 199 water well records with apparent yield values, of which 129 have an apparent yield of between 10 and 100 m³/day. In addition to the 199 water well records, there are 29 records that indicate dry, or abandoned with "insufficient water". The large area of lower yields shown in the north-central part of the County is based on a few control points.

An extended aquifer test conducted with a water supply well completed in the Oldman Aquifer in 16-32-017-01 W4M indicated a long-term yield of 52 m³/day (HCL, 1981). The water supply well is not currently licensed.

In the County, there are 11 licensed water wells that are completed in the Oldman Aquifer. The highest allocation is 40 m³/day for a Bauer Farm Ltd. water supply well used for agricultural purposes in 16-09-018-02 W4M. Three of the 11 licensed water wells completed through the Oldman Aquifer could be linked to a water well in the AENV groundwater database.

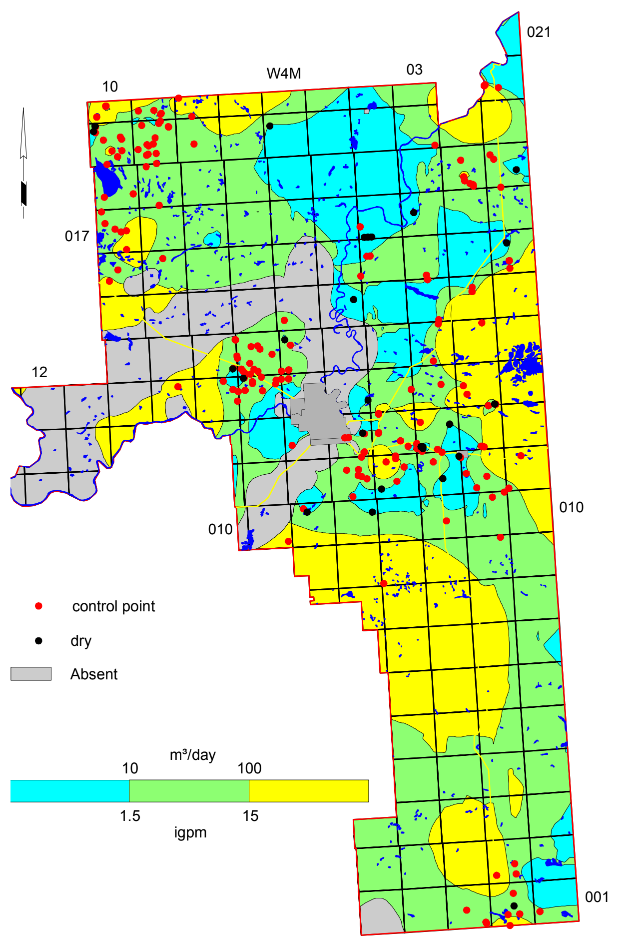


Figure 24. Apparent Yield for Water Wells Completed through Oldman Aquifer

5.3.7.3 Quality

The groundwaters from the Oldman Aquifer are mainly a sodium-bicarbonate or sodium-sulfate type (see Piper diagram on CD-ROM). Total dissolved solids concentrations are expected to be mainly greater than 1,000 mg/L, with lower concentrations expected in the southwestern part of the County. The sulfate concentrations are mainly below 1,000 mg/L. The indications are that chloride concentrations in the Oldman Aquifer are expected to be mainly less than 250 mg/L. There are 21 out of 183 analyses where fluoride concentrations exceed 1.5 mg/L. There is a higher percentage of fluoride exceedances in the Oldman Aquifer than in the other bedrock aquifers within the County (see CD-ROM).

5.3.8 Foremost Aquifer

The Foremost Aquifer comprises the permeable parts of the Foremost Formation. The Foremost Formation is present under all of the County and subcrops mainly along the Bow River Valley and the South Saskatchewan River Valley in the west-central part of the County. The thickness of the Foremost Formation is mostly less than 150 metres. Groundwater flow in the Foremost Aquifer is both downdip and toward the Buried Medicine Hat Valley (see CD-ROM).

5.3.8.1 Depth to Top

The depth to the top of the Foremost Formation is variable, ranging from less than 50 metres where it subcrops to more than 700 metres below the Cypress Hills (page A-48).

5.3.8.2 Apparent Yield

There are 106 water well records in the database with sufficient information to calculate apparent yields for individual water wells completed through the Foremost Aquifer; these water wells are located mainly in the vicinity of Medicine Hat. Of the 106 water well records, 61 have apparent yields that range from 10 to 100 and 42 are greater than 100 m³/day. There are four records that indicate dry, or abandoned with “insufficient water”.

A water test hole was completed from 155 to 180 metres below ground surface in the Foremost Aquifer in 16-36-015-07 W4M; however, because a suitable aquifer was not encountered (less than 200 m³/day was required), the water test hole was reclaimed (HCL, 1998). This test hole is located in an area where yields of greater than 300 m³/day are expected.

In the County, there are two licensed water wells that are completed in the Foremost Aquifer. The highest allocation is 54 m³/day for a Petro-Canada Resources water source well used for commercial purposes in 10-10-015-10 W4M. Both of the licensed water wells completed through the Foremost Aquifer could be linked to a water well in the AENV groundwater database.

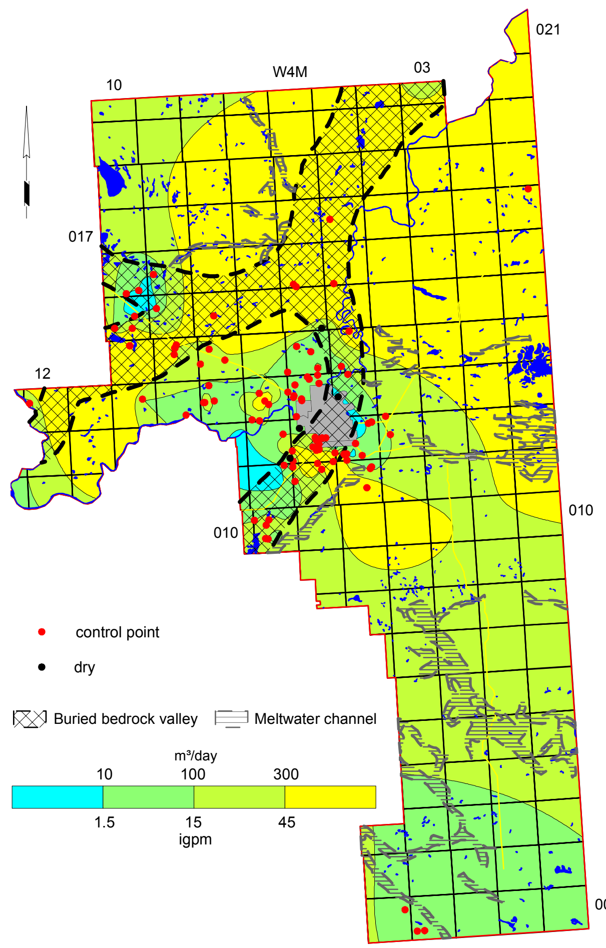


Figure 25. Apparent Yield for Water Wells Completed through the Foremost Aquifer

5.3.8.3 Quality

The groundwaters from the Foremost Aquifer are mainly a sodium-bicarbonate or sulfate type (see Piper diagram on CD-ROM). Total dissolved solids concentrations are mainly greater than 1,000 mg/L. Most of the 241 TDS control points available for the Foremost Aquifer are in the vicinity of Medicine Hat (see page A-50). The sulfate concentrations are mainly below 1,000 mg/L. The indications are that chloride concentrations in the Foremost Aquifer are expected to be mainly less than 100 mg/L. There are six out of 105 analyses where fluoride concentrations exceed 1.5 mg/L.

5.3.9 Milk River Aquifer

The Milk River Aquifer comprises the permeable parts of the Milk River Formation and underlies all of the County. The thickness of the Milk River Formation is mostly less than 100 metres. The main regional groundwater flow in the Milk River Aquifer is downdip and toward the South Saskatchewan River (see CD-ROM).

5.3.9.1 Depth to Top

The depth to the top of the Milk River Formation is variable, ranging from less than 150 metres to more than 1,000 metres in the Cypress Hills area (page A-52).

5.3.9.2 Apparent Yield

In the County, there are three water well records in the database with sufficient information to calculate apparent yields for individual water wells completed through the Milk River Aquifer. In the buffer area, west of the County, there are an additional 160 apparent yield values for the Milk River Aquifer. But with limited data available within the County, the summary results of drill stem tests (DSTs) available from the EUB database were also used. The DST summaries often provide a description of fluid obtained and interval tested during the DST. Therefore, the DST summaries can be used to determine an apparent yield and the quality of fluid available from the Milk River Aquifer.

There was sufficient information to allow for the calculation of an apparent yield from 150 DSTs (County plus buffer area) where at least some part of the fluid type is water. The data from the DSTs combined with the 163 apparent yield values available from individual water wells completed in the Milk River Aquifer have been used to prepare the adjacent figure.

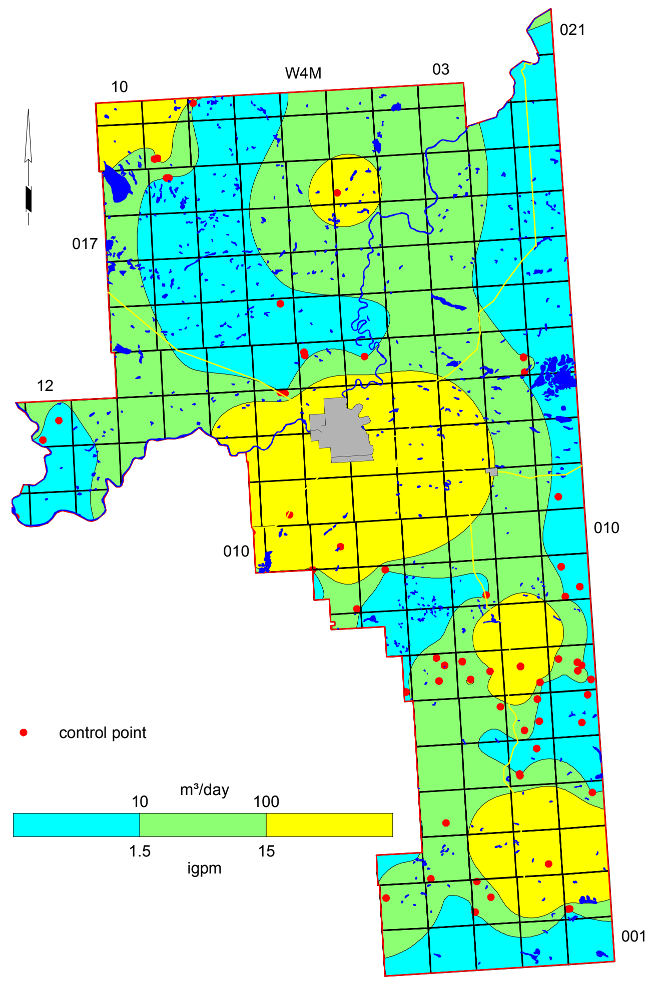


Figure 26. Apparent Yield for Water Wells Completed through the Milk River Aquifer

A water well drilled for inventory purposes in --07-018-05 W4M has an anticipated yield of 165 m³/day (PFRA, 1978). This water well was completed from 298.7 to 304.8 metres below ground level in the Milk River Aquifer.

Following the completion of a water supply well in SW 15-002-04 W4M at a depth of 335 metres below ground level in the Milk River Aquifer, "it was noted that this unit is generally very fine grained and well screens and low pumping rates are required to avoid bringing fine grained sediment into the completed wells" (PFRA, 1997 Memorandum Communication).

In the County, there are four licensed water wells in township 001, range 02, W4M that are completed in the Milk River Aquifer. The four water wells are licensed to Kusler Ranches Ltd. for agricultural purposes and have a combined authorized total of 81 m^3/day. All four of the licensed water wells completed through the Milk River Aquifer could be linked to a water well in the AENV groundwater database.

5.3.9.3 Quality

In the County, there are two water wells completed in the Milk River Aquifer with groundwater quality data. Three samples have been collected from a water well in 08-31-001-01 W4M from 1966 to 1982. Total dissolved solids concentrations from this water well are in the order of 3,500 mg/L, sulfates are less than 15 mg/L and chloride concentrations average 1,720 mg/L.

The groundwater from the water supply well in SW 15-002-04 W4M has a TDS concentration of 1,064 mg/L, a sulfate concentration of 3 mg/L, and a chloride concentration of 127 mg/L (PFRA, 1997 Memorandum Communication).

6. Groundwater Budget

6.1 Hydrographs

There are sixteen locations in the County where water levels are being or have been measured and recorded with time, as shown on the adjacent figure. However, of the sixteen observation water wells that are part of the AENV regional groundwater-monitoring network, only five are currently active; the remaining eleven are either inactive or have been reclaimed. There are no active AENV Obs WWs north of Medicine Hat. Water-level measurements are available for 14 of the 16 AENV Obs WWs, but five are of limited use, and are not presented in the report. One additional water well site that is being monitored over time by Mow-Tech Ltd. is also discussed in the text below.

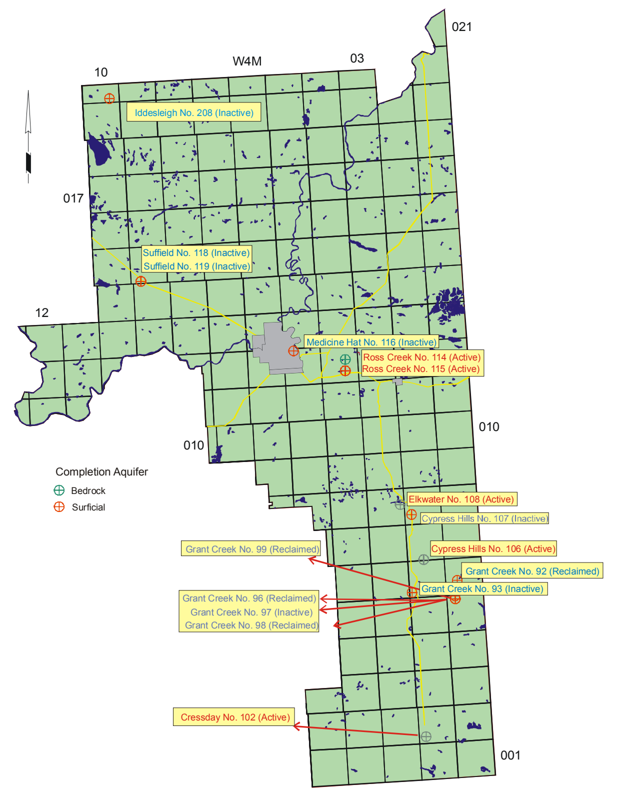


Figure 27. Location of AENV Obs WWs

Two AENV Obs WWs, Nos. 114 and 115, in 16-10-012-04 W4M, are used by AENV as an indicator of drought (AEP, 1998 Fax Communication). AENV Obs WW No. 114 is completed at a depth of 73.8 metres below ground level in the Oldman Aquifer and AENV Obs WW No. 115 is completed at a depth of 36.0 metres below ground level in the Lower Sand and Gravel Aquifer. Both hydrographs show similar water-level fluctuations, but because AENV Obs WW No. 114 has a more complete record, the water-level fluctuations in No. 114 have been compared to the annual precipitation measured at the Medicine Hat weather station from 1984 to 1998. There appears to be no correlation between precipitation and water level (page A-57).

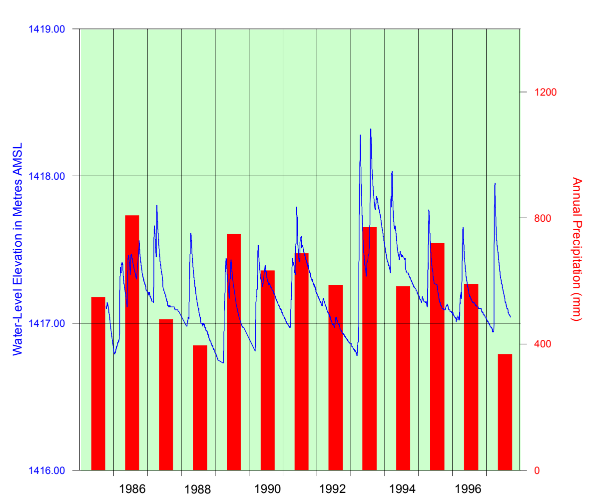


Figure 28. Annual Precipitation vs Water Levels in AENV Obs WW No. 107

There are three AENV Obs WWs in the Cypress Hills/Elkwater area, of which two are currently active. Of the three AENV Obs WWs, one is completed in the Lower Sand and Gravel Aquifer (107), one in the Horseshoe Canyon Aquifer (108), and one in the Bearpaw Aquifer (106). All three hydrographs show at least one peak during the year. The water-level fluctuations in AENV Obs WW No. 107 (12-08-008-02 W4M) show at least two peaks in 1986, 1987, and from 1989 to 1993. The first peak in a given year would be associated with recharge when the frost leaves the ground and the second peak coincides with the end of the growing season. In order to determine if the water-level fluctuations correspond to precipitation, several scenarios of spring, summer and annual precipitation measured at the Cypress Hills, Saskatchewan weather station were applied. Overall, there appeared to be an inconsistent correlation, with the best relationship occurring between annual precipitation and the water levels in AENV Obs WW No. 107 (Figure 28).

In a further attempt to find the closest relationship with water levels and climatic factors in AENV Obs WW No. 107, water levels were compared to monthly temperatures measured at the Cypress Hills, Saskatchewan weather station. In nearly every year, when temperatures rose above 0°C, water levels also rose. The exception that occurred in 1992 was because there was below-average winter precipitation. As a result of the below-average winter precipitation, in 1992 there was no recharge to the Sand and Gravel Aquifer in which AENV Obs WW No. 107 is completed, as shown on the adjacent figure. This water-level decline from 1991 to 1992 is also evident in AENV Obs WW Nos. 106 and 108, both of which are completed in bedrock aquifers (page A-56).

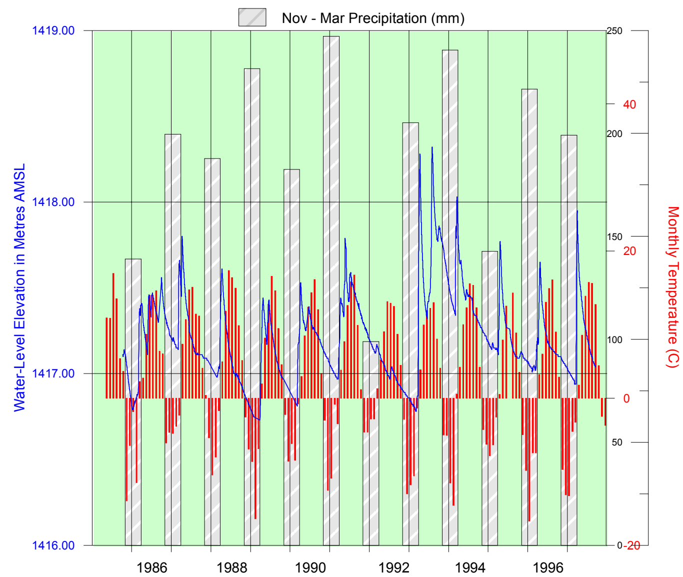


Figure 29. Monthly Temperature and Winter Precipitation vs. Water Levels in AENV Obs WW No. 107

Another example where there appears to be a relationship between water levels, ambient temperature and the November to March precipitation is in the Grant Creek AENV Obs WW No. 93 in 14-06-006-02 W4M (page A-60). A longer record would be necessary to establish this relationship. There have been as many as six AENV observation water wells in the Grant Creek area, with the longest record being from 1994 to 1996. Of the six Grant Creek AENV Obs WWs, four have been reclaimed, and two are inactive. AENV Obs WW No. 93 is completed in the Lower Sand and Gravel Aquifer and was active from 1994 to 1996.

There are two inactive AENV Obs WWs in 07-05-015-09 W4M completed in the surficial deposits. AENV Obs WW No. 118 is completed in the Lower Sand and Gravel Aquifer associated with the Buried Lethbridge Valley and AENV Obs WW No. 119 is completed in the Upper Sand and Gravel Aquifer. AENV Obs WW No. 118 has a water-level record from 1985 to 1992 and AENV Obs WW No. 119 has a water-level record from 1985 to 1995. Only the hydrograph from AENV Obs WW No. 119 is shown in Appendix A and has been included on the CD-ROM. The water level in AENV Obs WW No. 119 has declined in the order of 1.8 metres, with the decline occurring from 1986 to 1990, and from 1993 to 1995. The closest licensed groundwater user to the Obs WW is a water source well completed in the Lower Sand and Gravel Aquifer in NW 13-015-09 W4M, licensed in 1985 to National Defence for commercial purposes. Whether this water source well had an impact on the water level in the two inactive observation water wells cannot be determined without additional groundwater data.

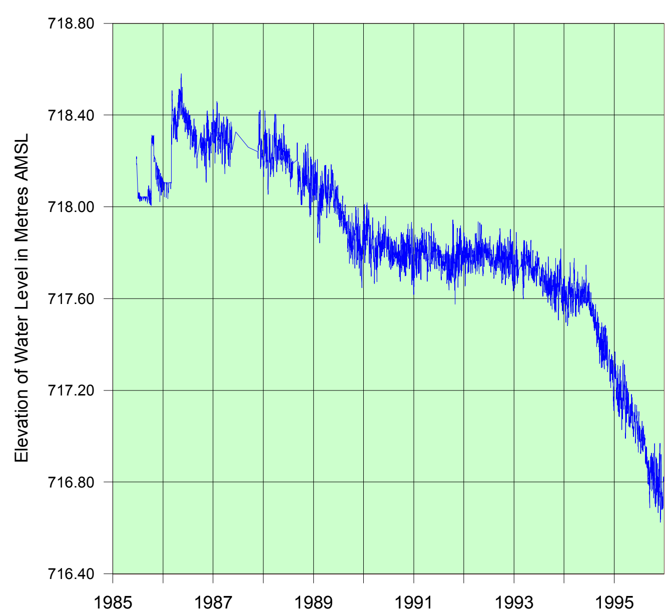


Figure 30. Hydrograph - AENV Obs WW No. 119

In the vicinity of Medicine Hat, there are a large number of water wells completed in the Lower Sand and Gravel Aquifer plus there are nine groundwater users licensed to divert a total of more than 8,000 m³/day from the Lower Sand and Gravel Aquifer. AENV Obs WW No. 116, also inactive and completed in the Lower Sand and Gravel Aquifer, is located in 10-32-012-05 W4M in the Medicine Hat area. The hydrograph for this Obs WW shows an overall water-level decline of approximately 0.5 metres. This water-level decline may be the result of heavy groundwater usage.

The only AENV Obs WW hydrograph that shows an overall water-level rise is in AENV Obs WW No. 102 (page A-56). This observation water well is located in 04-08-002-02 W4M and is completed in the Oldman Aquifer. From 1989 to 1999, there was a water-level rise of approximately 0.4 metres. This active observation water well is used by AENV for international/interprovincial purposes (AEP, 1998 Fax Communication).

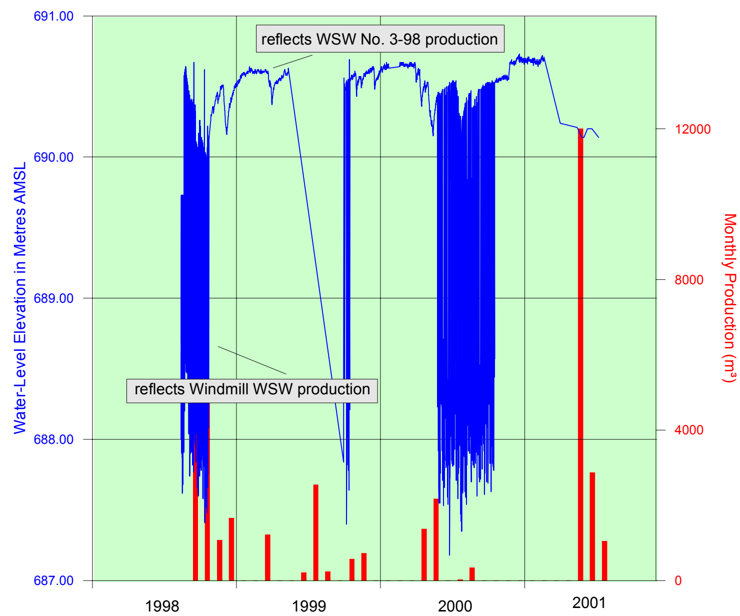


Figure 31. PFRA Windmill WSW Water Levels vs WSW No. 3-98 Groundwater Production

Alberta Energy Company Ltd. operates a water source well (WSW No. 3-98) in 04-04-016-06 W4M, approximately 25 kilometres northwest of Medicine Hat. This water source well is authorized to divert 200 m³/day. The PFRA Windmill Water Supply Well in NW 04-016-06 W4M is used as an observation water well by AECL. Both water wells are completed in the Lower Sand and Gravel Aquifer. The Windmill WSW is licensed to divert 6.7 m³/day. The water-level fluctuations in the Windmill WSW are mainly a result of production from the Windmill WSW, as opposed to the groundwater diversion from WSW No. 3-98, as shown on Figure 31.

Hydrographs for the nine AENV Obs WWs and the PFRA Windmill WSW cited in the above text are in Appendix A and on the CD-ROM.

6.2 Estimated Water Use from Unlicensed Groundwater Users

An estimate of the quantity of groundwater removed from each geologic unit in Cypress County must include both the licensed diversions and the unlicensed use. As stated previously on page 7 of this report, the daily water requirement for livestock for the County based on the 1996 census is estimated to be 13,767 cubic metres. Of the 13,767 m³/day required for livestock, 6,071 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 7,696 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 2,695 water wells that are used for domestic/stock purposes. These 2,695 water wells include both licensed and unlicensed water wells. Of the 2,695 water wells, 500 water wells are used for stock, 766 are used for domestic/stock purposes, and 1,429 are for domestic purposes only.

There are 1,266 water wells that are used for stock or domestic/stock purposes. There are 36 licensed groundwater users for agricultural (stock) purposes, giving 1,230 unlicensed stock water wells. (Please refer to Table 2 on page 7 for the breakdown by aquifer of the 36 licensed stock groundwater users). By dividing the number of unlicensed stock and domestic/stock water wells (1,230) into the quantity of groundwater required for stock purposes that is not licensed (7,696 m³/day), the average unlicensed water well diverts 6.3 m³/day. 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 6.3 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.

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 1.1 m³/day
Stock 6.3 m³/day
Domestic/stock 7.4 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 2,695 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 most of the 9,830 m³/day, estimated to be diverted from unlicensed domestic, stock, or domestic/stock water wells, is from the Upper and Lower Sand and Gravel aquifers, and from the Oldman Aquifer.

	Unlicensed and Licensed Groundwater Diversions							*Licensed Groundwater Diversions*	*Unlicensed Groundwater Diversions*
Aquifer Designation	Number of Domestic	Daily Use (1.1 m³/day)	Number of Stock	Daily Use (6.3 m³/day)	Number of Domestic and Stock	Daily Use (7.4 m³/day)	Totals m³/day	Totals (m³/day)	Totals m³/day
Upper Sand/Gravel	457	503	202	1,264	283	2,082	3,849	17	3,832
Lower Sand/Gravel	446	491	110	688	212	1,560	2,739	200	2,539
Bedrock	28	31	11	69	3	22	122	0	122
Paskapoo	3	3	0	0	0	0	3	0	3
Scollard	5	6	0	0	0	0	6	0	6
Horseshoe Canyon	8	9	0	0	1	7	16	0	16
Bearpaw	109	120	35	219	71	522	861	0	861
Oldman	168	185	91	63	142	1,045	1,293	68	1,225
Foremost	119	131	35	219	38	280	629	20	609
Lea Park	1	1	1	6	1	7	15	0	15
Milk River	2	2	6	38	0	0	40	81	0
Unknown	83	91	9	56	15	110	258	180	78
Totals	1,429	1,572	500	2,622	766	5,636	9,830	566	9,264

Table 6. Unlicensed and Licensed Groundwater Diversions

By assigning 1.1 m³/day for domestic use, 6.3 m³/day for stock use and 7.4 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 5,383 sections in the County. In 79% (4,245) of the sections in the County, there is no domestic or stock or licensed groundwater user. The range in groundwater use from the remaining 1,138 sections with groundwater use is from 1.1 to more than 4,000 m³/day, with an average use per section of 13.5 m³/day (2.1 igpm). Of the 78 licensed users, eight have an authorized diversion of 0 m³/day. The estimated water well use per section can be more than 30 m³/day in 43 of the 1,138 sections. The most notable areas where water well use of more than 30 m³/day is expected occur mainly in the vicinity of linear bedrock lows and near populated centres, as shown on Figure 32.

Groundwater Use within Cypress County (m³/day)		%
Domestic/Stock (licensed and unlicensed)	9,830	33
Municipal (licensed)	5,463	18
Commercial/Irrigation/Recreation et al (licensed)	14,361	48
Total	29,654	100

Table 7. Total Groundwater Diversions

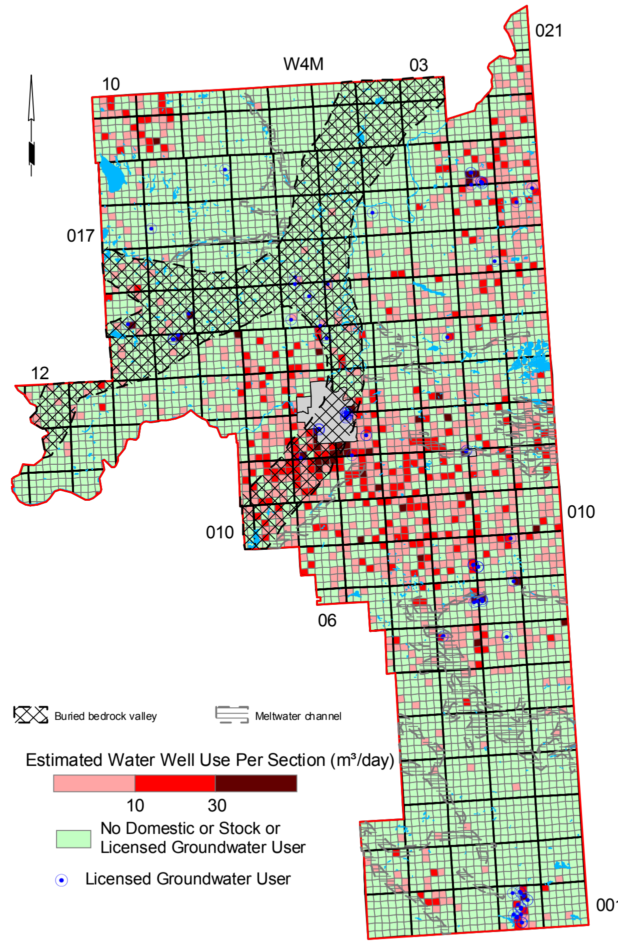


Figure 32. Estimated Water Well Use Per Section

In summary, the estimated total groundwater use within Cypress County is 29,654 m³/day, with the breakdown as shown in the table above. Approximately 862 m³/day is being withdrawn from unknown aquifer units. The remaining 24,337 m³/day has been assigned to specific aquifer units.

Approximately 69% 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 can be summarized below in Table 9:

Aquifer/Area	Trans (m²/day)	Gradient (m/m)	Width (m)	Flow (m³/day)	Aquifer Flow (m³/day)	Licensed Diversion (m³/day)	Unlicensed Diversion (m³/day)	Total (m³/day)
Upper Sand and Gravel					1,600	206	3,832	4,142
Lethbridge								
north	60	0.0013	20,000	1500				
Northeastern								
northeast	1	0.0050	25,000	125				
southwest	1	0.0050	25,000	125				
Lower Sand and Gravel					2,500	18,944	2,538	21,482
Medicine Hat								
north	500	0.0025	1,100	1375				
Lethbridge								
east	240	0.0006	1,100	158				
Dunmore								
west	125	0.0028	1,000	347				
East Boundary								
north	125	0.0010	1,000	125				
North slopes								
southwest	18	0.0083	3,000	450				
Horseshoe Canyon					4,300	328	16	344
Central								
northeast	25	0.004	16,000	1500				
northwest	25	0.011	10,000	2813				
Bearpaw					8,100	0	861	861
South								
North	6.6	0.012	50,000	3850				
South	6.6	0.005	40,000	1320				
Northeast								
southwest	7	0.010	30,000	2100				
north	7	0.006	20,000	840				
Oldman					9,900	152	1,225	1,377
Northwest								
East	5	0.025	50,000	6133				
Northeast								
northwest	3	0.001	60,000	167				
West central								
East	4	0.003	40,000	500				
East central								
north	7	0.006	22,000	963				
east and northeast	7	0.003	70,000	1531				
Southern								
east/south/west	7	0.003	29,000	634				
Foremost					4,320	74	609	683
Northwest								
Northeast	8	0.002	70,000	1120				
East								
North/northwest	8	0.005	75,000	3000				
South								
South	1	0.005	40,000	200				

Table 8. Groundwater Budget

Table 8 indicates that there is more groundwater flowing through the aquifers than has been authorized to be diverted from the individual aquifers, except for the Upper Sand and Gravel and Lower Sand and Gravel 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 sand and gravel aquifers in the surficial deposits is 2.5 to 15 cubic kilometres. This volume is based on an areal extent of 10,000 square kilometres and a saturated sand and gravel thickness of five metres. The variation in the total volume is based on the value of porosity that is used for the sand and gravel. One estimate of porosity is 5%, which gives the low value of the total volume. The high estimate is based on a porosity of 30% (Ozoray, Dubord and Cowen, 1990).

The adjacent water-level map has been prepared from water levels associated with water wells completed in aquifers in the surficial deposits. 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 grey areas on the map). The water-level map for the surficial deposits shows a general flow direction toward the buried bedrock valleys.

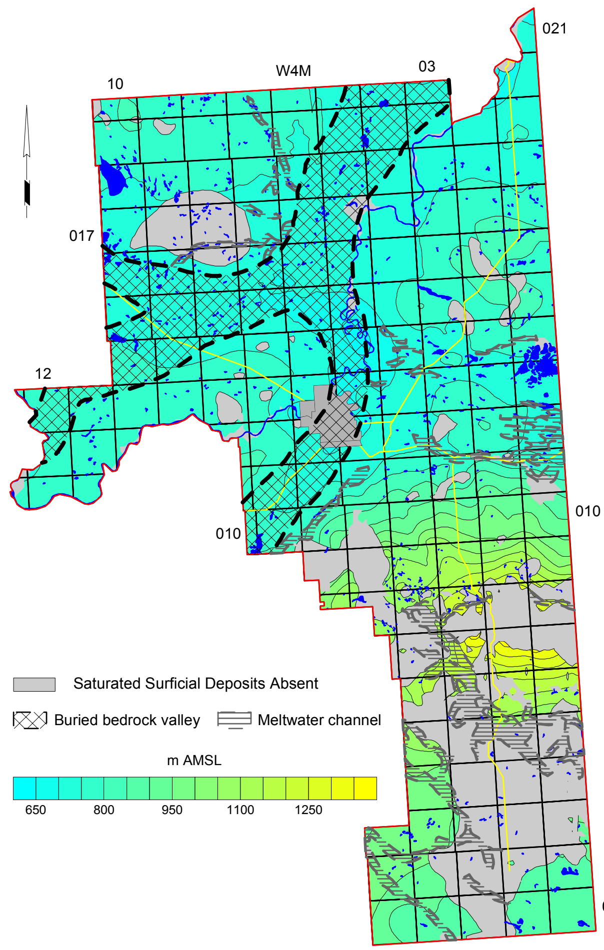


Figure 33. Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep

6.3.2 Recharge/Discharge

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

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

6.3.2.1 Surficial Deposits/Bedrock Aquifers

The hydraulic gradient between the surficial deposits and the upper bedrock aquifer(s) has been determined by subtracting the elevation of the non-pumping water-level surface associated with all water wells completed in the upper bedrock aquifer(s) from the elevation of the non-pumping water-level surface determined for all water wells in the surficial deposits. The recharge classification shown on Figure 34 includes those areas where the water-level surface in the surficial deposits is more than five metres above the water-level surface in the upper bedrock aquifer(s). The discharge areas are where the water level in the surficial deposits is more than five metres lower than the water level in the bedrock. When the water level in the surficial deposits is between five metres above and five metres below the water level in the bedrock, the area is classified as a transition.

The adjacent map shows that, in more than 70% of the County, there is a downward hydraulic gradient (recharge) from the surficial deposits toward the upper bedrock aquifer(s).

The few areas where there is an upward hydraulic gradient (i.e. discharge), from the bedrock to the surficial deposits, are mainly in the vicinity of linear bedrock lows. The remaining parts of the County are areas where there is a transition condition.

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

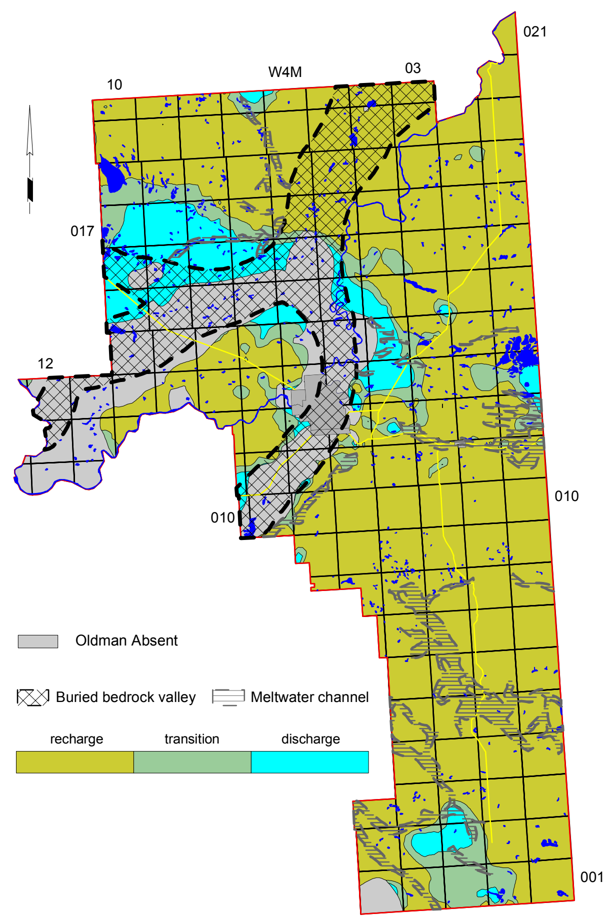


Figure 34. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)

6.3.2.2 Bedrock Aquifers

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

The hydraulic relationship between the surficial deposits and the Oldman Aquifer indicates that in more than 80% of the County where the Oldman Aquifer is present and where there is data control, there is a downward hydraulic gradient (i.e. recharge). Discharge areas for the Oldman Aquifer are mainly associated with the edge of the Aquifer or in areas of linear bedrock lows.

The hydraulic relationship between the surficial deposits and the remainder of the bedrock aquifers indicates there is mainly a downward hydraulic gradient (see CD ROM).

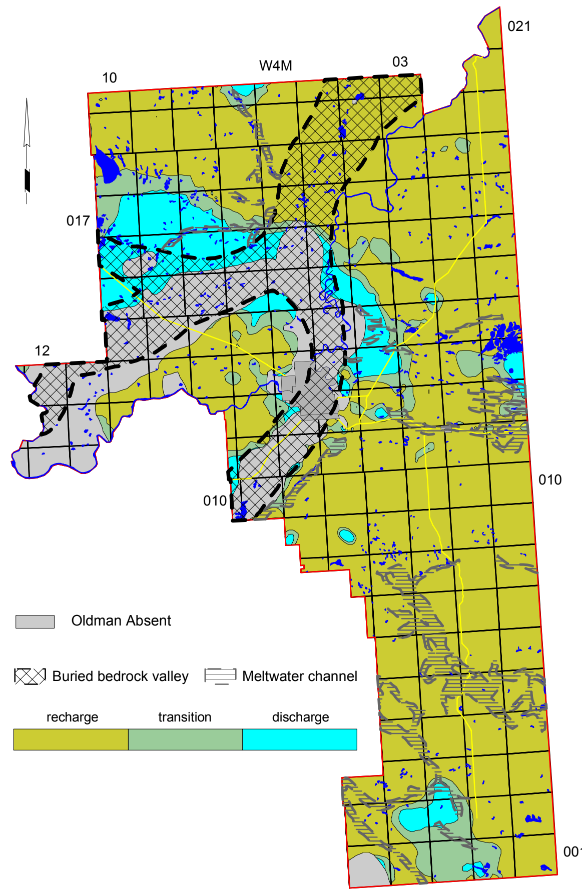


Figure 35. Recharge/Discharge Areas between Surficial Deposits and Oldman Aquifer

6.4 Areas of Groundwater Decline

The areas of groundwater decline in both the sand and gravel aquifer(s) and in the bedrock aquifers have been determined by using a similar procedure in both situations. Because major development began occurring in the 1970s, the changes in water-level maps are based on the differences between water-level elevations available before 1970 and after 1984. Where the earliest water level is at a higher elevation than the latest water level, 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 bedrock 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.

Of the 920 water wells completed in the sand and gravel aquifer(s) with a non-pumping water level and date, 383 are from water wells completed before 1970 and 216 are from water wells completed after 1984. Of the 383 water-level measurements, 175 were measured as part of the Federal Well Survey, with 152 being measured from 1935 to 1937. As a result of the disproportionate location of control points prior to and after major development, the adjacent map has been masked with a solid brown color to indicate areas of no control.

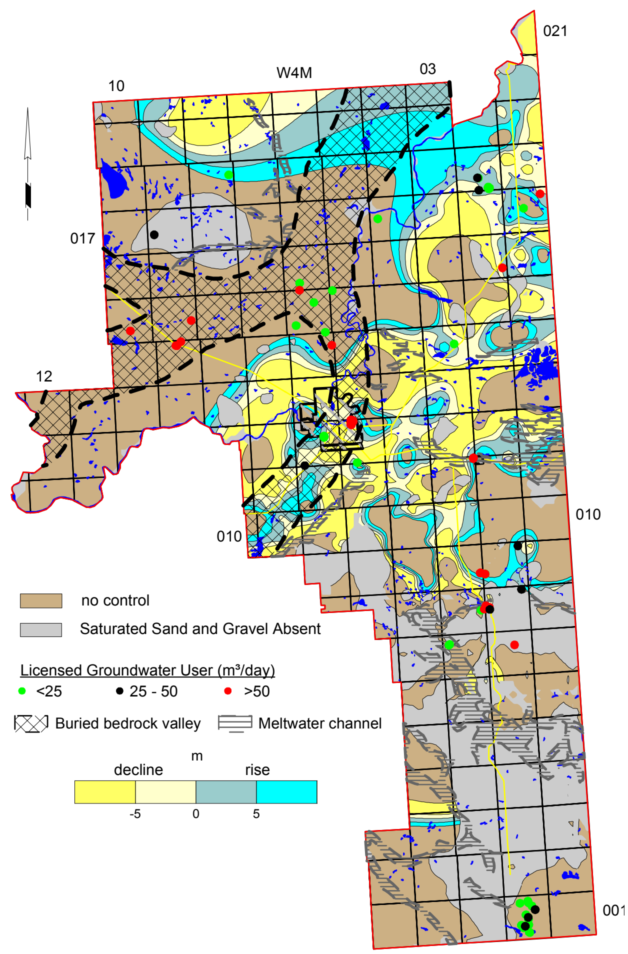


Figure 36. Changes in Water Levels in Sand and Gravel Aquifer(s) Based on Water Wells Less than 20 Metres Deep

The adjacent map indicates that in 80% of the County where there is control, it is possible that the non-pumping water level has declined. The large area indicating that a water-level rise may have occurred in the northern part of the County, may be a result of the gridding process. Of the 78 licensed groundwater users, most occur in areas where a water-level decline may exist or there is no control.

Nine percent of the areas where there has been a water-level decline of more than five metres in the sand and gravel aquifer(s) 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; 22% of the declines occurred where the estimated water well use is less than 10 m³/day per section; the remaining 68% occurred where there is no groundwater use per section, as shown on Figure 32.

Of the 806 bedrock water wells with a non-pumping water level and date, 201 are from water wells completed before 1970 and 269 are from water wells completed after 1984. Of the 201 water-level measurements, 55 were measured as part of the Federal Well Survey, with 43 being measured from 1935 to 1937. As a result of the disproportionate location of control points prior to and after major development, the adjacent map has been masked with a solid brown color to indicate these areas of no control and figures for the individual bedrock aquifers have not been created.

The adjacent map indicates that in 60% of the County, it is possible that the non-pumping water level has declined. Of the 78 licensed groundwater users, most occur in areas where a water-level decline may exist or there is no control.

Seven percent of the areas where there has been a water-level decline of more than five metres in upper bedrock aquifer(s) 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; 16% of the declines occurred where the estimated water well use is less than 10 m³/day per section; the remaining 76% occurred where there is no groundwater use per section, as shown on Figure 32.

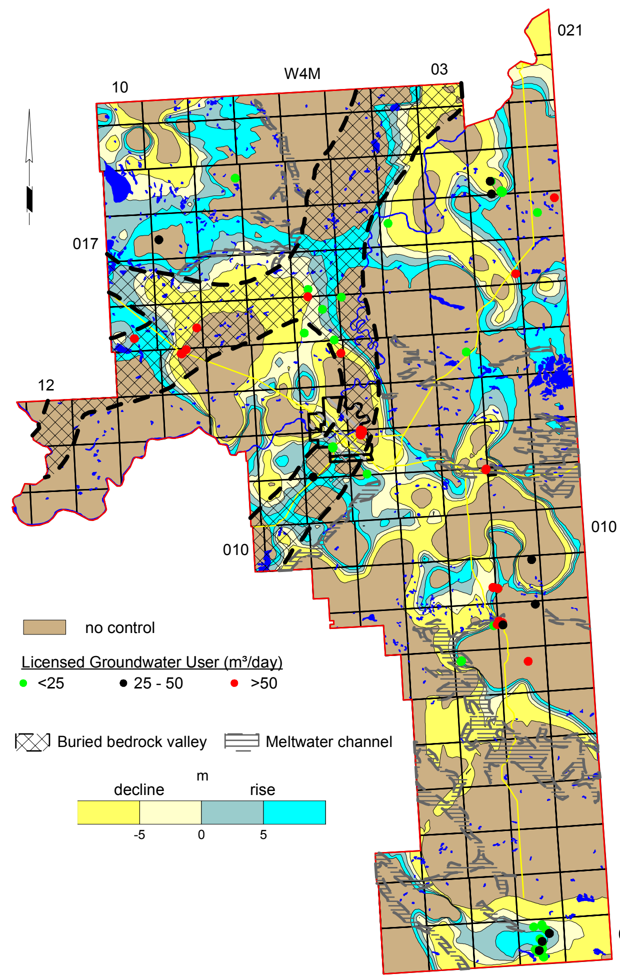


Figure 37. Changes in Water Levels in Upper Bedrock Aquifer(s)

6.5 Discussion on Specific Study Areas

As per the Request for Proposal, Cypress County requested that comments be made, where possible, on the following study areas and issues. The issue is stated at the beginning of each of the following sections.

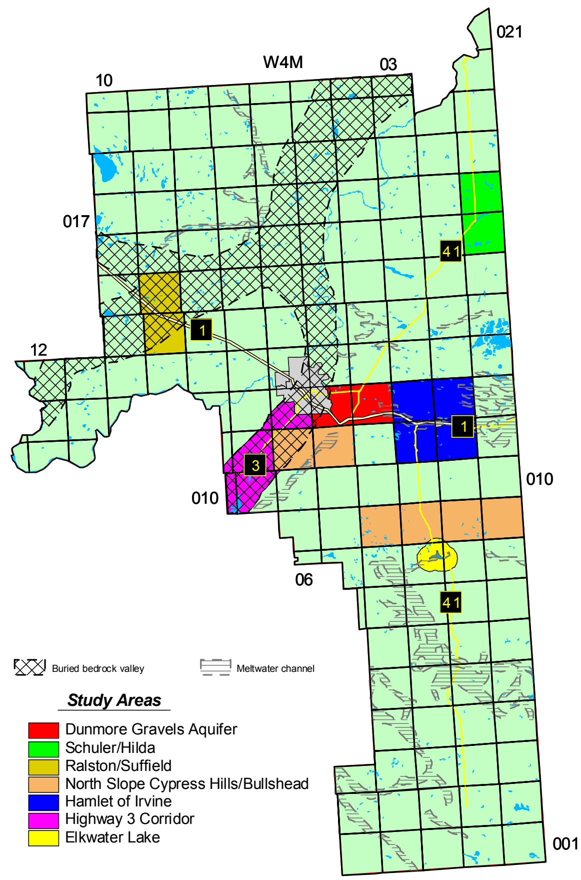


Figure 38. Specific Study Areas

6.5.1 Dunmore Gravels Aquifer Area

What is the approximate extent and potential (yield and water quality) of this Aquifer? Can the primary recharge areas for this Aquifer be identified?

The presence of sand and gravel occurring within one metre of the land surface can be expected in the Dunmore area in the eastern and southwestern parts of township 012, range 05, W4M. The thickness of the first sand and gravel is mainly less than five metres. Westgate shows that kame[18] deposits of limited areal extent can be expected north, northeast and northwest of Dunmore and are primarily associated with the hills and knobs. The importance of these hills and knobs is mainly related to how they may restrict recharge to the near-surface glacial gravel unit (PFRA, 1998 Memorandum Communication).

Both the Upper and Lower Sand and Gravel aquifers are present in parts of the Dunmore area. In township 012, range 05, W4M, the Lower Sand and Gravel Aquifer is the main Aquifer in surficial deposits present. Apparent yields of more than 100 m³/day in the southwestern part of township 012, range 05, W4M are not uncommon (see page A-29). In township 012, range 04, W4M, the Upper Sand and Gravel Aquifer is the main Aquifer in surficial deposits present, with apparent yields mainly in the range from 10 to 100 m³/day.

Groundwater from water wells completed in SW 04-012-05 W4M in the aquifers in the surficial deposits are expected to have TDS concentrations of approximately 1,815 mg/L, as shown in the adjacent table containing an abbreviated version of the Groundwater Query Results.

The apparent yield for individual water wells completed in SW 04-012-05 W4M through the Lower Sand and Gravel Aquifer is estimated to be 167 m³/day.

Dunmore Area
Mow-Tech Ltd. gwQuery Results (metric)
SW 04-012-05 W4M

Detailed Results Formation Name	Top metre	Yield m³/day	NPWL metre	TDS mg/L	Sulfate mg/L	Chloride mg/L
Upper Surficial Deposits	--	--	--	1815	1097	23
Lower Surficial Deposits	0	167	5	1815	1097	23
Bedrock Surface	11					
Oldman Formation	11	34	8	1021	394	24
Foremost Formation	41	20	13	2018	1786	355

Table 9. Groundwater Query Results – Dunmore Area

18 See glossary

6.5.2 Schuler/Hilda Area

What is the groundwater potential of this general area and where would be a suitable location that would produce a yield of greater than or equal to 200 m³/day? What groundwater quality can be expected?

The Upper Sand and Gravel Aquifer is present in most of the Schuler/Hilda area; the Lower Sand and Gravel Aquifer is absent. Although surficial deposits are mostly between 50 and 100 metres thick in the Schuler/Hilda area, the Upper Sand and Gravel deposits are expected to be less than five metres thick below Schuler but could be between 10 and 30 metres thick below Hilda. Apparent yields of less than 50 m³/day can be expected, although an apparent yield of 110 m³/day was calculated in NW 16-017-01 W4M from a bored water well completed at a depth of 15.2 metres below ground surface. There is one licensed groundwater user in the Schuler/Hilda area and the water well is completed in the Upper Sand and Gravel Aquifer. The M.D. of Cypress is licensed to divert 60.2 m³/day from a water supply well in 04-36-017-01 W4M for municipal purposes.

The upper bedrock in the Schuler/Hilda area is both Bearpaw and Oldman formations. The upper bedrock below Hilda and Schuler is the Oldman Formation. A water supply well was completed for Alberta Housing & Public Works at the Hilda Maintenance Garage in 16-32-017-01 W4M. The water supply well was completed from 94.2 to 116.4 metres below ground surface in the Oldman Aquifer. An extended aquifer test conducted with this water supply well indicated a long-term yield of 52 m³/day. Groundwater from this water supply well has TDS concentrations of 4,060 mg/L, sulfate of 2,067, chloride of 105 mg/L, sodium of 1,194 mg/L, and a total hardness of 365 mg/L (HCL, 1981).

Groundwater from water wells completed in 16-32-017-01 W4M in the Oldman Aquifer are expected to have TDS concentrations of approximately 3,449 mg/L, as shown in the adjacent table containing an abbreviated version of the Groundwater Query Results. The apparent yield for individual water wells completed in 16-32-017-01 W4M through the Oldman Aquifer is estimated to be 51 m³/day. In order to obtain the potentially higher yields and lower TDS concentrations associated with the Foremost Aquifer, a water well would need to be completed more than 150 metres below ground surface at this location.

Schuler/Hilda Area
Mow-Tech Ltd. gwQuery Results (metric)
16-32-017-01 W4M

Detailed Results Formation Name	Top metre	Yield m³/day	NPWL metre	TDS mg/L	Sulfate mg/L	Chloride mg/L
Upper Surficial Deposits	--	10	6	2130	1088	52
Bedrock Surface	60					
Oldman Formation	60	51	21	3449	1874	210
Foremost Formation	150	553	63	1255	156	120

Table 10. Groundwater Query Results – Schuler/Hilda Area

In 1962, the Hamlet of Hilda completed a water well in NW 35-017-01 W4M, in the depth interval from 190.5 to 198.1 metres below ground surface in the Foremost Aquifer. An apparent yield of more than 500 m³/day has been calculated at this location. Groundwater quality data are not available for this water well.

The Hamlet of Schuler has one water well completed in the Oldman Aquifer in NW 09-016-01 W4M that was completed from 146 to 184.4 metres below ground surface. Four aquifer tests were conducted with this water well in September 1962. Apparent yields ranging from 31.3 to 77.2 m³/day have been calculated from the resulting data. Groundwater quality data are not available for this water well.

6.5.3 Ralston/Suffield Area

What is the approximate extent and development potential of the groundwater in this general area? Based on the available water-level data, is there any evidence of depletion?

Although the Upper Sand and Gravel Aquifer is present in most of the Ralston/Suffield area, it is the Lower Sand and Gravel Aquifer that is being utilized for groundwater purposes (see Page A-29 for extent). There are no water wells with apparent yield data in the Ralston/Suffield area that are completed in the Upper Sand and Gravel Aquifer. The closest water well completed in the Upper Sand and Gravel Aquifer with apparent yield data is in 08-24-016-10 W4M, having an apparent yield of 130 m³/day.

In the Ralston/Suffield Area, there are nine water wells with apparent yield data that are completed in the Lower Sand and Gravel Aquifer, including four that have been licensed by AENV. The National Defence is licensed to divert more than 4,100 m³/day from three water wells for municipal and commercial purposes. The fourth licensed user in the area is the Suffield Co-op. The Suffield Co-op water supply well in NW 34-014-09 W4M is completed in the depth interval from 106.7 to 109.7 metres below ground surface in the Lower Sand and Gravel Aquifer and is licensed to divert 196 m³/day. Based on an aquifer test conducted with the Suffield Co-op water supply well, Marciniuk (1975) determined that the buried valley gravels at Suffield were capable of producing an estimate of between 650 and 6,500 m³/day.

An extended aquifer test conducted with a National Defence water supply well and two observation water wells completed in the Lower Sand and Gravel Aquifer in SW 34-014-09 W4M indicated a long-term sustainable pumping rate of more than 25,000 m³/day (CH_2MHILL, 1990).

Groundwater from water wells completed in SW 34-014-09 W4M in the aquifers in the surficial deposits are expected to have TDS concentrations of approximately 925 mg/L, as shown in the adjacent table containing an abbreviated version of the Groundwater Query Results. The apparent yield for individual water wells completed in SW 34-014-09 W4M through the Lower Sand and Gravel Aquifer is estimated to be 447 m³/day.

Ralston/Suffield Area
Mow-Tech Ltd. gwQuery Results (metric)
SW 34-014-09 W4M

Detailed Results Formation Name	Top metre	Yield m³/day	NPWL metre	TDS mg/L	Sulfate mg/L	Chloride mg/L
Upper Surficial Deposits	--	58	11	925	242	11
Lower Surficial Deposits	76	447	44	925	242	11
Bedrock Surface	111					
Foremost Formation	111	333	44	1669	55	520

Table 11. Groundwater Query Results – Ralston/Suffield Area

The upper bedrock in the Ralston/Suffield Area is mainly the Foremost Formation; however, in parts of townships 014 and 015, range 09, W4M, the Oldman Formation is present. In township 014, range 09, W4M, there are five water wells completed in the Foremost Aquifer with apparent yield data. Apparent yields of more than 200 m³/day may be encountered. There is one water well completed in bedrock in township 015, range 09, W4M with apparent yield data. This water well, completed in the Foremost Aquifer, has an apparent yield of less than ten m³/day.

There are two inactive AENV Obs WWs in 07-05-015-09 W4M completed in the surficial deposits. AENV Obs WW No. 118 is completed in the Lower Sand and Gravel Aquifer associated with the Buried Lethbridge Valley and AENV Obs WW No. 119 is completed in the Upper Sand and Gravel Aquifer. AENV Obs WW No. 118 has a water-level record from 1985 to 1992 and AENV Obs WW No. 119 has a water-level record from 1985 to 1995. The water level in AENV Obs WW No. 119 has declined in the order of 1.8 metres, with the decline occurring from 1986 to 1990, and from 1993 to 1995. The water level in AENV Obs WW No. 118 has also declined; however, between mid-1988 and late 1989, no water levels were recorded. When water-level measurements were recorded again in late 1989, the water level was nearly 0.5 metres lower. It is possible that a new recorder was installed and the reference point had changed. Given this assumption, the water-level decline measured in the Lower Sand and Gravel Aquifer at the site of AENV Obs WW No. 118 would be approximately 0.5 metres from 1985 to 1992.

6.5.4 North Slope Cypress Hills/Bullshead Area

What is the development potential and quality of the groundwater in this general area? Are there any aquifers capable of producing more than 200 m³/day that would be suitable for the construction of a regional pipeline system? Could the upslope springs around an elevation of 1,130 m AMSL be a potential source for a regional pipeline?

The Lower Sand and Gravel Aquifer is the primary Aquifer in the surficial deposits that underlie the Bullshead area of township 011, ranges 05 and 06, W4M. There are 67 water wells with apparent yield data that are completed in the Lower Sand and Gravel Aquifer in the Bullshead area. The average apparent yield from these 67 water wells is 75 m³/day. The yields that are greater than 100 m³/day are mainly in water wells that are located in the Buried Medicine Hat Valley in township 011, range 06, W4M or in the meltwater channel in township 011, range 05, W4M. There are less than ten water wells that have apparent yields that are greater than 200 m³/day. There are no licensed groundwater users in the Bullshead area.

Groundwater from water wells completed in NW 16-011-06 W4M in the aquifers in the surficial deposits are expected to have TDS concentrations of approximately 1,623 mg/L, as shown in the adjacent table containing an abbreviated version of the Groundwater Query Results. The apparent yield for individual water wells completed in NW 16-011-06 W4M through the Lower Sand and Gravel Aquifer is estimated to be 82 m³/day.

North Slope Cypress Hills/Bullshead Area
Mow-Tech Ltd. gwQuery Results (metric)
NW 16-011-06 W4M

Detailed Results Formation Name	Top metre	Yield m³/day	NPWL metre	TDS mg/L	Sulfate mg/L	Chloride mg/L
Upper Surficial Deposits	--	--	--	1623	889	32
Lower Surficial Deposits	0	82	17	1623	889	32
Bedrock Surface	49					
Foremost Formation	49	171	41	1983	812	53

Table 12. Groundwater Query Results – North Slope Cypress Hills/Bullshead Area

There are 15 water wells with apparent yield data that are completed in bedrock in the Bullshead area, eleven in township 011, range 04, W4M and four in township 011, range 05, W4M. Of the 15 water wells, seven are completed in the Oldman Aquifer and eight are in the Foremost Aquifer. Apparent yields from water wells completed in bedrock aquifers in the Bullshead area are expected to mainly range from 10 to 100 m³/day. There are ten water wells with apparent yield data that are completed in township 009, ranges 01 to 04, W4M. The seven surficial water wells are in ranges 03 and 04, W4M, with higher yields occurring in the Lower Sand and Gravel Aquifer in range 03, W4M. Of the three bedrock water wells, one is completed in the Bearpaw Aquifer and two are in the Oldman Aquifer. Apparent yields from water wells completed in bedrock aquifers are higher than 10 m³/day, with the two highest yields occurring in ranges 03 and 04, W4M, as shown in Table 13.

Water Wells in Township 009, Ranges 01 to 04, W4M

Aquifer	No. of Water Wells with Values for Apparent Yield	Number of Water Wells with Apparent Yields <10 m³/day	10 to 100 m³/day	>100 m³/day	TDS mg/L
Upper Sand and Gravel	2	0	2	0	#N/A
Lower Sand and Gravel	5	1	2	2	350
Bearpaw	1	0	1	0	1464
Oldman	2	0	1	1	#N/A

Table 13. Water Wells in Tp 009, Rg 01 to 04, W4M

In the groundwater database, there are 35 springs located in township 009, ranges 01 to 03, W4M, of which eight are at an elevation of between 1,100 and 1,150 metres AMSL. The measured flow rate is available for only one of the 35 springs; a spring in 16-09-009-03 W4M at an elevation of 770 metres AMSL has a flow rate of 1.51 lpm. There are two known licensed spring users in Cypress County: one at NW 07-009-02 W4M at an elevation of 1,130 metres AMSL and one at SE 13-009-03 W4M at an elevation of 1,115 m AMSL. The Hutterian Brethren Church of Elkwater is licensed to divert 142 m³/day from the spring in NW 07-009-02 W4M. Fawn Springs Water Company and the Ross Creek Water Co-op Ltd. are licensed to divert 277 m³/day from the spring in SE 13-009-03 W4M. Both springs had TDS concentrations of approximately 770 mg/L, sulfate concentrations of mainly less than 170 mg/L, chloride concentrations of less than 5 mg/L, and a total hardness concentration of less than 300 (Groundwater Exploration & Research Ltd., 1997). One example where a spring has been monitored over time is at the Paetku (Lick) Spring in NW 14-043-28 W4M, in Ponoka County. This spring was monitored by Mow-Tech Ltd. from 1989 to 1998. The hydrograph shows that during the ten-year interval, the 1989-1990 flow rate of around 200 lpm had more than doubled by 1991 to more than 500 lpm, and had also declined by half to less than 100 lpm in 1996-1997 (page A-69).

6.5.5 Hamlet of Irvine Area

What is the likely extent and groundwater development potential of the aquifer into which the Hamlet of Irvine water supply wells are installed?

The Hamlet of Irvine occupies section 31, township 011, range 02, W4M and the NE ¼ of section 36, township 011, range 02, W4M (M.D. of Cypress No. 1, Ownership Map, March 1996). The area of interest for the County includes townships 011 and 012, ranges 02 and 03, W4M. The Hamlet of Irvine is located on a meltwater channel that extends east from Dunmore near section 06, township 012, range 03, W4M to east of Irvine near section 03, township 012, range 02, W4M, as shown on the west-east cross-section D-D' (pages 14 and A-15). The cross-section shows that upper surficial deposits can be more than 40 metres thick, and lower surficial deposits are not only limited to within a few kilometres of NE 36-011-03 W4M but are less than ten metres thick. The lower sand and gravel deposits are generally less than five metres near Irvine (see CD-ROM).

In July 1973, the Groundwater Branch of Alberta Environment drilled seven water test holes in the Irvine area in an attempt to provide Irvine with a new water supply well. Of the seven water test holes drilled, only one was completed as a water well; the remaining six were abandoned. Of the seven water test holes drilled, only three encountered lower sand and gravel deposits of at least three metres in thickness. Water Test Hole 998E in 10-36-011-03 W4M encountered three metres of lower sand and gravel, WTH 1000E located closest to Irvine in 15-36-011-03 W4M encountered 7.3 metres of lower sand and gravel, and WTH 995E in 14-36-011-03 W4M encountered 7.6 metres of lower sand and gravel deposits. Water Test Hole 996E in 16-36-011-03 had encountered 1.5 metres of lower sand and gravel deposits, but due to drilling difficulties the test hole had to be abandoned before bedrock was reached (Lorberg, 1973). Because the AENV drill rig was unable to pull the casing from the water well (test hole 1000E), the water well was completed without a screen and was now to be used as an observation water well (HCL, 1975). A two-hour recovery-only aquifer test was conducted by AENV with WTH 1000E. Based on a maximum apparent transmissivity value of 39.5 m²/day, a maximum apparent yield of 1,100 m³/day was calculated (Lorberg, 1973).

In May 1975, a water supply well was drilled for the Hamlet of Irvine in 16-36-011-03 W4M, approximately 35 metres east of WTH 1000E. During the drilling of the new water supply well, 5.5 metres of lower sand and gravel deposits was encountered. This water supply well was drilled to a depth of 59.1 metres, but did not encounter bedrock. The water supply well was completed from 55.8 to 59.1 metres below ground surface. An extended pumping and recovery aquifer test with the new water supply well, using WTH 1000E as the observation water well, indicated an apparent yield of more than 1,300 m³/day.

Two new water supply wells were drilled for the Hamlet of Irvine in 1988 in 15-36-011-03 W4M after the casing collapsed in the 1975 water supply well. The drilling records show that 4.8 metres of lower sand and gravel were encountered during the drilling of each of the two water supply wells. PFRA (1990) reports that the expected long-term safe yield of more than 770 m³/day is limited by the water well screens. It is estimated that up to 1,300 m³/day could be obtained from the Lower Sand and Gravel Aquifer.

The apparent yield for individual water wells completed in NW 15-36-011-03 W4M through the Lower Sand and Gravel Aquifer is estimated to be 351 m³/day, as shown in the adjacent table containing an abbreviated version of the Groundwater Query Results.

Irvine Area
Mow-Tech Ltd. gwQuery Results (metric)
15-36-011-03 W4M

Detailed Results Formation Name	Top metre	Yield m³/day	NPWL metre	TDS mg/L	Sulfate mg/L	Chloride mg/L
Upper Surficial Deposits	--	6	3	1719	686	14
Lower Surficial Deposits	44	351	15	1719	686	14
Bedrock Surface	49					
Oldman Formation	49	--	50	1369	296	98
Foremost Formation	114	281	-23	1211	--	--

Table 14. Groundwater Query Results – Hamlet of Irvine Area

6.5.6 Highway 3 Corridor – Medicine Hat to Seven Persons

What is the groundwater development potential of this area? Based on the available water-level data and current withdrawals, is there a risk of depletion?

The Highway 3 Corridor, underlain by the Buried Medicine Hat Valley, is the area where there are the largest number of water wells completed in the lower surficial deposits (Figure 13, page 18). There are more than 90 water wells with apparent yield data that are completed in the Lower Sand and Gravel Aquifer in this Area. The average apparent yield from these 90 water wells is 110 m³/day, with 86% having an apparent yield of less than 200 m³/day. There are eight records that indicate dry, or abandoned with "insufficient water". There is only one licensed groundwater user in the Highway 3 Corridor. This groundwater user in 04-05-012-06 W4M is licensed to divert 40 m³/day for stock purposes. Within the Medicine Hat city limits, there are 13 groundwater users licensed to divert a total of 13,400 m³/day, or an average of 1,030 m³/day per user.

Groundwater from water wells completed in 04-01-011-07 W4M in the aquifers in the surficial deposits are expected to have TDS concentrations of approximately 1,534 mg/L, as shown in the adjacent table containing an abbreviated version of the Groundwater Query Results. The apparent yield for individual water wells completed through the Lower Sand and Gravel Aquifer is estimated to be 110 m³/day.

Highway 3 Corridor
Mow-Tech Ltd. gwQuery Results (metric)
04-01-011-07 W4M

Detailed Results	Top	Yield	NPWL	TDS	Sulfate	Chloride
Formation Name	metre	m³/day	metre	mg/L	mg/L	mg/L
Upper Surficial Deposits	--	--	--	1534	1058	38
Lower Surficial Deposits	0	110	16	1534	1058	38
Bedrock Surface	68					
Foremost Formation	68	74	38	2277	1039	50

Table 15. Groundwater Query Results – Highway 3 Corridor – Medicine Hat to Seven Persons

Of the 244 effective transmissivity values that were added to the groundwater database, more than 70 were from aquifer test results from water wells in the Highway 3 Corridor area. The flow through the Lower Sand and Gravel Aquifer is calculated to be 2,500 m³/day.

There are 28 water wells with apparent yield data that are completed in the Foremost Aquifer in the Highway 3 Corridor. More than 75% of the apparent yields from water wells completed in bedrock aquifers in the Highway 3 Corridor range from 10 to 100 m³/day.

The closest AENV observation water well to the Highway 3 Corridor is the inactive AENV Obs WW No. 116. This AENV Obs WW, completed in the Lower Sand and Gravel Aquifer, is located in 10-32-012-05 W4M in the east-central part of the City of Medicine Hat. The hydrograph for this Obs WW shows an overall water-level decline of approximately 0.5 metres from 1959 to 1995.

6.5.7 Elkwater Lake

What is the reliability of springs feeding Elkwater Lake and the potential impact of further residential development outside the park to the north and west.

Water levels have been measured at Elkwater Lake since 1917; however, it has only been since 1972 that consistent measurements have been recorded by Environment Canada. The water-level data were obtained by HCL and the available mean monthly water levels have been compared to annual precipitation measured at the Cypress Hills, Saskatchewan weather station. The graph below shows that a good correlation exists between the lowest annual water level measured and the total annual precipitation. In order to determine the reliability of the spring(s) feeding Elkwater Lake, the flow rate would need to be monitored and the relationship between the flow rate of the spring(s) and Elkwater Lake water level be investigated.

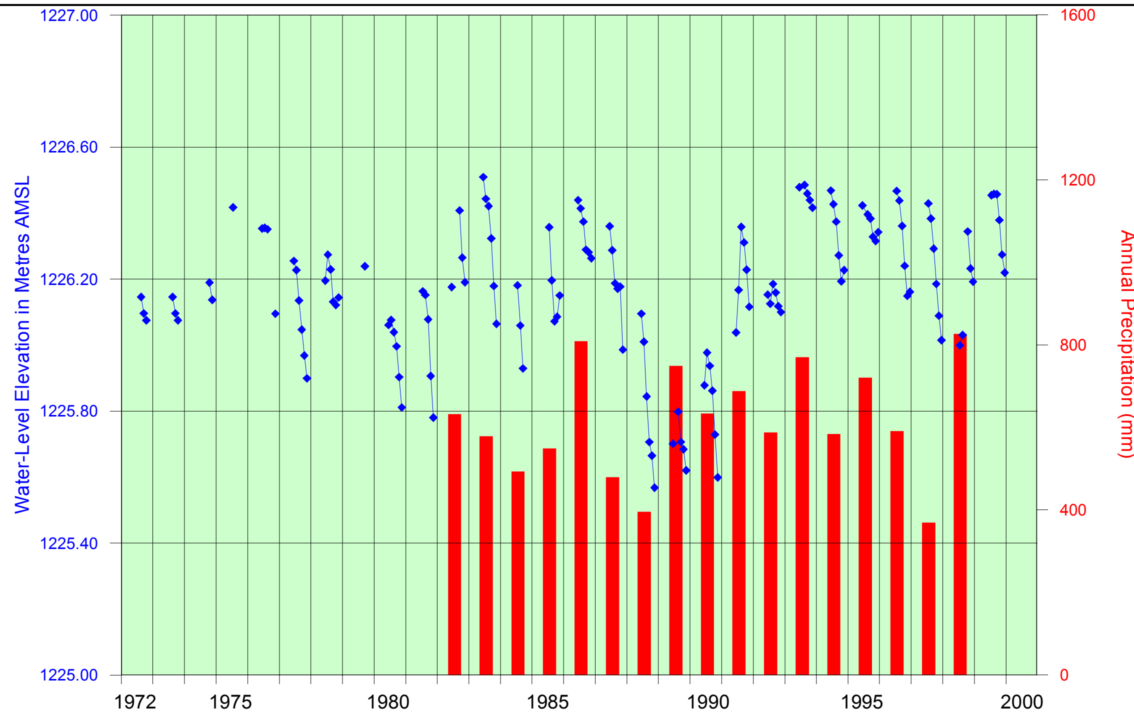


Figure 39. Elkwater Lake Mean Monthly Water Levels vs. Annual Precipitation

Because of the correlation between precipitation and the lake level, it could be concluded that either the spring discharge is directly related to precipitation and there is no apparent effect of development, or the spring discharge is insignificant relative to the water received from precipitation.

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 114 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. There are three water wells for which the County has responsibility, of which only one satisfies the above criteria. For the remaining two water wells, a legal location, an aquifer name, and a completed depth are available in the groundwater database; all three of the County-operated water wells are shown in Appendix E. It is recommended that these two County-operated water wells plus the 114 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.

An attempt to link the AENV groundwater and licensing databases was about 57% successful in this study (see CD-ROM). About 43% of licensed water wells do not appear to have corresponding records in the AENV groundwater database. There is a need to improve the quality of the AENV licensing database. It is recommended that attempts be made in a future study to find and add missing drilling records to the AENV groundwater database and to determine the aquifer in which the licensed water wells are completed.

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). Of the 114 water wells recommended for field verification, ten of the bedrock water wells and 15 of the surficial water wells are in areas of water-level decline. Because the flow through the Lower Sand and Gravel Aquifer is significantly less than the total of the licensed and unlicensed diversions, it is strongly recommended that a groundwater-monitoring program be established.

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

Before an attempt is made to 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 114 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.

A list of the 114 water wells that could be considered for the above program is given in Appendix E and on the CD-ROM.

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 and conducting of seismic programs.

Groundwater is a renewable resource and it must be managed.

8. References

Agriculture Canada Prairie Farm Rehabilitation Administration. Regina, Saskatchewan. 1996. 1996 Agriculture Census (CD-ROM).

Agriculture, Food and Rural Development. 1995. Water Requirements for Livestock. Agdex 400/716-1.

Alberta Department of Environment. 1977. Earth Sciences Division. Walsh Rest Area, NW 28-11-1 W4M.

Alberta Energy and Utilities Board. June 1995. AEUB ST-55. Alberta's Usable Groundwater Database.

Alberta Research Council. March 31, 1995. Mapping and Resource Exploration of the Tertiary and Preglacial Formations of Alberta. Canada/Alberta Partnership on Minerals. Project Number: M92-04-008.

Allong, A. F. 1967. Sedimentation and Stratigraphy of the Saskatchewan Gravels and Sands in Central and Southern Alberta. University of Wisconsin. M. Sc. (Geology) Thesis. 130 p.

Bel-MK Engineering Ltd. March 1998. Prepared for Municipal District of Cypress. Watewater Disposal Study. Hamlet of Dunmore. 02-012-05 W4M.

Bland, G. O. Sep 1975. Department of Environment, Environmental Protection Services, Earth Sciences and Licensing Division, Groundwater Development Branch. Groundwater Investigation, Hilda, Alberta. 36-017-01 W4M.

Borneuf, D. M. 1976. Alberta Geological Survey. Hydrogeology of the Foremost Area, Alberta. Foremost Area. Report 74-4.

Borneuf, D. M. 1983. Alberta Geological Survey. Springs of Alberta. Report 82-3.

Buchanan, Bob; Alberta Agriculture, Food and Rural Development. Engineering Services Branch; Alberta Environment. Licensing and Permitting Standards Branch; Canada. Prairie Farm Rehabilitation Administration. 1996. Water Wells … that Last for Generations.

Cable, Dave. 12 Jan 98. Fax from AEP Water Science Branch to Terry Dash (PFRA).

CAESA. November 1997. Alberta Farmstead Water Quality Survey. Prepared for CAESA Water Quality Monitoring Committee.

CAESA-Soil Inventory Project Working Group. 1998. AGRASID: Agricultural Region of Alberta Soil Inventory Database (Version 1.0). Edited by J. A. Brierley, B. D. Walker, P. E. Smith, and W. L. Nikiforuk. Alberta Agriculture Food & Rural Development, publications.

Campbell Geoscience Ltd. Aug-1984. Hi-Rate Drilling Company Ltd. Report on the Construction and Testing of a Water Well, Department of National Defence, CFB Suffield, Alberta. 34-014-09 W4M.

Carlson, V. A. 1970. Research Council of Alberta. Bedrock Topography of the Medicine Hat Map-Area. NTS 72L, Alberta.

Canadian Council of Resource and Environment Ministers. 1992. Canadian Water Quality Guidelines.

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

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

CH_2M Hill Engineering Ltd. May 1990. Hi-Rate Drilling Company Ltd. Report on the Construction and Testing of a Water Well. Department of National Defence. CFB Suffield. Alberta. 34-014-09 W4M.

Cressie, N. A. C. 1990. The Origins of Kriging. Mathematical Geology. Vol. 22, Pages 239-252.

Dash, Terry. October 26, 1998. Memorandum from PFRA Calgary to PFRA Medicine Hat. Hamlet of Dunmore.

Dash, Terry. November 25, 1997. Memorandum PFRA Calgary to PFRA Medicine Hat. One-Four Experimental Station Wells.

Edwards, W. A. D. 1984. Aggregate Resources of the Irvine Map Area. NTS 72E/16. Alberta Research Council. OFM. 1984-08p. 1:50,000 Map.

Farvolden, R. N. 1963. Figure 14. Bedrock Topography. Edmonton-Red Deer Map Area, Alberta in Early Contributions to the Groundwater Hydrology of Alberta.

Fox, J. C. 1984. Aggregate Resources of the Pedley Map Area. NTS 83 F/6. Alberta Research Council. OFM. 1984 – 14f. 1:50,000 Map.

Freeze, R. Allan and John A. Cherry. 1979. Groundwater. Pages 249-252.

Gabert, G. M. Alberta Research Council. 1986. Earth Sciences Report 86-1. Alberta Groundwater Observation-Well Network.

Glass, D. J. [editor]. 1990. Lexicon of Canadian Stratigraphy, Volume 4: Western Canada, including British Columbia, Alberta, Saskatchewan and southern Manitoba. Canadian Society of Petroleum Geologists, Calgary.

Glen, P. 1978. Canada Department of Regional Economic Expansion. Prairie Farm Rehabilitation Administraiton Engineering Service. PFRA Community Pastures. 1977 Groundwater Investigations Summary Report.

Green, R. 1972. Alberta Geological Survey. Geological Map of Alberta.

Groundwater Exploration & Research Ltd. 1997. Groundwater Supply Evaulation. 14-07-09-02 W4M.

Hamilton, W. N., M. C. Price, and C. W. Langenberg (co-compilers). 1999. Geological Map of Alberta. Alberta Geological Survey. Alberta Energy and Utilities Board. Map No. 236. Scale 1:1,000,000. Revised from 1972 edition, R. Green.

Hudson, B. 1984. Aggregate Resources of the Medicine Hat Map Area. NTS 72L. Alberta Research Council. OFM. 1984-02p. 1:250,000 Map.

Hydrogeological Consultants Ltd. Sep 1971a. Medicine Hat Disposal Pits. Waste Water Disposal Site. Medicine Hat Area. 34-012-03 W4M. Unpublished Contract Report.

Hydrogeological Consultants Ltd. Sep 1971b. Waste Water Disposal Site, 11-34-12-03 W4M. 34-012-03 W4M. Unpublished Contract Report.

Hydrogeological Consultants Ltd. Apr 1972. Department of Lands and Forests, Parks Planning Branch. Group Camp Area: Water Well. Cypress Hills Provincial Park. 19-008-02 W4M. Unpublished Contract Report.

Hydrogeological Consultants Ltd. Sep 1974. Alberta Public Works. Community of Elkwater. Groundwater Report. Elkwater Area. 007-01, 007-02, 007-03, 008-01, 008-02, 008-03 W4M. Unpublished Contract Report.

Hydrogeological Consultants Ltd. Jun 1975. Town of Irvine. 1975 Well Drilling and Aquifer Testing Program. Irvine Area. 36-011-03 W4M. Unpublished Contract Report.

Hydrogeological Consultants Ltd. Dec 1981. Alberta Housing and Public Works. Hilda Maintenance Garage. 1981 Groundwater Program. Hilda Area. 32-017-01 W4M. Unpublished Contract Report.

Hydrogeological Consultants Ltd. Mar 1982. Alberta Housing and Public Works. 1981 Groundwater Program. Cypress Hills Provincial Park. 24-008-03 W4M. Unpublished Contract Report.

Hydrogeological Consultants Ltd. Nov 1983. Alberta Public Works, Supply and Services. 1983 Water Well Maintenance Program. Cypress Hills Provincial Park. 24-008-03 W4M. Unpublished Contract Report.

Hydrogeological Consultants Ltd. Jun 1985. Alberta Environment, Earth Sciences Division, Hydrogeology Branch. Emergency Groundwater Testing Program: Draft. Part of Alberta. Unpublished Contract Report.

Hydrogeological Consultants Ltd. Sep 1994. PanCanadian Petroleum Limited. Exploration Permit Applications. Brooks Area. 26-015-11 W4M. Unpublished Contract Report.

Hydrogeological Consultants Ltd. Oct 1994. PanCanadian Petroleum Limited. Water Source Well Application. Brooks Area. 36-014-11 W4M. Unpublished Contract Report.

Hydrogeological Consultants Ltd. Mar 1999. Alberta Energy Company Ltd. Suffield Block. Groundwater Supply. Suffield Area. 04-016-06 W4M. Unpublished Contract Report.

Hydrogeological Consultants Ltd. Mar 2000. Alberta Energy Company Ltd. 1999 Groundwater Monitoring Report. Suffield Area. 04-04-016-06 W4M. Unpublished Contract Report.

Hydrogeological Consultants Ltd. Jan 2001. Alberta Energy Company Ltd. 2000 Groundwater Monitoring Report. Suffield Area. 04-04-016-06 W4M. Unpublished Contract Report.

Lorberg, E. Jul 1973. AENV; Earth Sciences and Licensing Division. Hydrological Evaluation, Town of Irvine. Irvine Area. 36-011-03 W4M.

Marciniuk, J. Feb 1975. Alberta Department of Environment. Environmental Protection Services. Earth Sciences and Licensing Division. Groundwater Development Branch. Groundwater Investigations. Hamlet of Suffield. NW 34-14-9 W4M.

McPherson, R. A., and C. P. Kathol. 1972. Alberta Geological Survey. Stratigraphic Sections and Drill Hole Logs. Edmonton Area. Alberta.

Meyboom, P. 1959. Research Council of Alberta. A Large Industrial Water Supply for the City of Medicine Hat, 12-05 W4M. 012-05 W4M. (Bulletin 12).

Minister of Supply and Services Canada. 1996. Guidelines for Canadian Drinking Water Quality, Sixth Edition. Prepared by the Federal-Provincial Subcommittee on Drinking Water of the Federal-Provincial Committee on Environmental and Occupational Health.

Moran, S. R. 1986. Surficial Geology of the Calgary Urban Area. Alberta Research Council. Bulletin 53. 46p.

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

National Hydrology Research Institute. December 1994. PPWB Report No. 128. Prepared for Prairie Provinces Water Board. Groundwater Vunerability Mapping along the Alberta-Saskatchewan Boundary.

Ophori, D. U. and J. Toth. 1983. University of Alberta. A Study of Groundwater Resources Development and Management in Ross Creek Basin – Alberta. Progress Report. Submitted to Planning Division. Alberta Environment.

Pawlowicz, J. G. and M. M. Fenton. 1995. Alberta Geological Survey. Bedrock Topography of Alberta.

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

Phinney, V. Laverne (Editor and publisher). 2001. The Alberta List.

Powley, R. 1990. Agriculture Canada. Prairie Farm Rehabilitation Administration. Engineering Service. Phase II Alberta Water Sourcing Studies. Municipal District of Cypress No. 1.

Shetsen, I. 1987. Quaternary Geology, Southern Alberta. Produced by the Natural Resources Division of the Alberta Research Council.

Stalker, A. MacS. 1960. Buried Valleys in Central and Southern Alberta. Paper 60-32. Geological Survey of Canada. Department of Mines and Technical Surveys.

Stalker, A. MacS. 1963. Quaternary Stratigraphy in Southern Alberta. Geological Survey of Canada. Paper 62-34. 52p.

Stalker, A. MacS. and J. S. Vincent, 1993. Subchapter 4K in Sedimentary Cover of the Craton in Canada. D.K. Stott and J. D. Aitken (ed); Geological Survey of Canada. Geology of Canada, no. 5. p. 466-482.

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

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

Tokarsky, O. 1985. Geoscience Consulting Ltd. Prepared for the Prairie Provinces Water Board. Hydrogeologic Profile. Alberta-Saskatchewan Boundary.

Underwood McLellan (1977) Ltd. Jan 1978. Report on Exploration Drilling and Pump Testing, Drowning Ford Region. 017-05 W4M.

Underwood McLellan (1977) Ltd. Apr 1978. Report on Production Well Installation, Drowning Ford Region. 017-05 W4M.

Westgate, J. A. 1968. Research Council of Alberta. Surficial Geology of the Foremost – Cypress Hills Area, Alberta. Bulletin 22.

Znak, M. Nov 1974. Alberta Department of Environment, Environmental Protection Services, Earth Sciences and Licensing Division, Groundwater Development Branch. Hamlet of Hilda. Groundwater Prospects. 35-017-01 W4M.

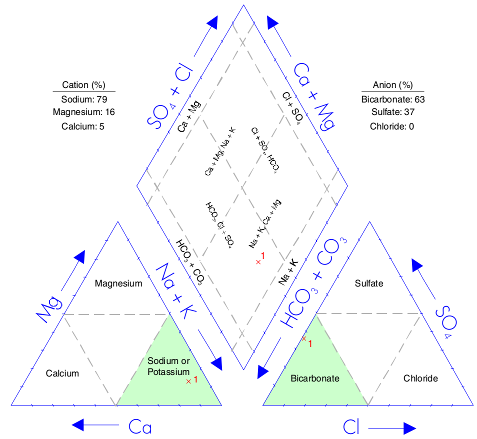
9. Conversions

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
inchs	25.400 000	millimetres
miles	1.609 344	kilometres
kilometer	0.621 370	miles (statute)
square feet (ft^2)	0.092 903	square metres (m^2)
square metres (m^2)	10.763 910	square feet (ft^2)
square metres (m^2)	0.000 001	square kilometres (km^2)
Concentration		
grains/gallon (UK)	14.270 050	parts per million (ppm)
ppm	0.998 859	mg/L
mg/L	1.001 142	ppm
Volume (capacity)		
acre feet	1233.481 838	cubic metres
cubic feet	0.028 317	cubic metres
cubic metres	35.314 667	cubic feet
cubic metres	219.969 248	gallons (UK)
cubic metres	264.172 050	gallons (US liquid)
cubic metres	1000.000 000	litres
gallons (UK)	0.004 546	cubic metres
imperial gallons	4.546 000	litres
Rate		
litres per minute (lpm)	0.219 974	UK gallons per minute (igpm)
litres per minute	1.440 000	cubic metres/day (m^3/day)
igpm	6.546 300	cubic metres/day (m^3/day)
cubic metres/day	0.152 759	igpm

10. Glossary

Aquifer	a formation, group of formations, or part of a formation that contains saturated permeable rocks capable of transmitting groundwater to water wells or springs in economical quantities
Aquitard	a confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer
Available Drawdown	in a confined aquifer, the distance between the non-pumping water level and the top of the aquifer in an unconfined aquifer (water table aquifer), two thirds of the saturated thickness of the aquifer
Borehole	includes all "work types" except springs
Bsk	a climate classification that is characterized by its moisture deficiency, where mean annual potential evapotranspiration exceeds the mean annual precipitation (Thornthwaite and Mather, 1957)
Dewatering	the removal of groundwater from an aquifer for purposes other than use
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
Friable	poorly cemented
Hydraulic Conductivity	the rate of flow of water through a unit cross-section under a unit hydraulic gradient; units are length/time
Kame	a steep-sided alluvial cone deposited against an ice front
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

Montane Region	is the most diverse of all the ecozones, ranging from alpine tundra to dense conifer forests to dry sagebrush and grasslands.
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

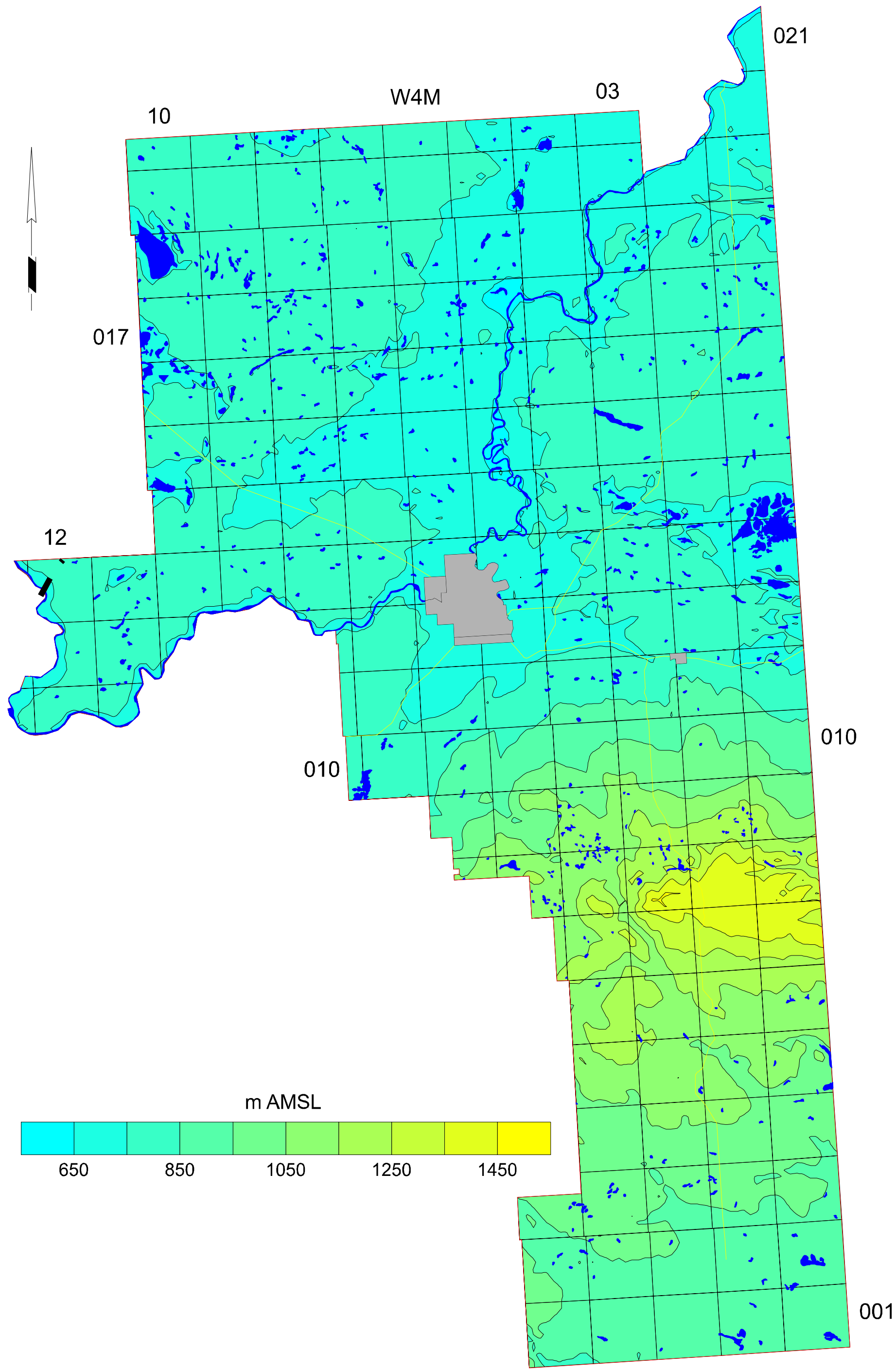
Rock	earth material below the root zone
Surficial Deposits	includes all sediments above the bedrock
Thalweg	the line connecting the lowest points along a stream bed or valley; *longitudinal profile*
Till	a sediment deposited directly by a glacier that is unsorted and consisting of any grain size ranging 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
PFRA	Prairie Farm Rehabilitation Administration
TDS	Total Dissolved Solids
WSW	Water Source Well or Water Supply Well

CYPRESS COUNTY
Appendix A

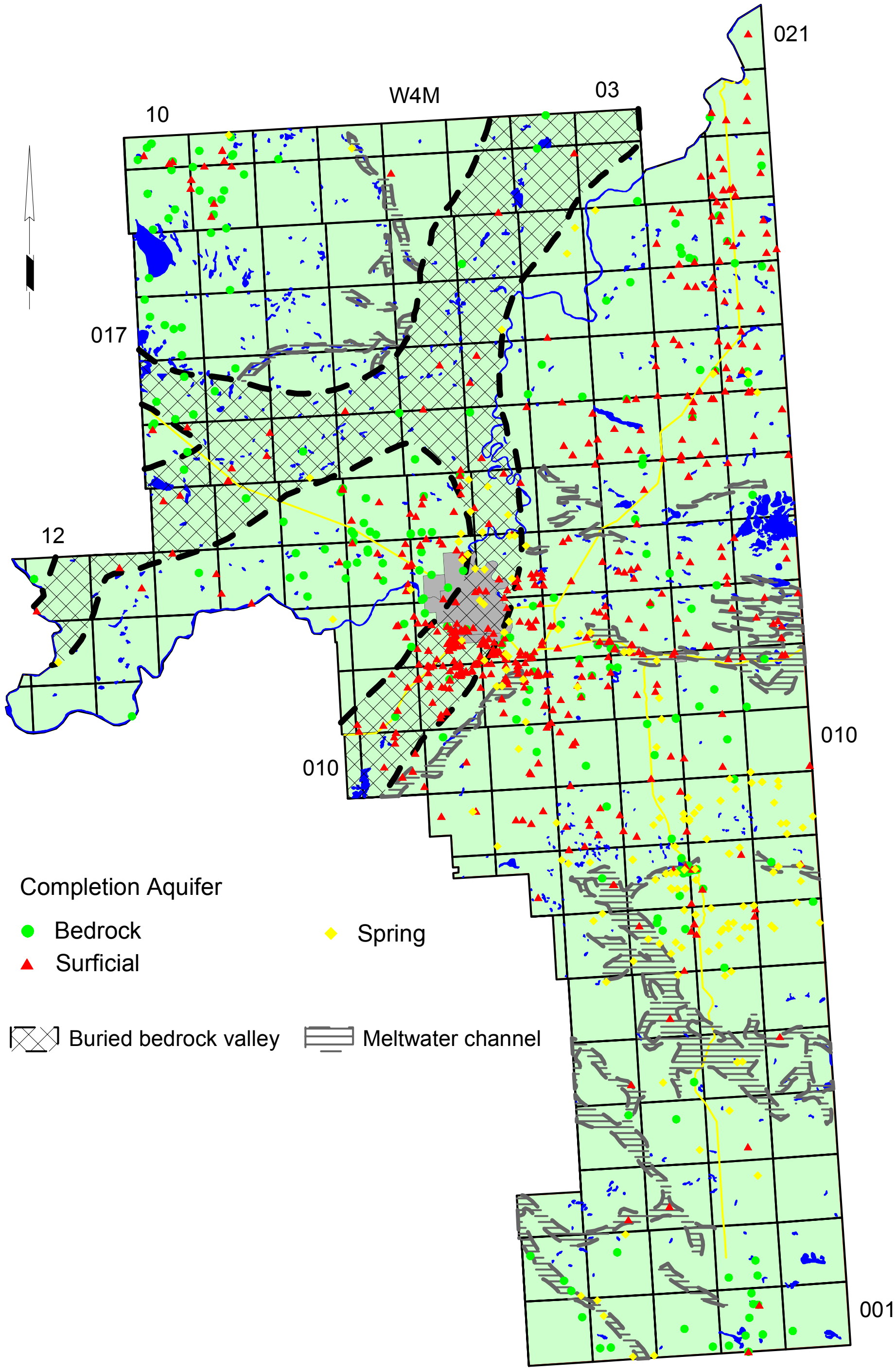
Hydrogeological Maps and Figures

Surface Topography

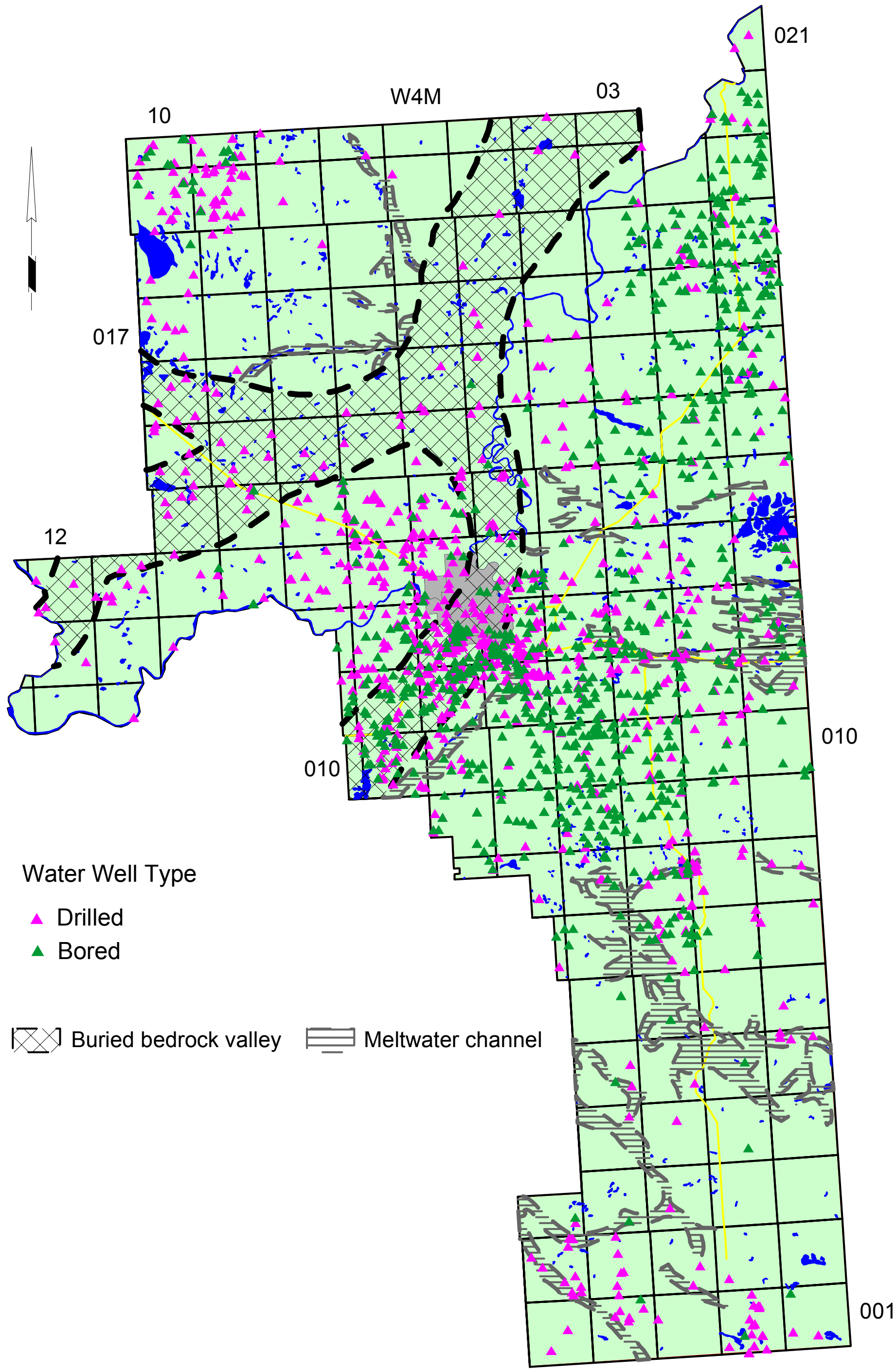


Cypress County

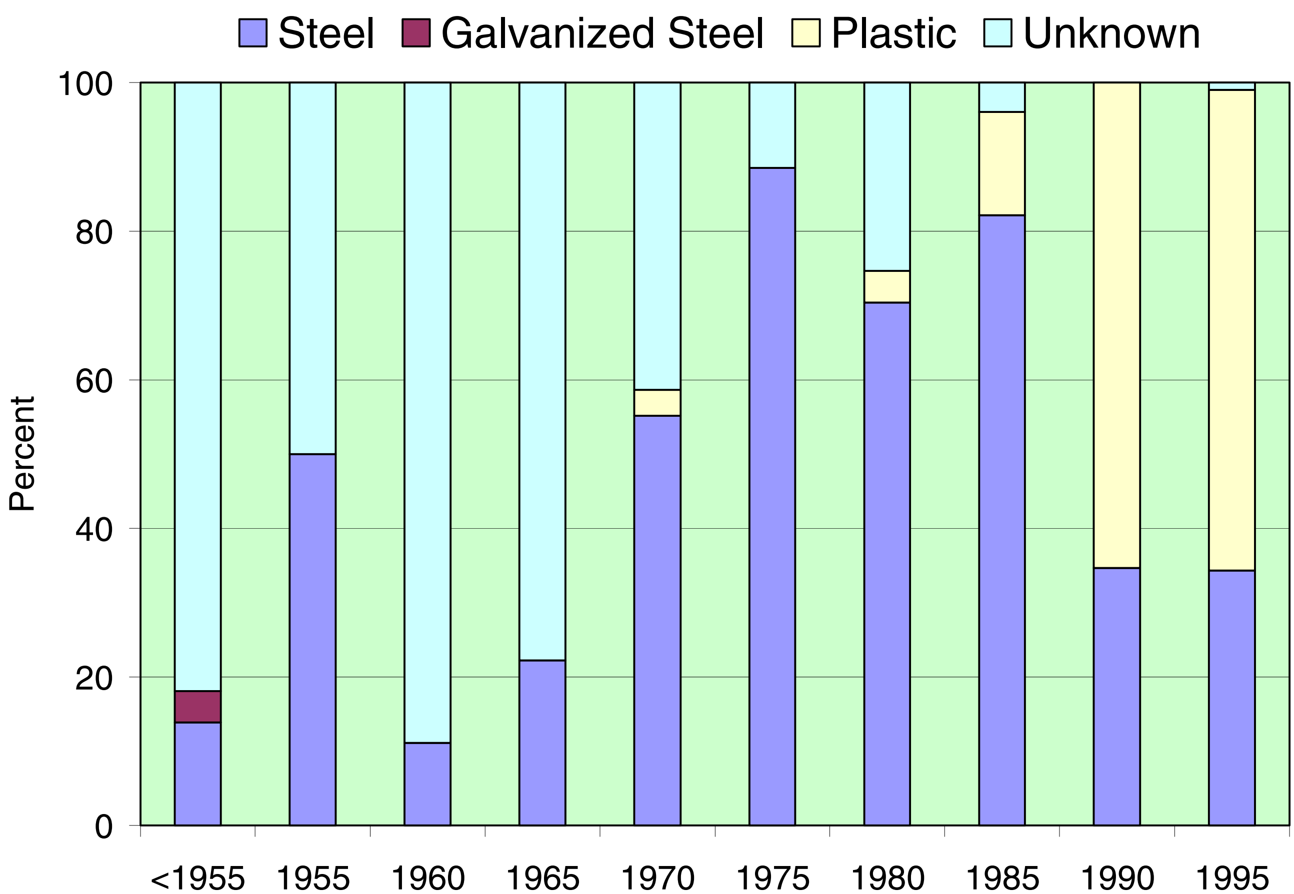
Location of Water Wells and Springs



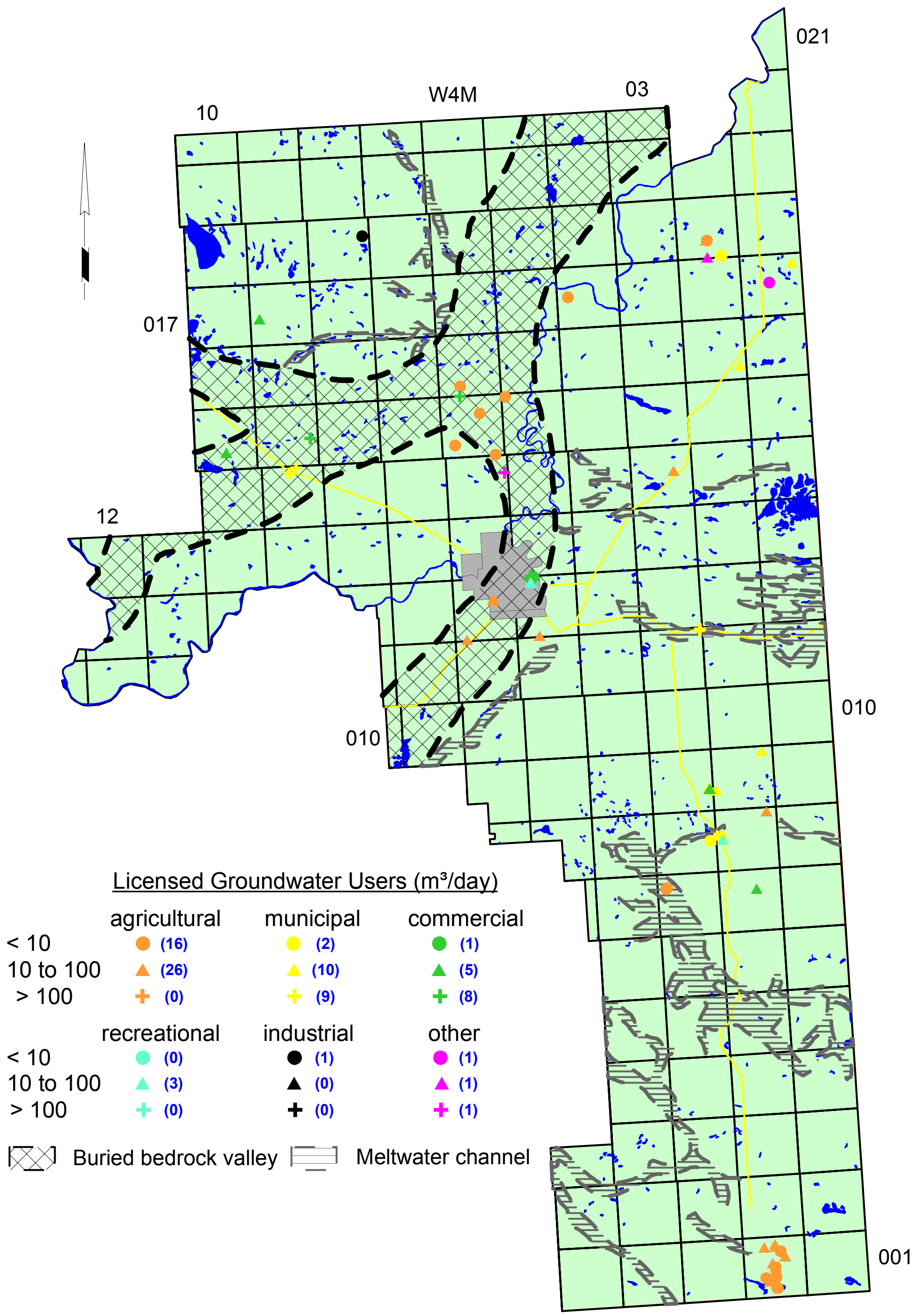
Location of Water Well Type



Surface Casing Types used in Drilled Water Wells



Licensed Water Wells



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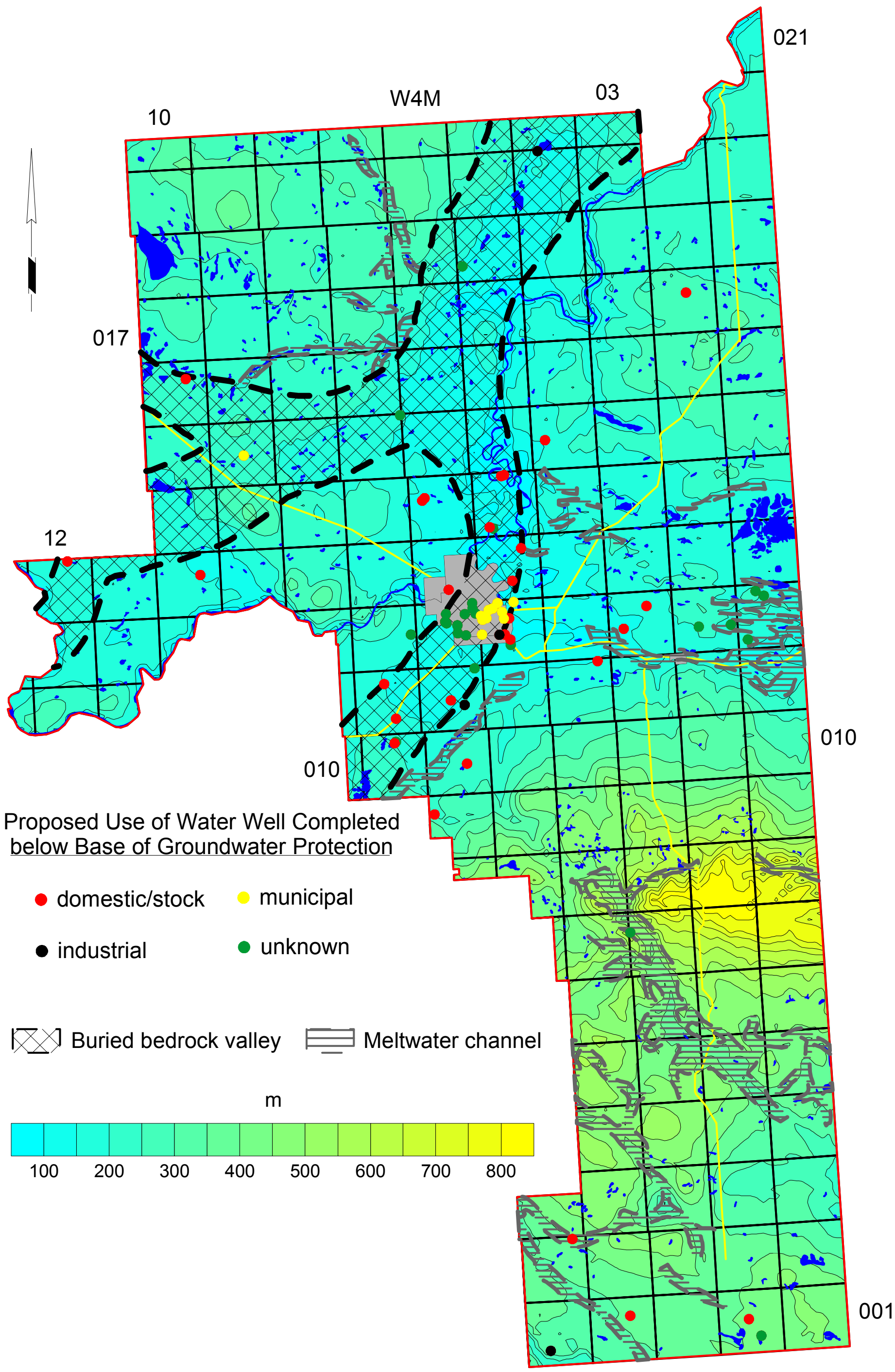
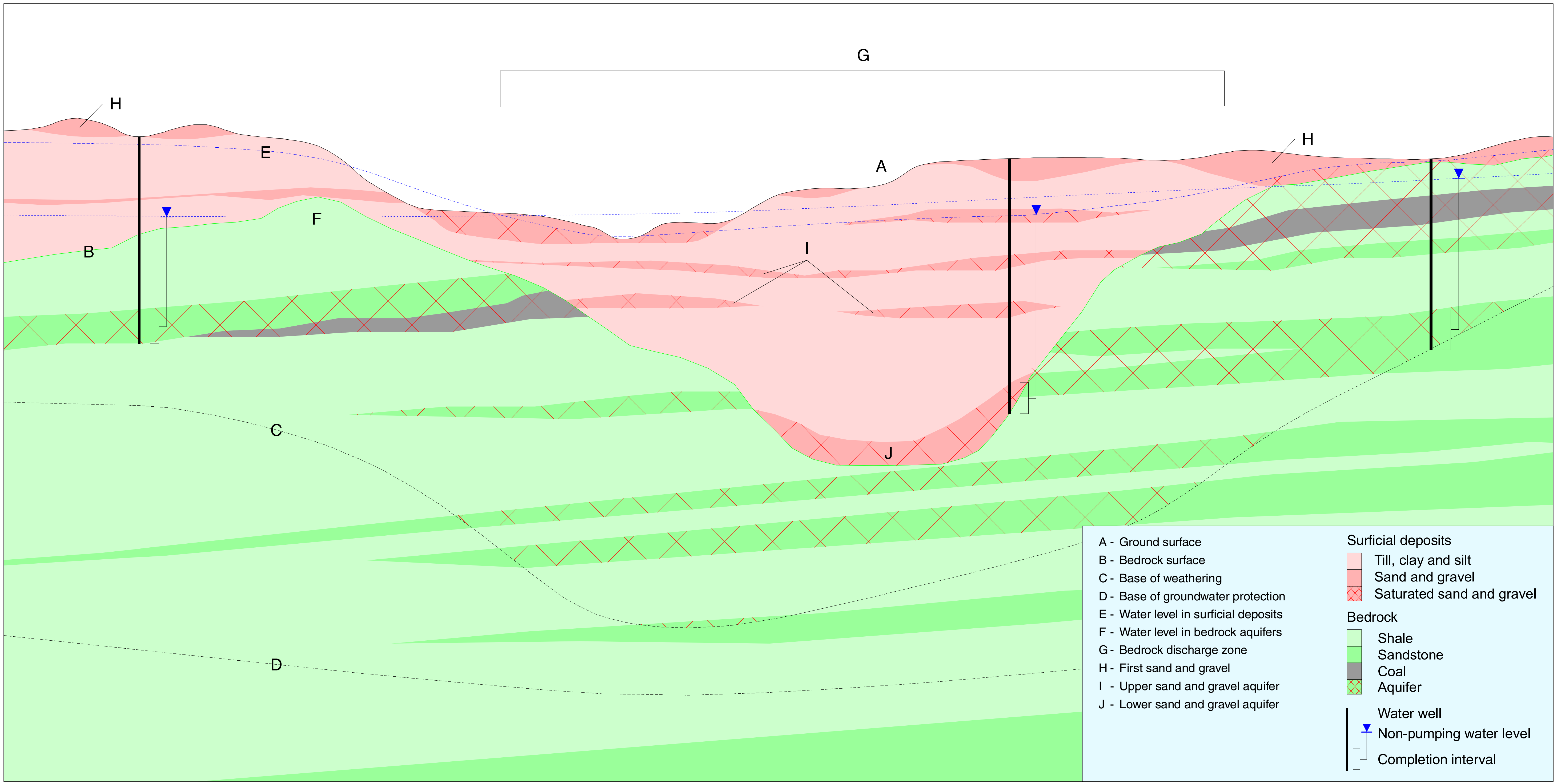
Depth to Base of Groundwater Protection

(modified after EUB, 1995)

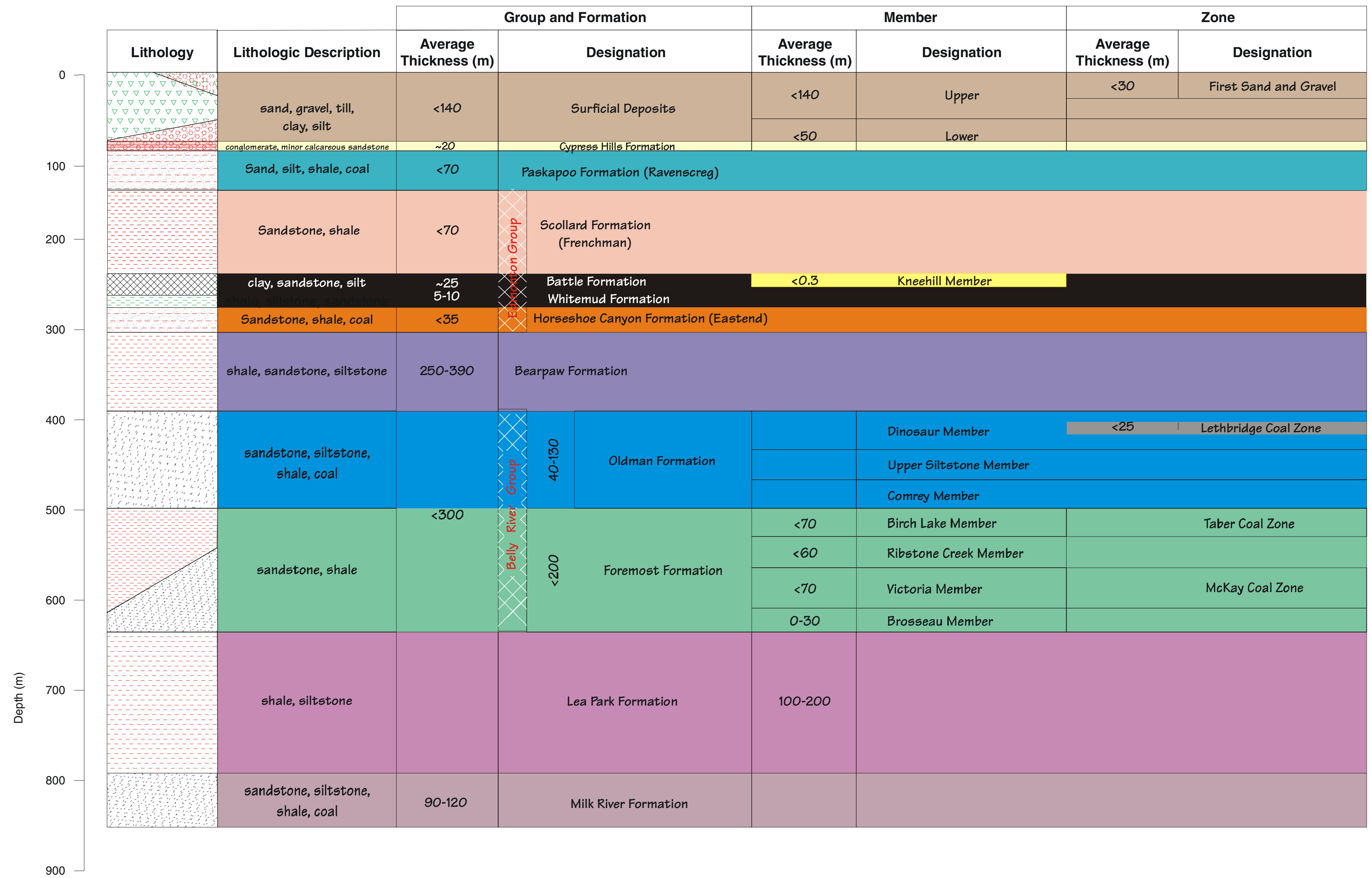


Generalized Cross-Section

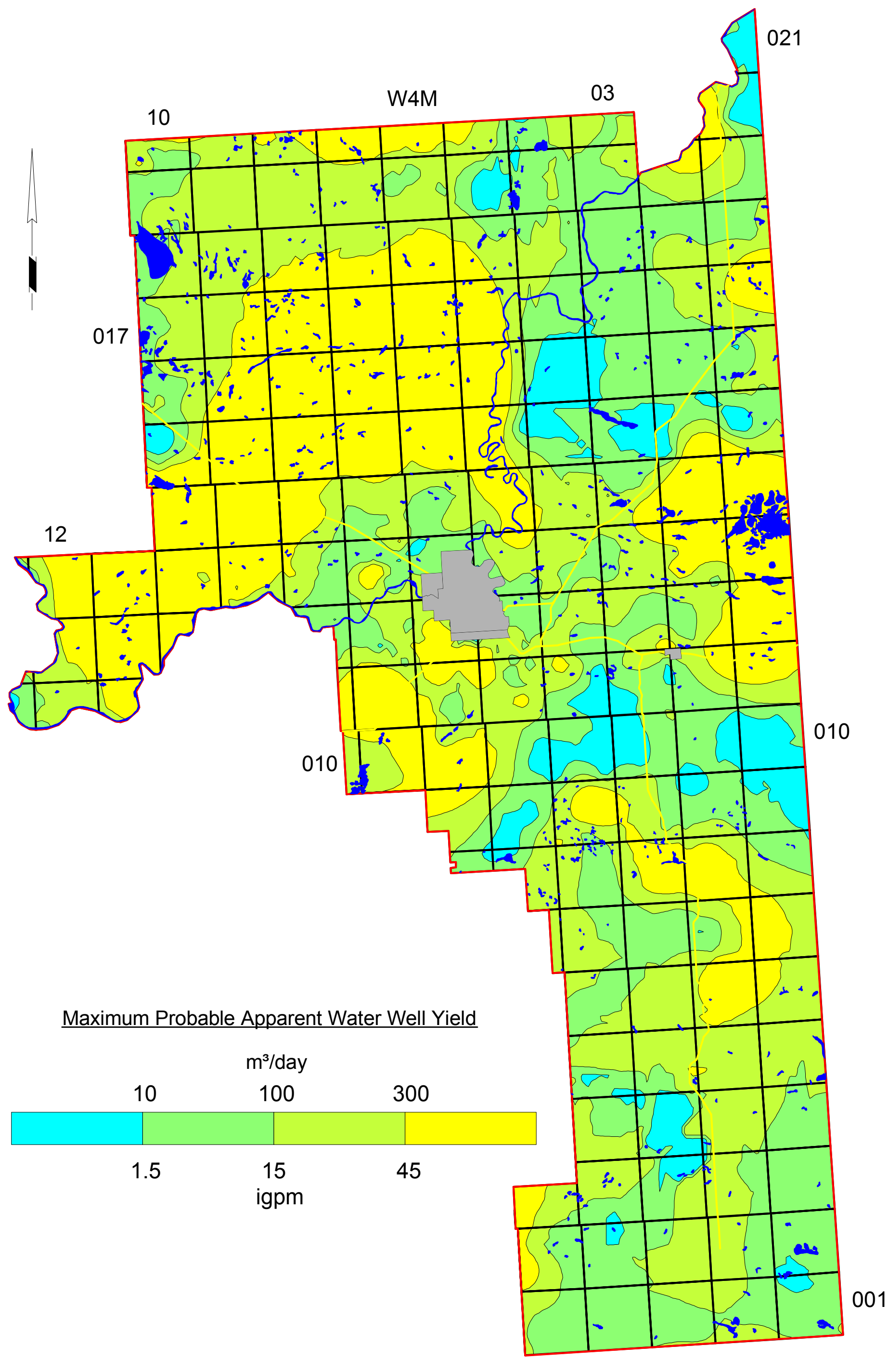
(for terminology only)



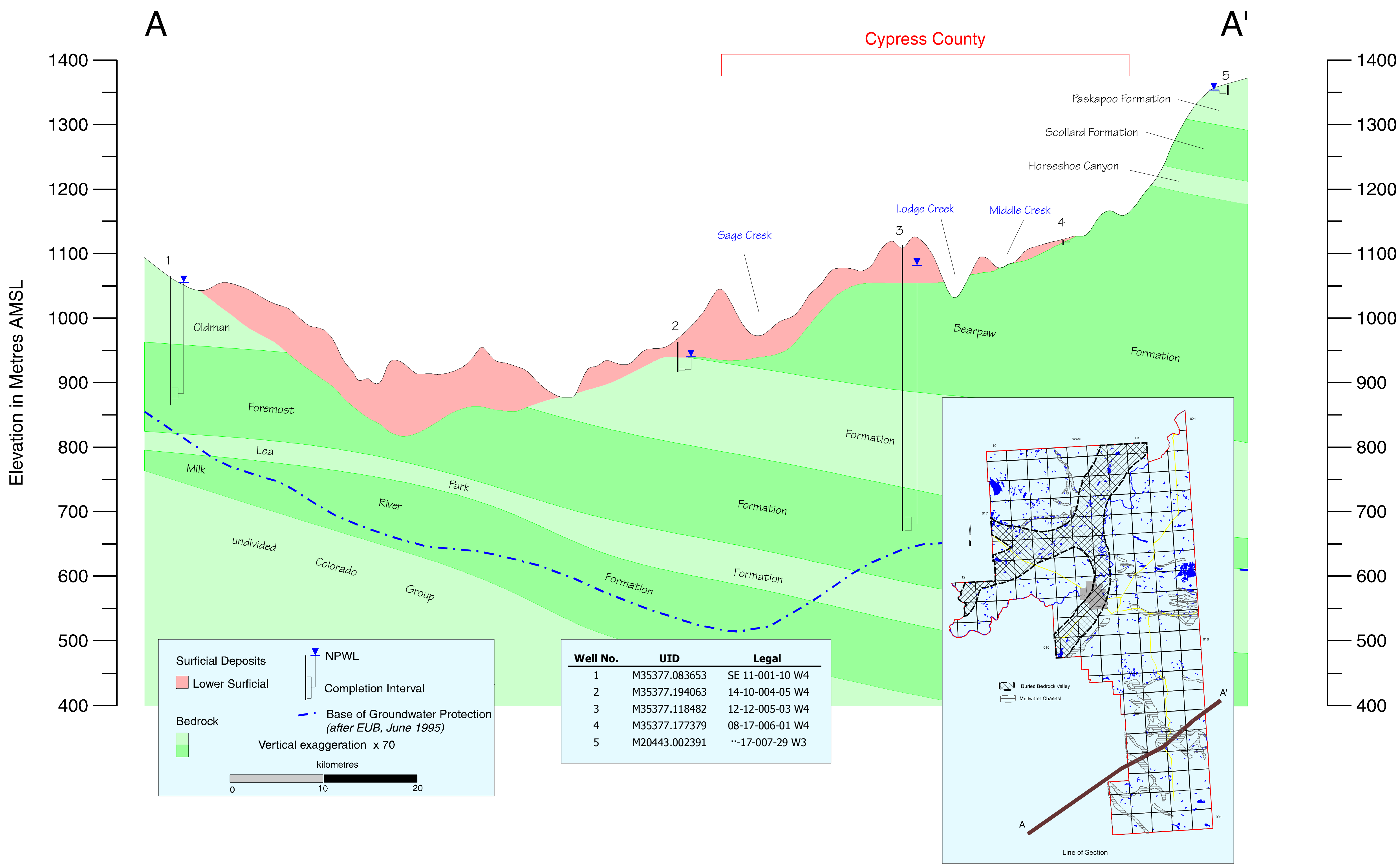
Geologic Column



Hydrogeological Map



Cross-Section A - A'



Well No.	UID	Legal
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3	M35377.118482	12-12-005-03 W4
4	M35377.177379	08-17-006-01 W4
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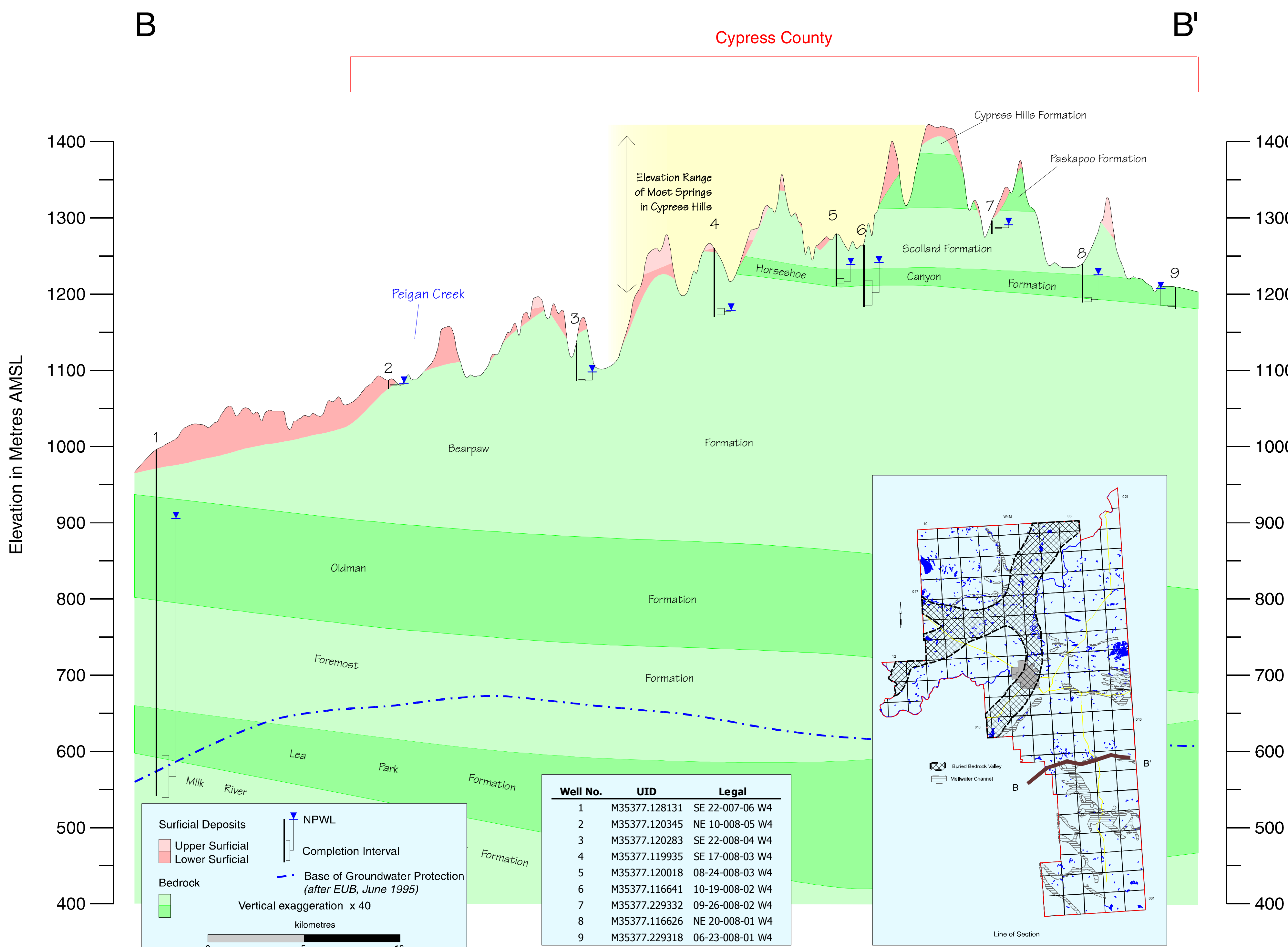
Cross-Section B - B'



Well No.	UID	Legal
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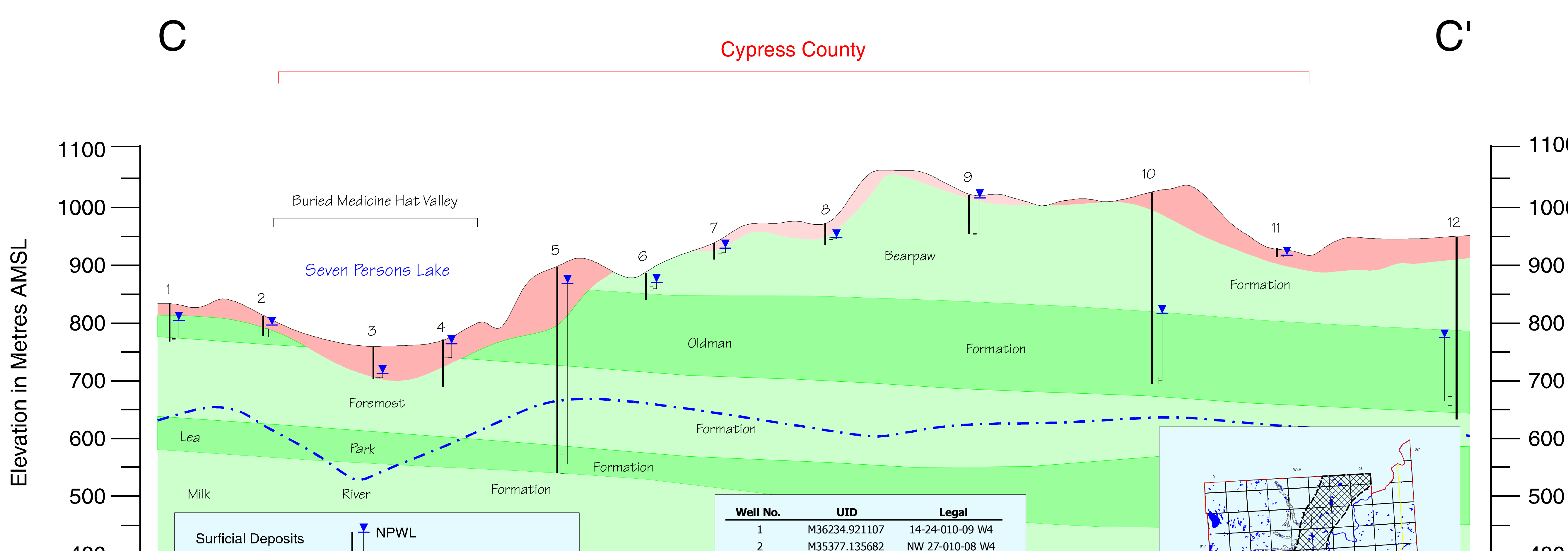
3	M35377.120283	SE 22-008-04 W4
4	M35377.119935	SE 17-008-03 W4
5	M35377.120018	08-24-008-03 W4
6	M35377.116641	10-19-008-02 W4
7	M35377.229332	09-26-008-02 W4
8	M35377.116626	NE 20-008-01 W4
9	M35377.229318	06-23-008-01 W4

Cross-Section B - B'

Cross-Section C - C'



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4	M36234.922910	NW 24-010-07 W4
5	M35377.130318	NE 15-010-06 W4
6	M35377.084485	SE 17-010-05 W4
7	M35377.130262	SW 14-010-05 W4
8	M35377.183415	SE 04-010-04 W4
9	M35377.120908	SE 04-010-03 W4
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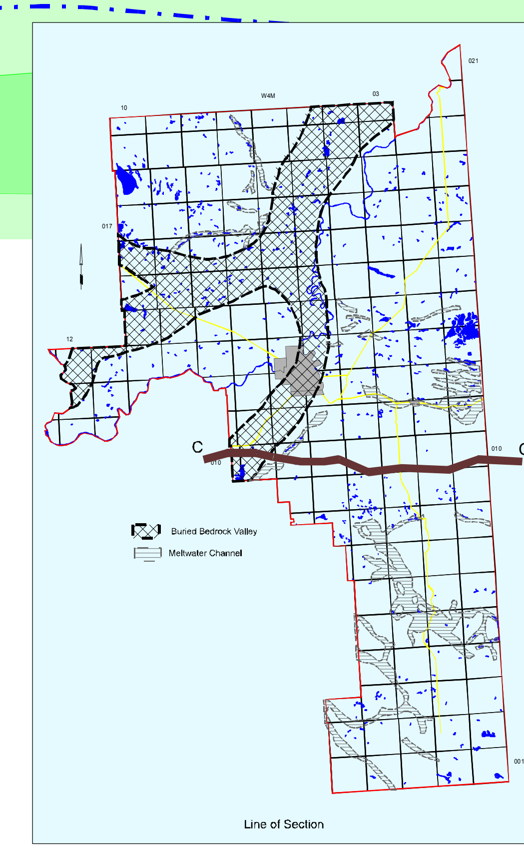
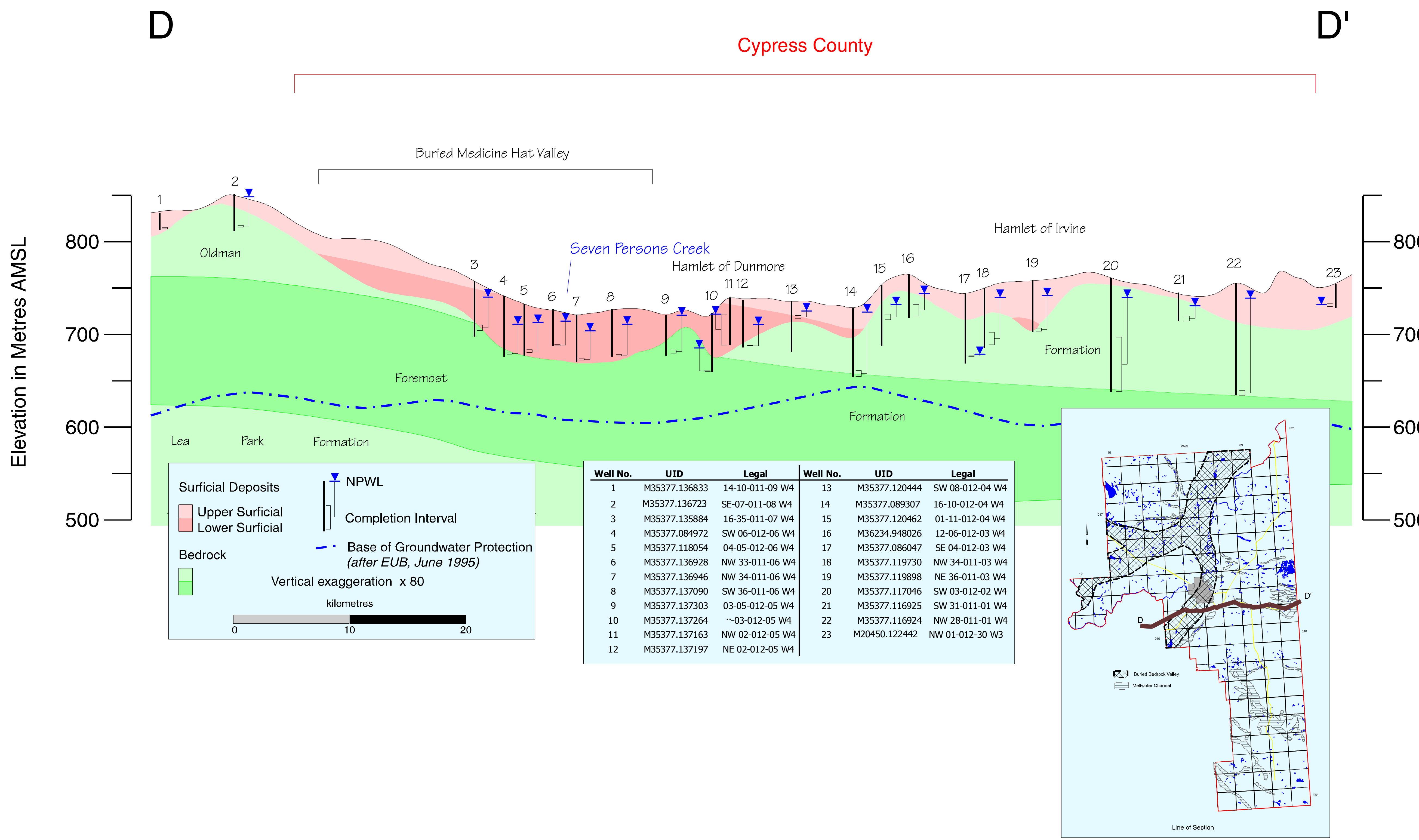


Cross-Section D - D'



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4	M35377.084972	SW 06-012-06 W4	16	M36234.948026	12-06-012-03 W4
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8	M35377.137090	SW 36-011-06 W4	20	M35377.117046	SW 03-012-02 W4
9	M35377.137303	03-05-012-05 W4	21	M35377.116925	SW 31-011-01 W4
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11	M35377.137163	NW 02-012-05 W4	23	M20450.122442	NW 01-012-30 W3
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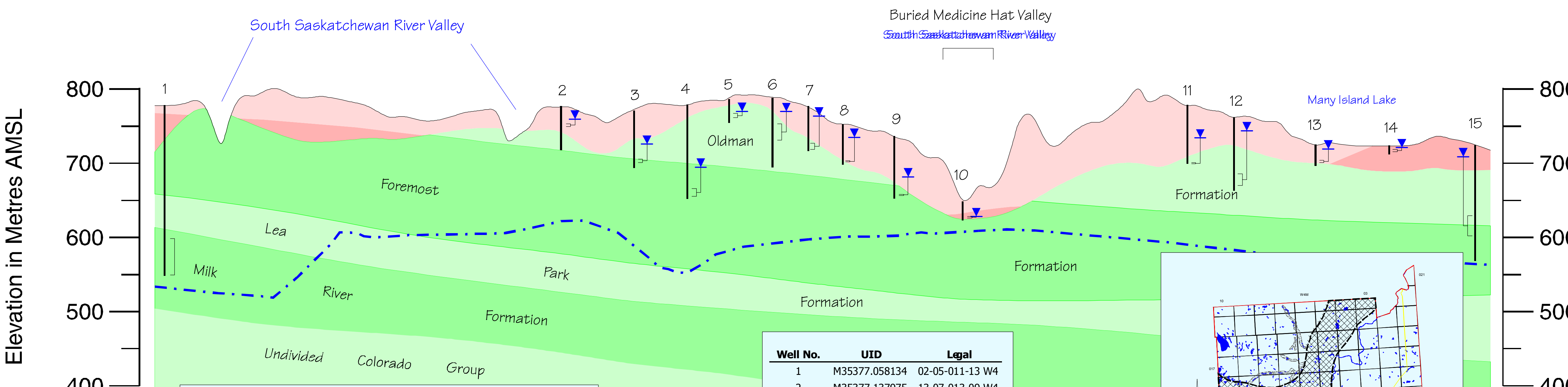
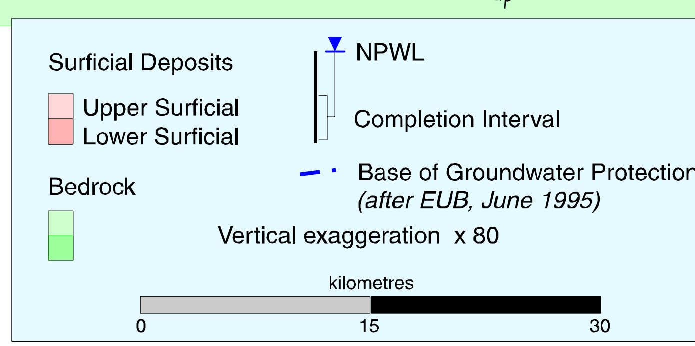
Cross-Section E - E'





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5	M35377.226288	SE 34-013-08 W4
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7	M35377.137964	13-34-013-07 W4
8	M35377.137977	10-36-013-07 W4
9	M35377.082851	SE 33-013-06 W4
10	M36234.921962	SW 05-014-05 W4
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12	M35377.120731	NE 18-013-02 W4
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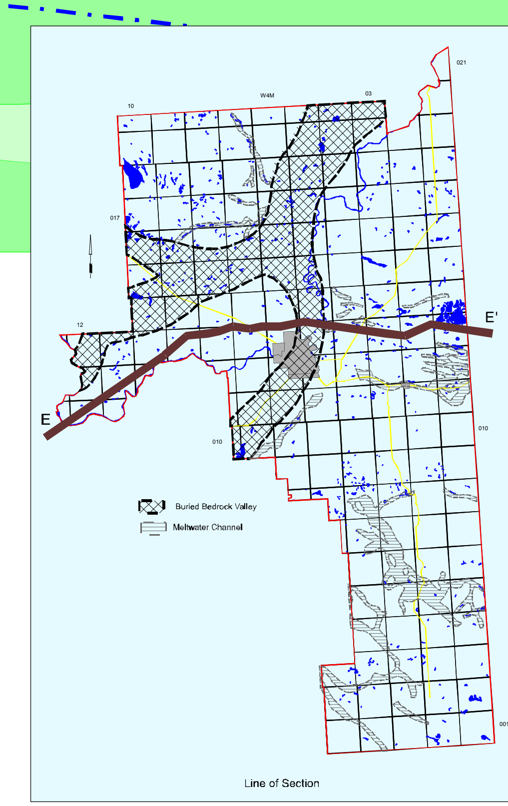
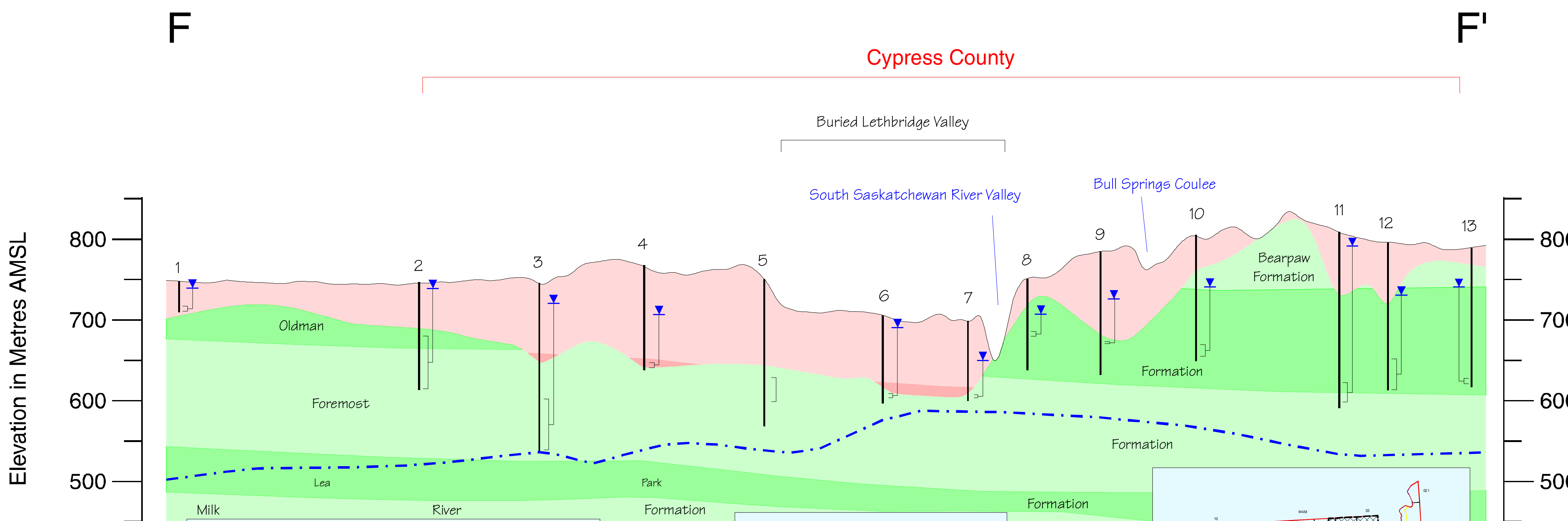
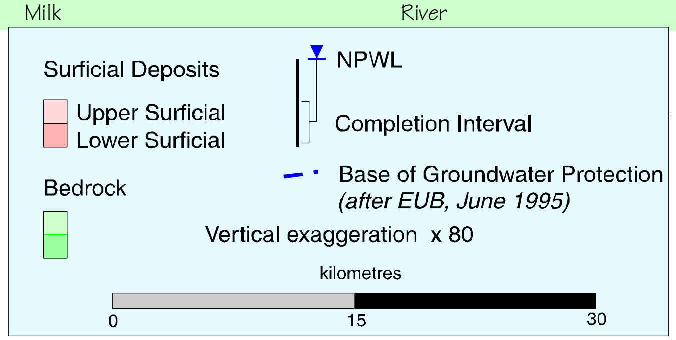


Cross-Section F - F'





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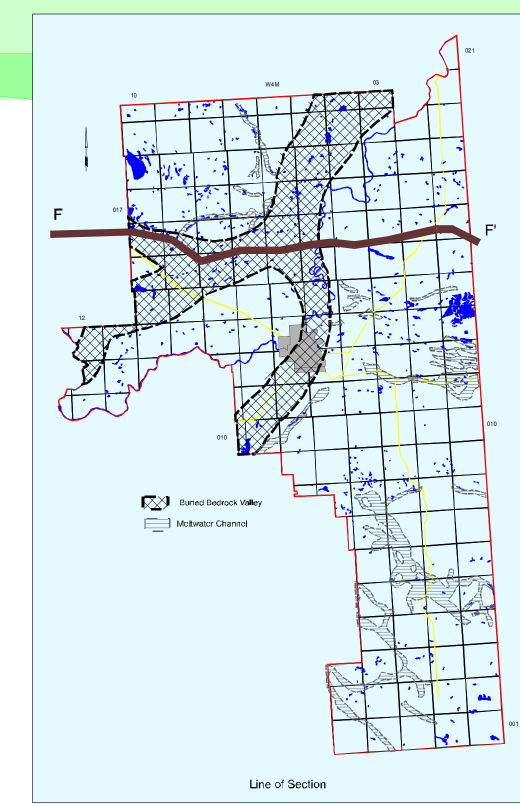
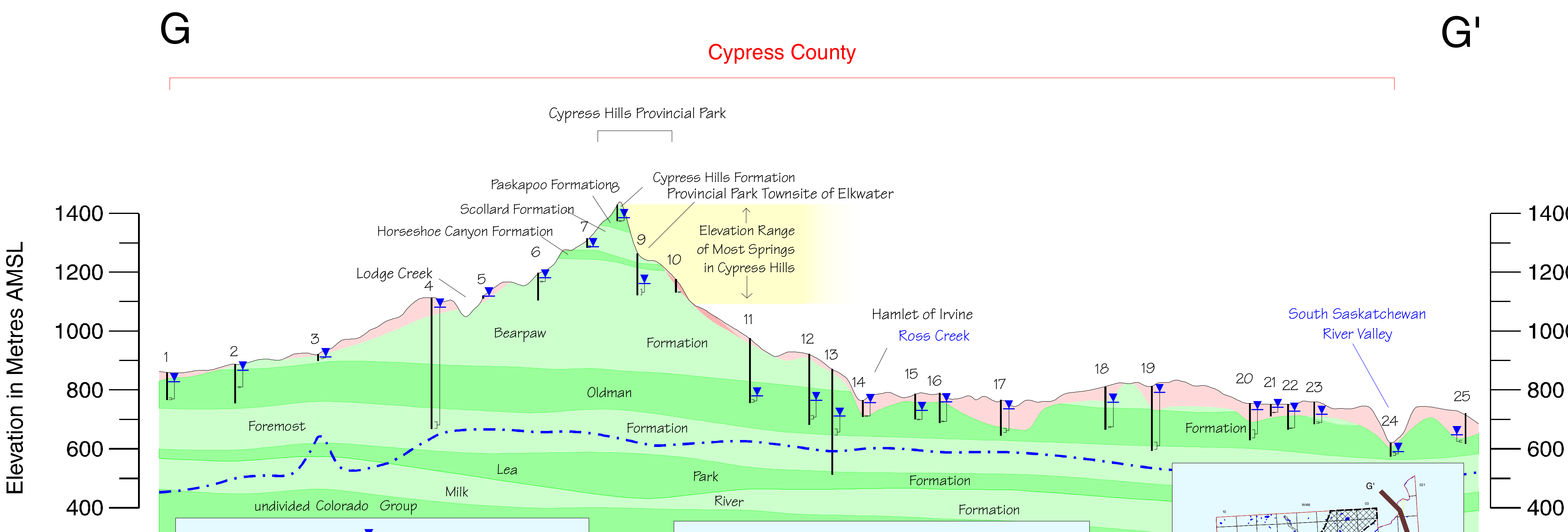
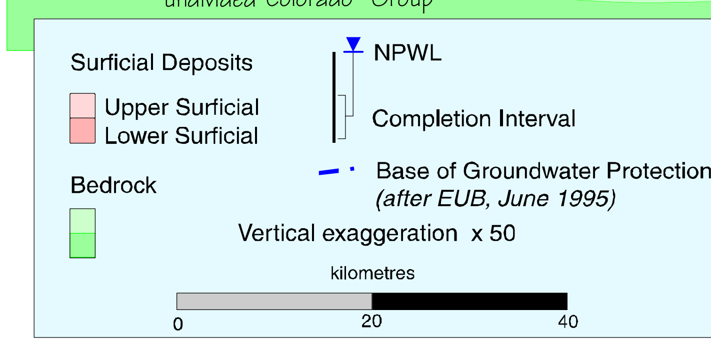


Cross-Section G - G'





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4	M35377.118482	12-12-005-03 W4	17	M35377.119712	NW 03-014-03 W4
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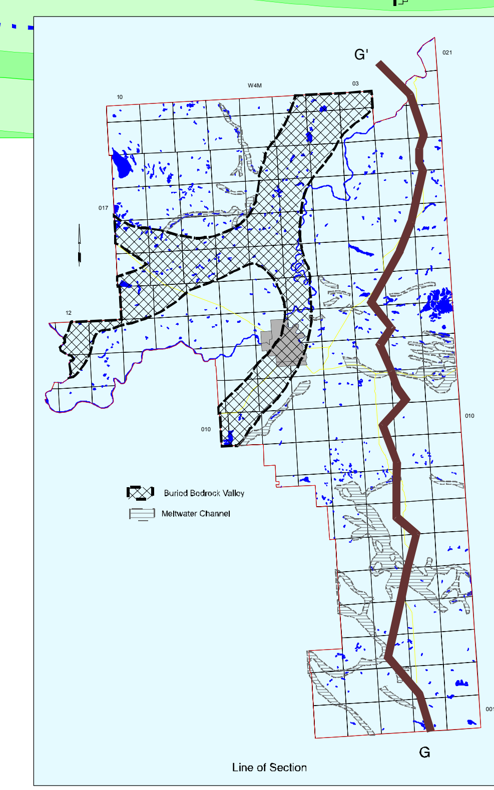
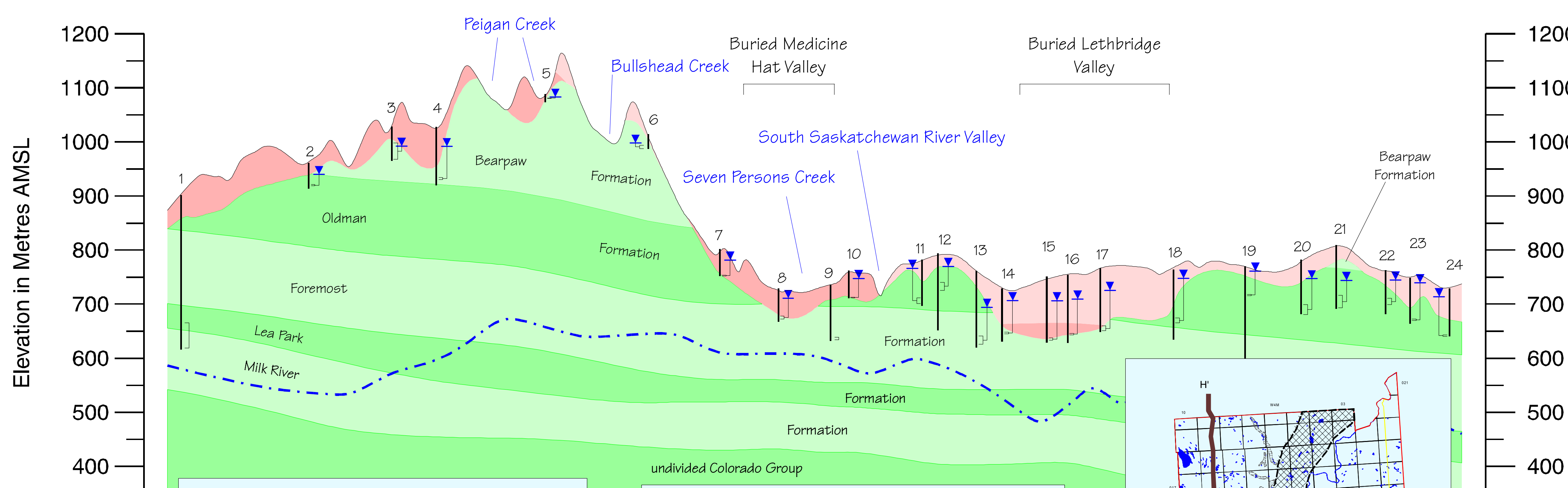
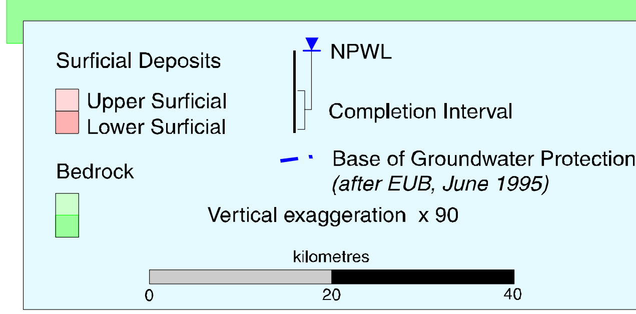


Cross-Section H - H'





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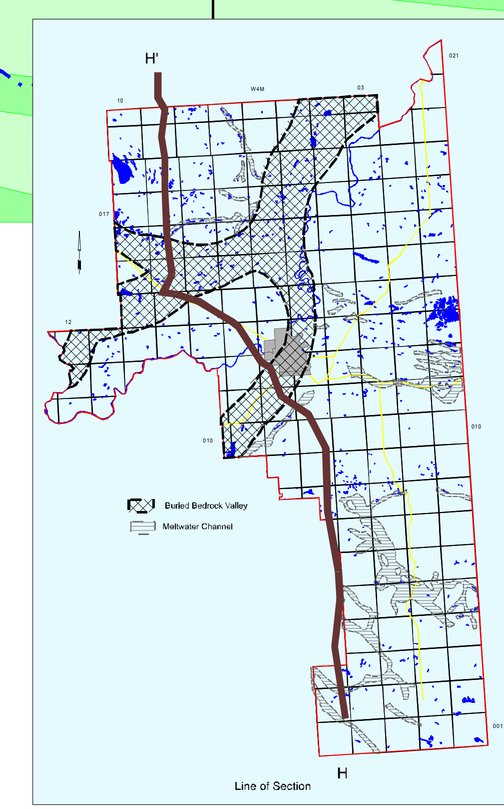
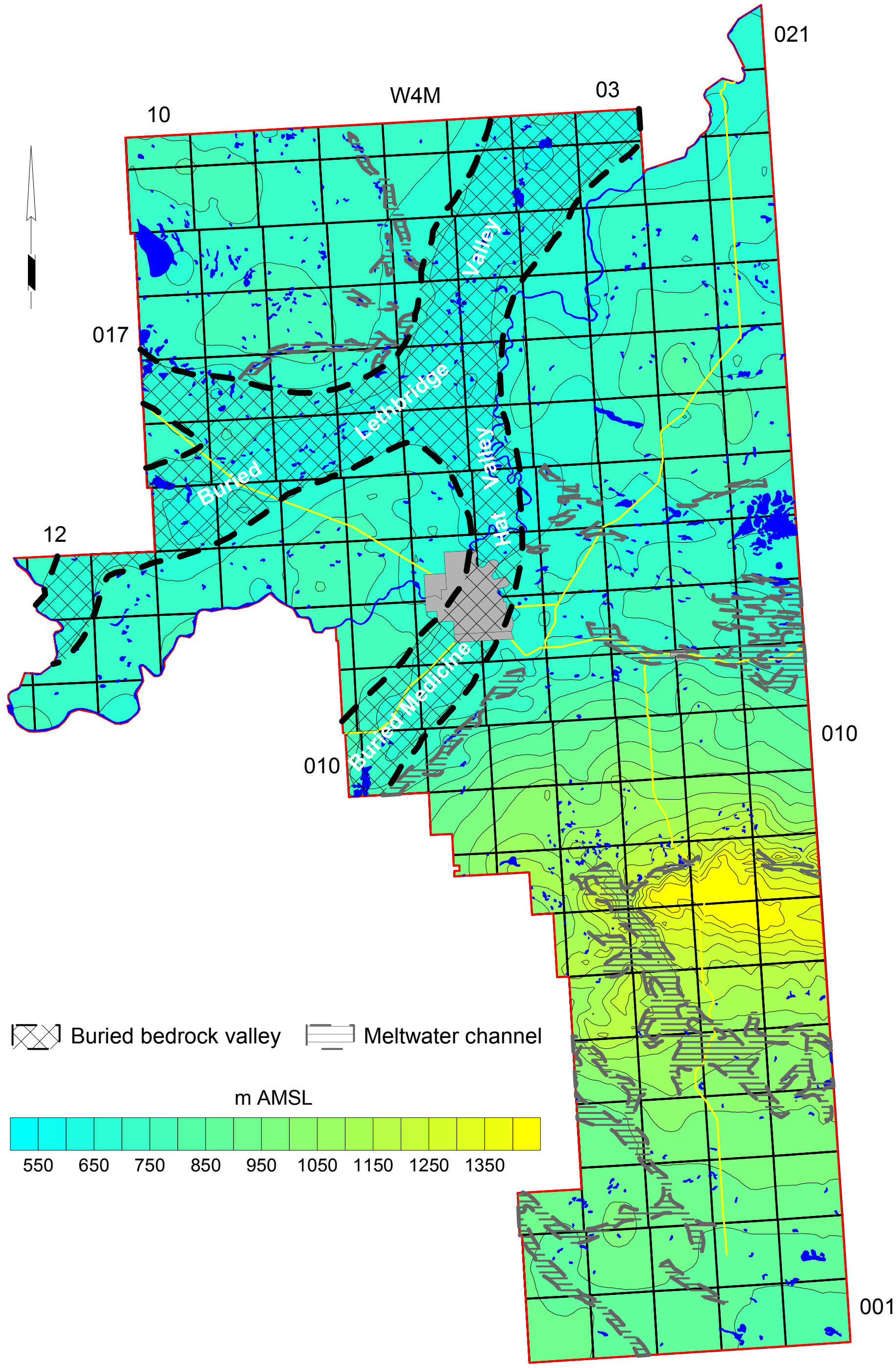
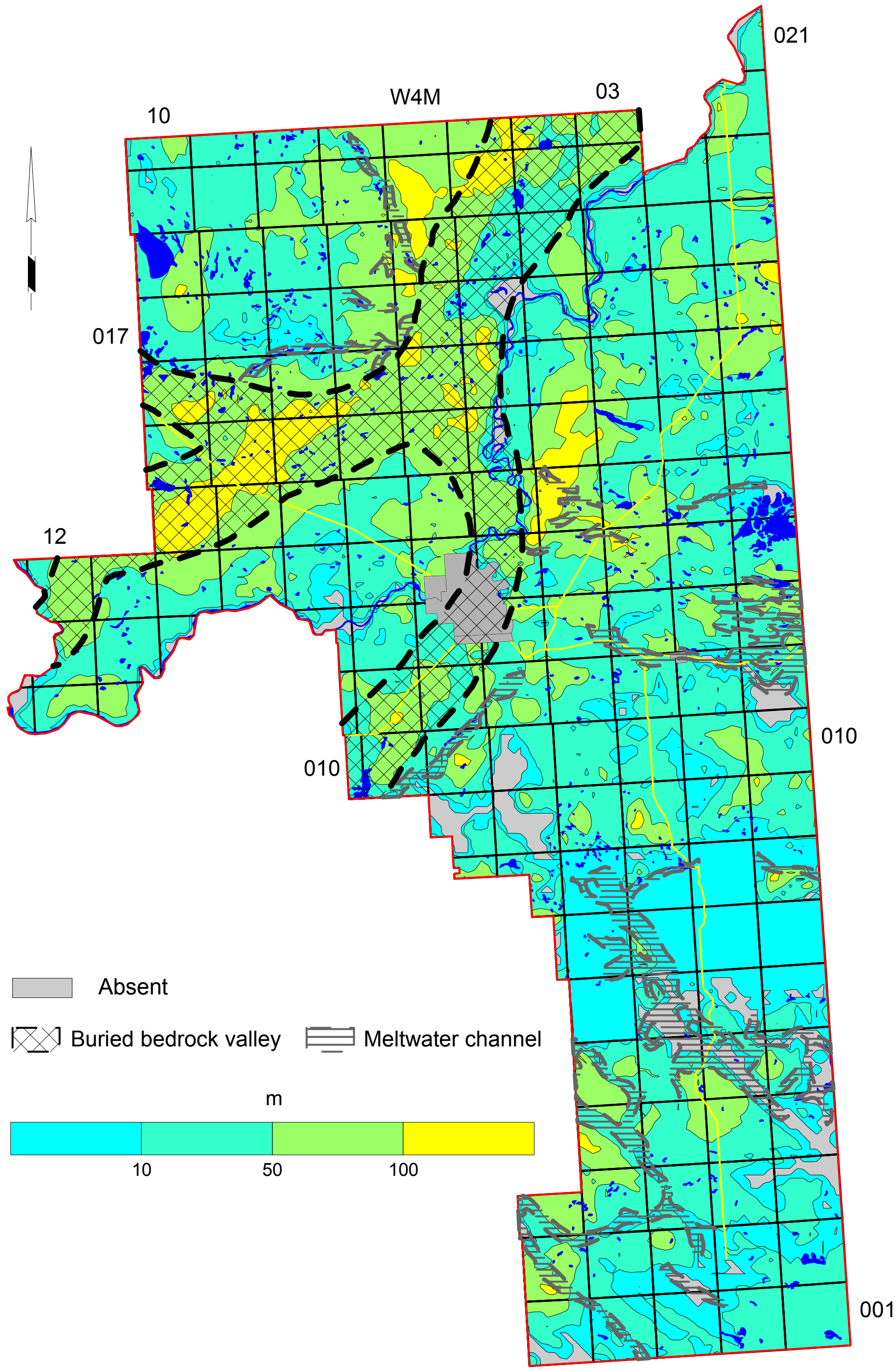


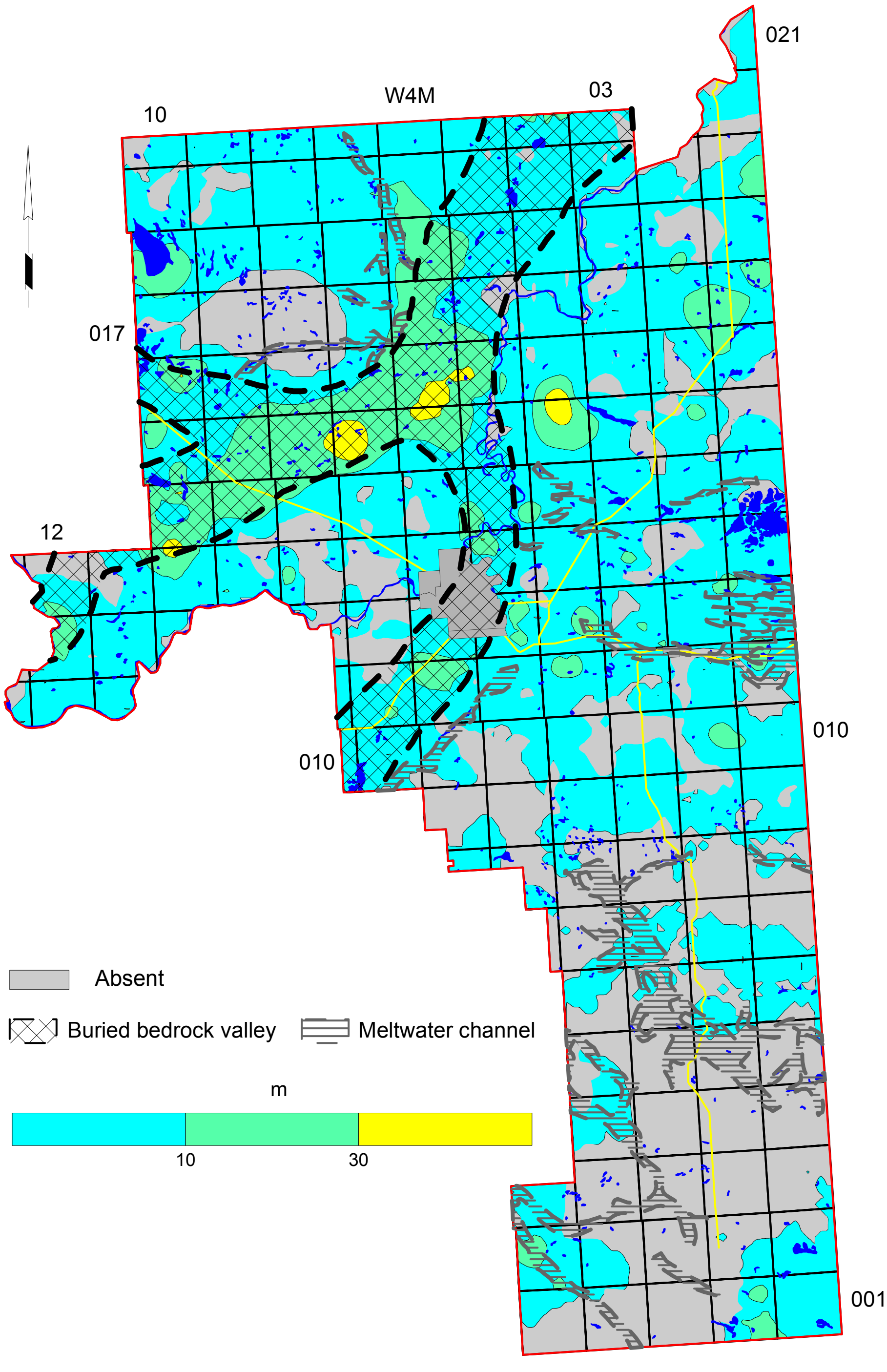
Bedrock Topography



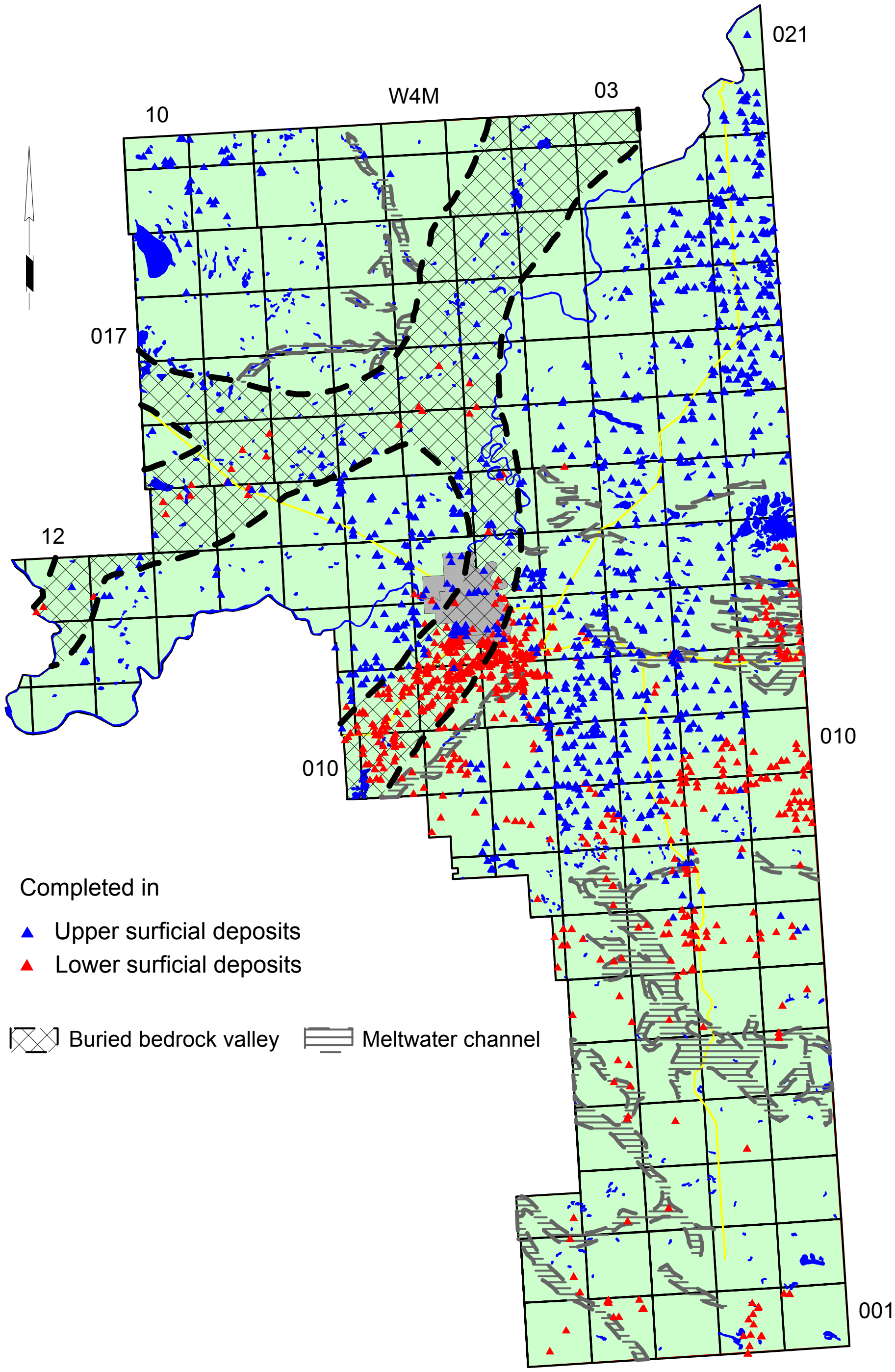
Thickness of Surficial Deposits



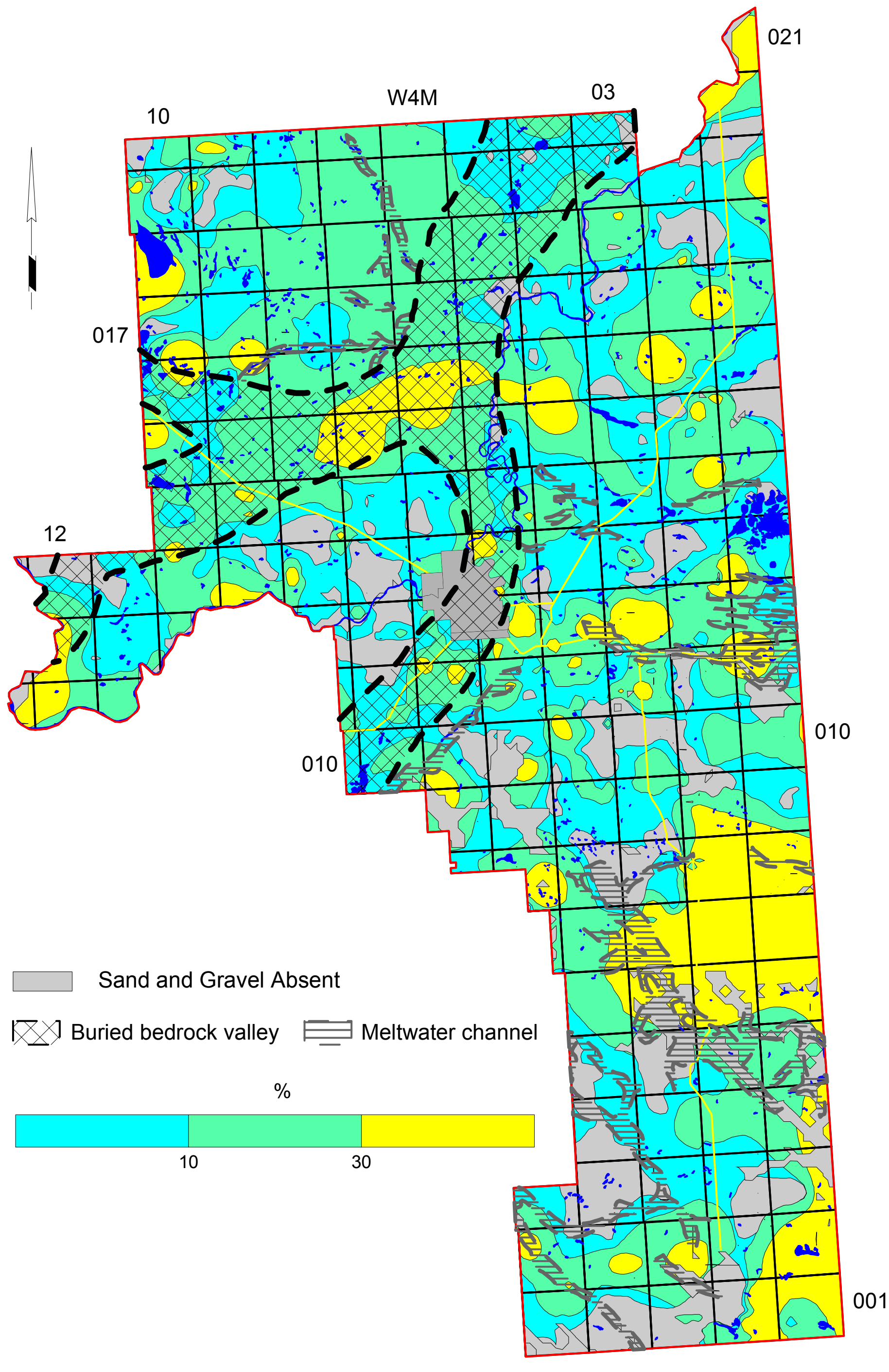
Thickness of Sand and Gravel Deposits



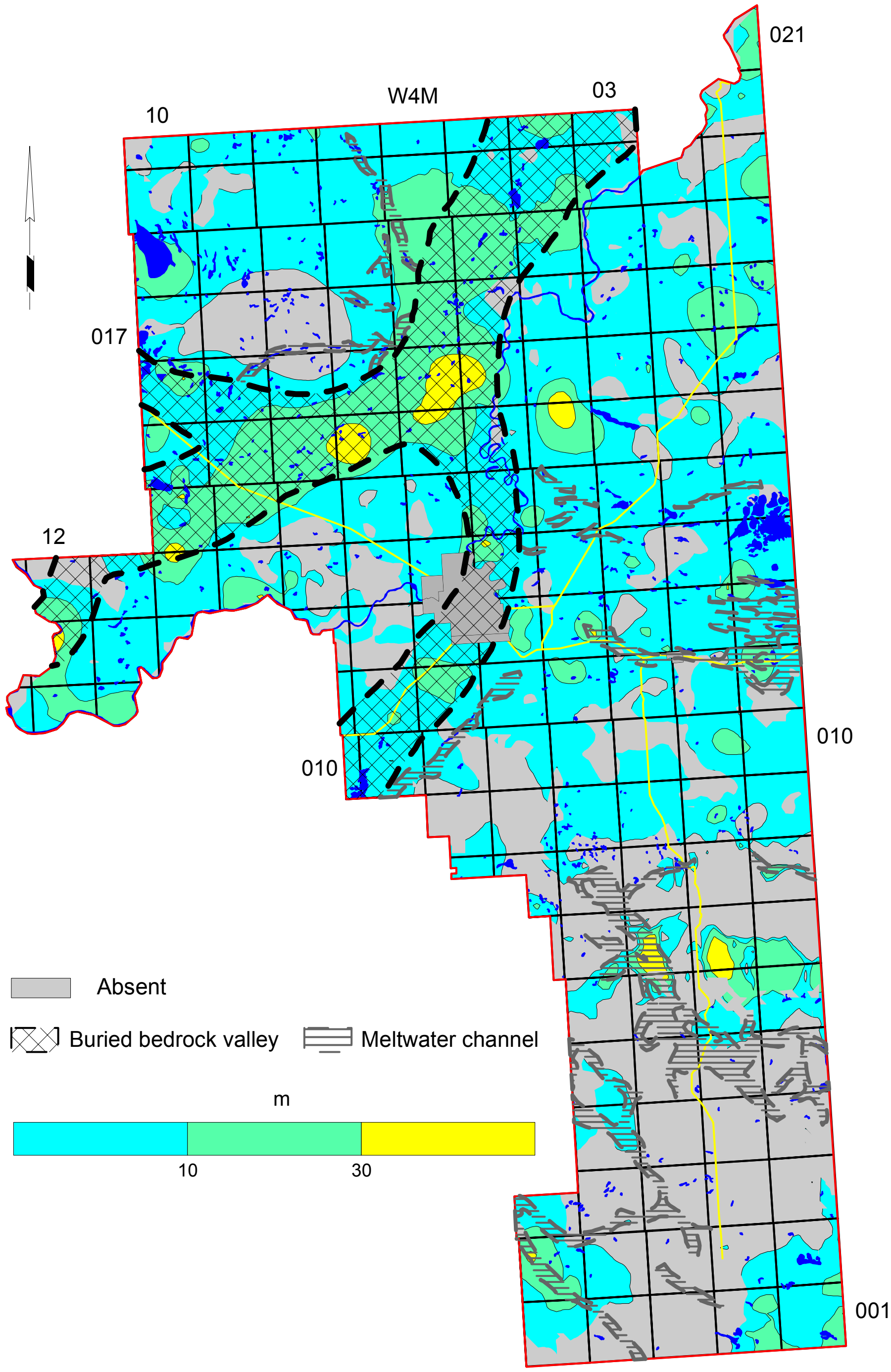
Water Wells Completed In Surficial Deposits



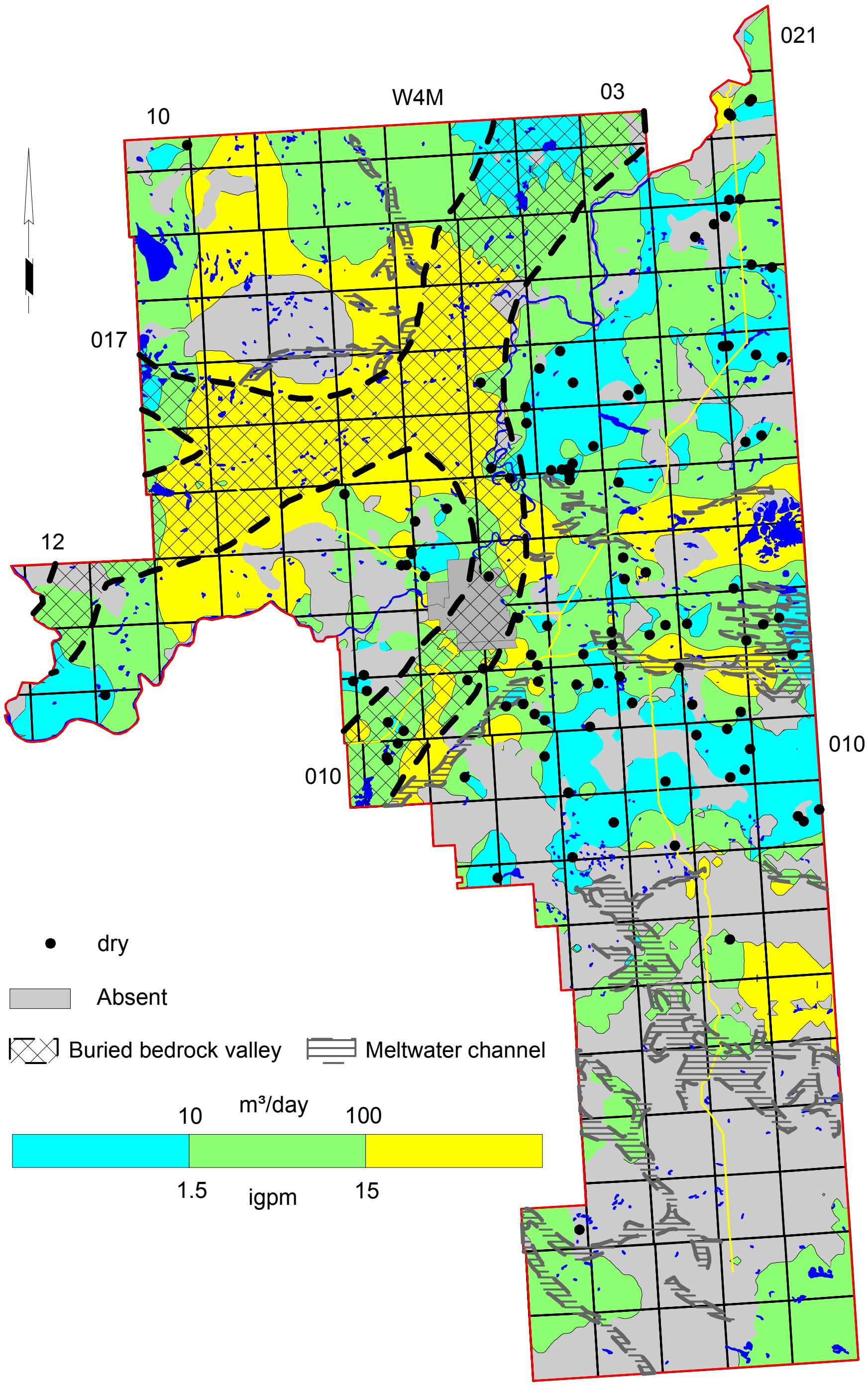
Amount of Sand and Gravel in Surficial Deposits



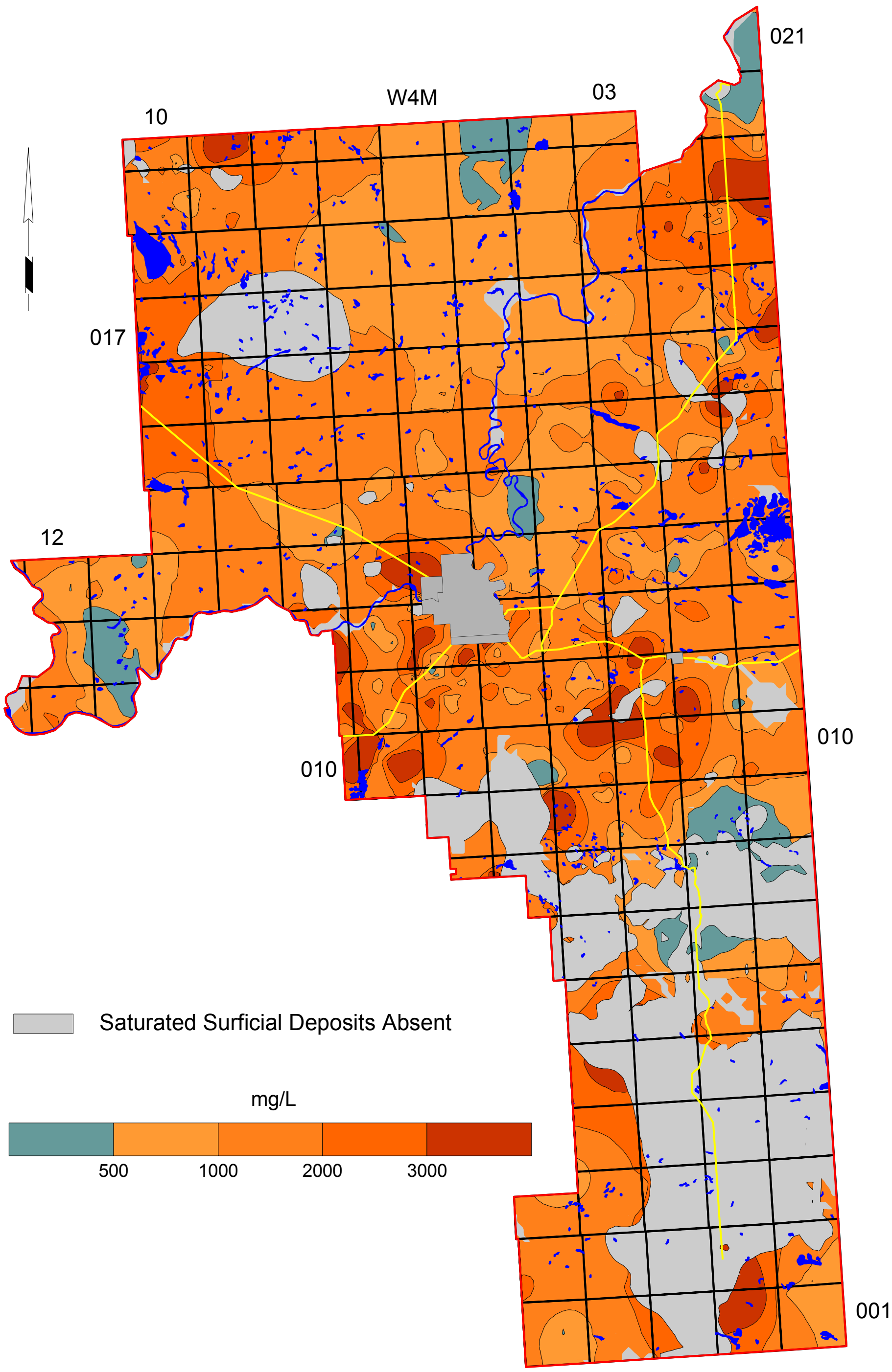
Thickness of Sand and Gravel Aquifer(s)



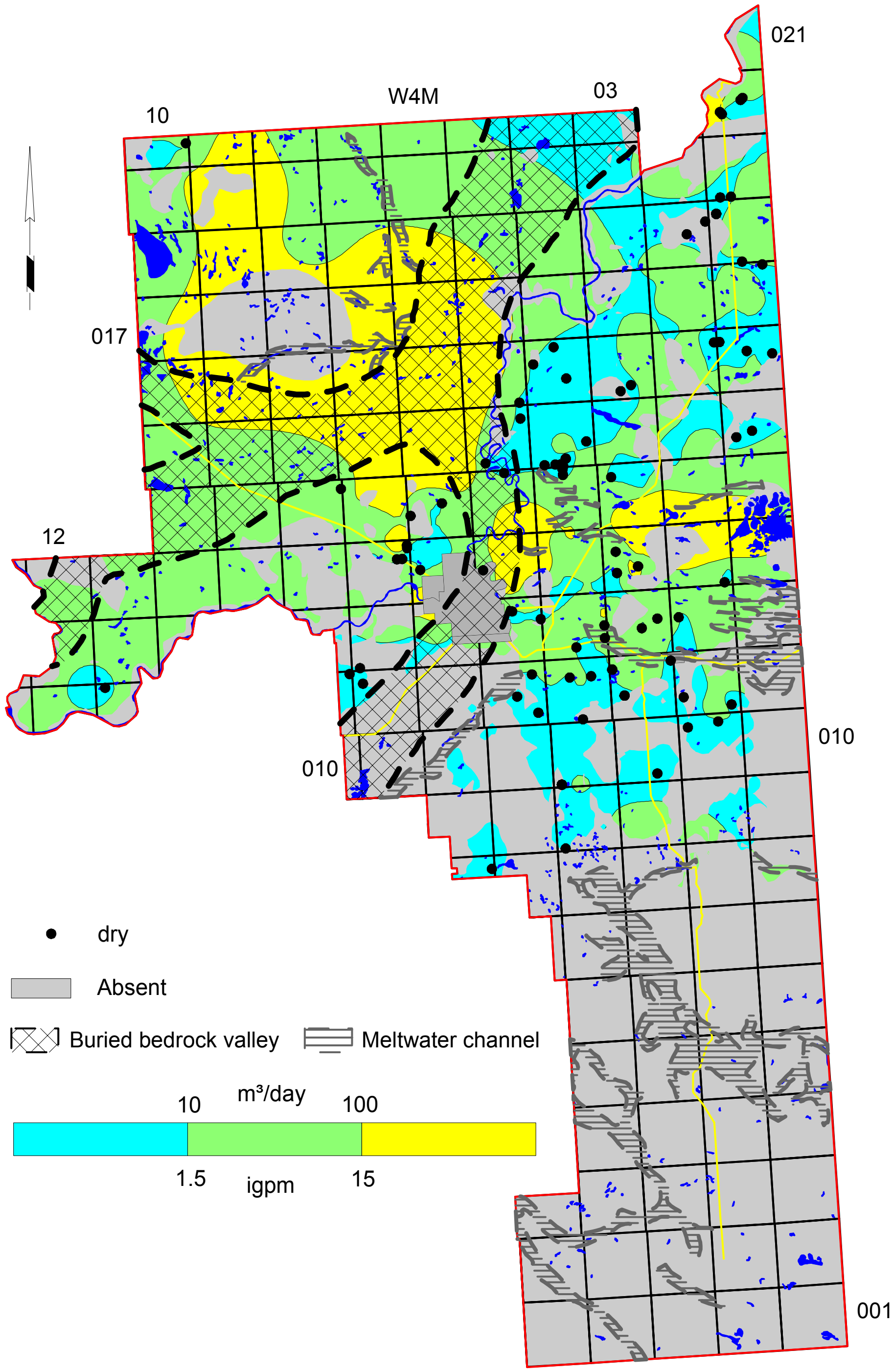
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)



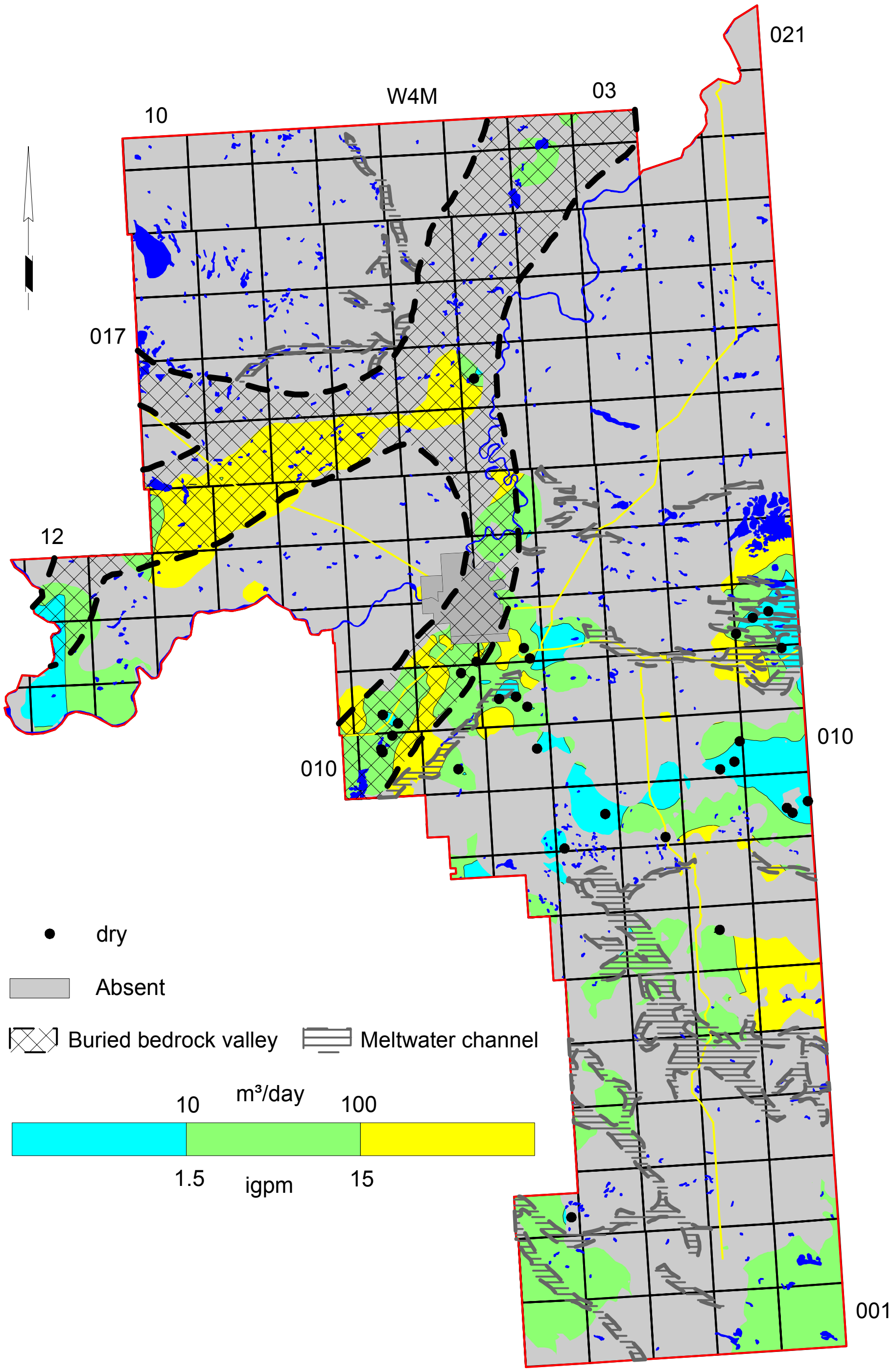
Total Dissolved Solids in Groundwater from Surficial Deposits



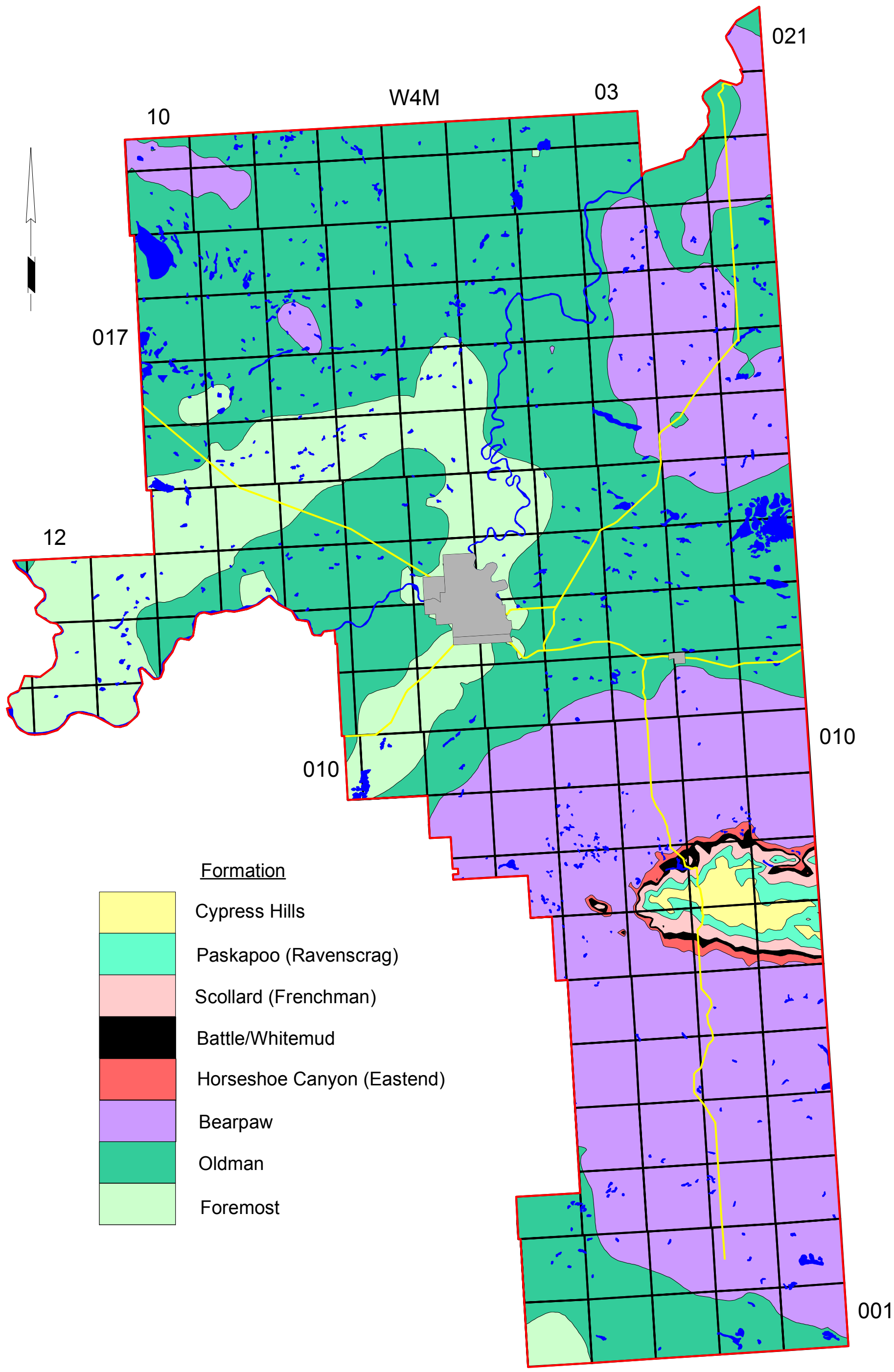
Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer



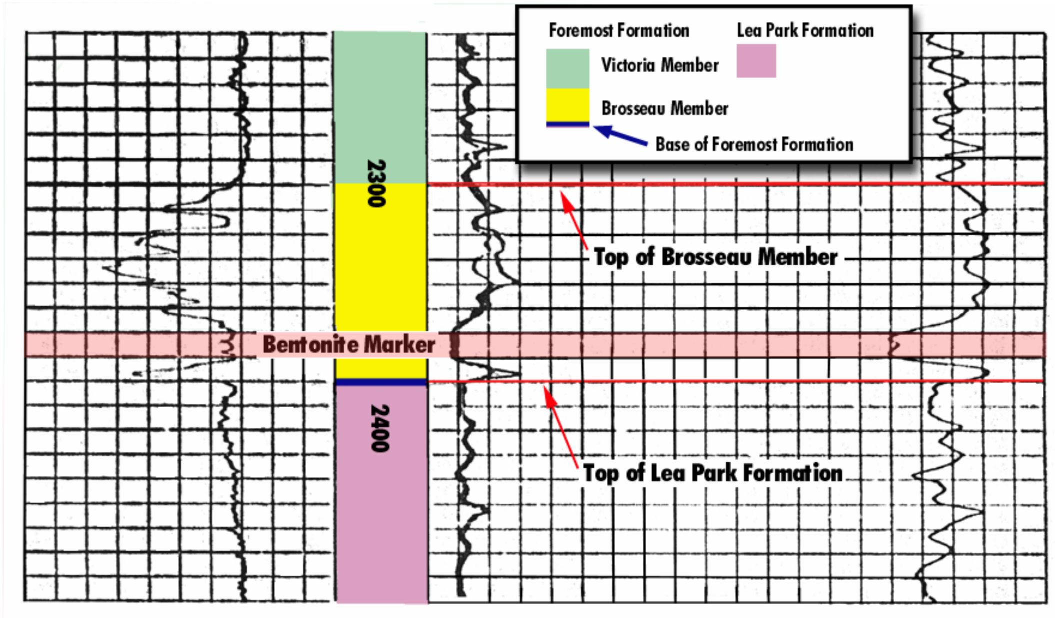
Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer



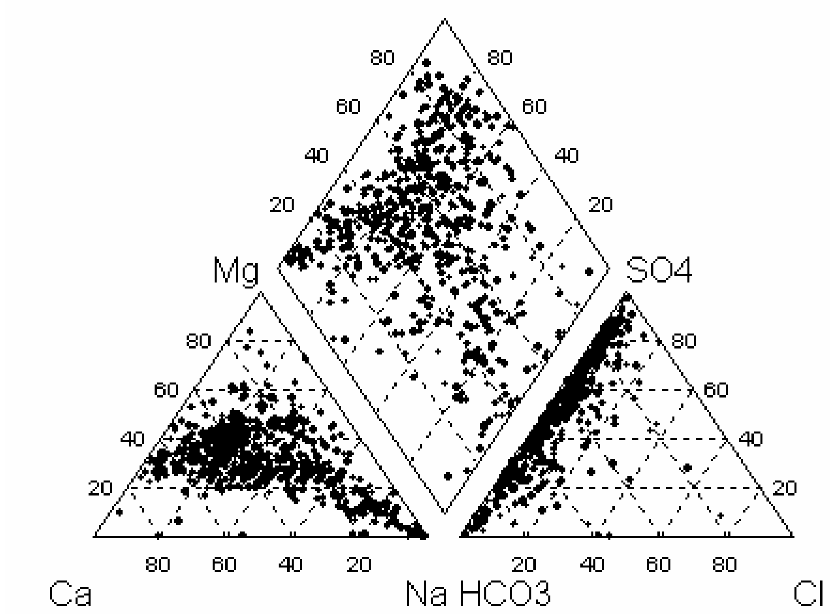
Bedrock Geology



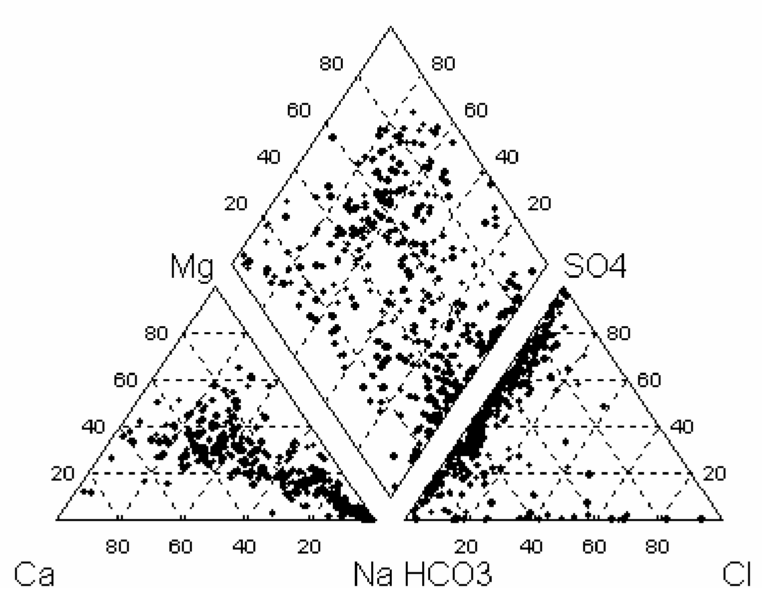
Elog Showing Base of Foremost Formation



Piper Diagrams

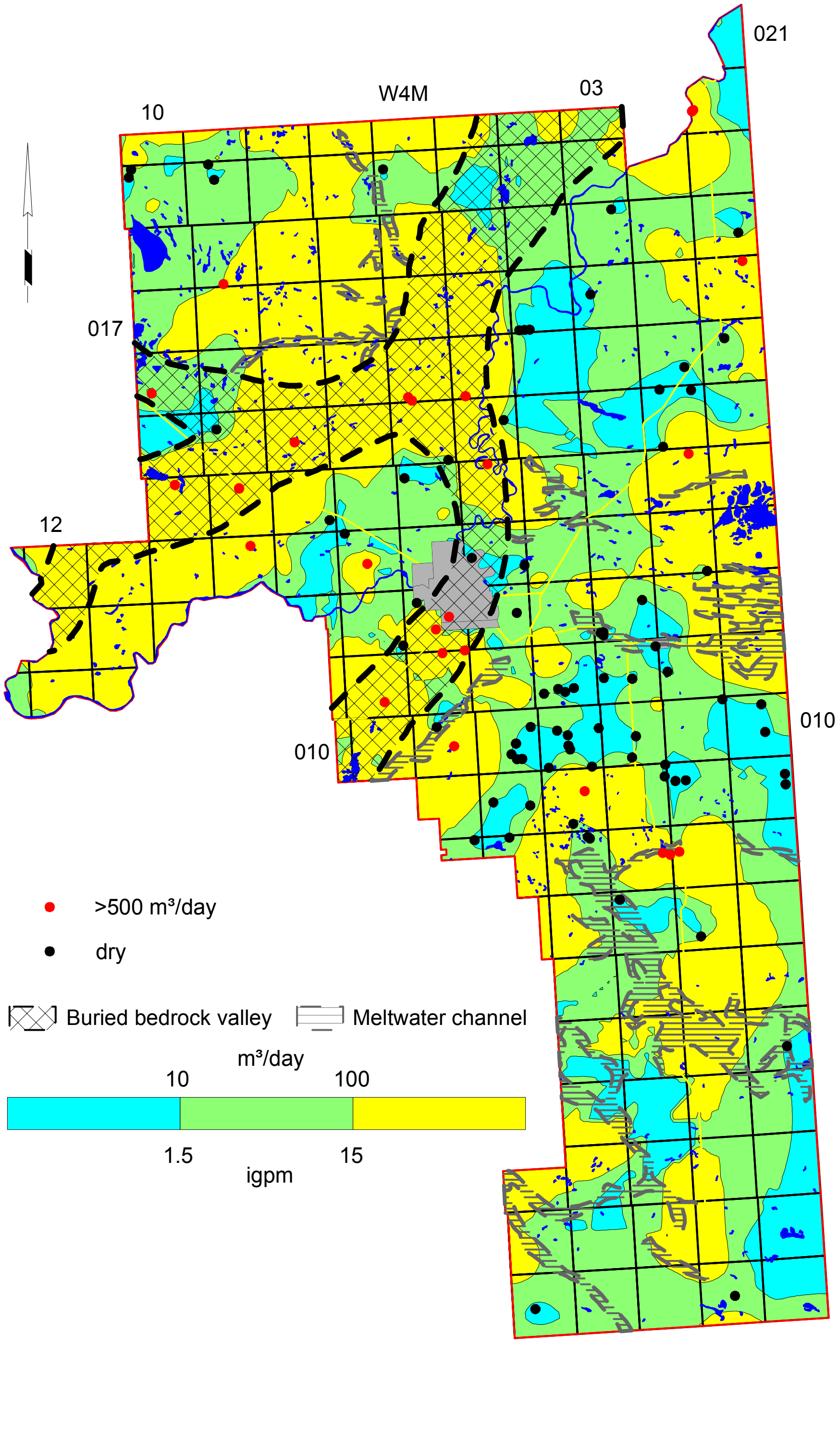


Surficial Deposits

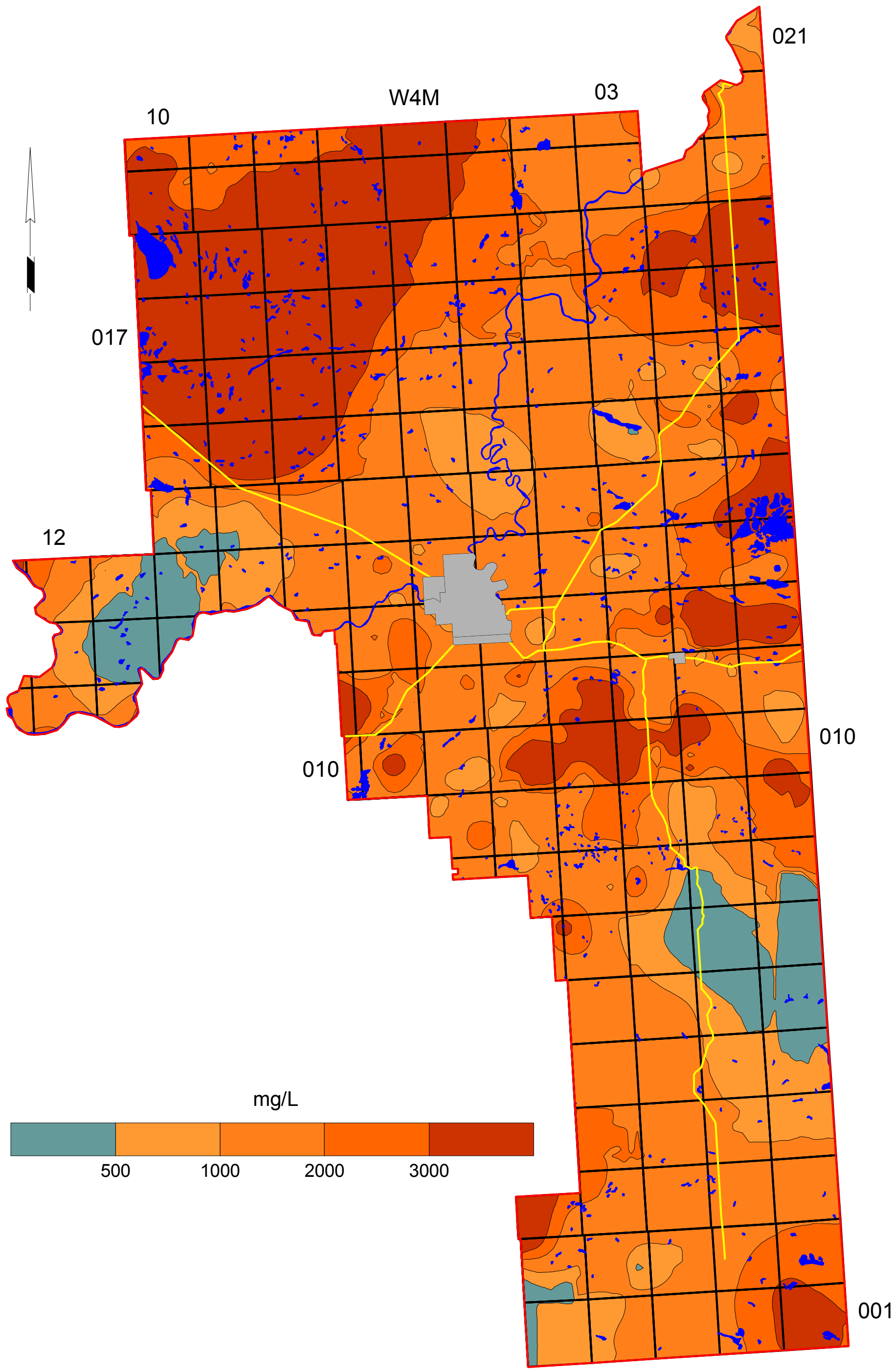


Bedrock Aquifers

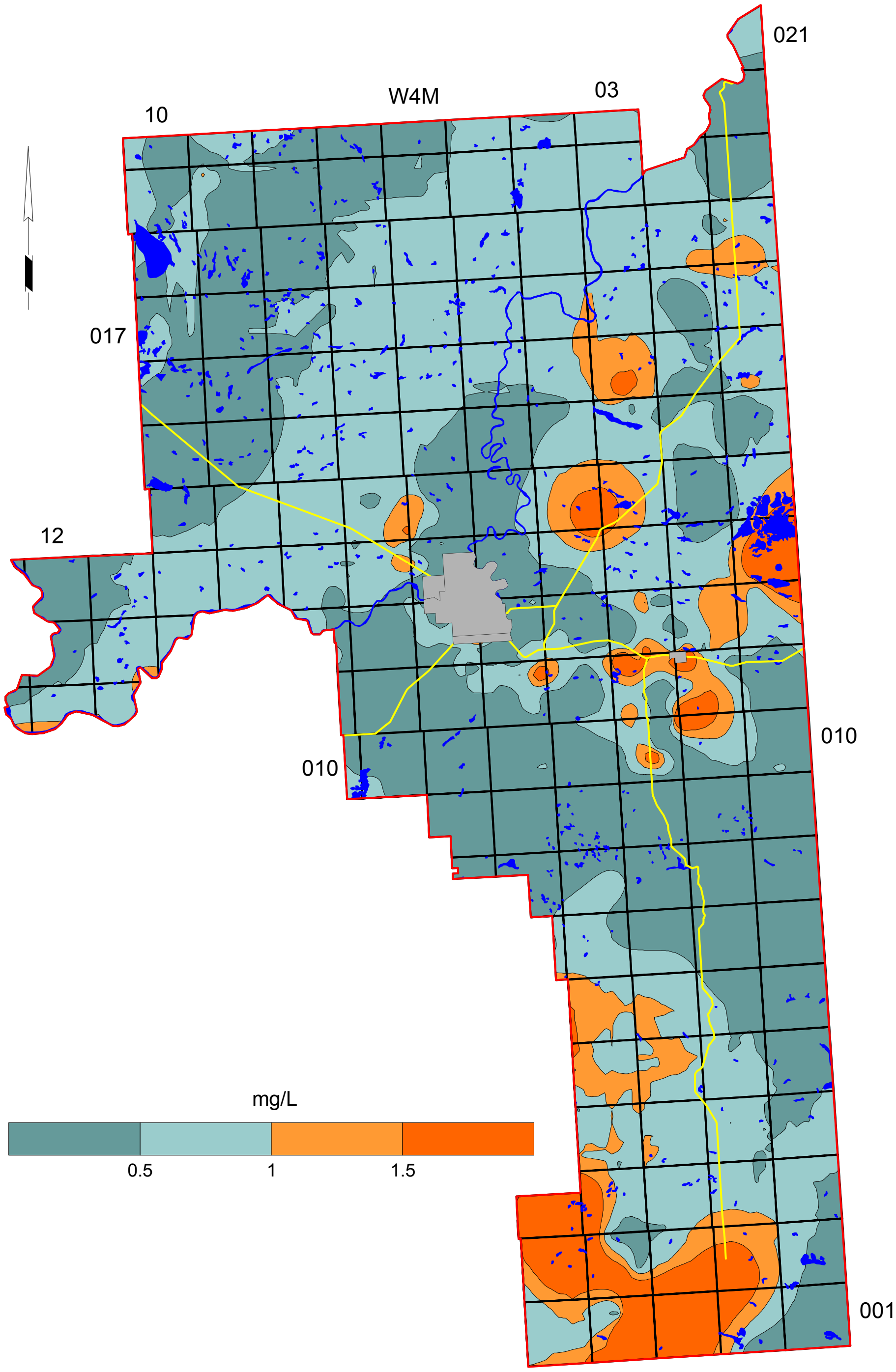
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



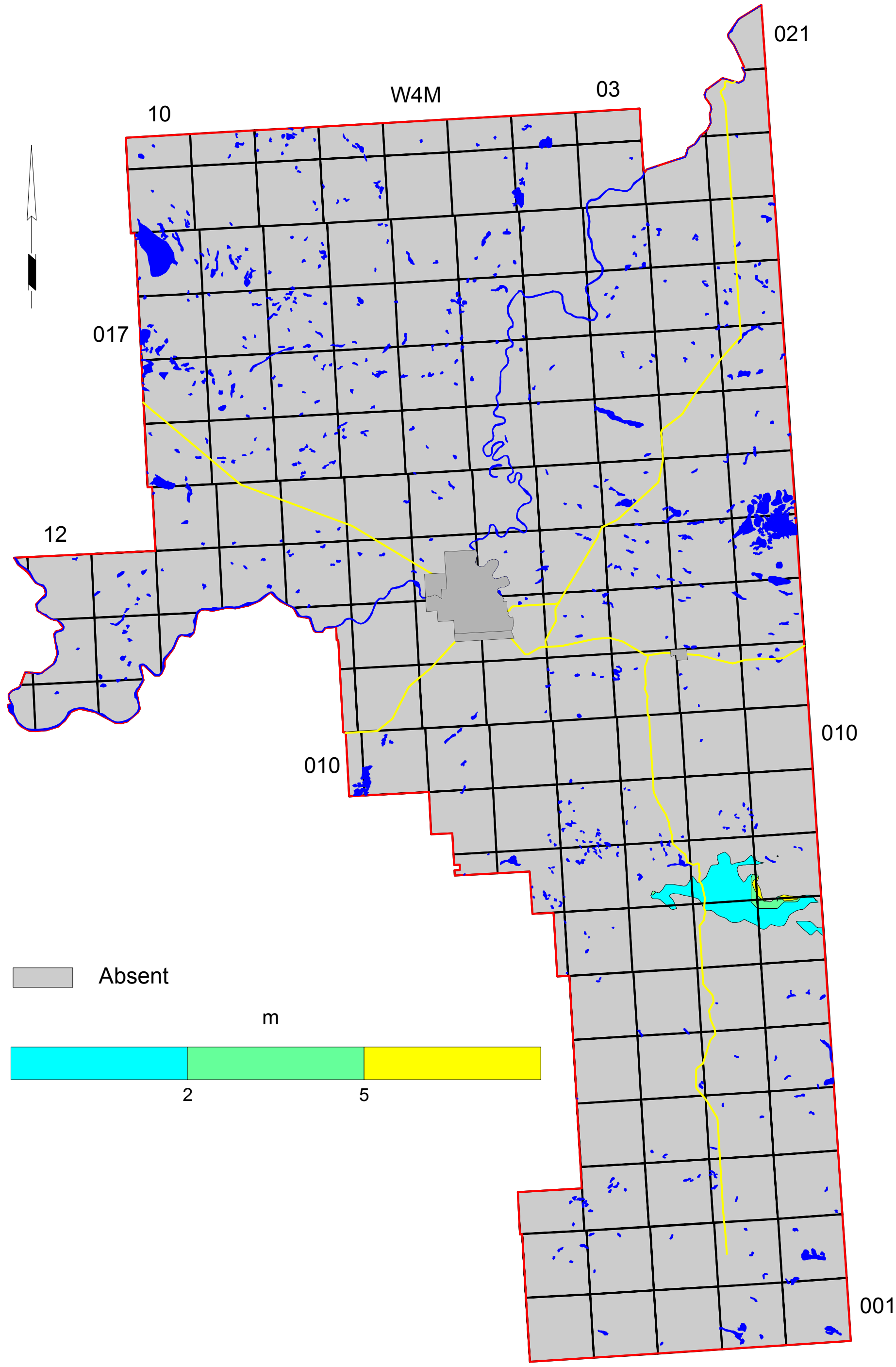
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



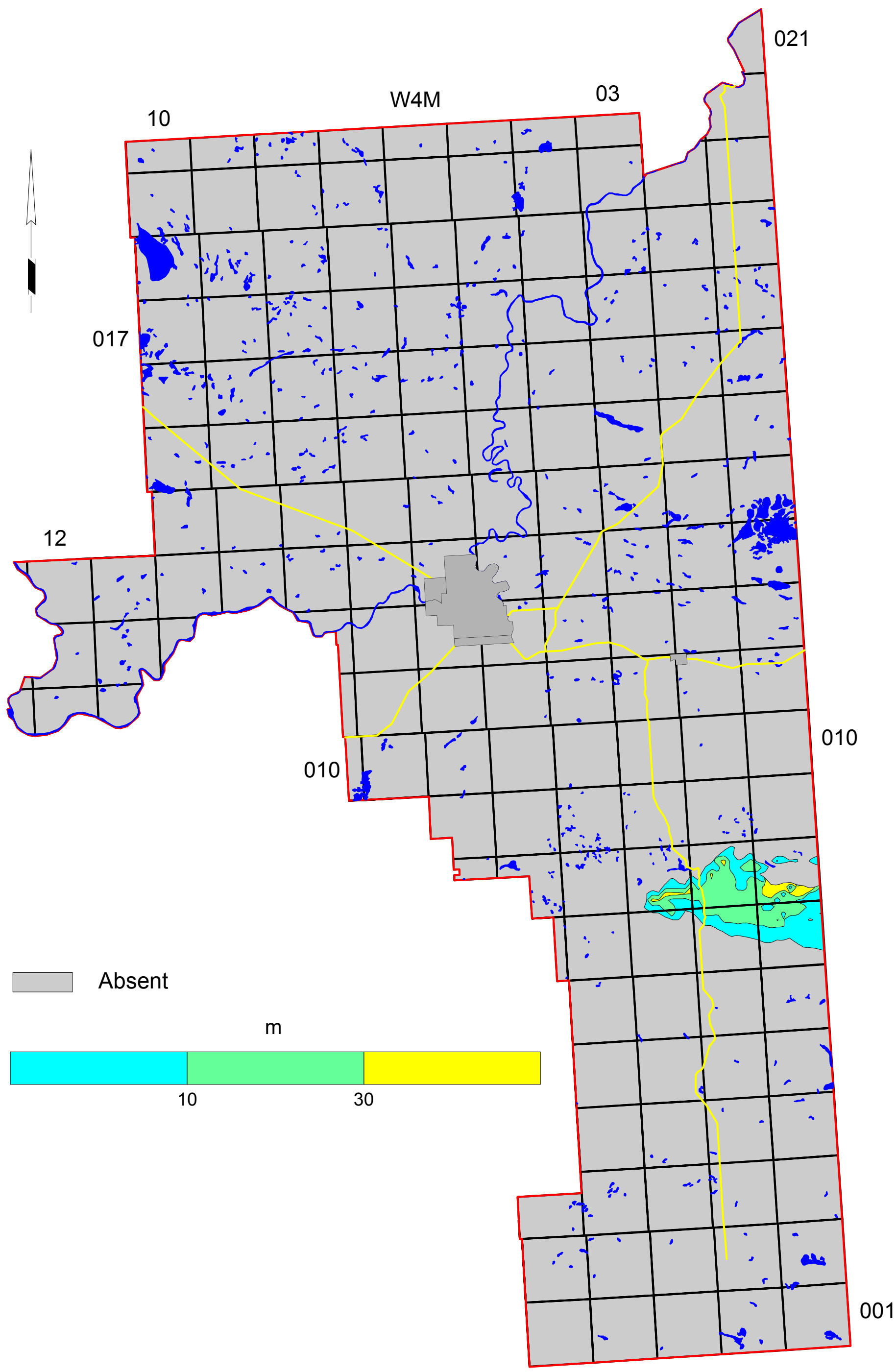
Fluoride in Groundwater from Upper Bedrock Aquifer(s)



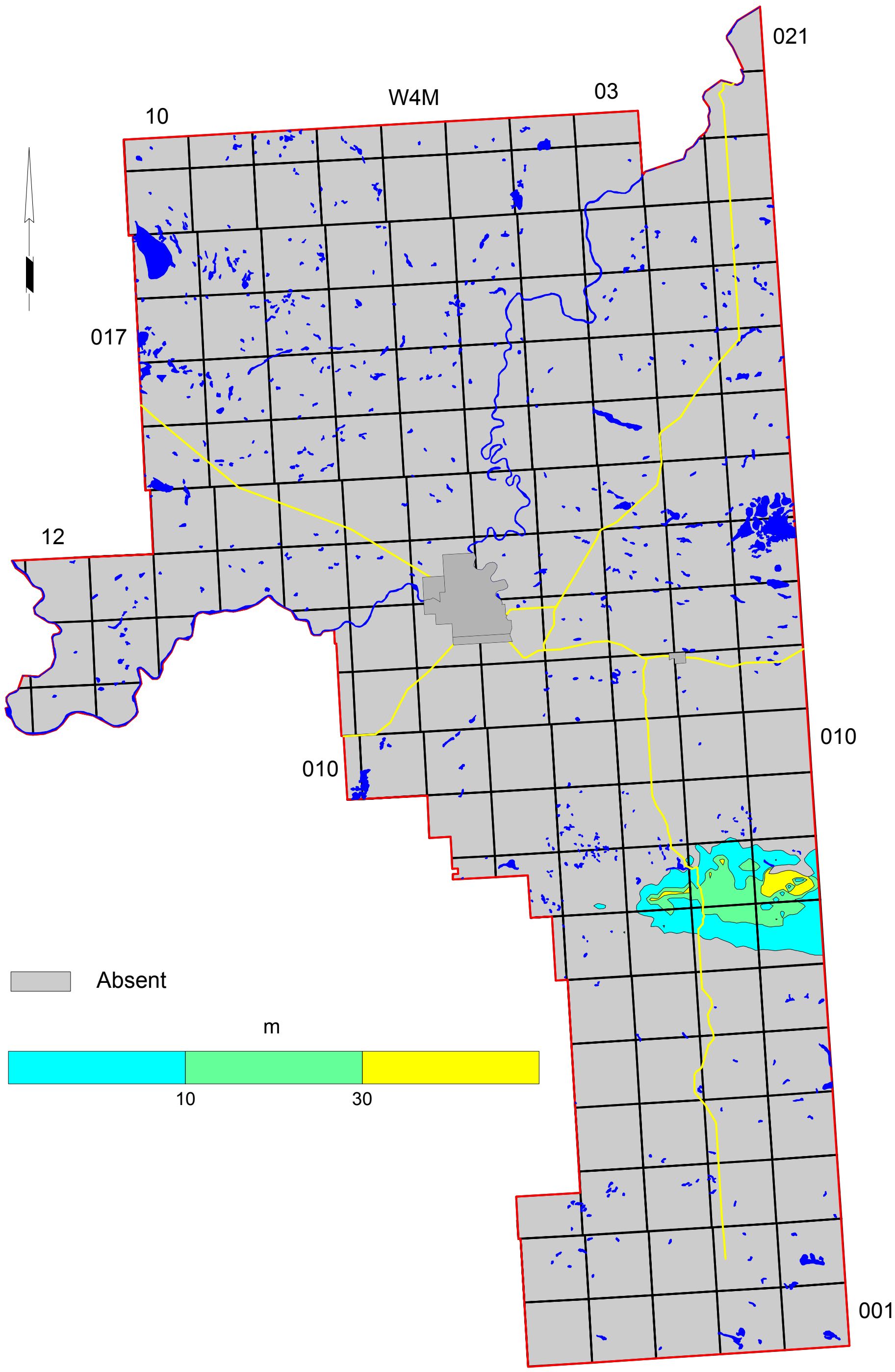
Depth to Top of Cypress Hills Formation



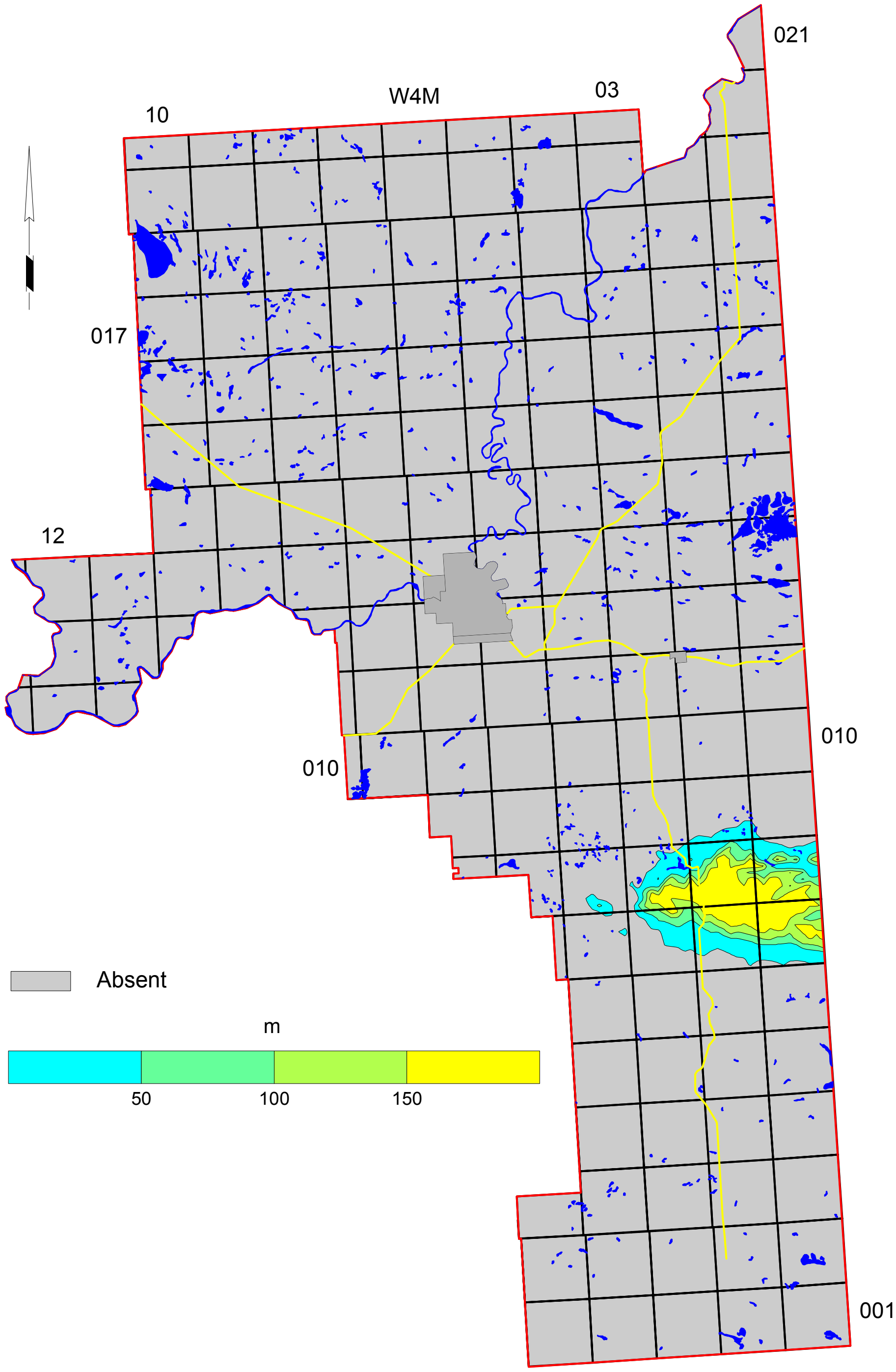
Depth to Top of Paskapoo (Ravenscrag) Formation



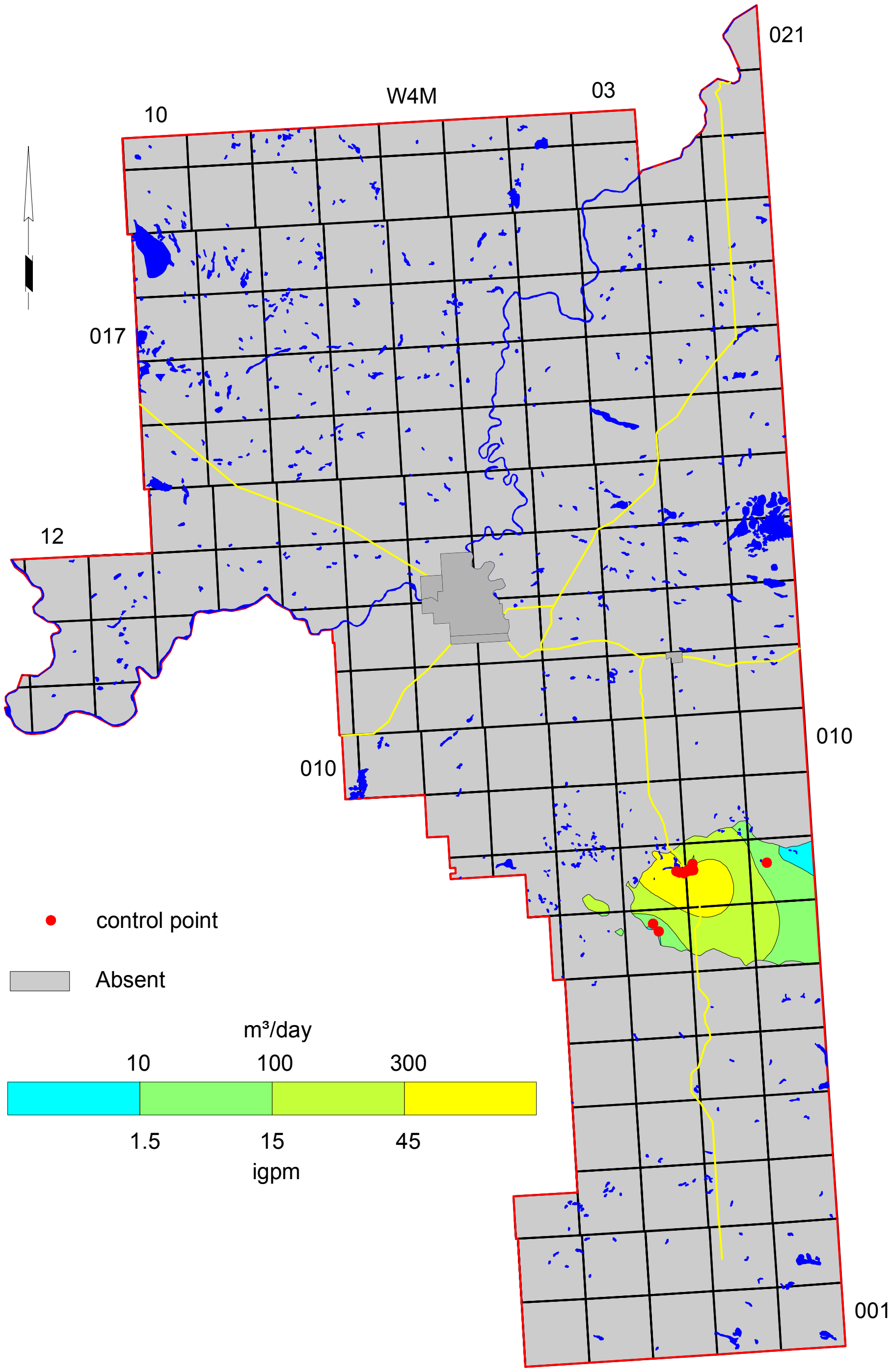
Depth to Top of Scollard (Frenchman) Formation



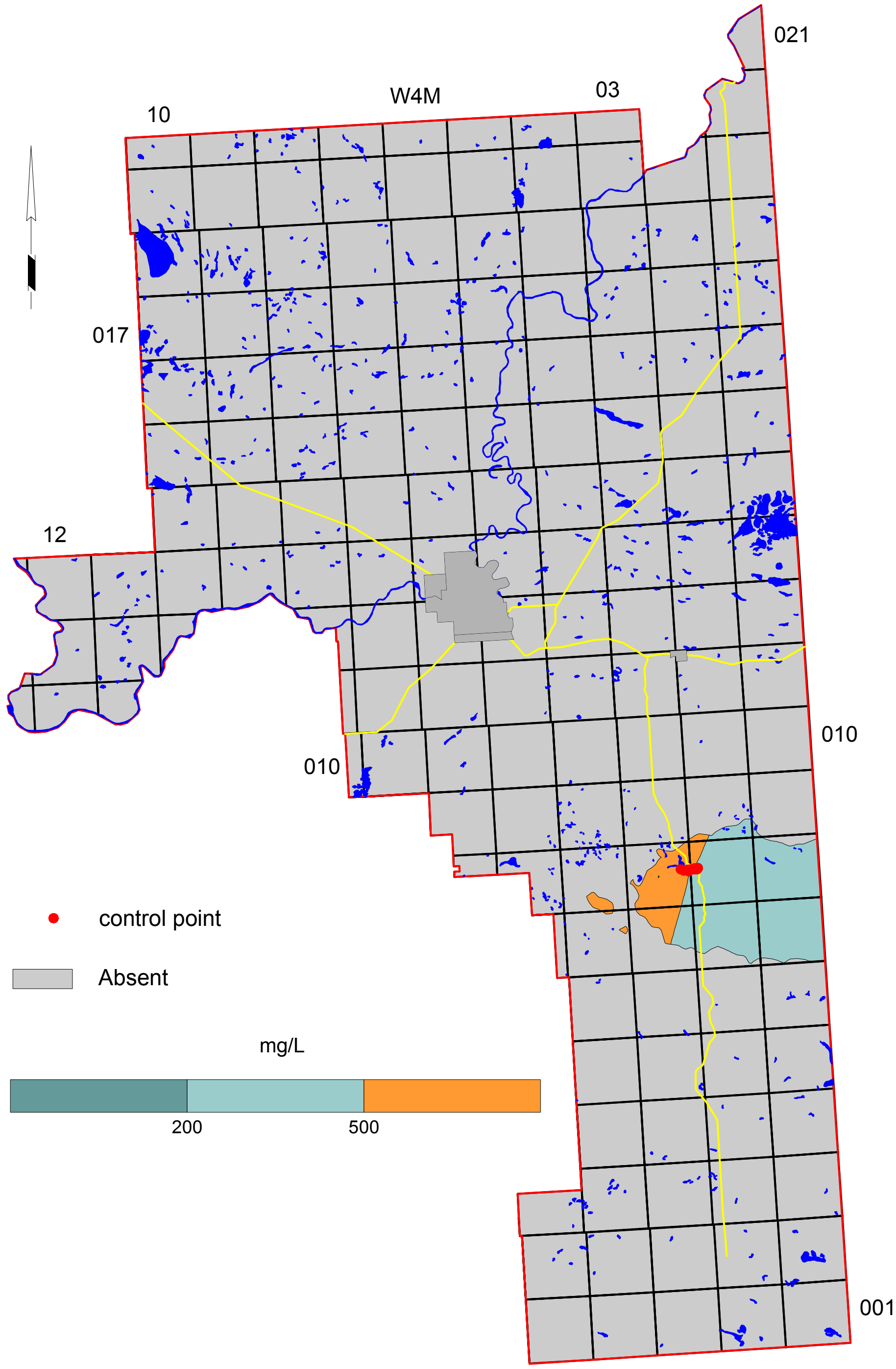
Depth to Top of Horseshoe Canyon (Eastend) Formation



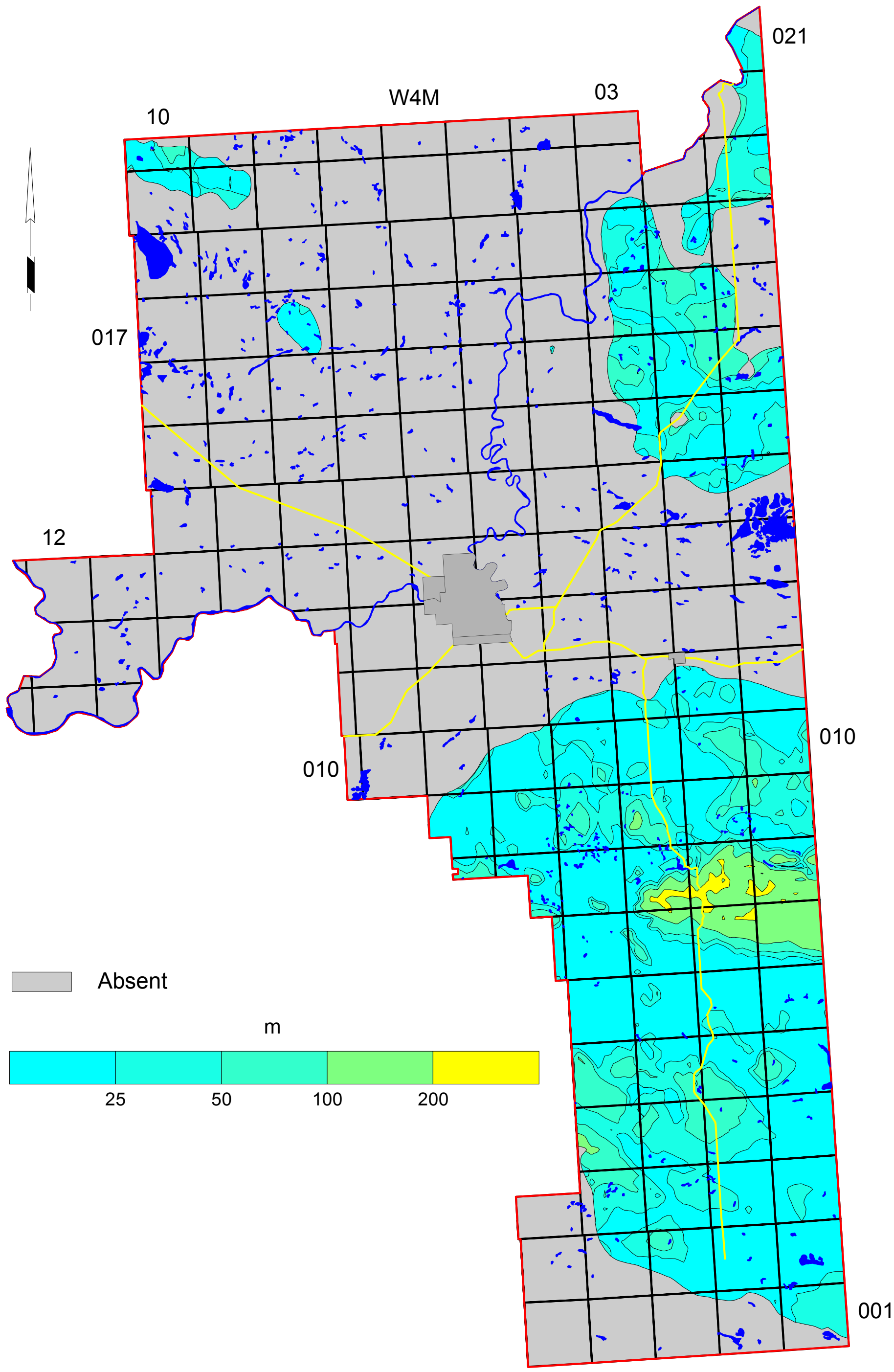
Apparent Yield for Water Wells Completed through Horseshoe Canyon (Eastend) Aquifer



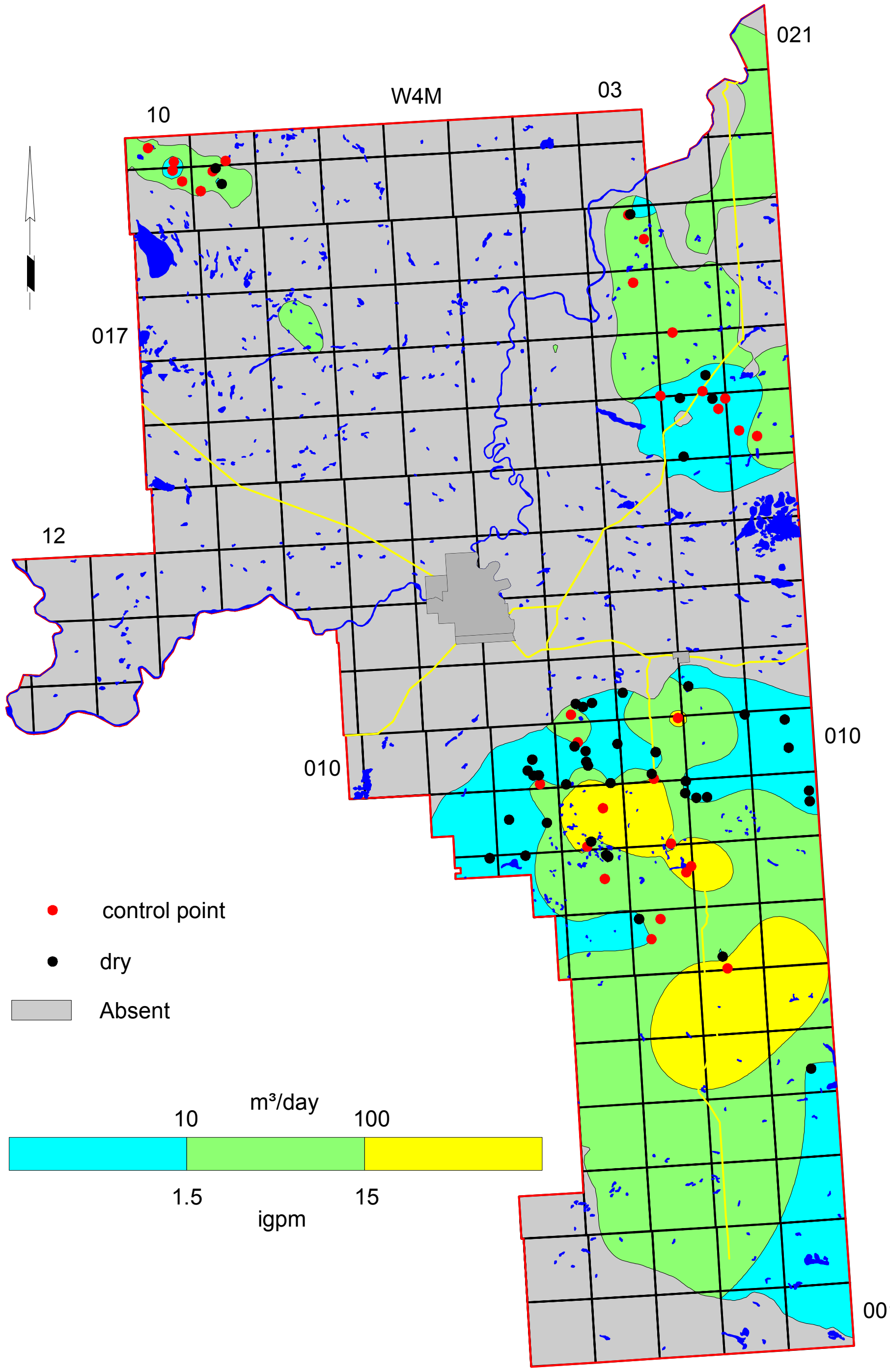
Total Dissolved Solids in Groundwater from Horseshoe Canyon (Eastend) Aquifer



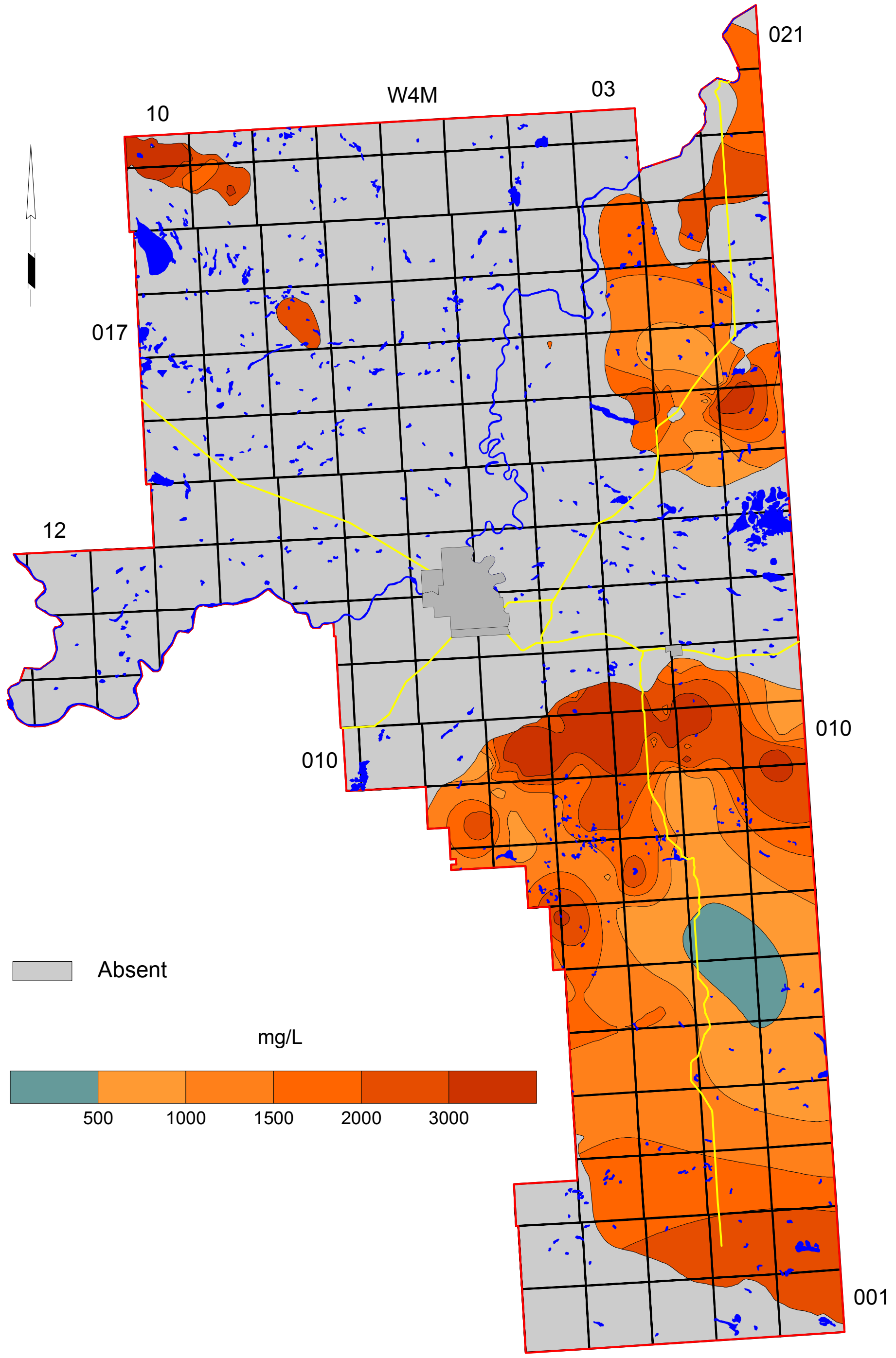
Depth to Top of Bearpaw Formation



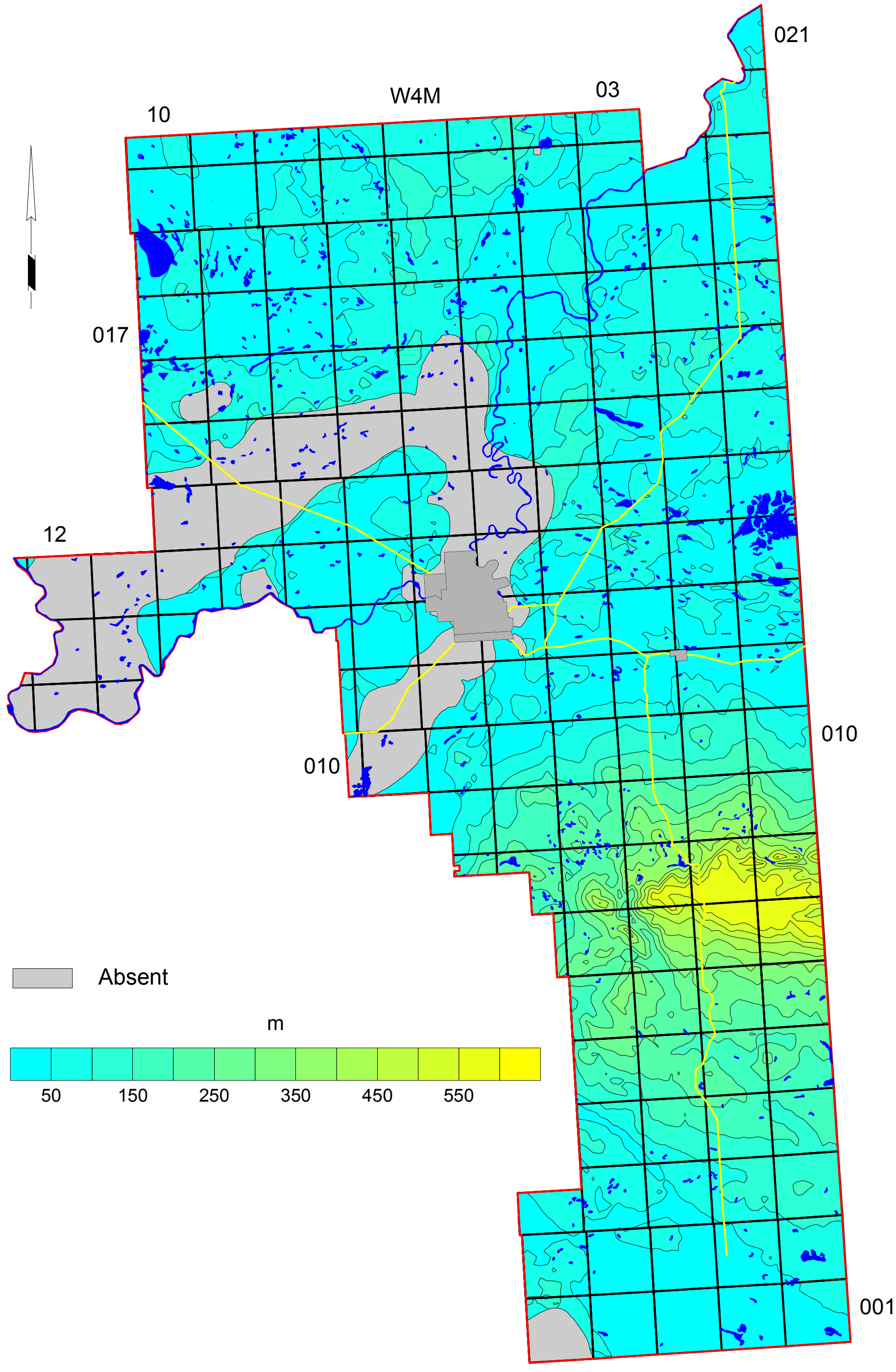
Apparent Yield for Water Wells Completed through Bearpaw Aquifer



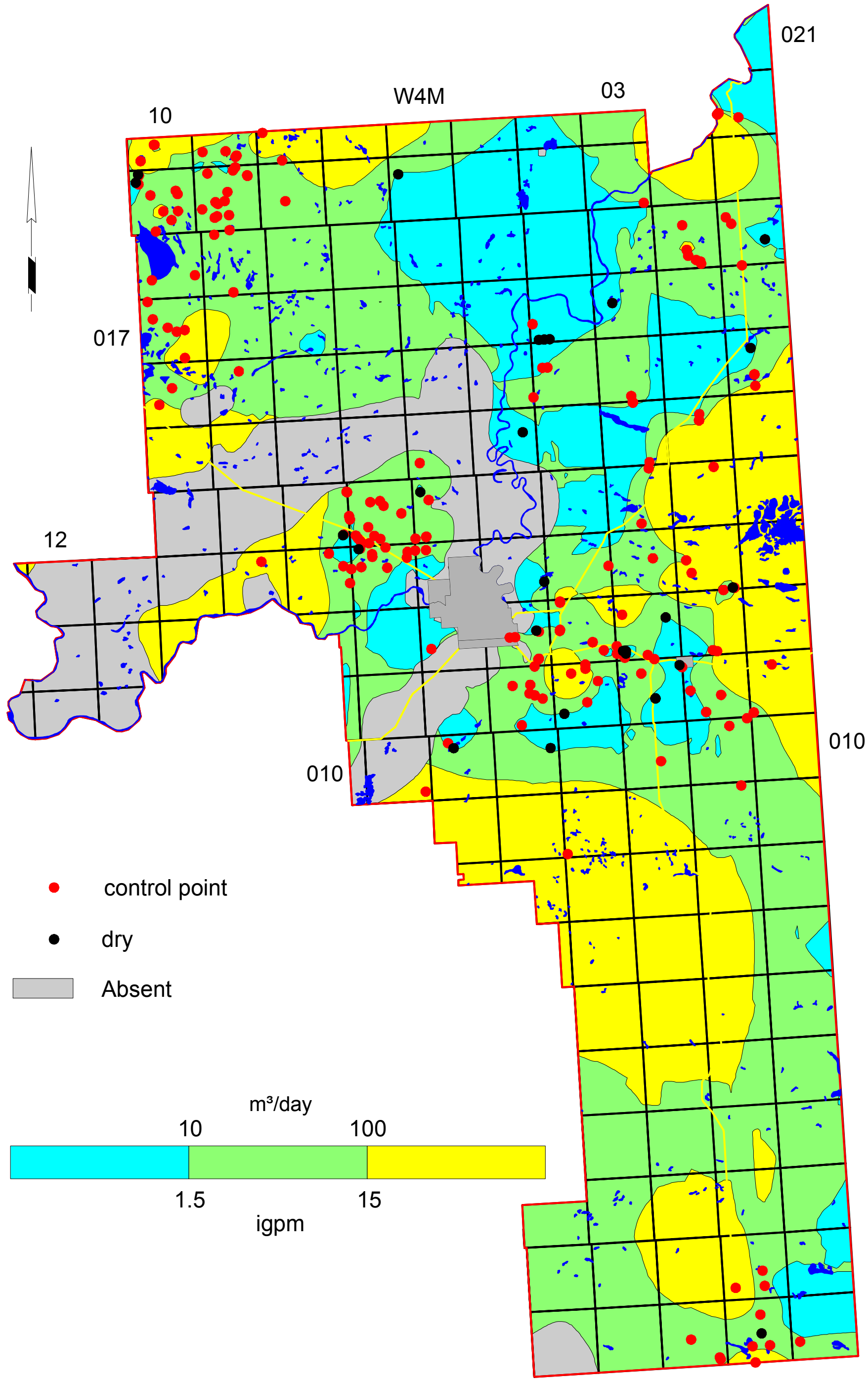
Total Dissolved Solids in Groundwater from Bearpaw Aquifer



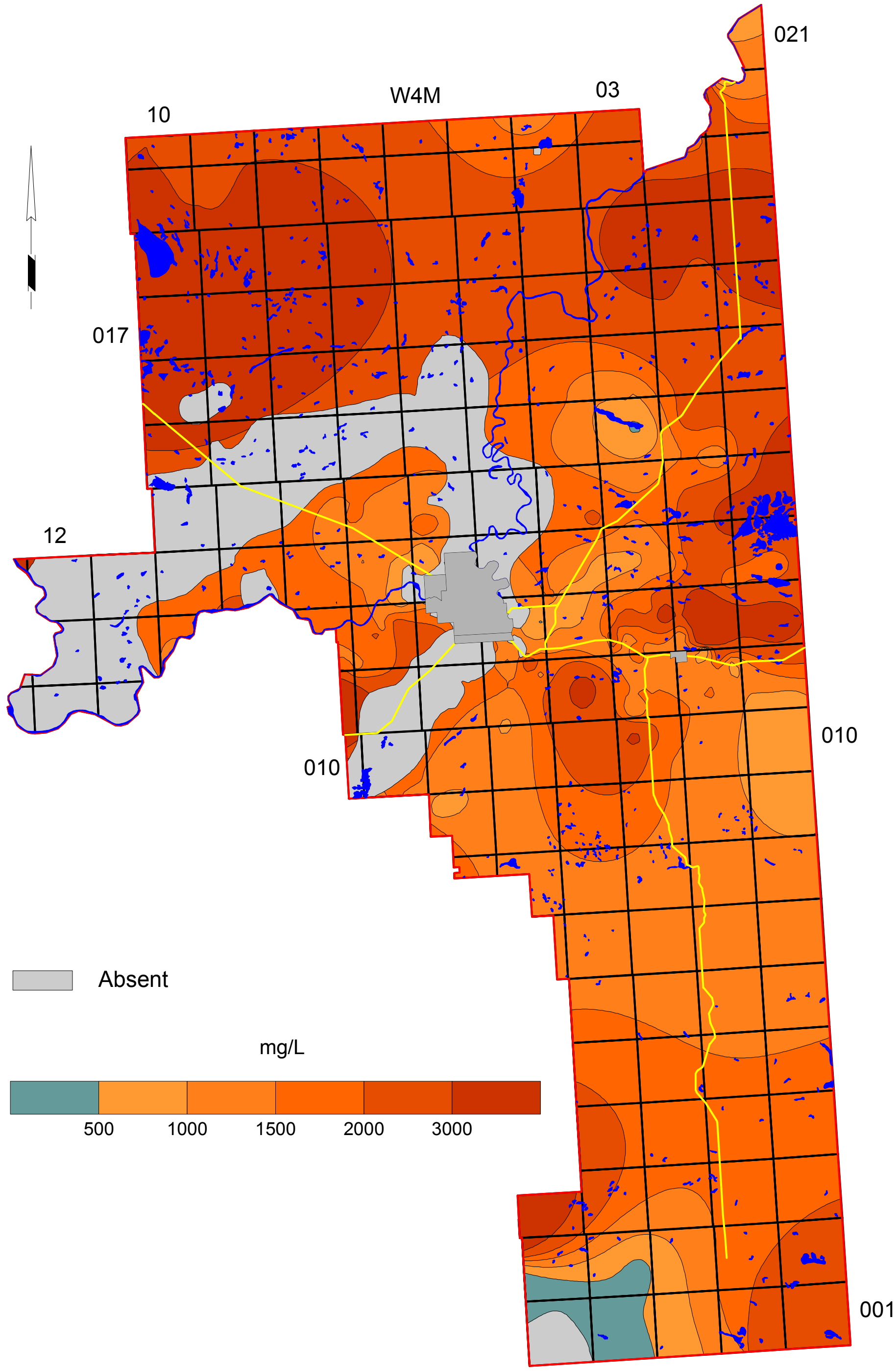
Depth to Top of Oldman Formation



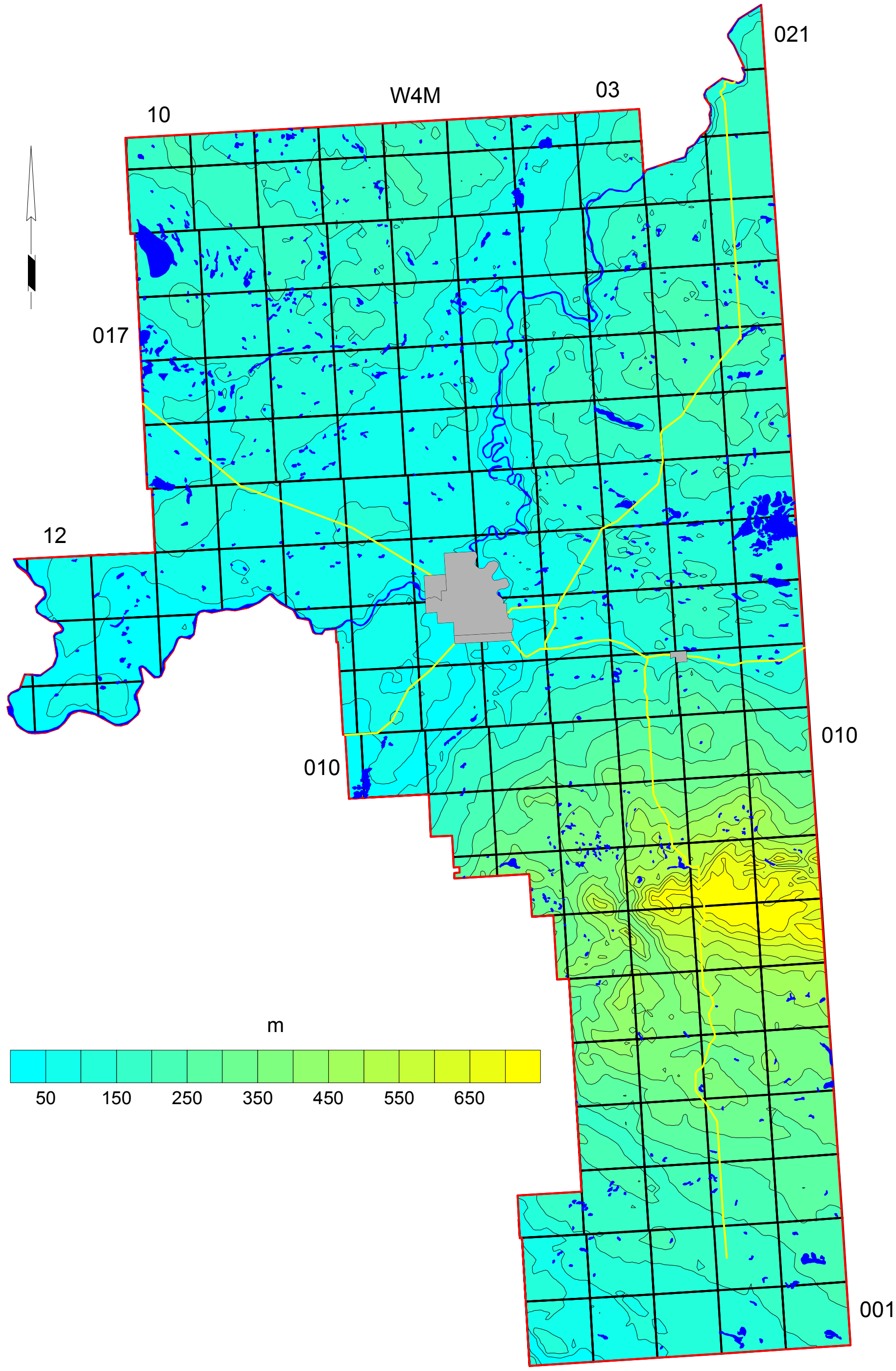
Apparent Yield for Water Wells Completed through Oldman Aquifer



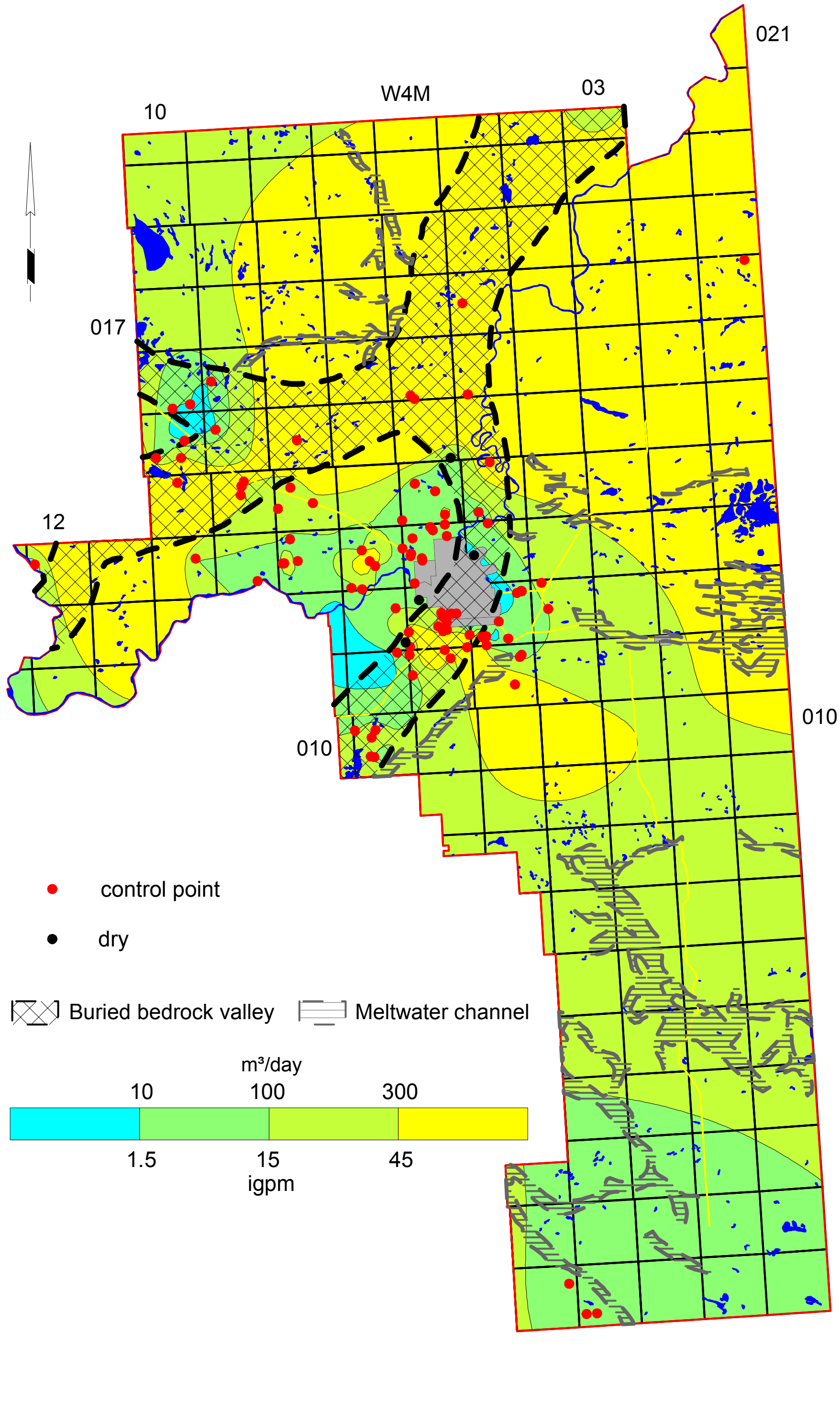
Total Dissolved Solids in Groundwater from Oldman Aquifer



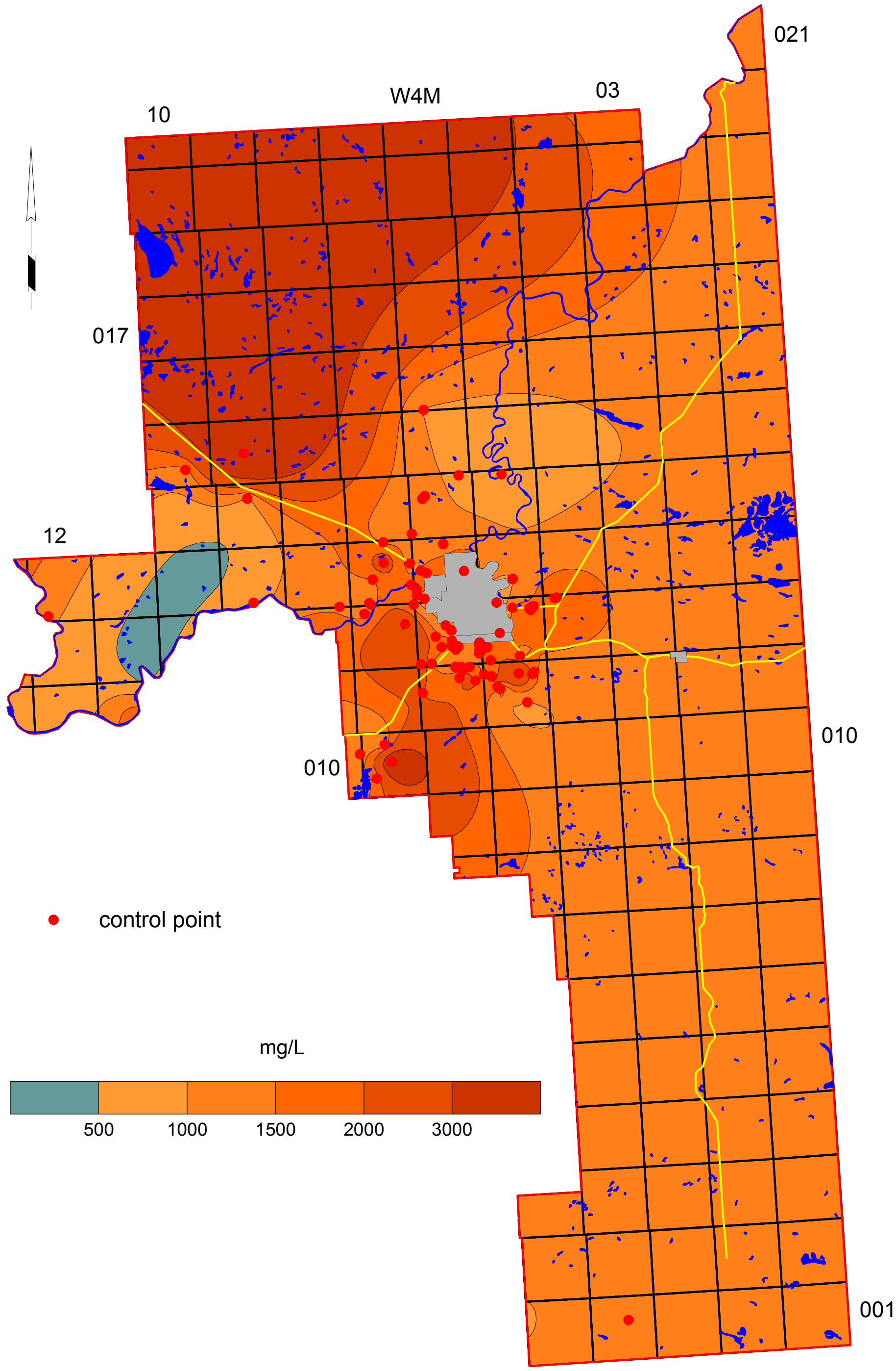
Depth to Top of Foremost Formation



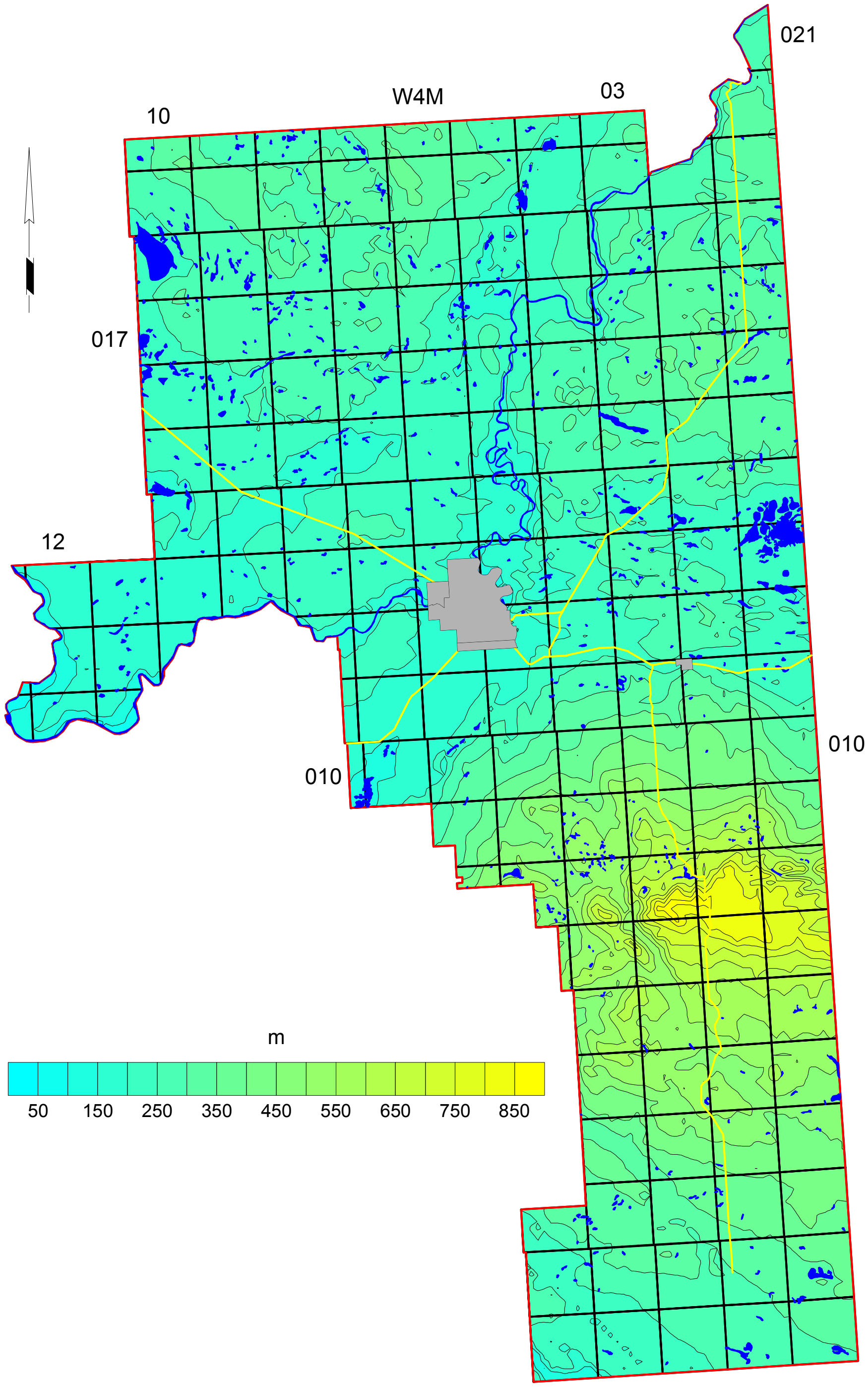
Apparent Yield for Water Wells Completed through Foremost Aquifer



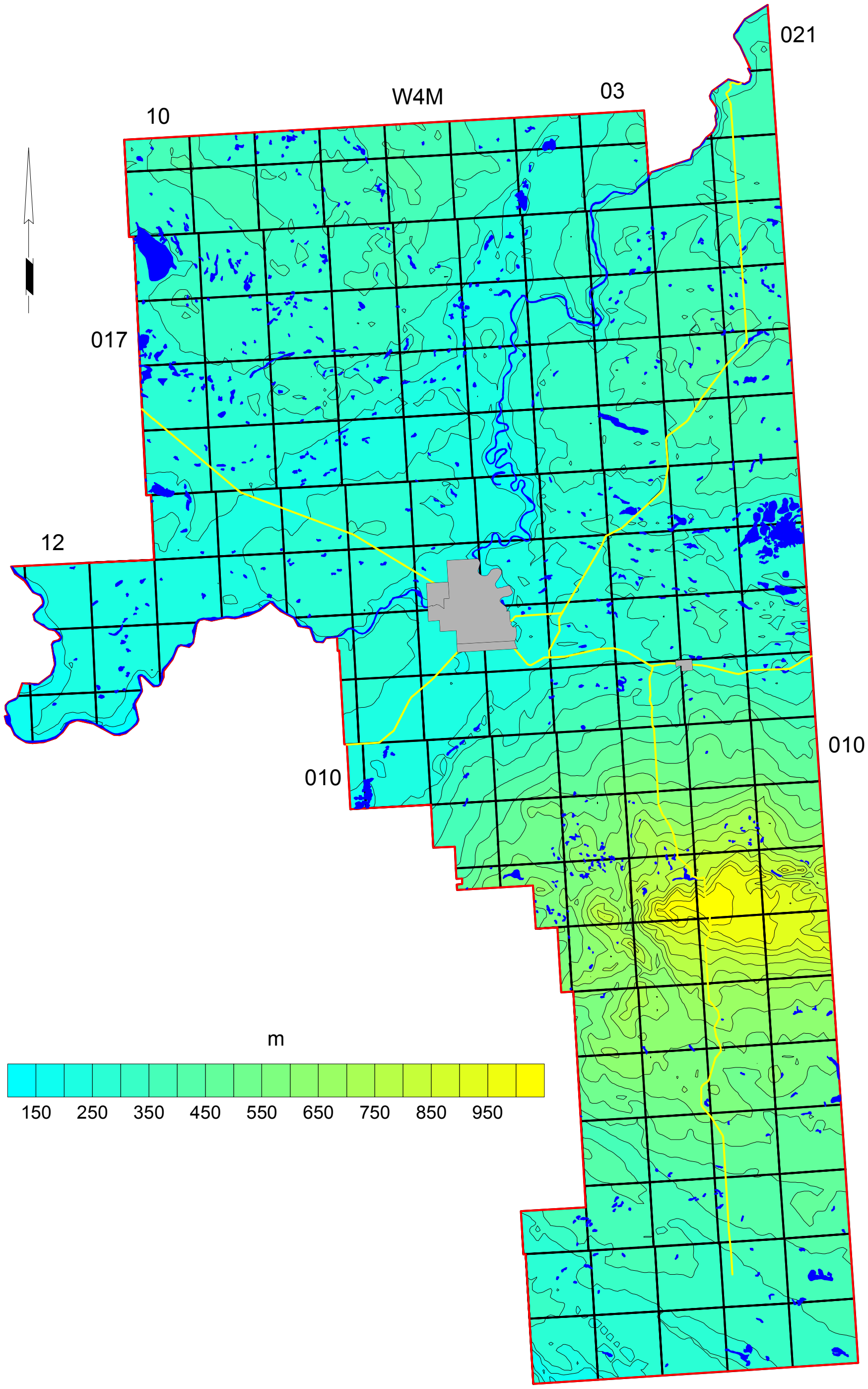
Total Dissolved Solids in Groundwater from Foremost Aquifer



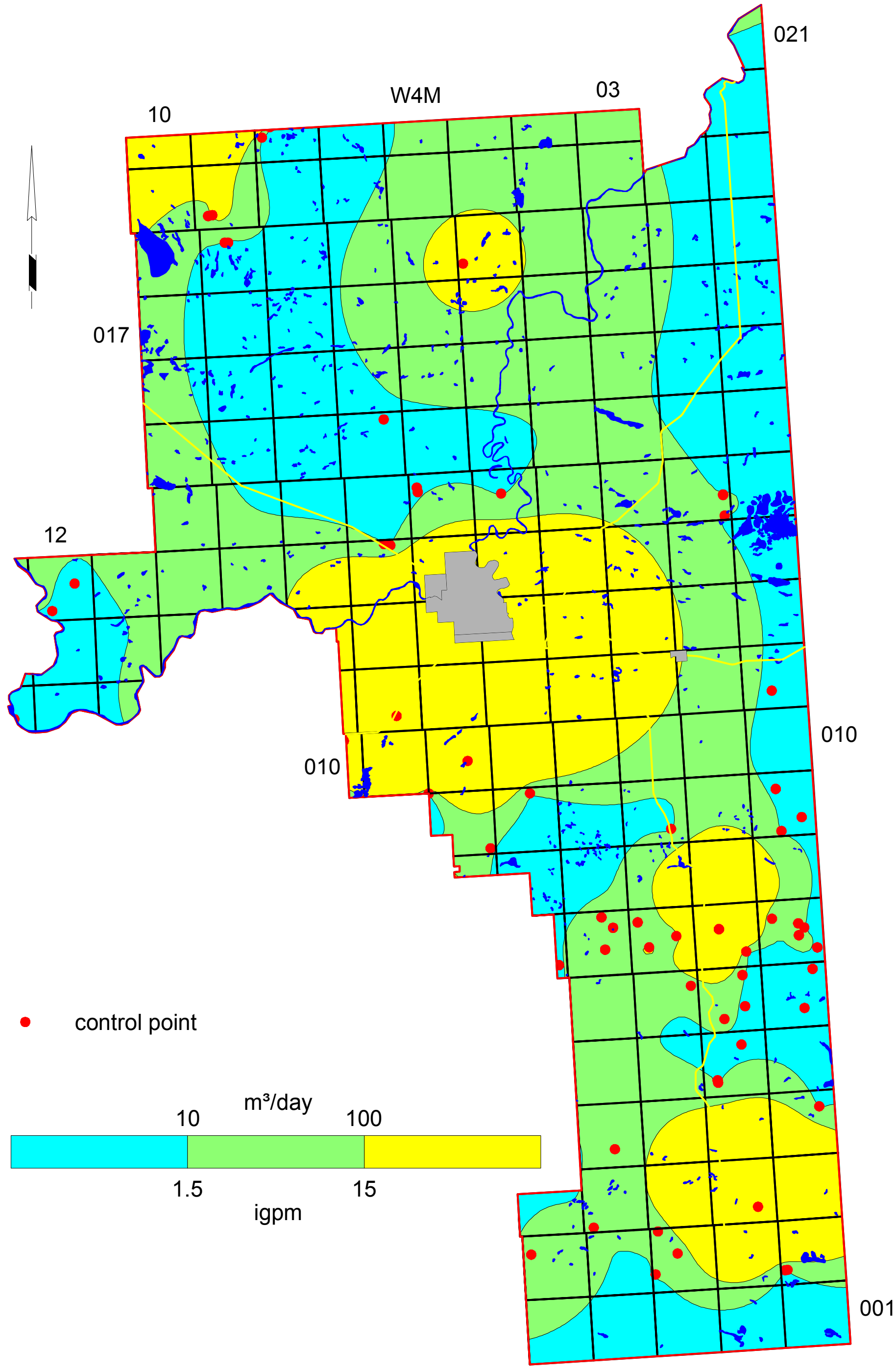
Depth to Top of Lea Park Formation



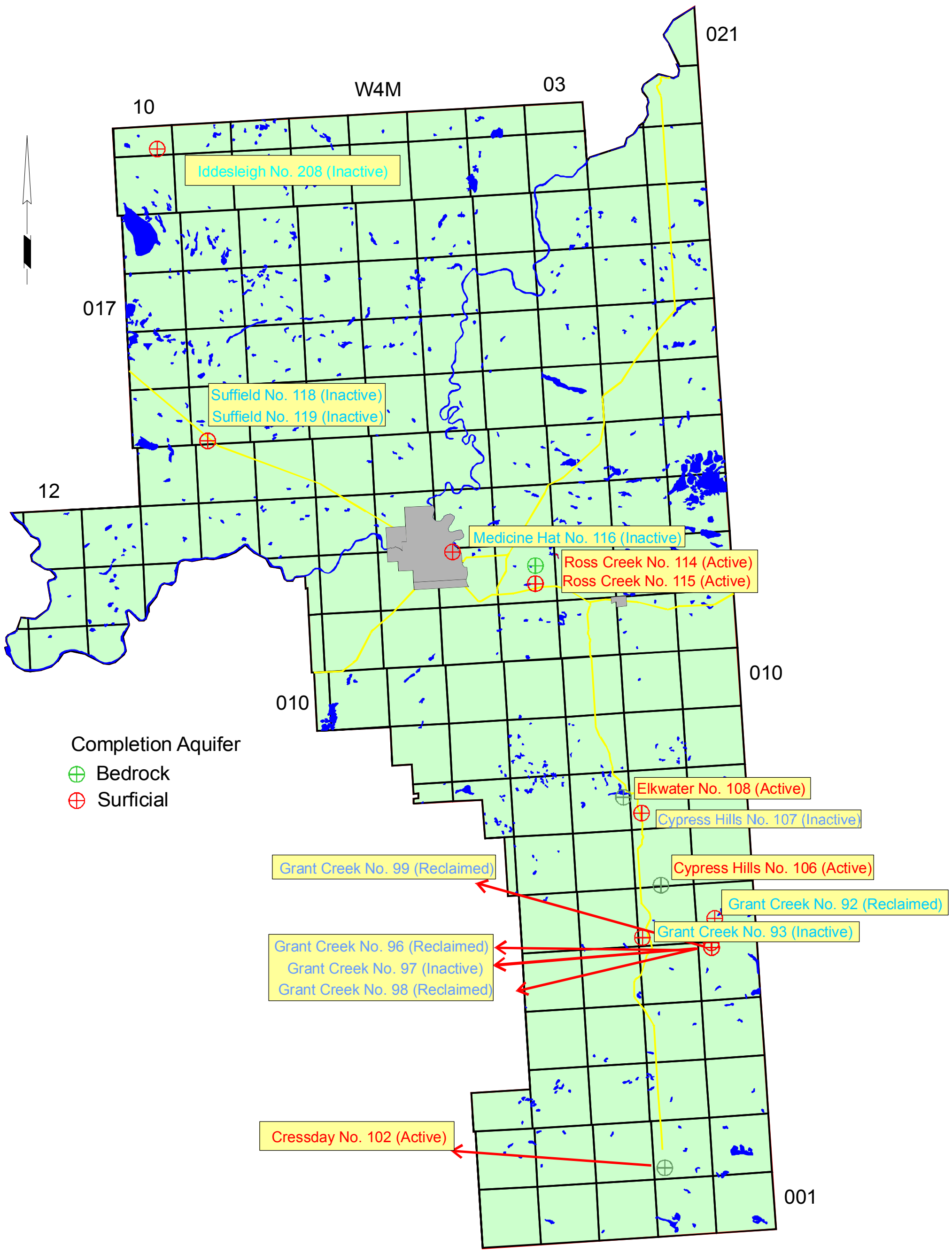
Depth to Top of Milk River Formation



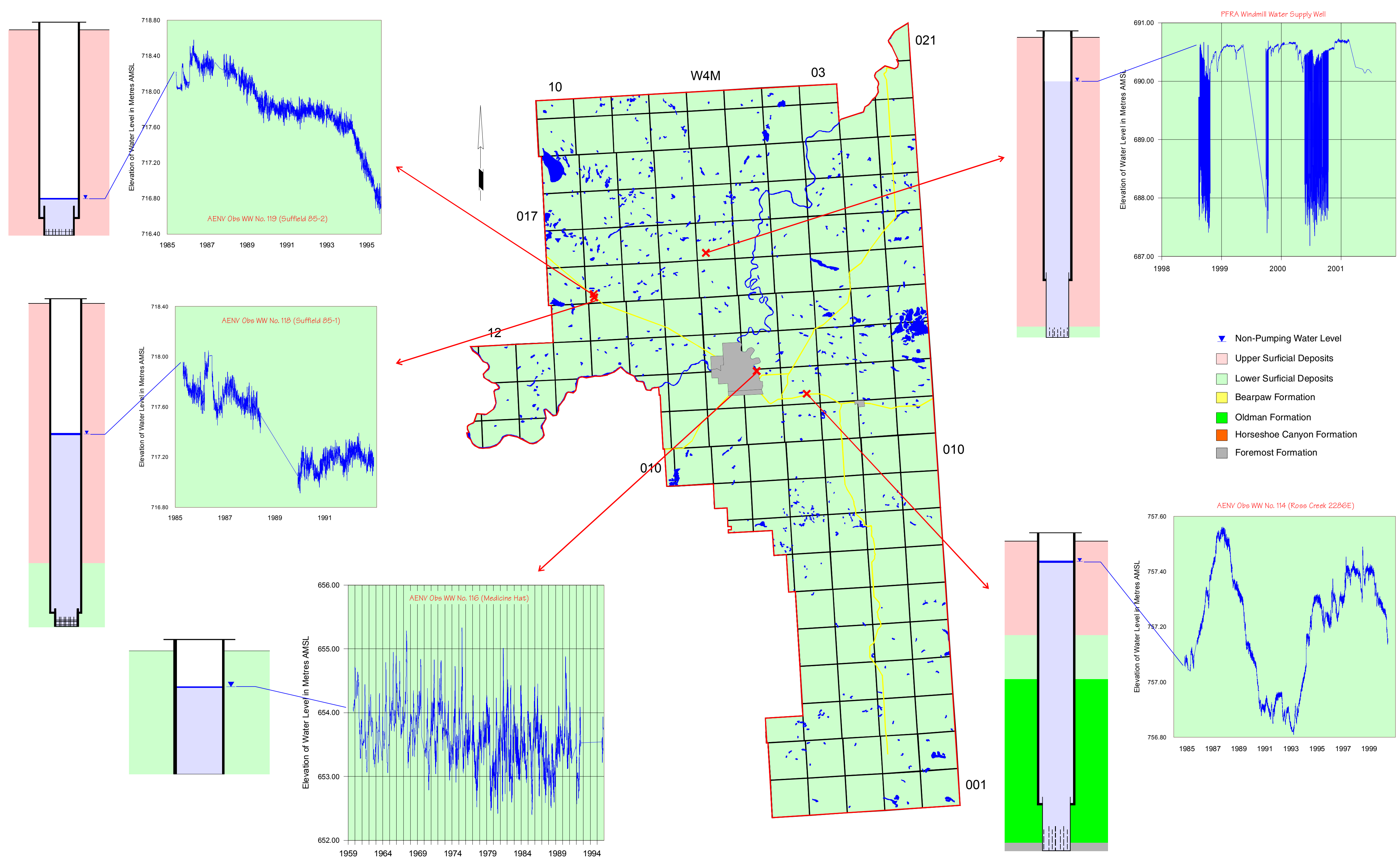
Apparent Yield for Water Wells Completed through Milk River Aquifer



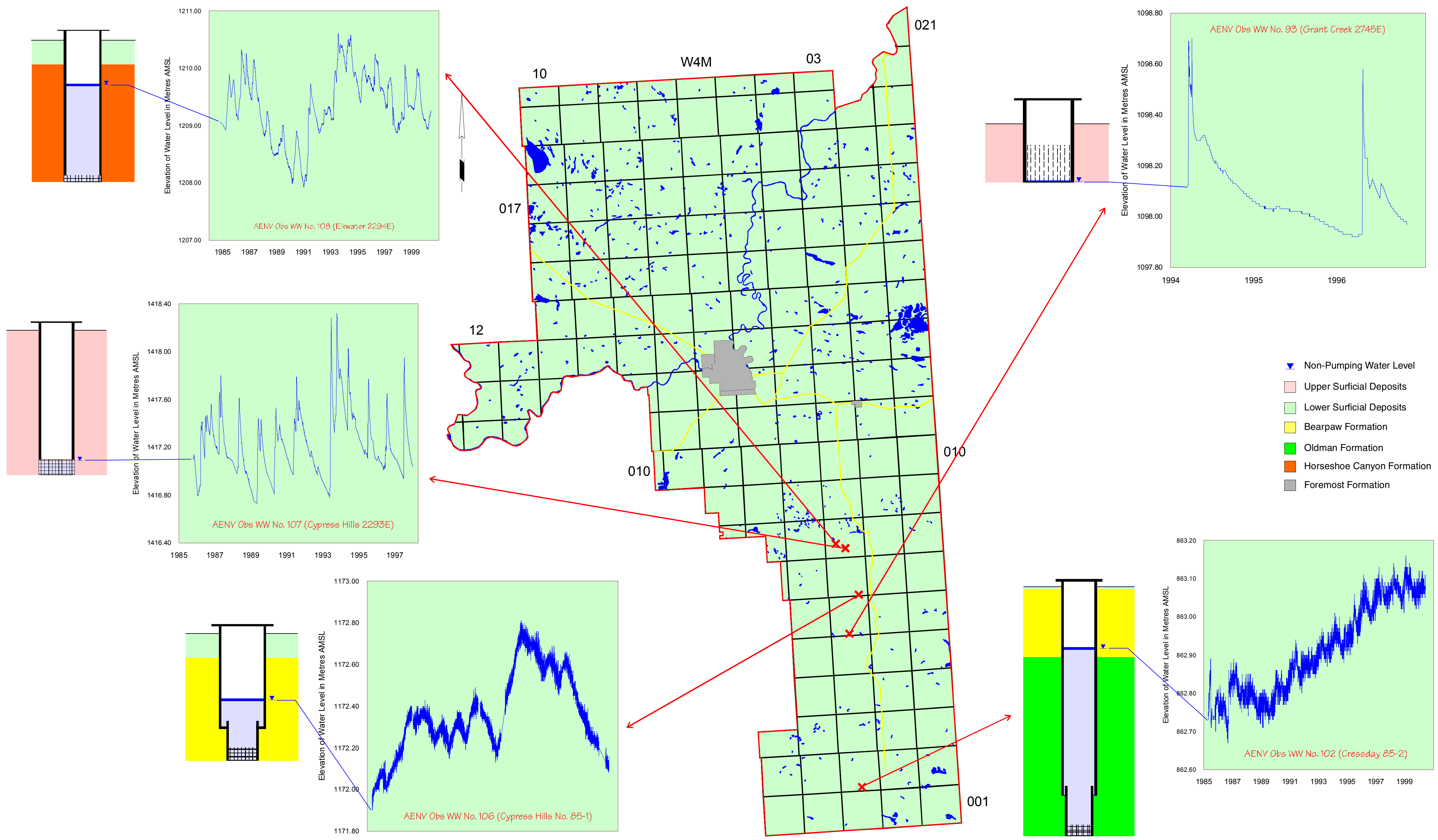
Location of AENV Observation Water Wells

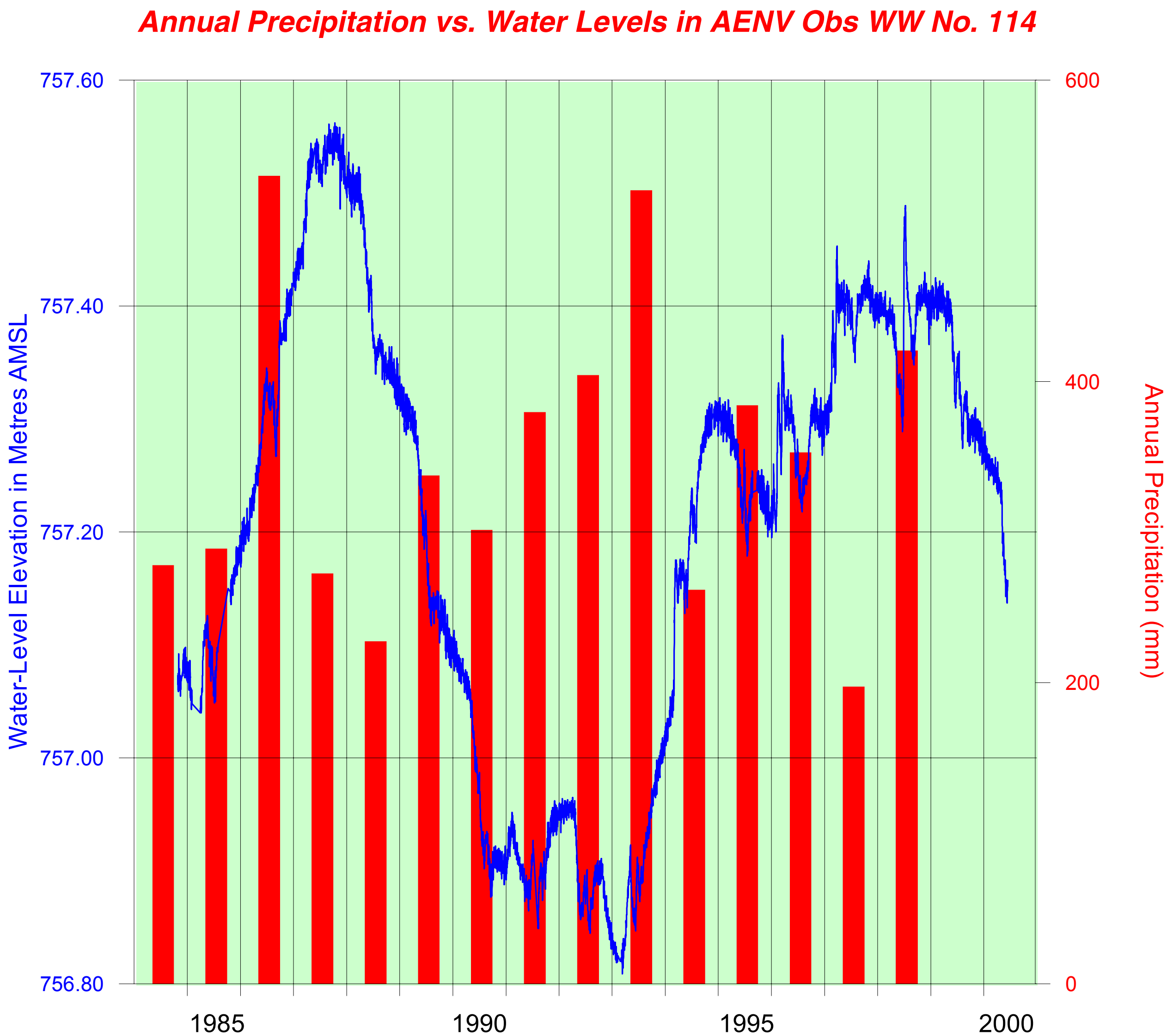


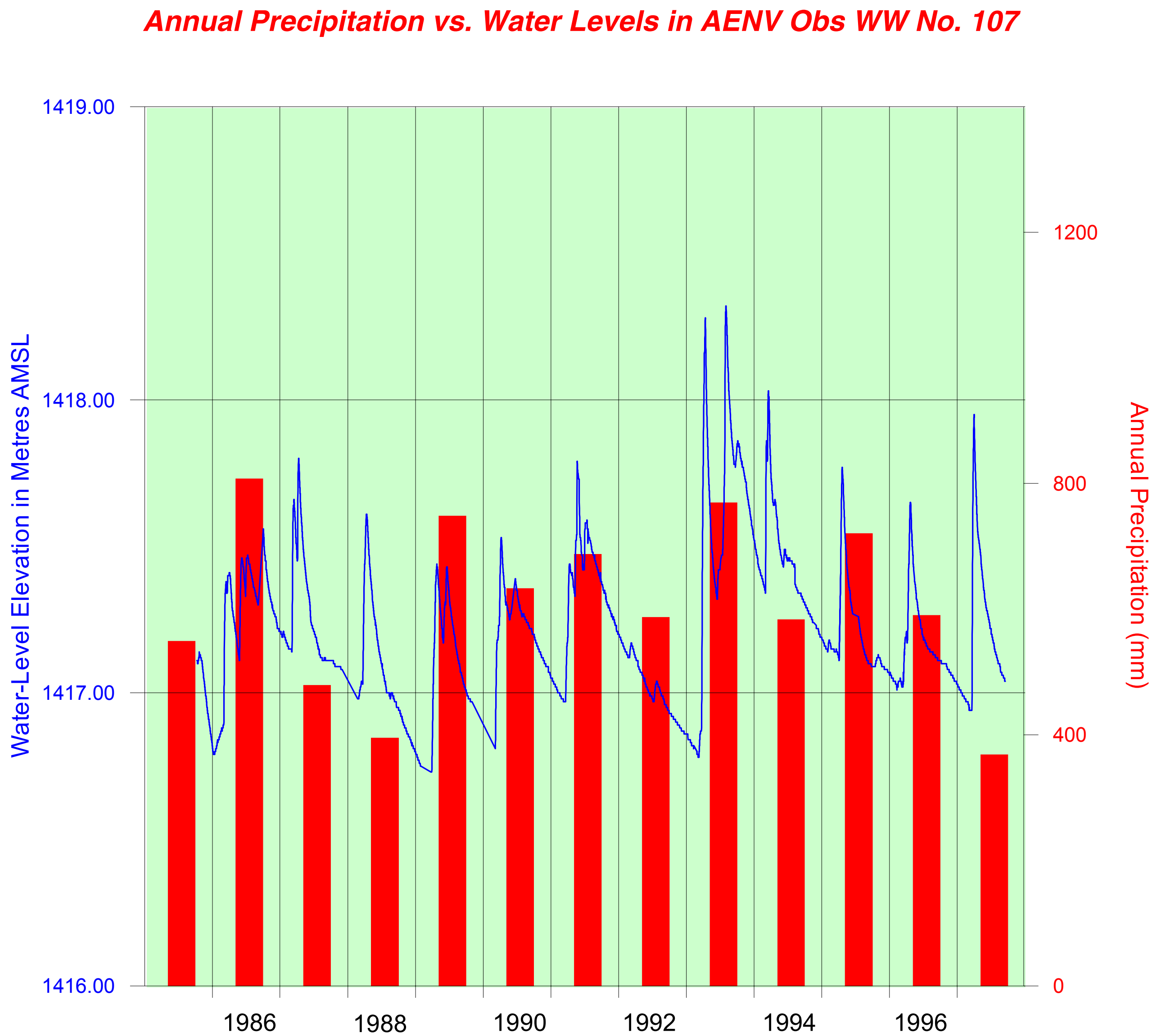
Hydrographs - North

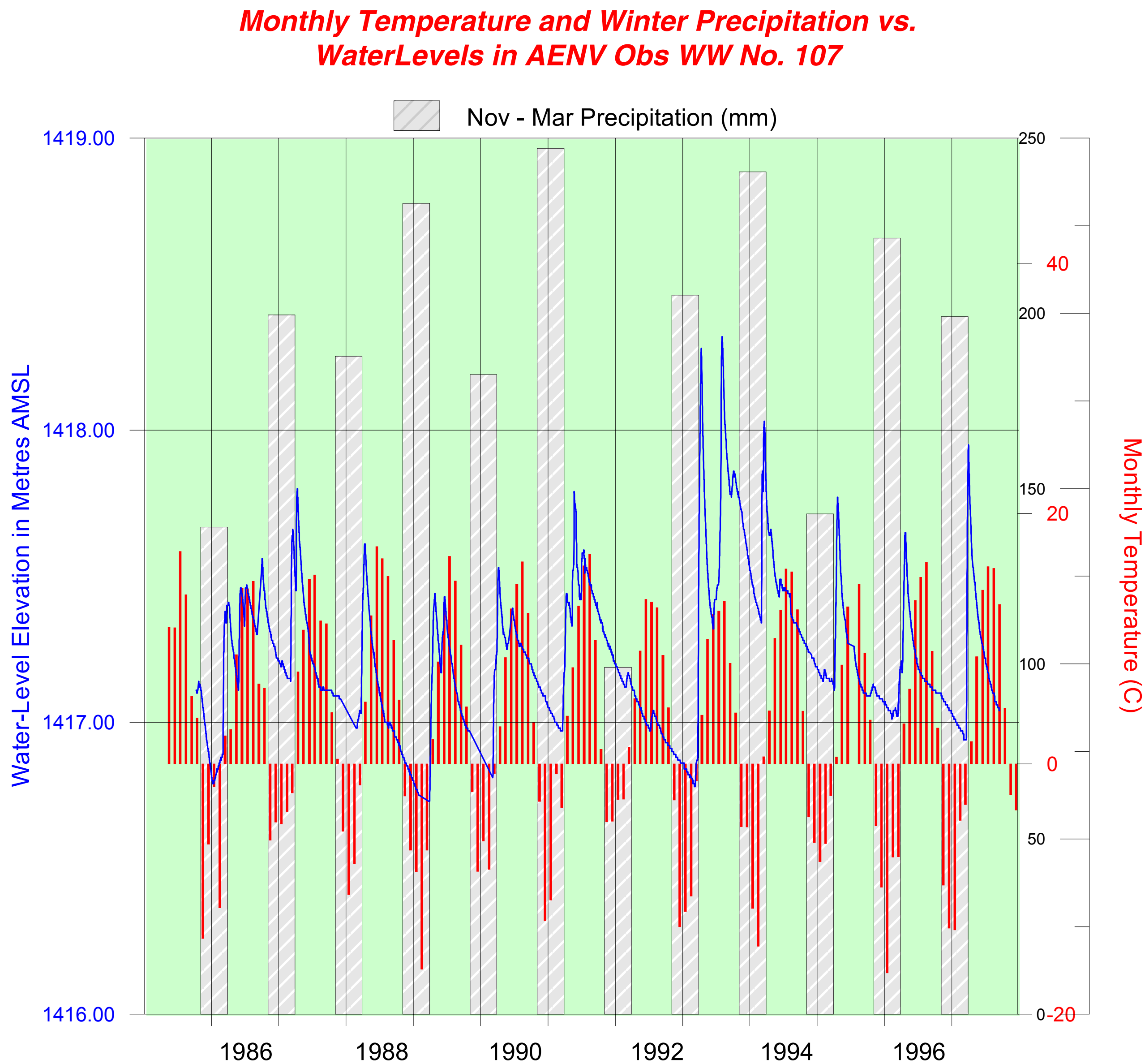


Hydrographs - South

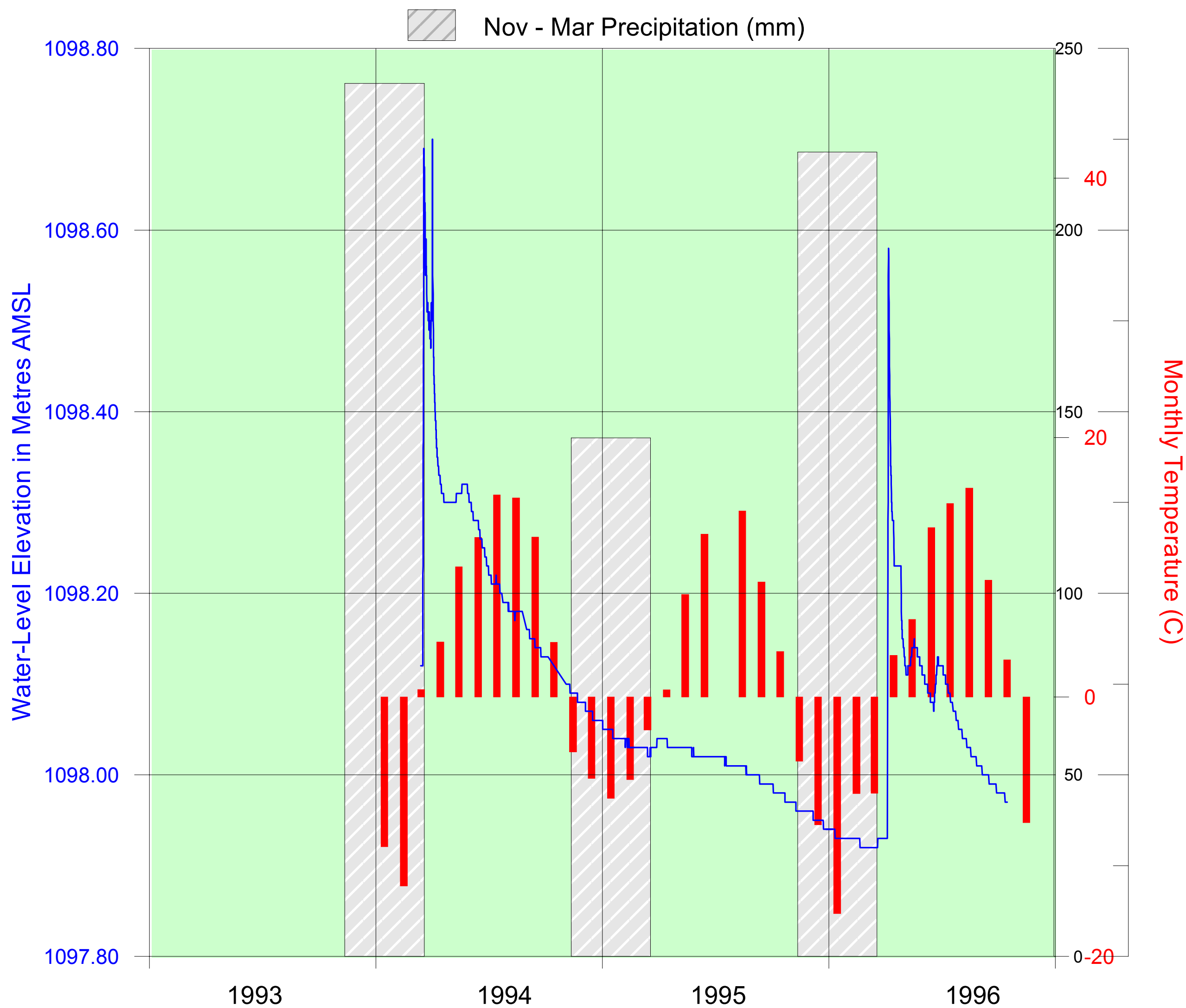


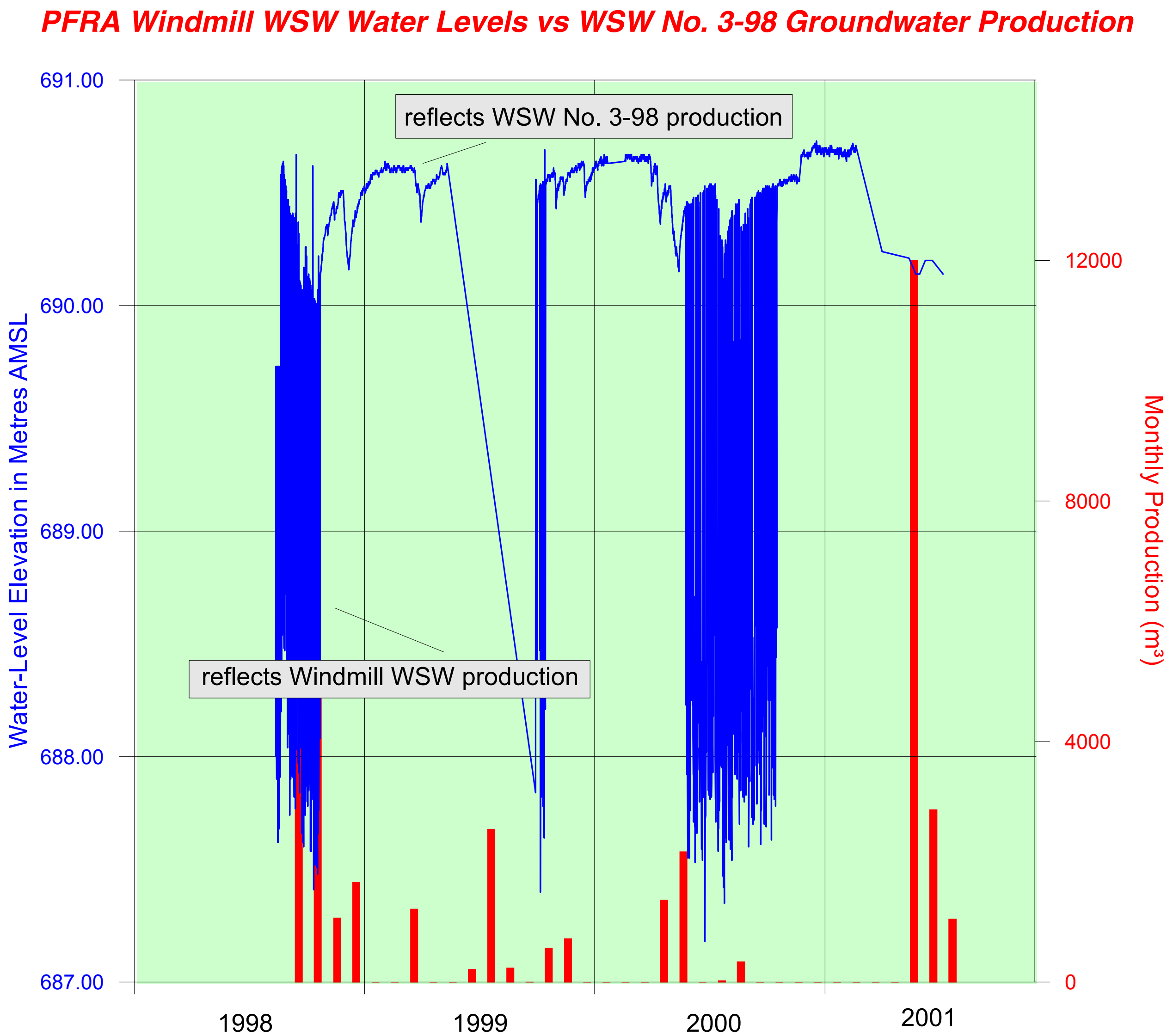

Annual Precipitation vs. Water Levels in AENV Obs WW No. 114
757.60
757.40
757.20
757.00
756.80
Water-Level Elevation in Metres AMSL
600
400
200
0
Annual Precipitation (mm)
1985
1990
1995
2000


Annual Precipitation vs. Water Levels in AENV Obs WW No. 107
Water-Level Elevation in Metres AMSL
Annual Precipitation (mm)
1419.00
1418.00
1417.00
1416.00
1200
800
400
0
1986
1988
1990
1992
1994
1996

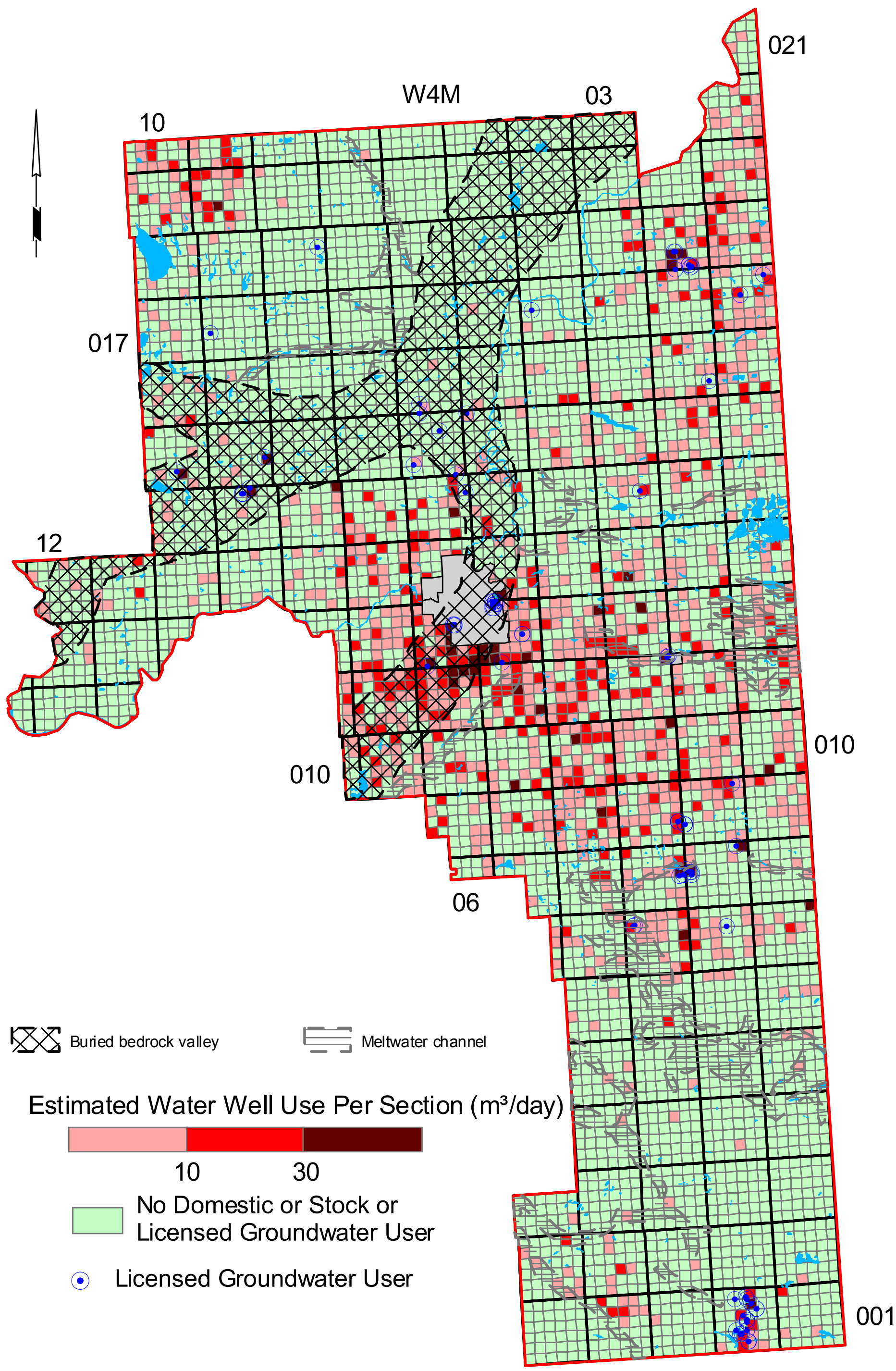

Monthly Temperature and Winter Precipitation vs. WaterLevels in AENV Obs WW No. 107
Nov - Mar Precipitation (mm)
Water-Level Elevation in Metres AMSL
1419.00
1418.00
1417.00
1416.00
Monthly Temperature (C)
40
20
0
-20
250
200
150
100
50
0
1986
1988
1990
1992
1994
1996

Monthly Temperature and Winter Precipitation vs. Water Levels in AENV Obs WW No. 93

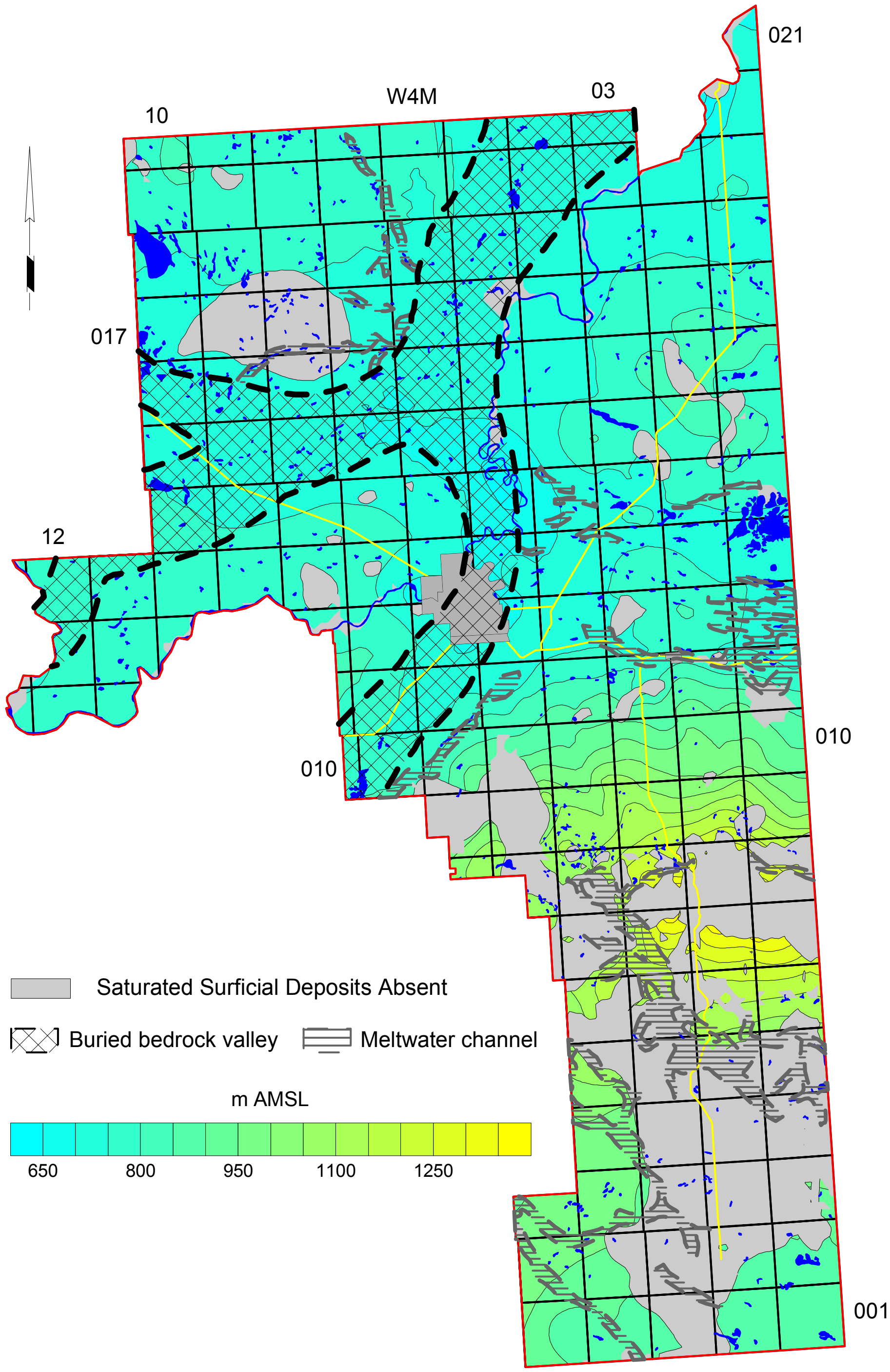



PFRA Windmill WSW Water Levels vs WSW No. 3-98 Groundwater Production
reflects WSW No. 3-98 production
reflects Windmill WSW production
Water-Level Elevation in Metres AMSL
691.00
690.00
689.00
688.00
687.00
Monthly Production (m³)
12000
8000
4000
0
1998
1999
2000
2001

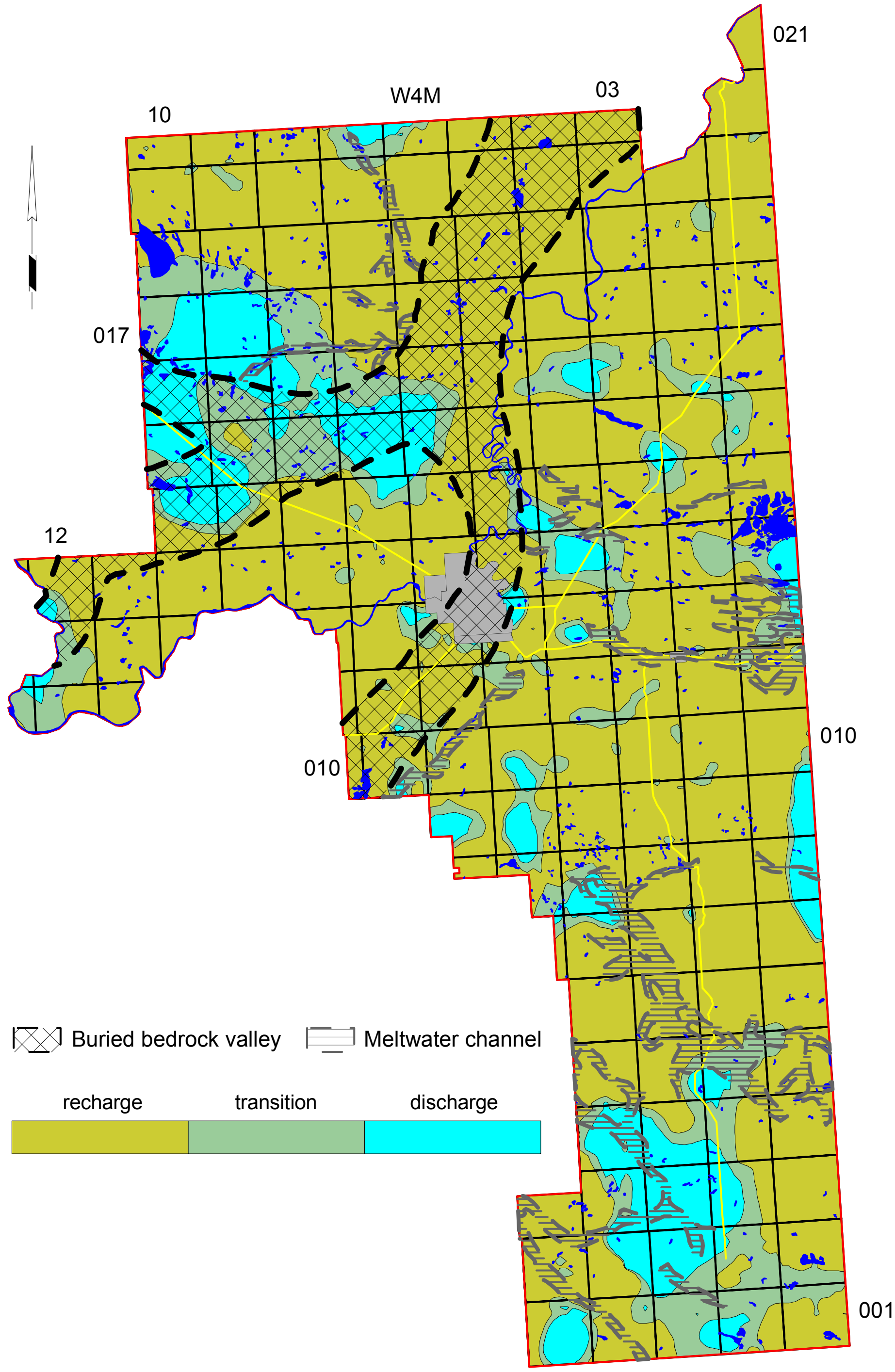
Estimated Water Well Use Per Section



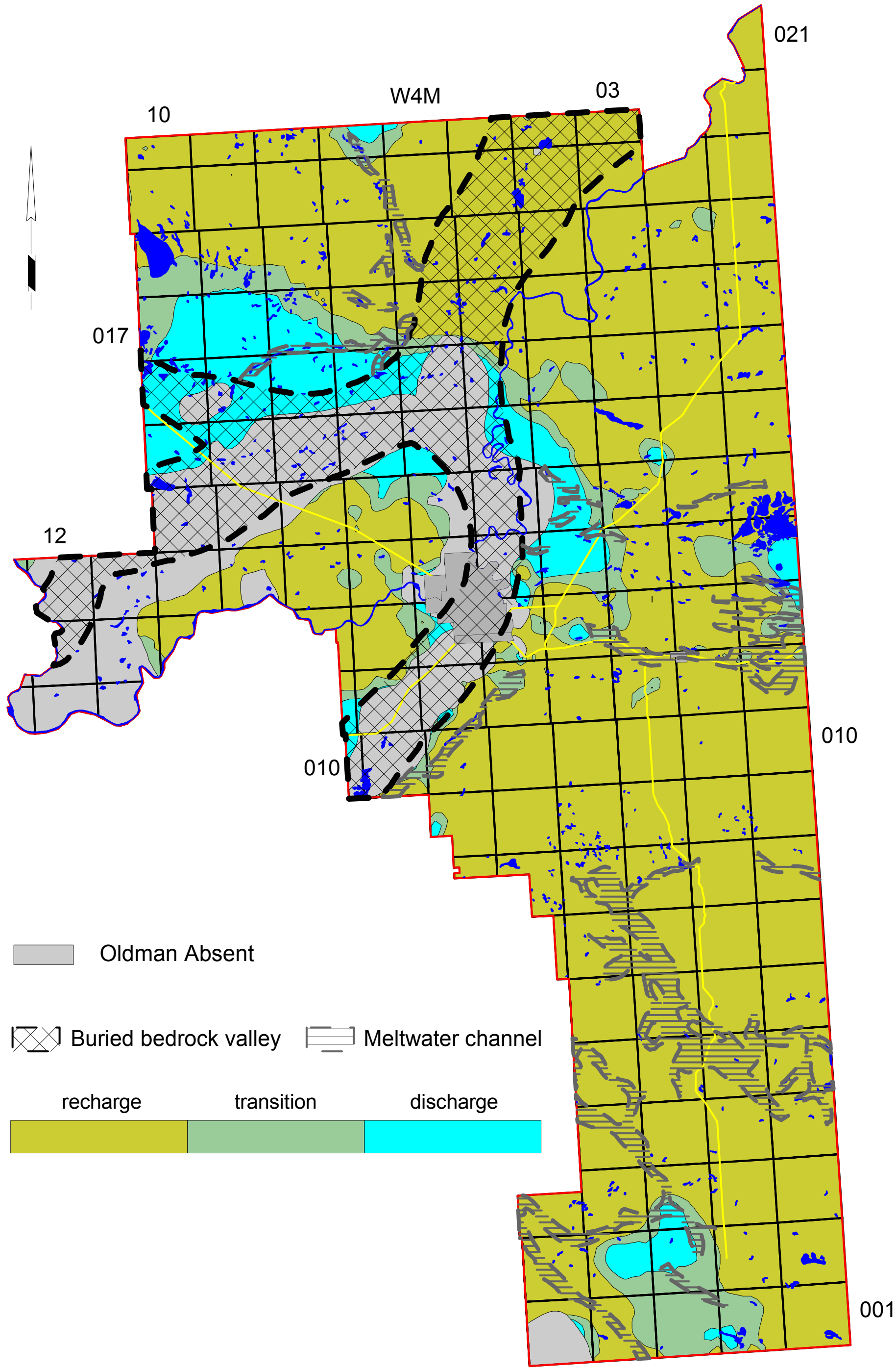
Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep



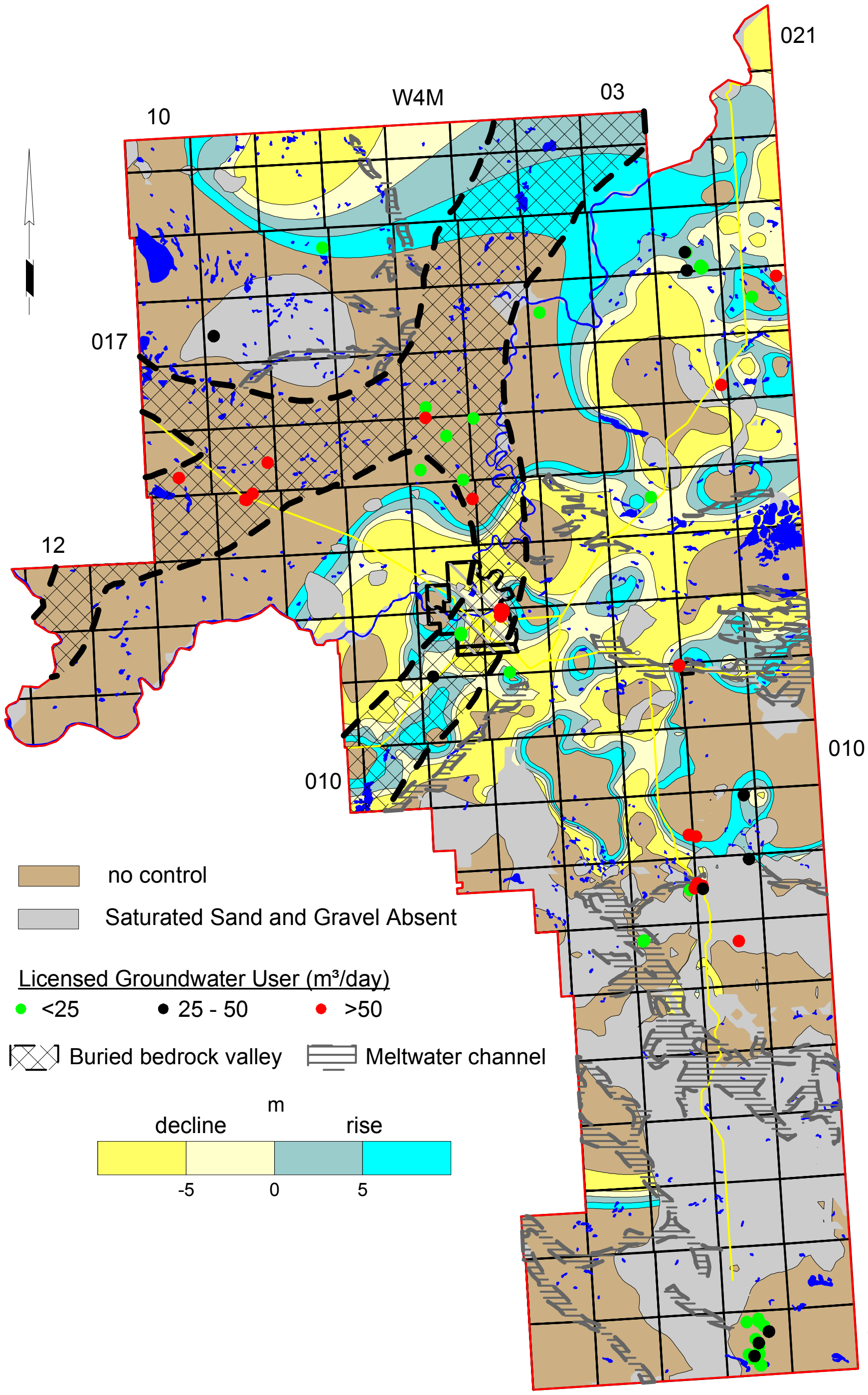
Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)



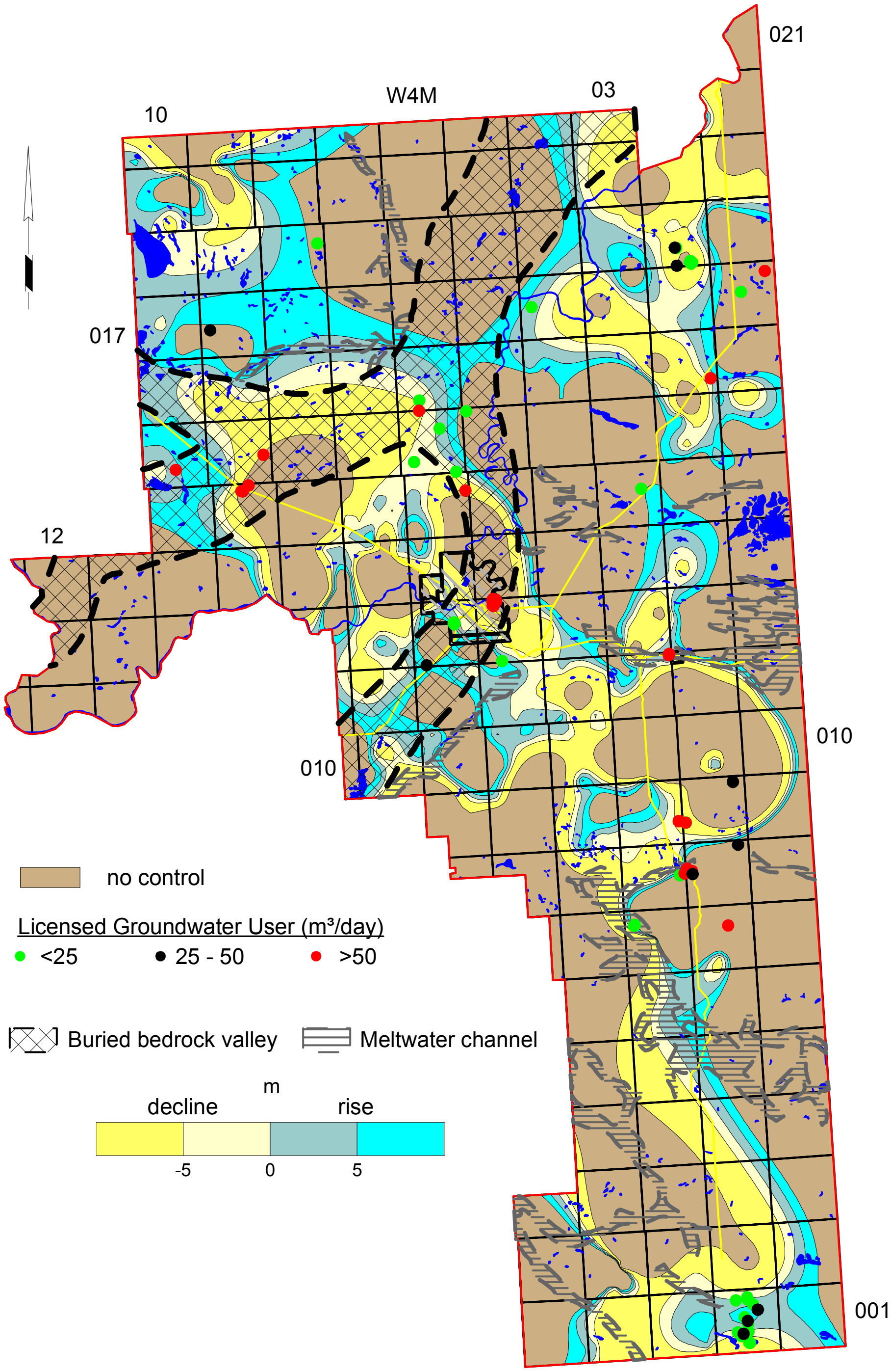
Recharge/Discharge Areas between Surficial Deposits and Oldman Aquifer



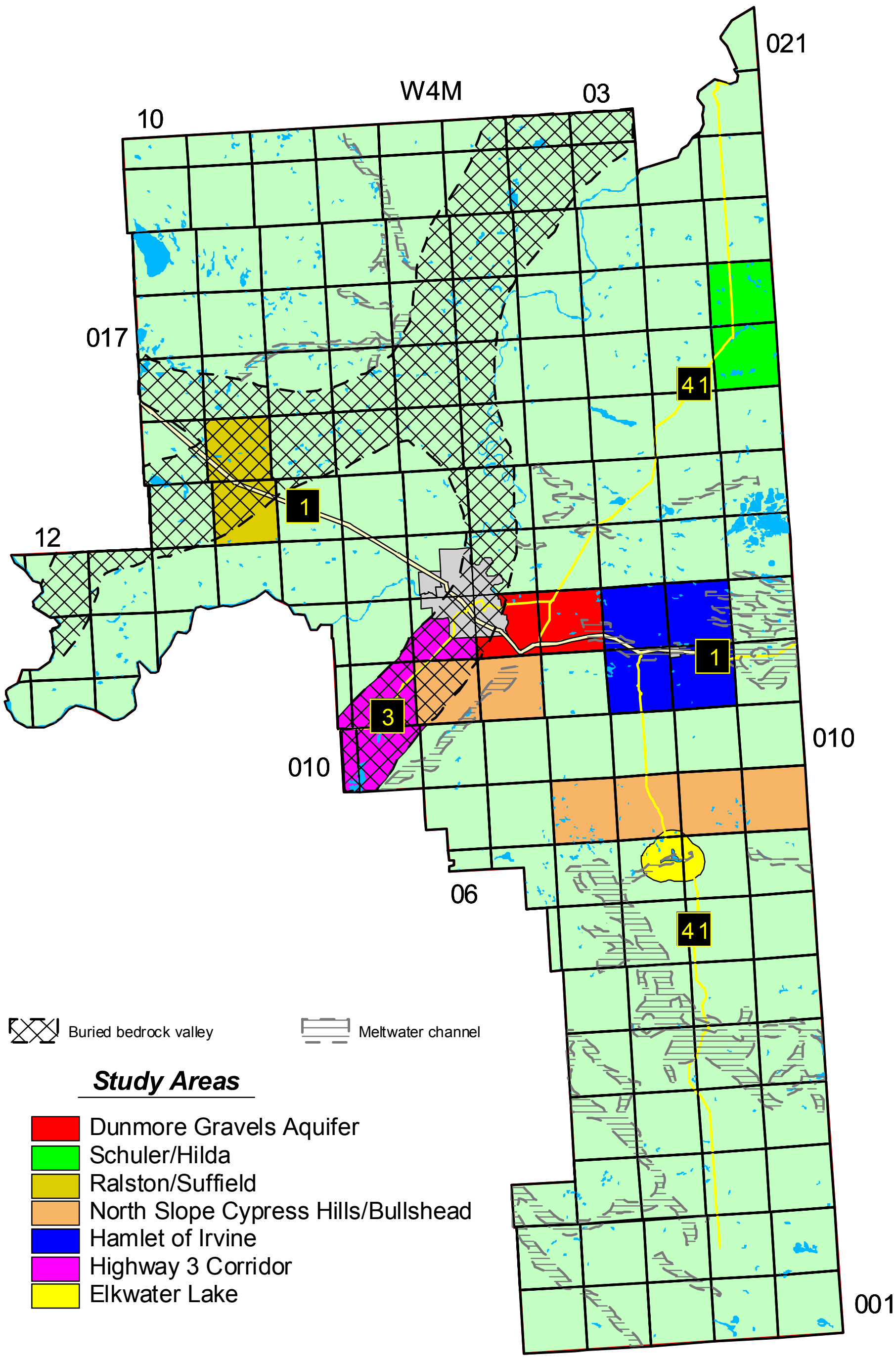
Changes in Water Levels in Sand and Gravel Aquifer(s) Based on Water Wells Less than 20 Metres Deep



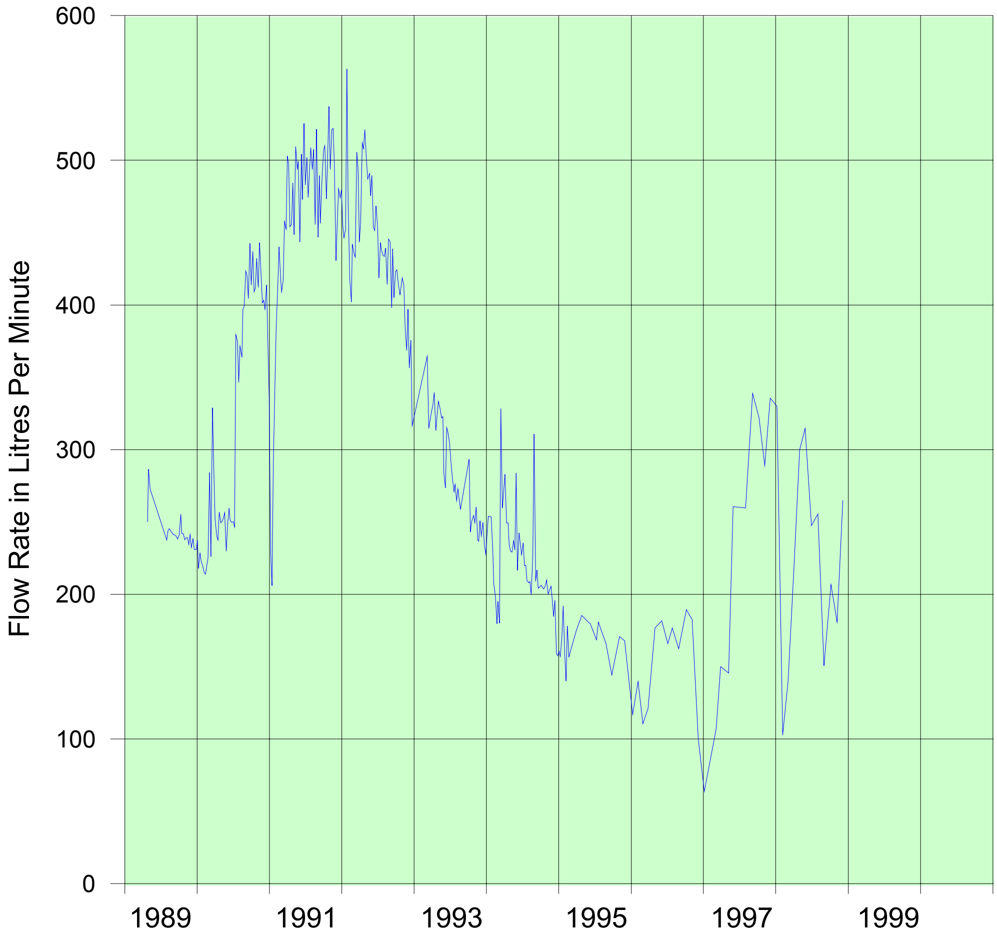
Changes in Water Levels in Upper Bedrock Aquifer(s)

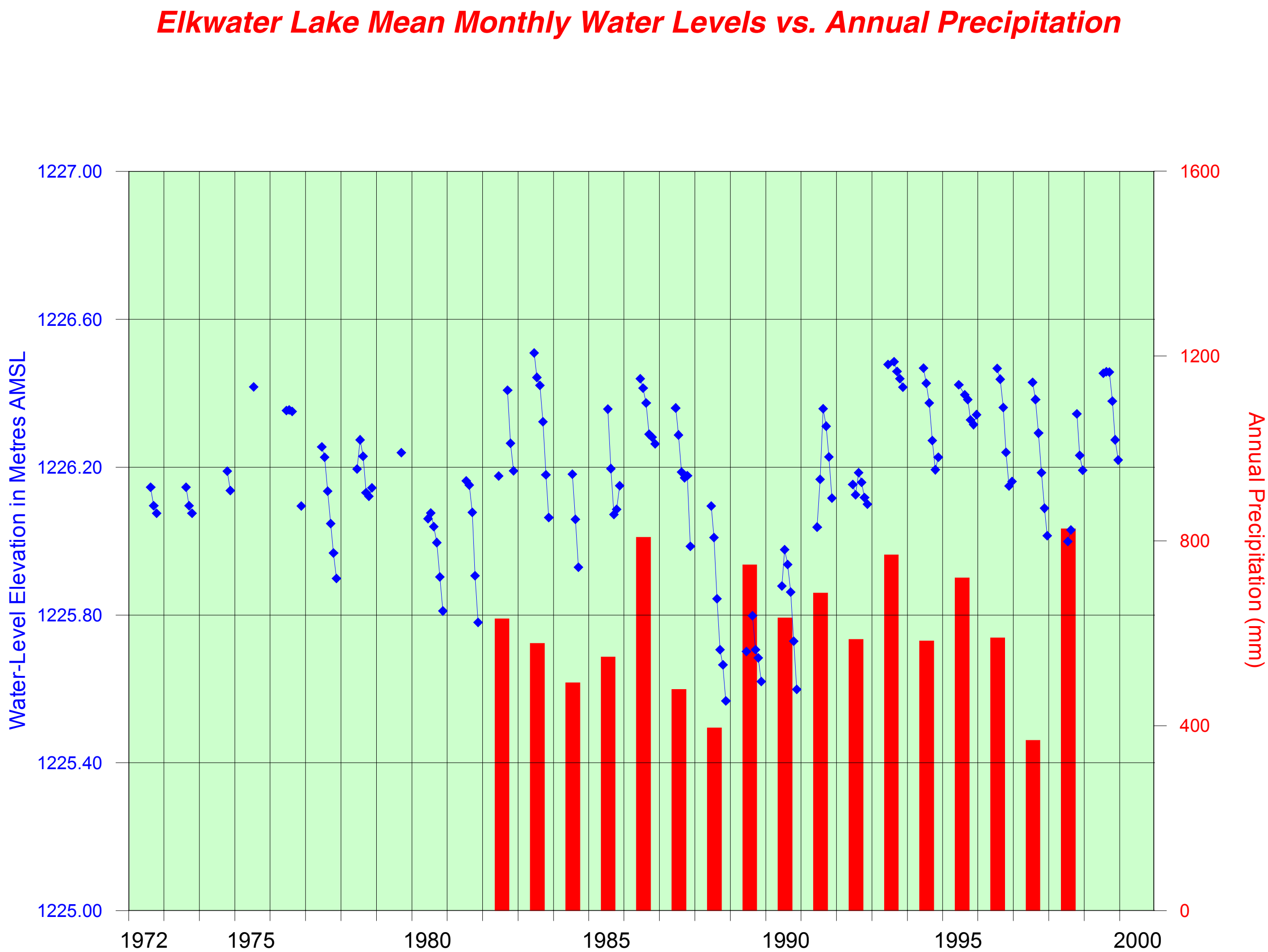


Specific Study Areas



Paetku Spring - Flow-Rate Measurements




Elkwater Lake Mean Monthly Water Levels vs. Annual Precipitation
Water-Level Elevation in Metres AMSL
Annual Precipitation (mm)
1227.00
1226.60
1226.20
1225.80
1225.40
1225.00
1600
1200
800
400
0
1972
1975
1980
1985
1990
1995
2000

CYPRESS COUNTY

Appendix B

Maps and Figures on CD-ROM

1) General

Index Map/Surface Topography
Location of Water Wells and Springs
Total Dissolved Solids from Springs
Location of Water Well Type
Surface Casing Types used in Drilled Water Wells
Licensed Water Wells
Depth to Base of Groundwater Protection
Generalized Cross-Section (for terminology only)
Geologic Column
Depth of Existing Water Wells
Hydrogeological Map
Cross-Section A - A'
Cross-Section B - B'
Cross-Section C - C'
Cross-Section D - D'
Cross-Section E - E'
Cross-Section F -F'
Cross-Section G - G'
Cross-Section H - H'
Bedrock Topography
Bedrock Geology
E-Log Showing Base of Foremost Formation
Relative Permeability
Estimated Water Well Use Per Section
Water Wells Recommended for Field Verification

2) Surficial Aquifers

a) Surficial Deposits

Thickness of Surficial Deposits
Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep
Total Dissolved Solids in Groundwater from Surficial Deposits
Sulfate in Groundwater from Surficial Deposits
Nitrate + Nitrite (as N) in Groundwater from Surficial Deposits
Chloride in Groundwater from Surficial Deposits
Total Hardness in Groundwater from Surficial Deposits
Piper Diagram - Surficial Deposits
Thickness of Sand and Gravel Deposits
Amount of Sand and Gravel in Surficial Deposits
Thickness of Sand and Gravel Aquifer(s)
Water Wells Completed in Surficial Deposits
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)
Changes in Water Levels in Sand and Gravel Aquifer(s) Based on Water Wells Less than 20 Metres Deep

b) Upper Sand and Gravel

Thickness of Upper Surficial Deposits
Thickness of Upper Sand and Gravel (not all drill holes fully penetrate surficial deposits)
Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

c) Lower Sand and Gravel

Structure-Contour Map - Top of Lower Surficial Deposits
Depth to Top of Lower Surficial Deposits
Thickness of Lower Surficial Deposits
Thickness of Lower Sand and Gravel (not all drill holes fully penetrate surficial deposits)
Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer
Non-Pumping Water-Level Surface in Lower Sand and Gravel Aquifer

3) Bedrock Aquifers

a) General

b) Cypress Hills Formation

c) Paskapoo Formation (Ravenscrag)

d) Scollard Formation (Frenchman)

e) Horseshoe Canyon Formation (Eastend)

f) Bearpaw Formation

CYPRESS COUNTY
Appendix C

General Water Well Information

Domestic Water Well Testing

Purpose and Requirements

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

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

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

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

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

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

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

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

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

Procedure

Site Diagrams

These diagrams are a map showing the distance to nearby significant features. This would include things like a corner of a building (house, barn, garage etc.) or the distance to the half-mile or mile fence. The description should allow anyone not familiar with the site to be able to unequivocally identify the water well that was tested. In lieu of a map, UTM coordinates accurate to within five metres would be acceptable. If a hand-held GPS is used, the post-processing correction details must be provided.

Surface Details

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

Groundwater Discharge Point

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

Water-Level Measurements

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

If water levels are obtained using a transducer and data logger, the serial numbers of both transducer and data logger are needed and a copy of the calibration sheet. The additional information required is the depth the transducer was set and the length of time between when the transducer was installed and when the calibration water level was measured, plus the length of time between the installation of the transducer and the start of the aquifer test. All water levels must be measured at least to the nearest 0.01 metres.

Discharge Measurements

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

Water Samples

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

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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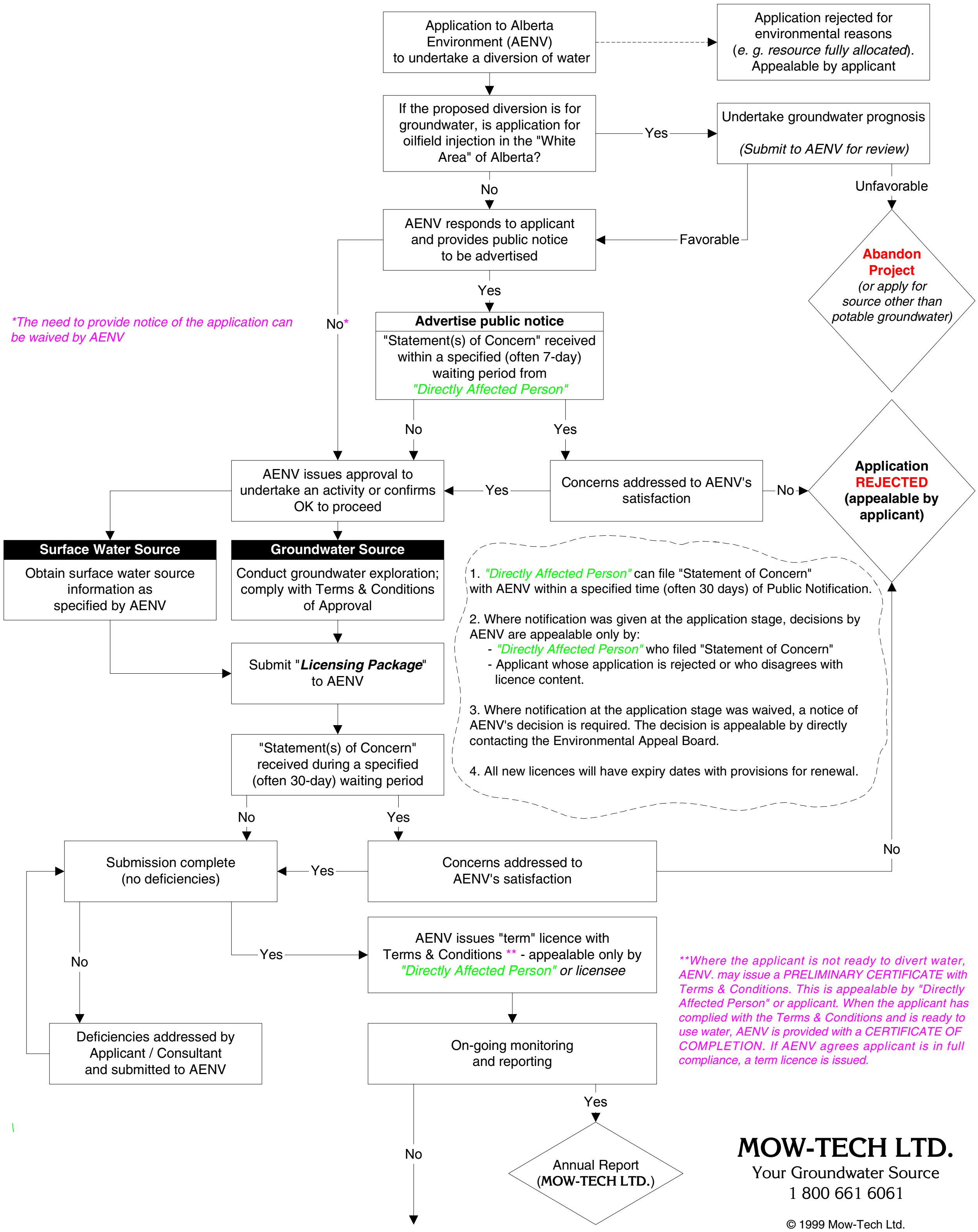
ALBERTA REGULATION 205/98

Water Act

WATER (MINISTERIAL) REGULATION

Table of Contents

Water Act – Flowchart



*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.*

Interpretation of Chemical Analysis of Drinking Water

Stony Plain - Lac Ste. Anne Health Unit

HEAD OFFICE
P.O. Box 210
Stony Plain, Alberta
Canada T0E 2G0
Telephone: 963-2206
Fax: 963-7612

SUB-OFFICES
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Spruce Grove, Alberta
T7X 3B5
Telephone: 962-4072

163 Provincial Bldg.
Whitecourt, Alberta
T0E 2L0
Telephone: 778-5555
Fax: 778-3852

Box 430
Fox Creek, Alberta
T0H 1P0
Telephone: 622-3730

HOME CARE:
Box 210
Stony Plain, Alberta
T0E 2G0
Telephone: 963-3366

INTERPRETATION OF CHEMICAL ANALYSIS OF DRINKING WATER

1. TOTAL DISSOLVED SOLIDS (TDS) - The recommended limit is 1000 mg/L for untreated and 500 mg/L for treated waters. TDS indicates the approximate organic and inorganic substances in the water. It will be high if other components of the analysis are high.

2. IRON - Amounts over 0.3 mg/L, usually stain laundry and plumbing fixtures and cause undesirable tastes. Iron filtration can be utilized. Iron bacteria may also be the cause of increased iron content.

3. CALCIUM - This is a constituent of hardness. Excessive calcium in drinking water may be a factor in disorders of the kidneys, bladder and urinary system.

4. MAGNESIUM - This is a constituent of hardness.

5. HARDNESS - A maximum acceptable concentration has not been established. Hardness is caused mainly by calcium and magnesium. Levels between 80 and 100 mg/L are satisfactory: 100 to 200 mg/L are less acceptable: more than 200 mg/L are considered to be poor and in excess of 500 mg/L are unacceptable for most domestic purposes. Softening can be helpful in given circumstances.

6. SODIUM - Ideally, there should be no more than 200mg/L. The average intake of sodium from water is only a small fraction of that consumed in a normal diet. Persons suffering from hypertension or congestive heart failure may require a sodium-restricted diet, in which case the intake of sodium from drinking water could become significant. Your physician should be informed of the sodium content.

7. NITRITE-NITROGEN & NITRATE-NITROGEN (NO2 + NO3) - The maximum acceptable concentration is 10 mg/L. Any amount over that may be harmful to children up to 12 months of age, causing a condition known as methaemoglobinaemia. Presence may indicate a contaminating source although other instances, e.g. fertilizer and decomposing vegetation can cause an elevated figure.

8. NITRITE-NITROGEN - The maximum acceptable concentration is 1.0 Mg/L. Nitrite is unstable in water and converts to nitrate. An elevated figure may indicate a pollution problem.

9. FLUORIDE - Approximately 1 mg/L of fluoride is recommended in drinking water in order to give developing teeth some protection against decay. If the fluoride is higher than 1.5 mg/L you should talk to the dental staff of the Health Unit about the possibility of mottled enamel; if the fluoride is lower than 0.7 mg/L please ask about fluoride supplements for your children.

10. SULPHATE - The maximum acceptable concentration is 500 mg/L. Taste becomes noticeable between 250 and 600 mg/L and a laxative effect may be noticed by new users when sulphate combines with sodium or magnesium.

11. CHLORIDE - The recommended limit is 250 mg/L. Chloride content is usually low and an increase may indicate a nearby source of pollution (particularly if NO2 and NO3 and nitrite are high). Some wells contain naturally occurring chlorides. A salty taste may be evident.

12. ALKALINITY T (Total) - Alkalinity below 500 mg/L is generally accepted. Excessive alkalinity may result in incrustations on utensils, service pipes and water heaters.

13. BICARBONATE _ Upper limit not established. Relates to alkalinity as bicarbonate of sodium, calcium and magnesium.

NOTE: mg/L = milligrams per litre.

The preceding notes and standards are for your guidance only based on an intake of 2 litres of water per day. The figures may be interpreted in a variety of ways and the public health inspector for your area can be contacted for further advice. Telephone: Stony Plain - 963-2206; Spruce Grove - 962-4072; Whitecourt - 778-5555.

For stock water and other agricultural uses the requirements are not necessarily the same as for domestic use. Please consult your District Agriculturalist for that kind of advice.

Additional Information

VIDEOS

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

BOOKLET

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

ALBERTA ENVIRONMENT

WATER WELL INSPECTORS

Jennifer McPherson (Edmonton: 780-427-6429)

GEOPHYSICAL INSPECTION SERVICE

Edmonton: 780-427-3932

COMPLAINT INVESTIGATIONS

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

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

Carl Mendoza (Edmonton: 780-492-2664)

UNIVERSITY OF CALGARY – Department of Geology and Geophysics - Hydrogeology

Larry Bentley (Calgary: 403-220-4512)

FARMERS ADVOCATE

Paul Vasseur (Edmonton: 780-427-2433)

PRAIRIE FARM REHABILITATION ADMINISTRATION

Ryan Davison (Medicine Hat: 403-526-2429)
Terry Dash (Calgary: 403-292-5719)

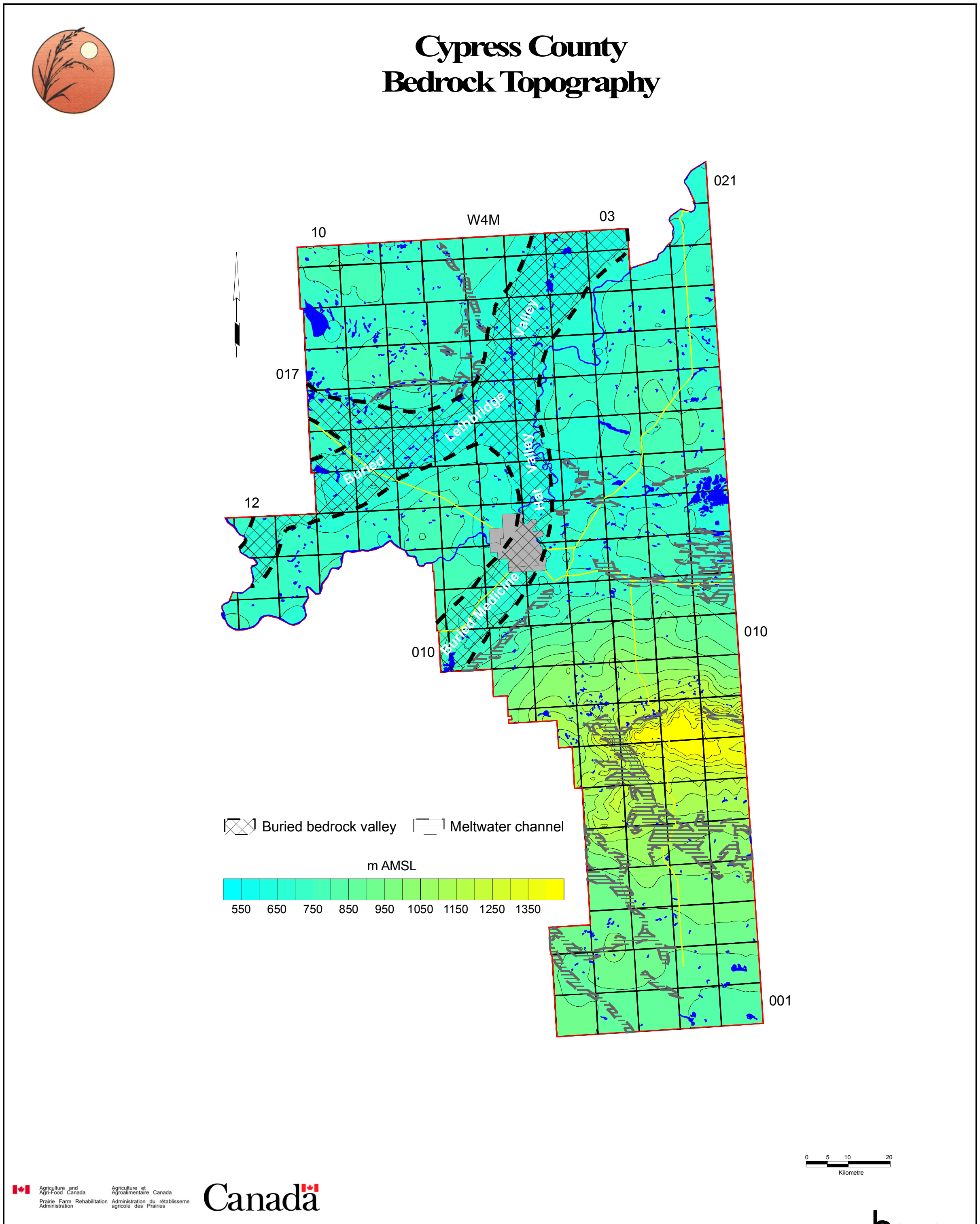
LOCAL HEALTH DEPARTMENTS

CYPRESS COUNTY

Appendix D

Maps and Figures Included as Large Plots

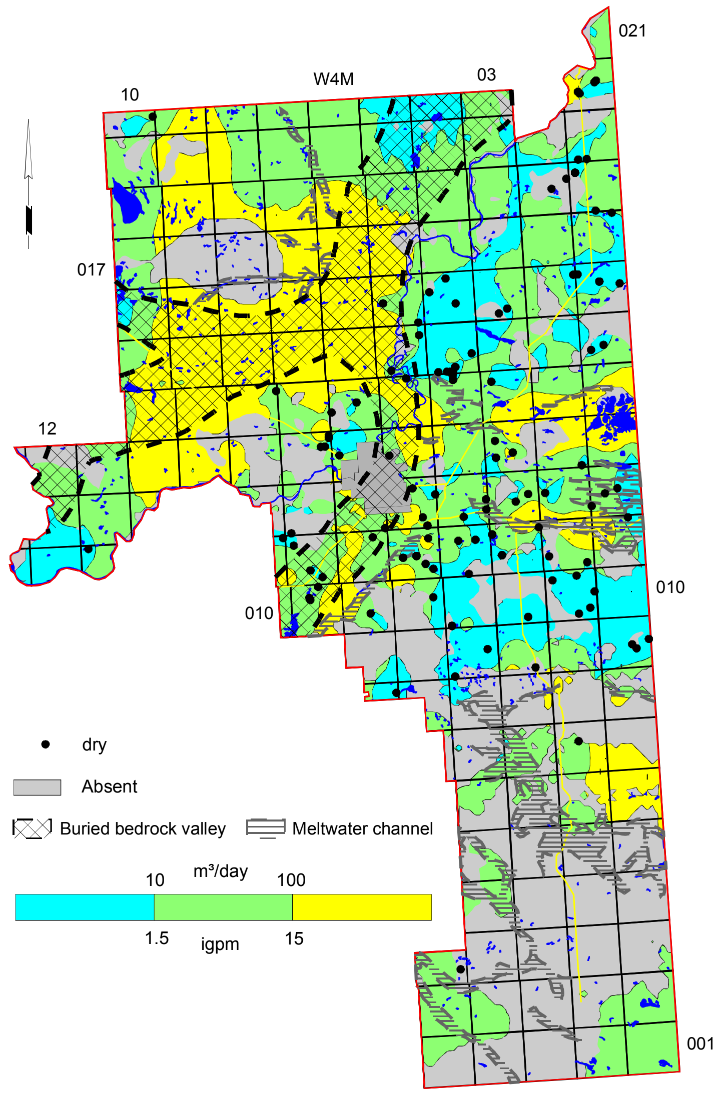
Bedrock Topography



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

Cypress County

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

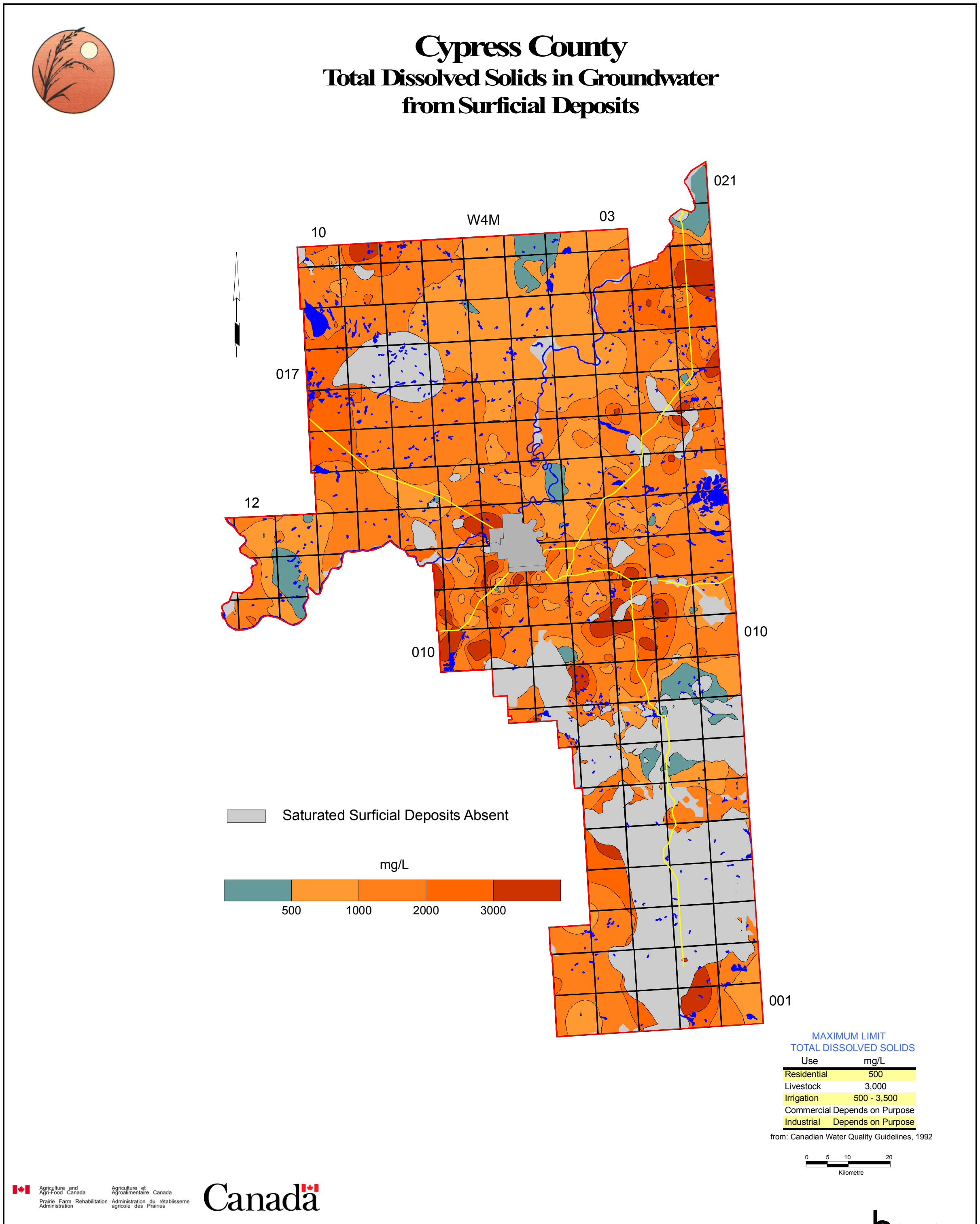
0 5 10 20
Kilometre

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

hydrogeological consultants ltd.

hydrogeological consultants ltd, edmonton, alberta - 1.800.661.7972 - project no. 01-149

Total Dissolved Solids in Groundwater from Surficial Deposits



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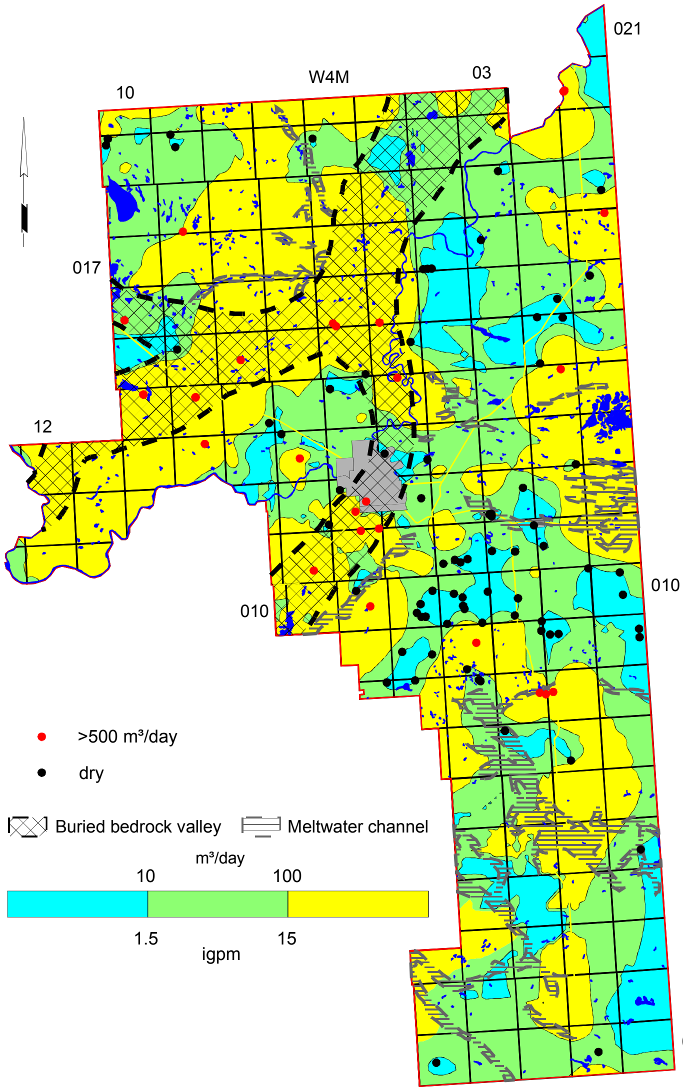
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

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



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Residential[1]	1.1	3.4
Multi Parcel[1]	1.1	3.4
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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 Prairie Farm Rehabilitation Administration
Agriculture et Agroalimentaire Canada Administration du rétablissement agricole des Prairies
Canada

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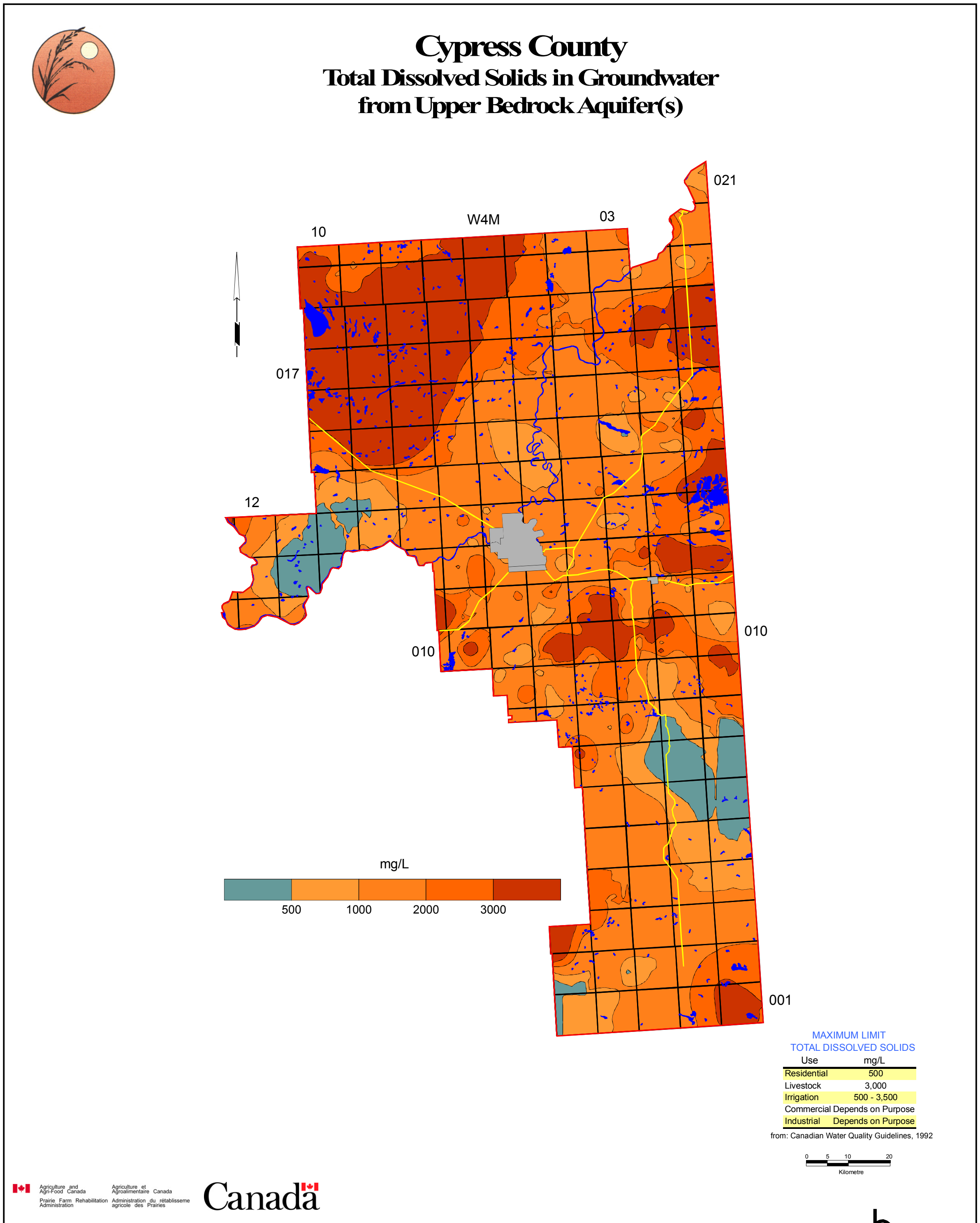
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



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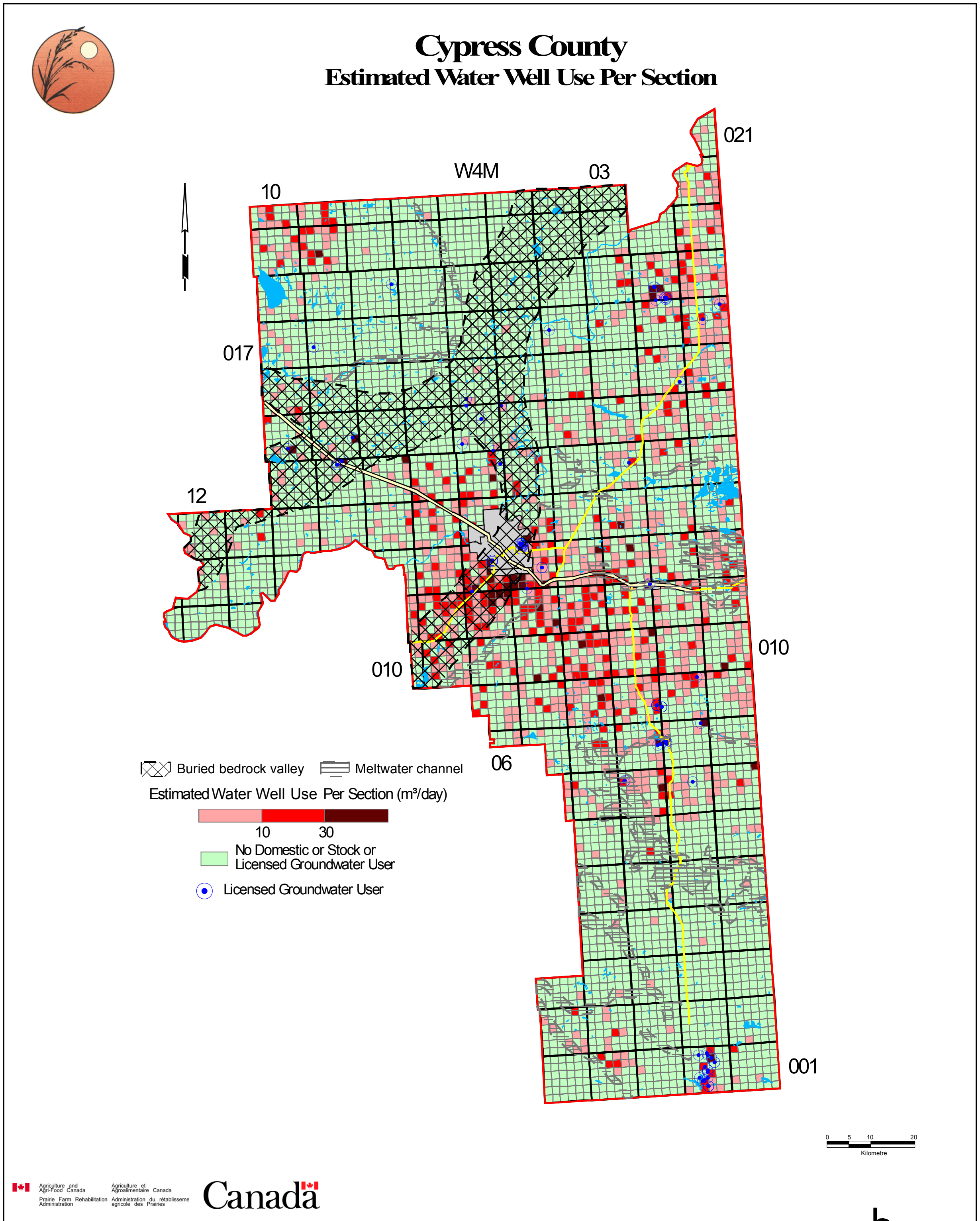
Estimated Water Well Use Per Section



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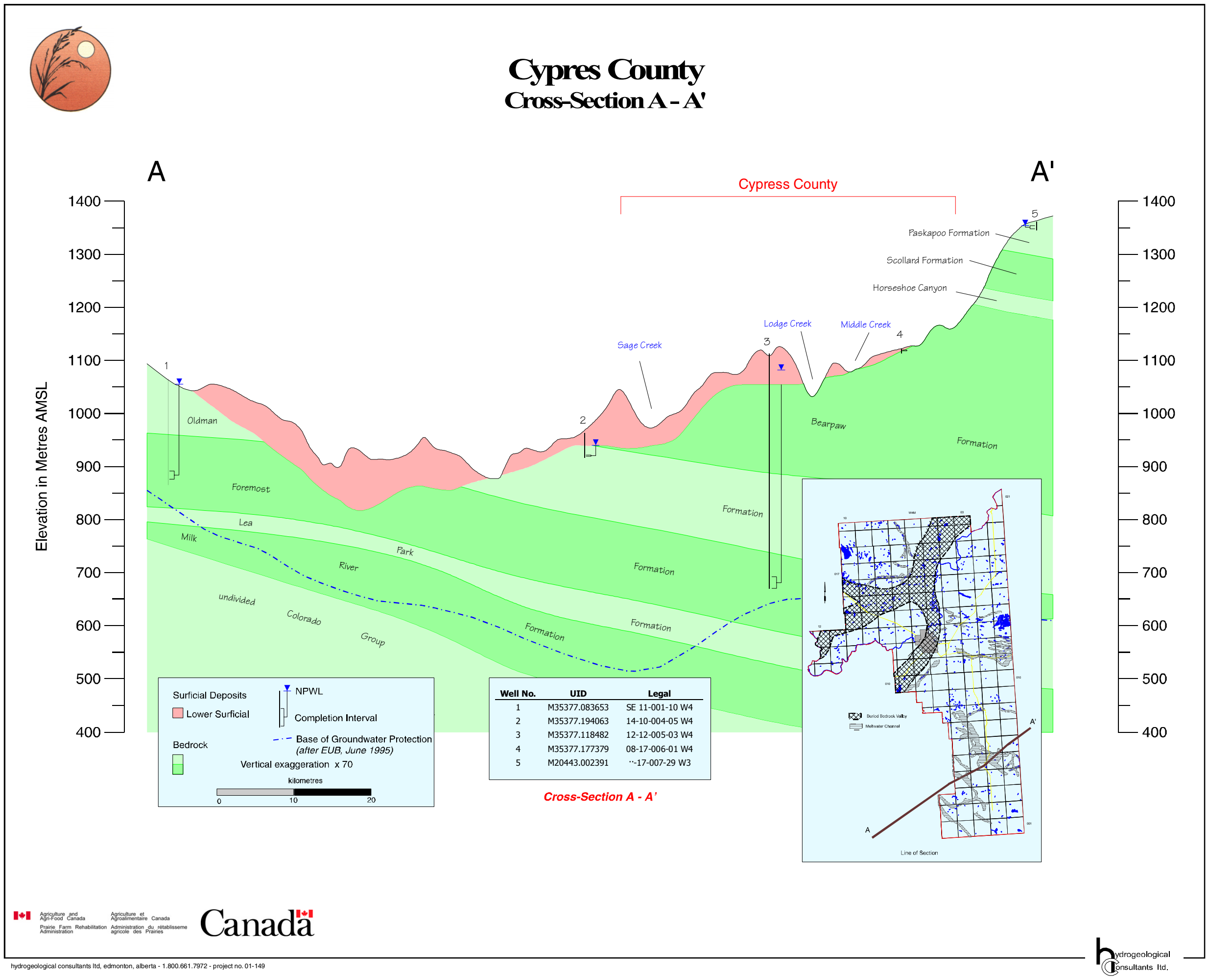
Cross-Section A - A'



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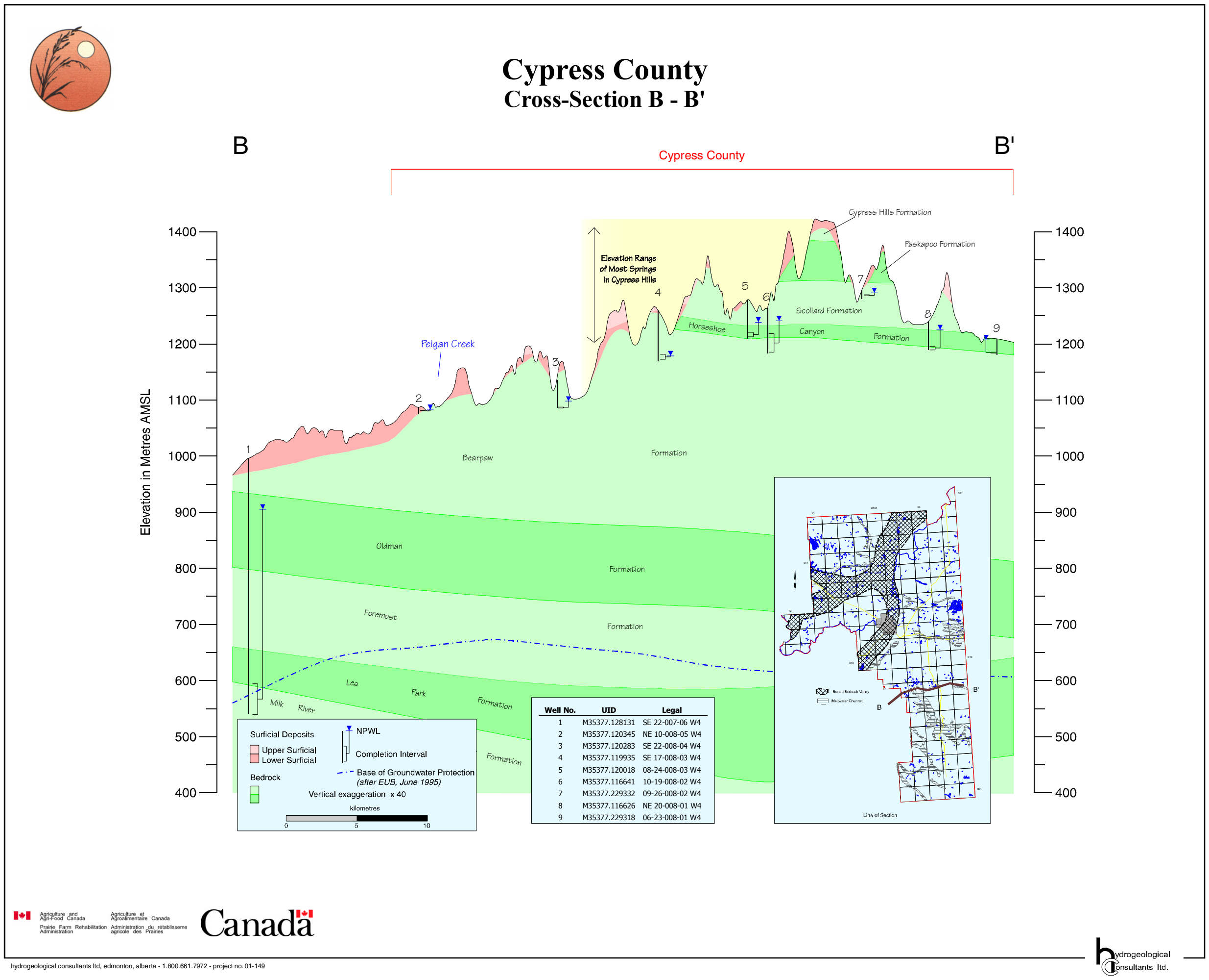
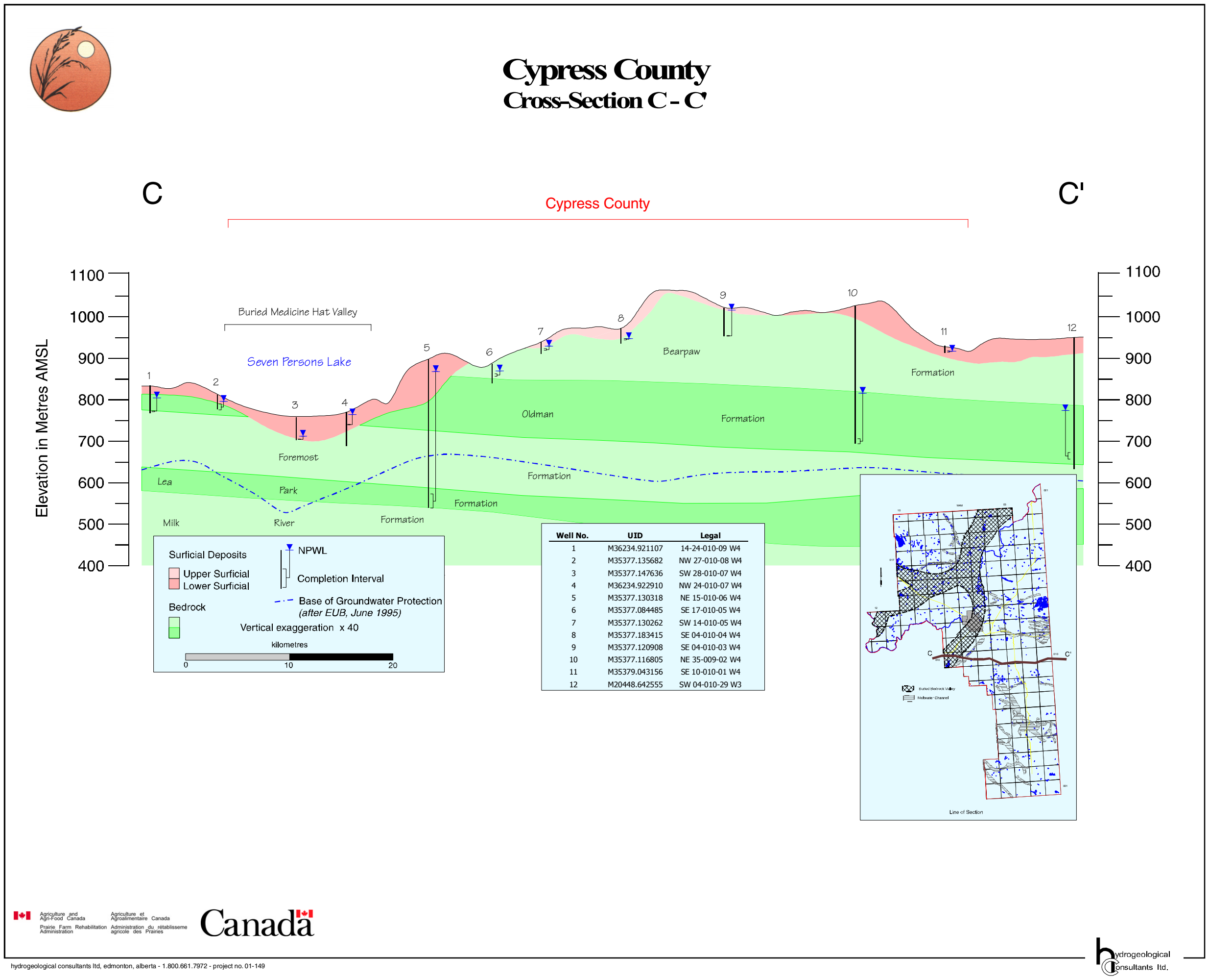
1	M35377.083653	SE 11-001-10 W4
2	M35377.194063	14-10-004-05 W4
3	M35377.118482	12-12-005-03 W4
4	M35377.177379	08-17-006-01 W4
5	M20443.002391	··-17-007-29 W3

Cross-Section B - B'



Well No.	UID	Legal
1	M35377.128131	SE 22-007-06 W4
2	M35377.120345	NE 10-008-05 W4
3	M35377.120283	SE 22-008-04 W4
4	M35377.119935	SE 17-008-03 W4
5	M35377.120018	08-24-008-03 W4
6	M35377.116641	10-19-008-02 W4
7	M35377.229332	09-26-008-02 W4
8	M35377.116626	NE 20-008-01 W4
9	M35377.229318	06-23-008-01 W4

Cross-Section C - C'



Well No.	UID	Legal
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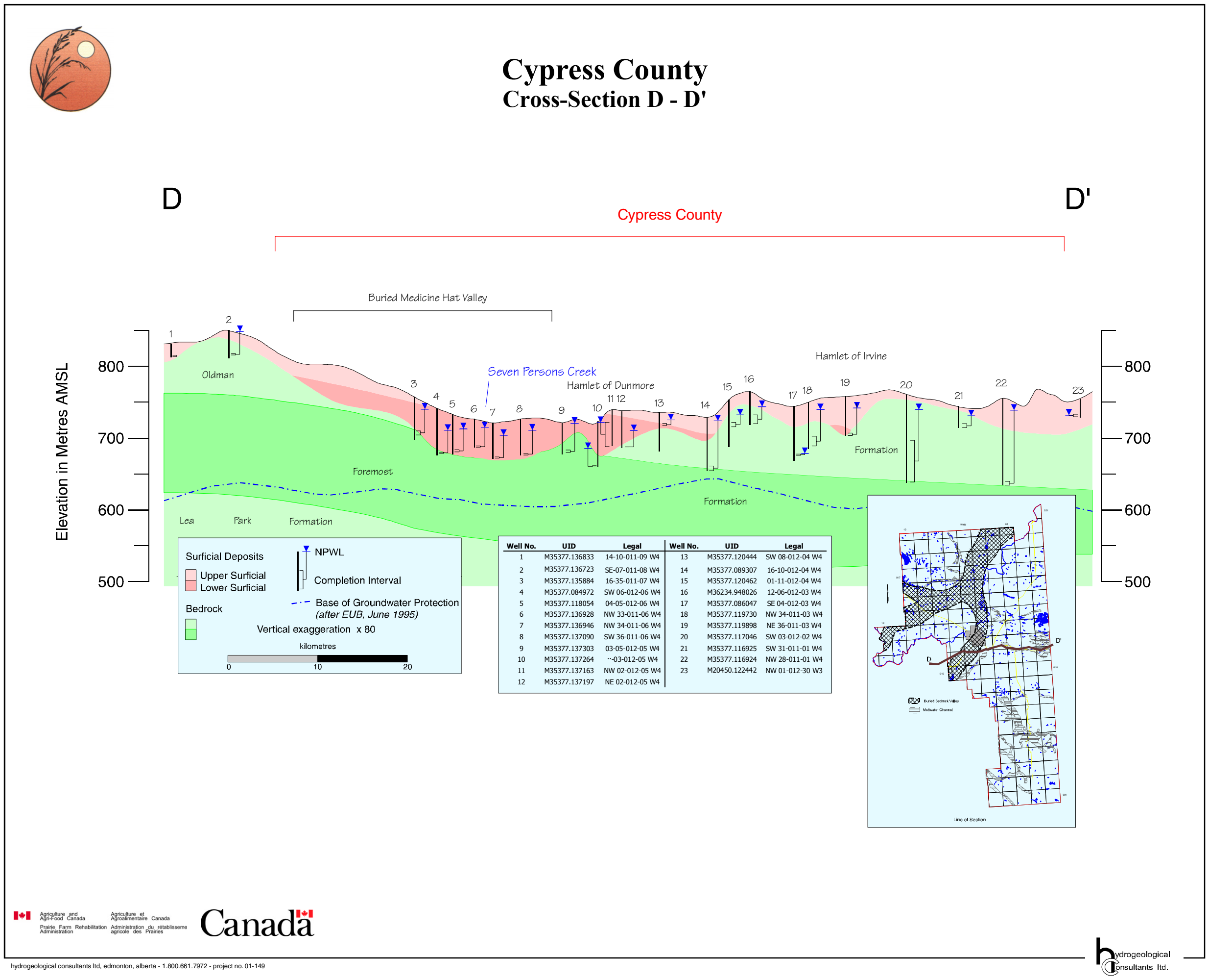
2	M35377.135682	NW 27-010-08 W4
3	M35377.147636	SW 28-010-07 W4
4	M36234.922910	NW 24-010-07 W4
5	M35377.130318	NE 15-010-06 W4
6	M35377.084485	SE 17-010-05 W4
7	M35377.130262	SW 14-010-05 W4
8	M35377.183415	SE 04-010-04 W4
9	M35377.120908	SE 04-010-03 W4
10	M35377.116805	NE 35-009-02 W4
11	M35379.043156	SE 10-010-01 W4
12	M20448.642555	SW 04-010-29 W3

Cross-Section D - D'



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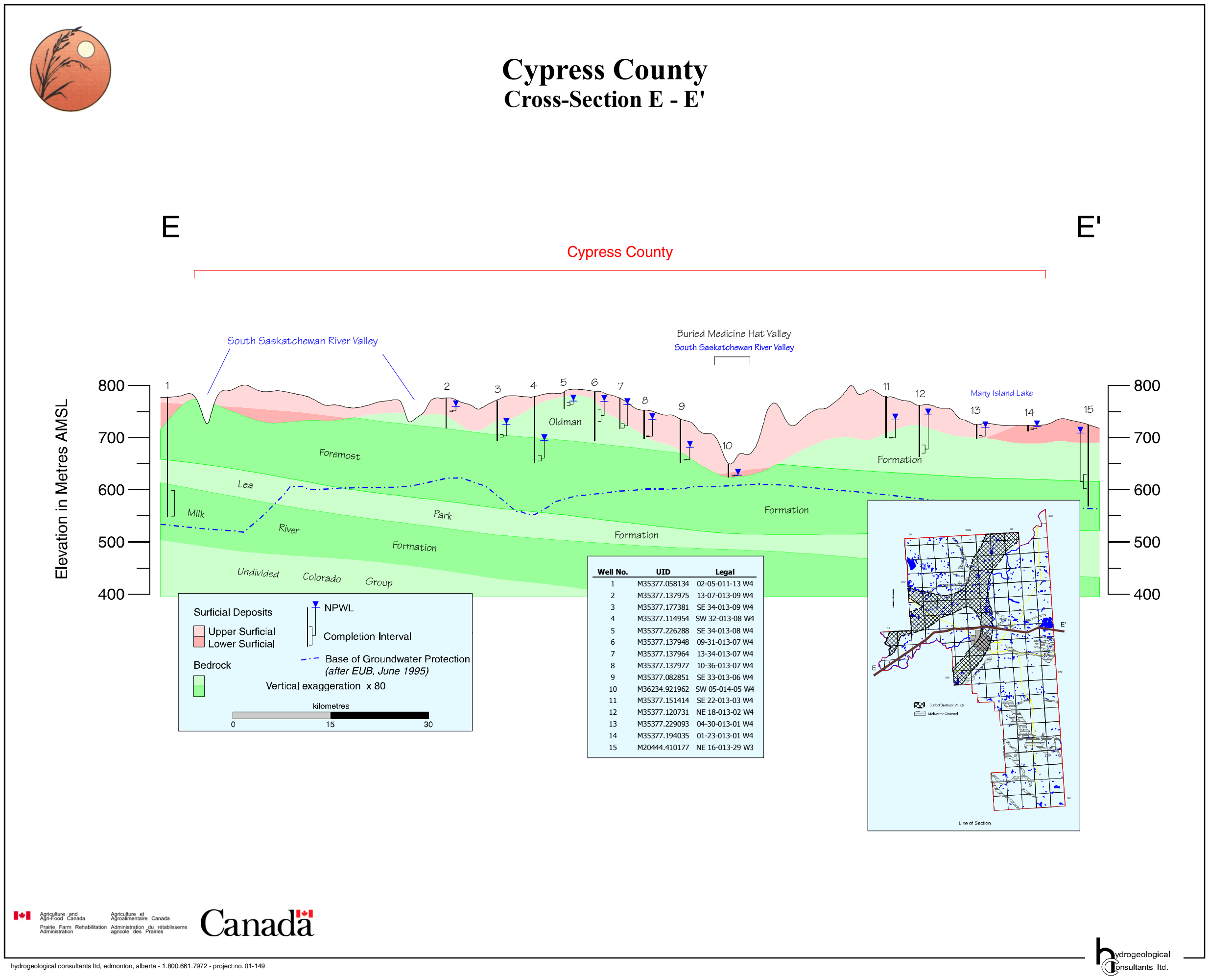
2	M35377.136723	SE-07-011-08 W4	14	M35377.089307	16-10-012-04 W4
3	M35377.135884	16-35-011-07 W4	15	M35377.120462	01-11-012-04 W4
4	M35377.084972	SW 06-012-06 W4	16	M36234.948026	12-06-012-03 W4
5	M35377.118054	04-05-012-06 W4	17	M35377.086047	SE 04-012-03 W4
6	M35377.136928	NW 33-011-06 W4	18	M35377.119730	NW 34-011-03 W4
7	M35377.136946	NW 34-011-06 W4	19	M35377.119898	NE 36-011-03 W4
8	M35377.137090	SW 36-011-06 W4	20	M35377.117046	SW 03-012-02 W4
9	M35377.137303	03-05-012-05 W4	21	M35377.116925	SW 31-011-01 W4
10	M35377.137264	··-03-012-05 W4	22	M35377.116924	NW 28-011-01 W4
11	M35377.137163	NW 02-012-05 W4	23	M20450.122442	NW 01-012-30 W3
12	M35377.137197	NE 02-012-05 W4			

Cross-Section E - E'



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2	M35377.137975	13-07-013-09 W4
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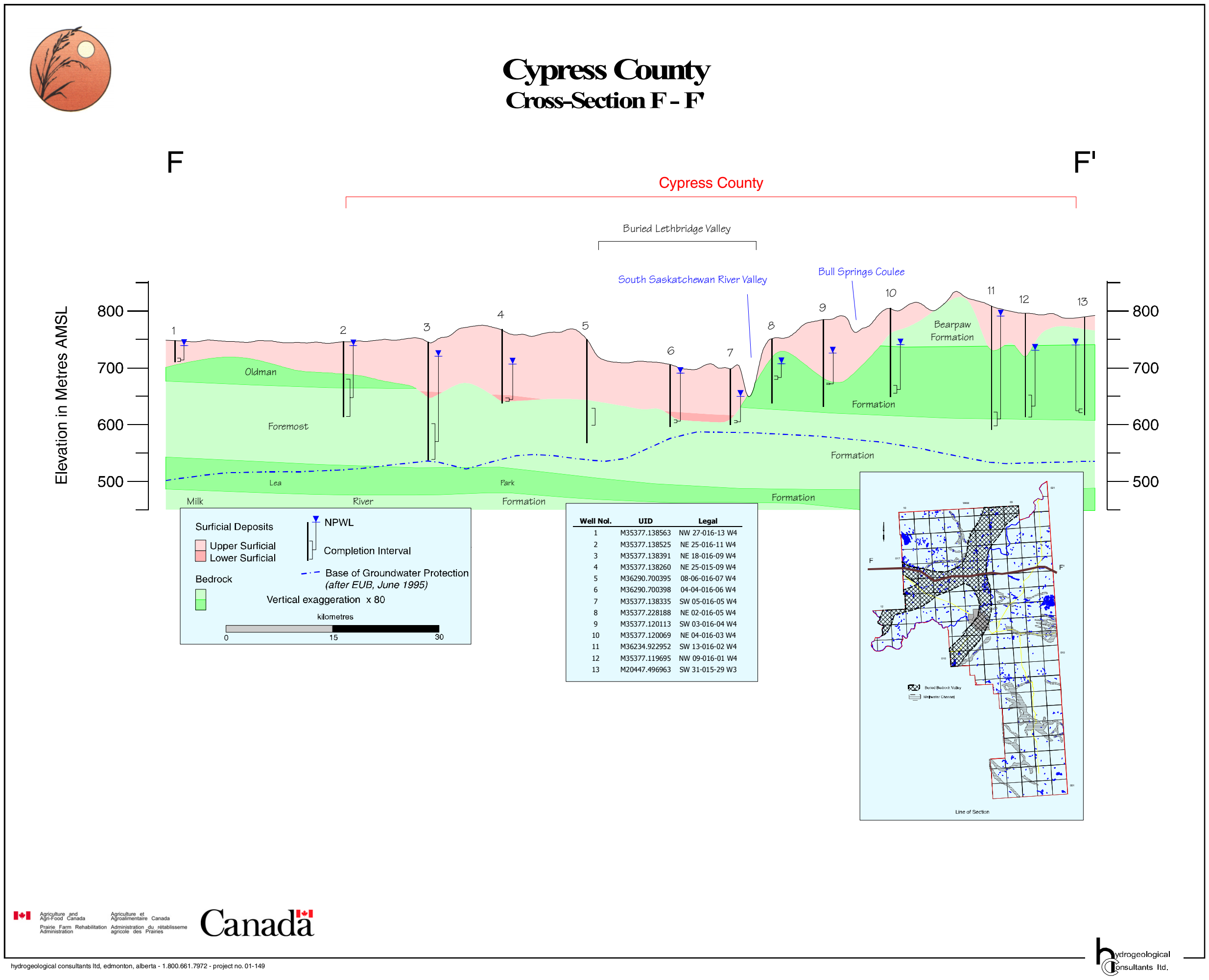
4	M35377.114954	SW 32-013-08 W4
5	M35377.226288	SE 34-013-08 W4
6	M35377.137948	09-31-013-07 W4
7	M35377.137964	13-34-013-07 W4
8	M35377.137977	10-36-013-07 W4
9	M35377.082851	SE 33-013-06 W4
10	M36234.921962	SW 05-014-05 W4
11	M35377.151414	SE 22-013-03 W4
12	M35377.120731	NE 18-013-02 W4
13	M35377.229093	04-30-013-01 W4
14	M35377.194035	01-23-013-01 W4
15	M20444.410177	NE 16-013-29 W3

Cross-Section F - F’



Well Nol.	UID	Legal
1	M35377.138563	NW 27-016-13 W4
2	M35377.138525	NE 25-016-11 W4
3	M35377.138391	NE 18-016-09 W4
4	M35377.138260	NE 25-015-09 W4
5	M36290.700395	08-06-016-07 W4
6	M36290.700398	04-04-016-06 W4
7	M35377.138335	SW 05-016-05 W4
8	M35377.228188	NE 02-016-05 W4
9	M35377.120113	SW 03-016-04 W4
10	M35377.120069	NE 04-016-03 W4
11	M36234.922952	SW 13-016-02 W4
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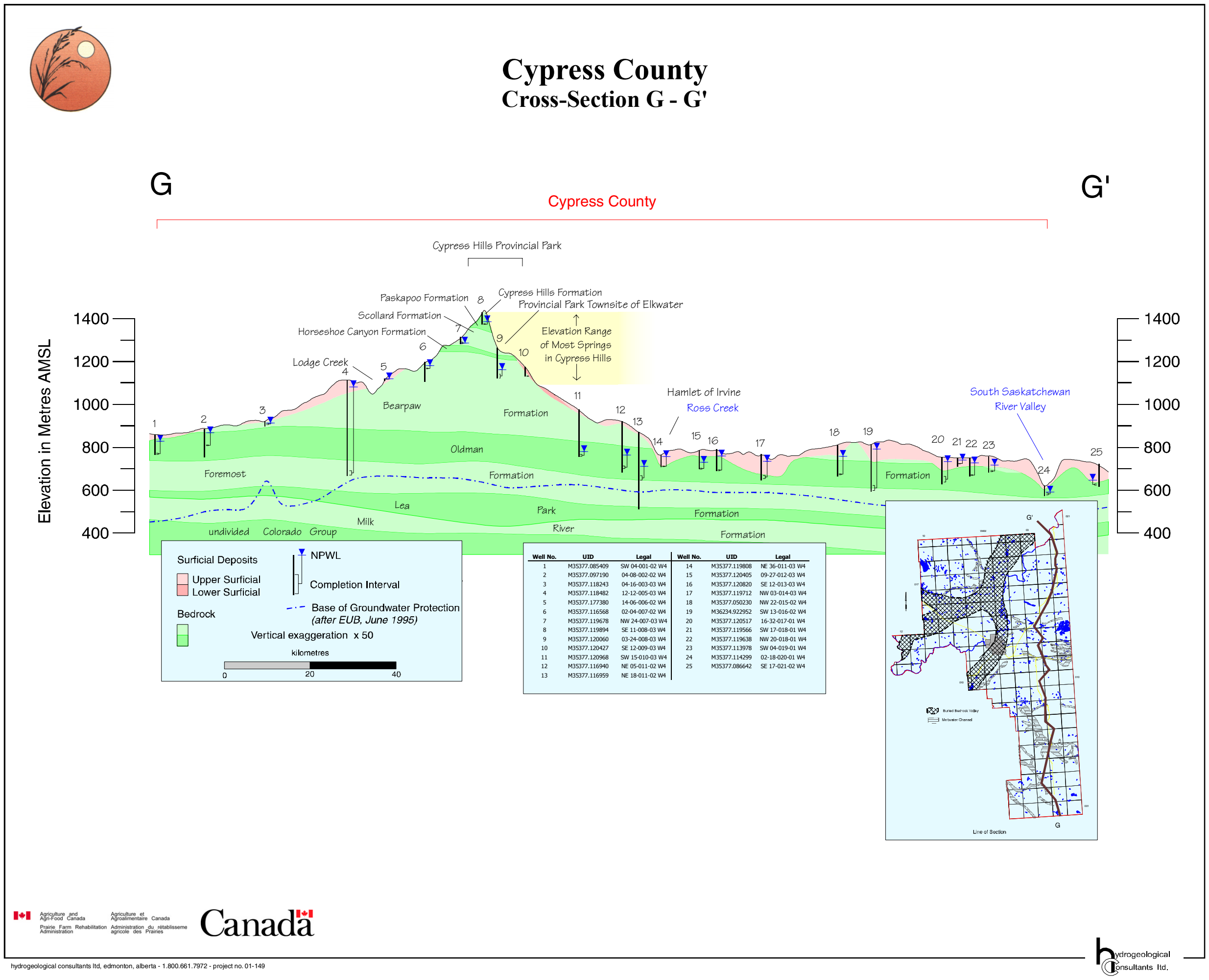
13	M20447.496963	SW 31-015-29 W3

Cross-Section G - G'



Well No.	UID	Legal	Well No.	UID	Legal
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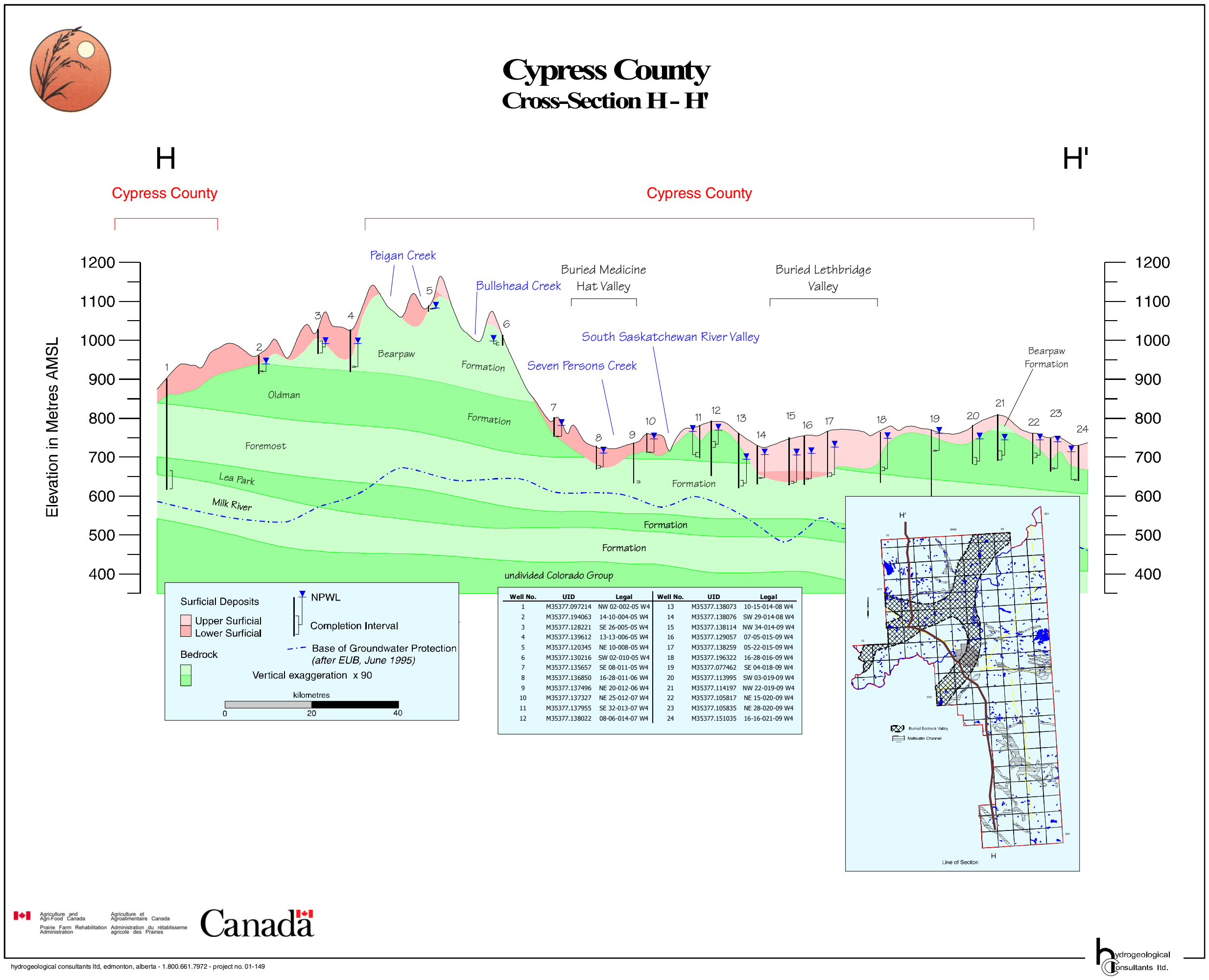
2	M35377.097190	04-08-002-02 W4	15	M35377.120405	09-27-012-03 W4
3	M35377.118243	04-16-003-03 W4	16	M35377.120820	SE 12-013-03 W4
4	M35377.118482	12-12-005-03 W4	17	M35377.119712	NW 03-014-03 W4
5	M35377.177380	14-06-006-02 W4	18	M35377.050230	NW 22-015-02 W4
6	M35377.116568	02-04-007-02 W4	19	M36234.922952	SW 13-016-02 W4
7	M35377.119678	NW 24-007-03 W4	20	M35377.120517	16-32-017-01 W4
8	M35377.119894	SE 11-008-03 W4	21	M35377.119566	SW 17-018-01 W4
9	M35377.120060	03-24-008-03 W4	22	M35377.119638	NW 20-018-01 W4
10	M35377.120427	SE 12-009-03 W4	23	M35377.113978	SW 04-019-01 W4
11	M35377.120968	SW 15-010-03 W4	24	M35377.114299	02-18-020-01 W4
12	M35377.116940	NE 05-011-02 W4	25	M35377.086642	SE 17-021-02 W4
13	M35377.116959	NE 18-011-02 W4			

Cross-Section H - H'



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3	M35377.128221	SE 26-005-05 W4	15	M35377.138114	NW 34-014-09 W4
4	M35377.139612	13-13-006-05 W4	16	M35377.129057	07-05-015-09 W4
5	M35377.120345	NE 10-008-05 W4	17	M35377.138259	05-22-015-09 W4
6	M35377.130216	SW 02-010-05 W4	18	M35377.196322	16-28-016-09 W4
7	M35377.135657	SE 08-011-05 W4	19	M35377.077462	SE 04-018-09 W4
8	M35377.136850	16-28-011-06 W4	20	M35377.113995	SW 03-019-09 W4
9	M35377.137496	NE 20-012-06 W4	21	M35377.114197	NW 22-019-09 W4
10	M35377.137327	NE 25-012-07 W4	22	M35377.105817	NE 15-020-09 W4
11	M35377.137955	SE 32-013-07 W4	23	M35377.105835	NE 28-020-09 W4
12	M35377.138022	08-06-014-07 W4	24	M35377.151035	16-16-021-09 W4

CYPRESS COUNTY

Appendix E

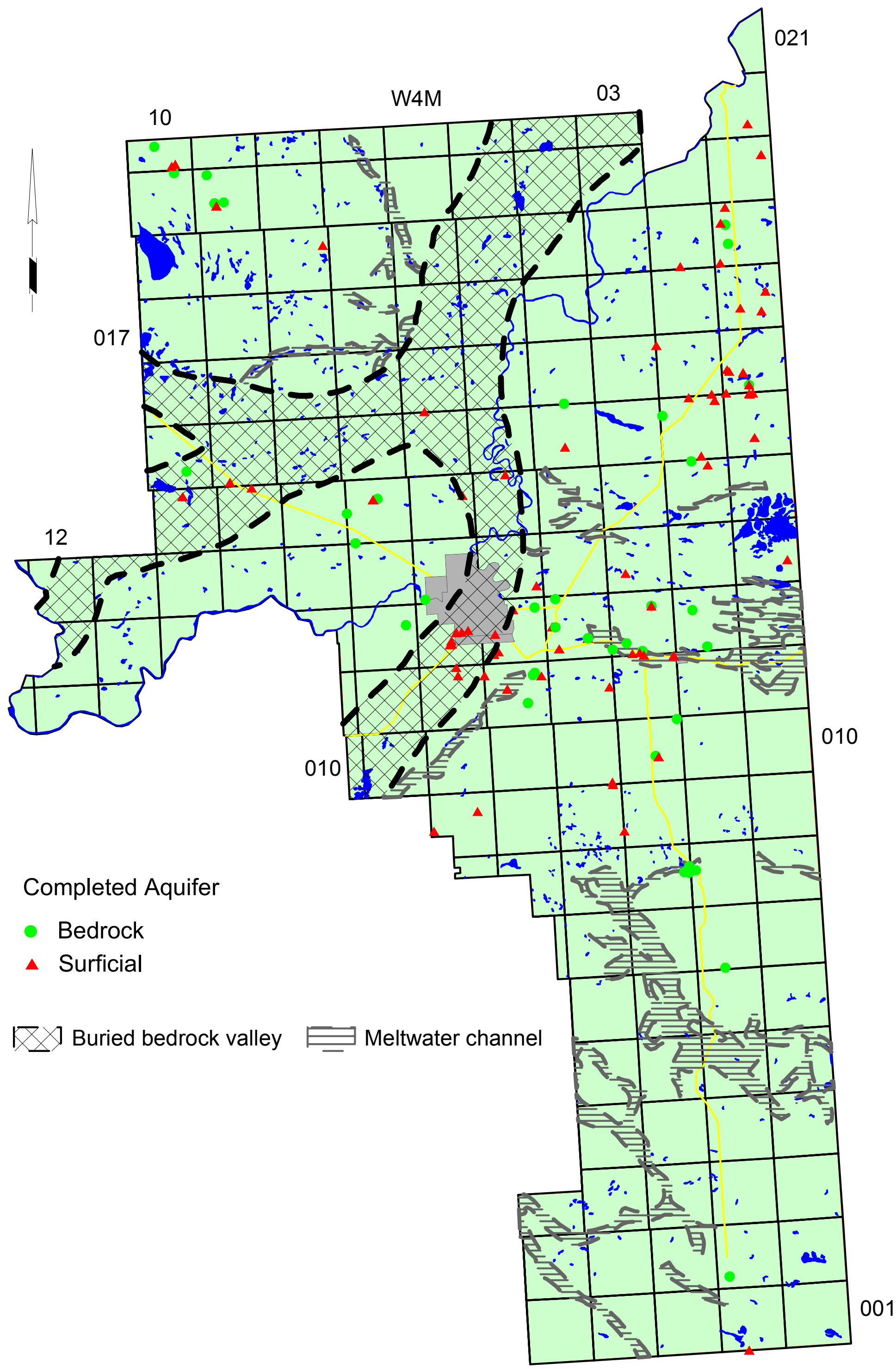
Water Wells Recommended for Field Verification

and

County-Operated Water Wells

Water Wells Recommended for Field Verification

(details on following pages)



WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

		Aquifer	Date Water	Completed Depth		NPWL		
Owner	Location	Name	Well Drilled	Metres	Feet	Metres	Feet	UID
Alberta Energy Company Ltd.	04-04-016-06 W4M	Lower Surficial	03-Aug-98	103.0	337.9	15.5	50.7	M36290.700398
Alberta Environment	02-04-007-02 W4M	Bearpaw	12-Mar-85	30.2	99.0	16.1	52.7	M35377.116568
Alberta Environment	06-24-008-03 W4M	Horseshoe Canyon	28-Sep-84	33.5	110.0	10.9	35.6	M35377.149387
Alberta Environment	16-10-012-04 W4M	Lower Surficial	14-Sep-84	36.0	118.0	3.9	12.8	M35377.088322
Alberta Environment	07-05-015-09 W4M	Lower Surficial	10-Mar-85	111.3	365.0	44.2	144.9	M35377.129057
Alberta Environment	16-10-012-04 W4M	Oldman	13-Sep-84	73.8	242.0	4.6	15.0	M35377.089307
Alberta Environment	04-08-002-02 W4M	Oldman	13-Mar-85	79.9	262.0	20.4	66.9	M35377.097190
Alberta Environment	11-02-020-10 W4M	Upper Surficial	12-Nov-85	7.6	25.0	4.6	15.0	M35377.089310
Alberta Transportation	SW 08-012-04 W4M	Lower Surficial	20-May-82	12.2	40.0	6.0	19.8	M35377.120442
Allan Reuer	NW 20-018-01 W4M	Oldman	06-Sep-84	82.3	270.0	24.4	80.0	M35377.119638
Amos, Helen E.	04-23-012-06 W4M	Upper Surficial	08-Apr-81	7.9	26.0	3.1	10.0	M35377.137770
Atlantic Richfield	10-10-015-10 W4M	Foremost	01-Jun-73	76.8	252.0	42.8	140.4	M35377.138264
Bechtold, Allan	SE 06-014-07 W4M	Oldman	26-May-78	39.6	130.0	15.2	50.0	M35377.138020
Bertrand, Wally	SE 19-012-04 W4M	Oldman	04-Oct-85	13.7	45.0	12.8	42.0	M35377.120511
Bill Fischer	NW 32-018-01 W4M	Upper Surficial	26-Oct-79	9.1	30.0	4.6	15.0	M35377.119717
Bjelland, Dennis	SW 16-020-10 W4M	Oldman	01-Apr-72	56.1	184.0	18.3	60.0	M35377.110967
Brost Bros.	09-27-012-03 W4M	Oldman	07-Nov-80	92.7	304.0	61.0	200.0	M35377.120405
Brost Bros.	09-27-012-03 W4M	Upper Surficial	07-Aug-81	26.8	88.0	4.0	13.0	M35377.120408
Bullanda, Ted	NW 30-011-05 W4M	Lower Surficial	18-Sep-76	61.0	200.0	20.1	66.0	M35377.136784
Canadian Customs/DPW	SW 04-001-02 W4M	Lower Surficial	27-Aug-76	18.3	60.0	6.7	22.0	M35377.085327
Clark, Jerry	SW 26-009-06 W4M	Lower Surficial	05-Aug-81	11.6	38.0	4.3	14.0	M35377.129847
Cotton, Ted	SE 19-012-04 W4M	Lower Surficial	01-Aug-79	6.7	22.0	5.2	17.0	M35377.120500
Crandall, Ken	NE 36-010-03 W4M	Bearpaw	29-Nov-85	10.7	35.0	3.1	10.0	M35377.121192
Department Public Works Pw#1	16-24-008-03 W4M	Bearpaw	20-Jul-63	33.2	109.0	11.7	38.5	M35377.120099
Dietz, Tony & Albert	NW 17-012-05 W4M	Lower Surficial	16-Aug-78	14.9	49.0	7.3	24.0	M35377.137592
Dola, Dale	02-22-012-06 W4M	Upper Surficial	21-Jun-77	6.7	22.0	3.1	10.0	M35377.137526
Dola, Henry	02-22-012-06 W4M	Upper Surficial	22-Nov-73	6.4	21.0	3.1	10.0	M35377.137521
Duchscherer, Joe	SW 06-016-01 W4M	Upper Surficial	27-Jun-75	7.6	25.0	6.1	20.0	M35377.119662
Ellis Ranching Co. Ltd.	NW 34-014-05 W4M	Lower Surficial	18-May-89	49.1	161.0	36.9	121.0	M35377.119897
Engel, Dorne	NE 20-012-02 W4M	Oldman	22-Jul-77	163.1	535.0	15.2	50.0	M35377.117073
Fai, Ron	01-16-012-06 W4M	Lower Surficial	16-Apr-83	48.8	160.0	12.2	40.0	M35377.137459
Fred Kirschenman	SE 30-018-01 W4M	Upper Surficial	16-Nov-83	7.3	24.0	4.6	15.0	M35377.119670
Freimark, Vern	SW 08-012-03 W4M	Oldman	10-Sep-88	11.3	37.0	4.6	15.0	M35377.120387
Frisch, Herb	08-04-012-02 W4M	Oldman	14-Dec-67	73.2	240.0	48.8	160.0	M35377.117054
Geigle, Harvey	NE 08-013-03 W4M	Upper Surficial	06-Aug-88	9.1	30.0	2.7	9.0	M35377.120760
Gerhard Brost Const Ltd.	NE 26-011-05 W4M	Foremost	05-Sep-79	103.6	340.0	33.5	110.0	M35377.136750
Grisak, Ken	NW 34-011-06 W4M	Upper Surficial	01-Jun-85	38.1	125.0	6.4	21.0	M35377.136946
Gust, Sam	SW 03-016-04 W4M	Oldman	07-Nov-84	110.0	361.0	53.0	174.0	M35377.120113
Hagel, Bob	NW 33-015-01 W4M	Upper Surficial	27-Jun-79	9.1	30.0	4.6	15.0	M35377.120203
Hagel, Clarence	SE 02-016-02 W4M	Upper Surficial	11-Apr-84	9.1	30.0	4.3	14.0	M35377.119930
Hagel, Robert J.	13-33-015-01 W4M	Upper Surficial	09-Mar-92	21.9	72.0	4.6	15.0	M35377.096380
Harlburt, Wayne	SW 16-019-09 W4M	Upper Surficial	01-Sep-73	15.2	50.0	5.5	18.0	M35377.114099
Hartung, Clay	SW 08-012-05 W4M	Lower Surficial	20-Sep-82	6.7	22.0	1.8	6.0	M35377.137479
Heller, Wayne	SE 14-013-01 W4M	Lower Surficial	07-Sep-82	6.4	21.0	2.4	8.0	M35377.117534
Herman, Ted	NW 05-012-05 W4M	Lower Surficial	03-Mar-75	12.8	42.0	3.7	12.0	M35377.137306
Herrmann, Edward	SE 03-015-02 W4M	Upper Surficial	12-Apr-84	9.1	30.0	4.6	15.0	M35377.120265
Herrmann, James	NE 33-014-02 W4M	Bearpaw	07-Aug-82	11.6	38.0	5.8	19.0	M35377.119677
Herrmann, Robin	NE 09-015-04 W4M	Upper Surficial	10-Aug-88	36.0	118.0	27.1	89.0	M35377.120989
Herter, Claig	SW 30-015-02 W4M	Bearpaw	08-Jul-82	17.7	58.0	9.1	30.0	M35377.120615
Houff, Brian	12-21-011-05 W4M	Lower Surficial	23-Apr-80	11.3	37.0	9.5	31.0	M35377.135801
Hulme, Doug	01-26-012-07 W4M	Foremost	18-Sep-75	77.7	255.0	12.2	40.0	M35377.137328
Hurlburt, Wayne	NE 16-019-09 W4M	Oldman	05-Mar-75	127.1	417.0	29.0	95.0	M35377.114108
Jackson, Ray	NE 26-011-05 W4M	Foremost	24-Aug-79	103.6	340.0	57.9	190.0	M35377.136739
Kahle, Eric	NW 32-012-04 W4M	Foremost	02-Nov-79	101.8	334.0	24.4	80.0	M35377.120590
Kallenberger, Lane	NW 25-011-05 W4M	Lower Surficial	21-Mar-84	45.4	149.0	24.4	80.0	M35377.136691

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION (continued)

		Aquifer	Date Water	Completed Depth		NPWL		
Owner	Location	Name	Well Drilled	Metres	Feet	Metres	Feet	UID
Kleinknecht, Edline	13-18-014-07 W4M	Oldman	28-May-86	71.3	234.0	34.1	112.0	M35377.138052
Knesh, Nick	03-12-013-05 W4M	Upper Surficial	07-Mar-78	6.7	22.0	3.1	10.0	M35377.137626
Knutson, Murray	NE 17-019-09 W4M	Oldman	22-Jan-76	75.6	248.0	36.6	120.0	M35377.114145
Kock, Jim	04-15-012-06 W4M	Lower Surficial	06-Apr-83	46.6	153.0	13.7	45.0	M35377.137284
Liboiron, James	NW 35-019-10 W4M	Bearpaw	07-Dec-76	49.1	161.0	39.6	130.0	M35377.114151
Liboiron, Jim	SW 02-020-10 W4M	Upper Surficial	11-Jun-82	14.6	48.0	6.1	20.0	M35377.110881
M.D. of Cypress	NW 34-014-09 W4M	Lower Surficial	21-Sep-87	116.7	383.0	43.7	143.3	M35377.138114
Mazer, Geo	SW 08-012-05 W4M	Lower Surficial	21-Sep-82	11.0	36.0	3.7	12.0	M35377.137470
Mcdougald	SE 33-014-10 W4M	Lower Surficial	12-Dec-70	105.2	345.0	43.6	143.0	M35377.138174
Nieman, Evult	SE 15-011-05 W4M	Foremost	21-Jun-77	143.3	470.0	61.0	200.0	M35377.135725
North Can Oils	13-09-017-01 W4M	Upper Surficial	12-Aug-77	34.1	112.0	13.7	45.0	M35377.114515
Olson, Kennth	SW 32-019-09 W4M	Oldman	28-Feb-86	115.5	379.0	50.6	166.0	M35377.136622
Pasiciel, Walter	02-34-011-06 W4M	Lower Surficial	24-Nov-78	9.1	30.0	2.1	7.0	M35377.136931
Pender, Rob	SE 15-010-03 W4M	Upper Surficial	19-Nov-79	10.7	35.0	6.1	20.0	M35377.120943
Pender, Robert	SW 15-010-03 W4M	Oldman	05-Feb-86	217.9	715.0	196.0	643.0	M35377.120968
Pfeifer, Lawrence	12-07-009-03 W4M	Lower Surficial	13-Aug-84	6.1	20.0	1.8	6.0	M35377.120417
Phaff, Reginald J.	SE 05-012-03 W4M	Upper Surficial	19-Aug-88	13.7	45.0	6.1	20.0	M35377.120334
Phoenex Constructors	SE 10-020-01 W4M	Upper Surficial	12-Aug-82	22.6	74.0	7.3	24.0	M35377.114281
Pilsl, Howard	SE 23-017-01 W4M	Upper Surficial	14-Mar-80	20.1	66.0	7.6	25.0	M35377.120315
Pinder, Edward	02-24-011-04 W4M	Upper Surficial	23-Apr-80	15.9	52.0	5.2	17.0	M35377.095367
Public Works - Supply Services	SW 08-012-04 W4M	Lower Surficial	06-Nov-85	14.6	48.0	6.7	22.0	M35377.120444
Pudwell, Philip	SW 36-012-05 W4M	Foremost	01-Jul-74	96.0	315.0	30.5	100.0	M35377.137753
Rath, Marvin	NW 36-009-04 W4M	Upper Surficial	14-Sep-88	4.3	14.0	1.8	6.0	M35377.120848
Rath, Marvin	SW 01-010-04 W4M	Upper Surficial	15-Sep-88	3.7	12.0	1.8	6.0	M35377.121221
Roseglen Colony	SE 04-018-02 W4M	Upper Surficial	16-Jun-77	7.9	26.0	2.4	8.0	M35377.119812
Roseglen Colony	SE 04-018-02 W4M	Upper Surficial	16-Jun-77	7.9	26.0	2.9	9.4	M35377.119812
Roth, Leslie	NE 33-015-02 W4M	Upper Surficial	26-May-78	5.5	18.0	2.4	8.0	M35377.120678
Ruben Ehret	SW 17-018-01 W4M	Oldman	25-Jul-79	130.5	428.0	26.5	87.0	M35377.119557
Schafer, Brian	SE 18-016-01 W4M	Upper Surficial	01-Mar-74	4.3	14.0	3.1	10.0	M35377.119761
Schafer, Leo	NE 09-015-01 W4M	Upper Surficial	08-Mar-77	17.7	58.0	10.7	35.0	M35377.120136
Schatz, Art	NW 11-017-01 W4M	Upper Surficial	19-Jul-77	29.9	98.0	9.1	30.0	M35377.120208
Schick, Lloyd	SW 25-019-01 W4M	Upper Surficial	01-Sep-77	7.3	24.0	4.6	15.0	M35377.114097
Schreiber, Stan	16-23-014-06 W4M	Upper Surficial	03-Sep-80	11.3	37.0	5.8	19.0	M35377.138195
Stenhouse, Robert	NW 18-009-06 W4M	Lower Surficial	13-Oct-84	102.4	336.0	51.8	170.0	M35377.129830
Town of Elkwater	08-24-008-03 W4M	Horseshoe Canyon	01-May-73	61.0	200.0	35.4	116.0	M35377.120018
Town of Elkwater	06-19-008-02 W4M	Horseshoe Canyon	23-Oct-81	40.2	132.0	23.5	77.2	M35377.120037
Town of Irvine	NE 36-011-03 W4M	Lower Surficial	19-May-75	59.1	194.0	11.6	38.0	M35377.119808
Trainer, Ken	05-15-012-06 W4M	Lower Surficial	14-Jul-83	56.7	186.0	24.4	80.0	M35377.137287
Trd Bldg Sales	SE 23-012-06 W4M	Upper Surficial	15-Oct-81	8.5	28.0	4.3	14.0	M35377.137576
Ulrich, Donald	SW 35-014-02 W4M	Upper Surficial	23-Apr-85	32.6	107.0	26.8	88.0	M35377.119690
Unreiner, Tony	NW 30-016-02 W4M	Upper Surficial	12-Apr-77	23.8	78.0	17.1	56.0	M35377.087048
Vossler, Roy	SE 06-013-06 W4M	Foremost	13-Aug-79	11.9	39.0	6.3	20.7	M35377.137734
Weisgerber, Charles	SW 36-015-02 W4M	Upper Surficial	10-Apr-81	11.6	38.0	3.1	10.0	M35377.120726
Weisgerber, John	NE 08-016-01 W4M	Upper Surficial	08-Jul-82	7.3	24.0	3.4	11.0	M35377.119685
Weisgerber, Tom	NE 33-015-01 W4M	Upper Surficial	01-Sep-74	9.1	30.0	3.1	10.0	M35377.120224
Weisner, E. G. Douglas	12-06-012-03 W4M	Oldman	20-May-83	51.8	170.0	29.9	98.0	M35377.120355
West Coast Petroleum Ltd.	03-25-018-08 W4M	Upper Surficial	16-Jun-76	8.5	28.0	1.5	4.8	M35377.138306
Will, William	08-04-012-03 W4M	Oldman		66.1	217.0	0.6	2.0	M35377.120280
Will, William	02-04-012-03 W4M	Upper Surficial	06-Mar-78	6.1	20.0	3.1	10.0	M35377.120276
Wittervrongel, M. J.	02-28-014-07 W4M	Upper Surficial	09-Jun-76	32.9	108.0	16.8	55.0	M35377.138058
Wittevrongel, Norman	SE 28-014-07 W4M	Oldman	16-Sep-81	56.7	186.0	13.7	45.0	M35377.138060
Wright, Dave & Sylvia	NW 27-012-05 W4M	Lower Surficial	28-Aug-75	74.1	243.0	71.6	235.0	M35377.137666
Wuerfel, Walter	SW 06-018-01 W4M	Upper Surficial	22-Jun-78	14.6	48.0	7.6	25.0	M35377.119469
Wunsch, Gordon	16-33-011-03 W4M	Upper Surficial	02-Mar-78	7.9	26.0	3.1	10.0	M35377.119716
Zahn, Don	NW 04-016-01 W4M	Upper Surficial	01-Sep-74	6.1	20.0	3.7	12.0	M35377.119649
Zahn, Don	SW 18-016-01 W4M	Upper Surficial	02-Mar-78	6.4	21.0	1.8	6.0	M35377.119780
Zahn, Donald	NW 04-016-01 W4M	Oldman	01-Sep-74	168.2	552.0	57.9	190.0	M35377.119605

CYPRESS COUNTY-OPERATED WATER WELLS

		Aquifer	Date Water	Completed Depth		NPWL		
Owner	Location	Name	Well Drilled	Metres	Feet	Metres	Feet	UID
M.D. of Cypress	NW 34-014-09 W4M	Lower Surficial	21-Sep-87	116.7	382.9	43.7	143.3	M35377.138114
M.D. of Cypress	06-12-016-04 W4M	Upper Surficial	Unknown	Unknown	4.8	Unknown	Unknown	Unknown
M.D. of Cypress	04-36-017-01 W4M	Upper Surficial	Unknown	36.5	54.9	Unknown	Unknown	Unknown