# Cardston County

Part of the South Saskatchewan and Missouri River Basins
Tp 001 to 007, R 19 to 29, W4M
Regional Groundwater Assessment

Prepared for Cardston 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
hydrogeological consultants ltd.
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Our File No.: **02-100**

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**PERMIT TO PRACTICE**
HYDROGEOLOGICAL CONSULTANTS LTD.

Signature______________________________

Date______________________________

**PERMIT NUMBER P 385**
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

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# Acknowledgements

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Mr. Vic Brown – AAFC-PFRA

Mr. Bryan Phillips – Cardston County

Mr. Rod Foggin – Cardston 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 Cardston 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 Cardston County prepared by Hydrogeological Consultants Ltd. (HCL) with financial and technical assistance from the Prairie Farm Rehabilitation Administration branch of Agriculture and Agri-Food Canada (AAFC-PFRA) and Cardston County. 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 Cardston 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 Cardston 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 shown in this report, plus additional maps, figures and cross-sections, are available on the CD-ROM. In order to avoid map-edge effects, all maps will be based on an analysis of hydrogeological data from townships 001 to 007, ranges 19 to 29, W4M, plus a buffer area of 5,000 metres. For convenience, poster-size maps and cross-sections have been prepared as a visual summary of the results presented in this report. Copies of these poster-size drawings have been forwarded with this report, and are included as page-size drawings in Appendix D.

Appendix A features page-size copies of the figures within the report plus additional maps and cross-sections. An index of the page-size maps and figures is given at the beginning of Appendix A. A plastic County map outline is provided to overlay the maps, and contains information such as towns, main rivers, etc.

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

Appendix C includes the following:

1) a procedure for conducting aquifer tests with water wells[3]
2) a table of contents for the Water (Ministerial) Regulation under the *Water Act*
3) interpretation of chemical analysis of drinking water
4) 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 *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.

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[3] See glossary

# 2. Introduction

## 2.1 Setting

Cardston County is situated in southern Alberta. Most of this area is part of the western Alberta Plains region. The County is within the South Saskatchewan River and the Missouri River basins; the two main sub-basins are the Oldman River and the Milk River (see CD-ROM). The Waterton River forms the western boundary and the St. Mary River forms the northeastern boundary. The study area includes much of the Blood First Nation lands. The Blood First Nation lands form the northern boundary; Waterton National Park forms the southwestern boundary, Montana forms the southern boundary, and the other County boundaries are as shown on the adjacent index map.

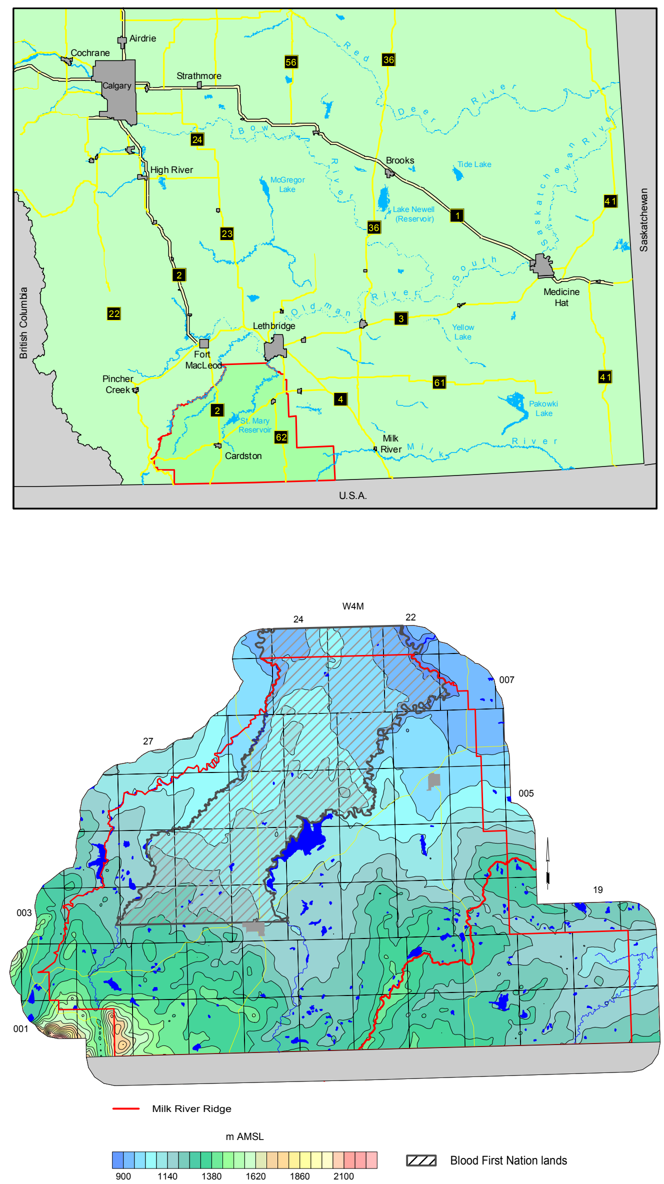


*Figure 1. Index Map*

Regionally, the topographic surface varies between 840 and 2,300 metres above mean sea level (AMSL). The lowest elevations occur mainly in the northern parts of the County in the Waterton and St. Mary rivers, and the highest are in the southwestern parts of the County as shown on Figure 1 and page A-4. The area is well drained by the Waterton River, the Belly River, the St. Mary River, and the Milk River.

## 2.2 Climate

Cardston County lies within the Dfb 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 Leggat, 1981) shows that the County is located in both the Mixed Grass and Fescue Grass regions. At higher elevations in the western part of the County, both the Montane and Subalpine regions are present.

A Dfb climate consists of long, cool summers and severe winters. The mean monthly temperature drops below -3° C in the coolest month, and exceeds 10° C in the warmest month.

The mean annual precipitation averaged from three meteorological stations within the County measured 568 millimetres (mm), based on data from 1961 to 1993. The mean annual temperature averaged 4.7° C, with the mean monthly temperature reaching a high of 16.6° C in July, and dropping to a low of –7.4° C in January. The calculated annual potential evapotranspiration is 510 millimetres.

4 See glossary

## 2.3 Background Information

### 2.3.1 Number, Type and Depth of Water Wells

There are currently 3,682 records in the groundwater database for the County, of which 2,671 are water wells[5]. Of the 3,682 records in the groundwater database for the County, 368 are within the Blood First Nation lands. Of the 2,671 water wells, 2,264 are for domestic/stock purposes. The remaining 407 water wells were completed for a variety of uses, including municipal, observation, industrial, irrigation and investigation; 274 of the 407 water wells have an “unknown” purpose. Based on a rural population of 4,565 (Phinney, 2001-2002), there are two domestic/stock water wells per family of four. There are 2,134 domestic or stock water wells with a completed depth, of which 1,734 (81%) are completed at depths of less than 50 metres below ground surface. Water wells within the Disturbed Belt portion of the County mainly have completion depths of less than 50 metres. Details for lithology[6] are available for 1,752 water wells.

### 2.3.2 Number of Water Wells in Surficial and Bedrock Aquifers

There are 886 water wells 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 886 water wells for which aquifers could be defined, 427 are completed in surficial aquifers, with 369 (86%) having a completion depth of less than 50 metres below ground surface. The adjacent map shows that the water wells completed in the surficial deposits occur mainly in the buried bedrock valleys and in the Disturbed Belt.

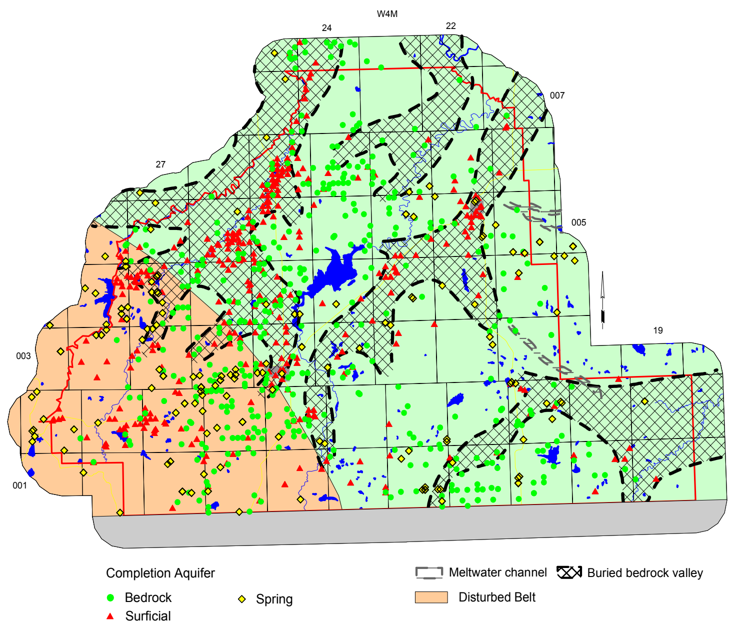


***Figure 2. Location of Water Wells and Springs***

The data for 459 water wells show that the top of the water well completion interval is below the bedrock surface, indicating that the water wells are completed in at least one bedrock aquifer. From Figure 2 (also see page A-5), it can be seen that water wells completed in bedrock aquifers occur throughout the County.

Within Cardston County and the 5,000-metre buffer area, there are currently records for 146 springs in the groundwater database, including sixteen springs that were documented by Borneuf (1983). There are 112 springs having at least one total dissolved solids (TDS) value, with a range from 174 to 5,076 milligrams per litre (mg/L). In the linear bedrock lows, springs mainly have a TDS value of greater than 500 mg/L, and springs having TDS values of less than 500 mgL are mainly within the Disturbed Belt area. There are 18 springs having flow rates/test rates, which range from 4.8 to 22,740 litres per minute (lpm). Of the 18 springs with a flow rate/test rate, four were tested in June of 1970 and 1971; for the remaining 14 springs, the flow rate/test rate was in 1983, and no month was provided.

5 See glossary
6 See glossary

### 2.3.3 Casing Diameter and Type

Data for casing diameters are available for 1,670 water wells, with 1,550 (93%) indicated as having a diameter of less than 275 mm and 120 (7%) having a 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 mainly drilled water wells. The groundwater database suggests that 203 of the water wells in the County were bored, hand dug, or dug by backhoe.

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. Within the County, casing-diameter information is available for 409 of the 427 water wells completed in the surficial deposits, of which 398 surficial water wells have a casing diameter of less than 275 millimetres and are assumed to be drilled water wells. Within the County, casing-diameter information is available for 448 of the 459 water wells completed below the top of bedrock. These 448 bedrock water wells have surface-casing diameters of less than 275 mm and have been mainly completed with either a perforated liner or as open hole; there are nine bedrock water wells completed with a water well screen.

In the County, steel surface casing materials have been used in 97.3% of the drilled water wells over the last 50 years. Of the remaining 2.7% of the drilled water wells with surface casing materials, 1.9% was for plastic, 0.7% was for galvanized steel, and 0.1 % was for a water well completed with concrete-type surface casing in the 1960s. Prior to 1955, and from 1960 to 1969, the type of surface casing used in drilled water wells was mainly undocumented. Steel casing was in use in the 1950s and, since 1995, is the only casing type being used in the water wells being drilled in the County. Galvanized steel and plastic surface casing was mainly used from 1980 to 1984. Only steel surface casing material has been used since 2000. Galvanized steel was last used in August 1999, and plastic surface casing was last used in October 1996.

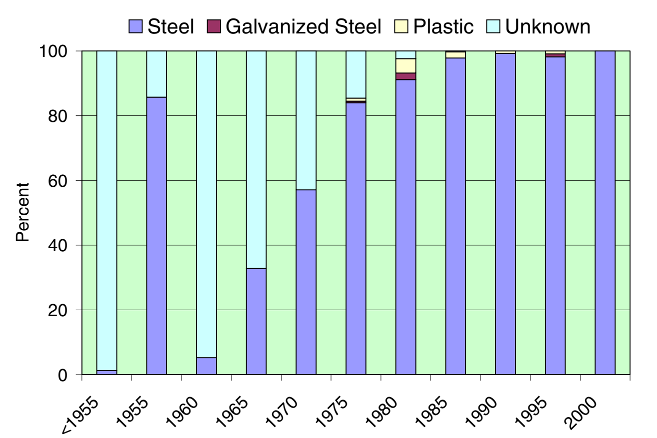


***Figure 3. Surface Casing Types Used in Drilled Water Wells***

Steel casing has been dominant in the County probably because it has resisted corrosion and also because water well drillers may be reluctant to use PVC if there have been no documented problems with steel casing in the area.

### 2.3.4 Dry Water Test Holes

In the County, there are 3,682 records in the groundwater database. Of these 3,682 records, 218 are indicated as being dry or abandoned with “insufficient water”. Also included in these dry test holes is any record that includes comments that state the water well goes dry in dry years. Of the 218 “dry” test hole records, 201 are completed in bedrock aquifers. Of the 201 dry test holes completed in bedrock aquifers, 129 (64%) are located within the Blood First Nation lands (see CD-ROM).

### 2.3.5 Requirements for Licensing

Water well use starting after 01 Jan 1999 must have a non-exempt authorization to divert and use groundwater unless (1) they are for household use in excess of 3.4 cubic metres per day (1,250 cubic metres per year (m³/year) or (750 imperial gallons per day[7]), (2) the diversion is from saline groundwaters with total dissolved solids in excess of 4,000 mg/L, or (3) the diversion of groundwater is from a manually pumped water well. A person diverting groundwater for agricultural purposes before 01 Jan 1999 to a maximum of 6,250 m³/year can continue to divert the groundwater without a licence or a registration as long as the person continues to own or occupy the land. The diversion of groundwater under this exemption has no priority, the right is non-transferable and the exemption ceases when the person no longer owns or occupies the land.

In the last update from the Alberta Environment (AENV) groundwater database in January 2003, 265 groundwater allocations were shown to be within the County, with the most recent groundwater user being authorized in May 2002. Of the 265 authorized non-exempt groundwater users (licences and registrations), 193 are registrations for traditional agriculture use under the *Water Act*. These 193 users will continue to have an industry activity code of ‘registration’ but the groundwater will be used for stock and/or crop spraying. Typically, the groundwater diversion for crop spraying is less than one m³/day. Of the 193 registrations, only 45 (23%) could be linked to the AENV groundwater database. Of the remaining 72 from the 265 authorized non-exempt groundwater users, 36 are for agricultural purposes (stock watering), 20 are for municipal purposes (six are for urban use, 14 are for water cooperatives), 11 are for dewatering purposes, three are for fishery purposes, one is for recreation purposes, and the remaining one is for commercial (water bottling). Of these 72 licensed groundwater users in the County, 48 (67%) could be linked to the AENV groundwater database. The total maximum authorized diversion from the water wells associated with these licences is 27,744 m³/day, although actual use could be less. Of the 27,744 m³/day, 18,587 m³/day (67%) is authorized for dewatering purposes. Of the remaining 9,157 m³/day, 335 m³/day (1.2%) is for registrations, 569 m³/day (2.1%) is authorized for agricultural purposes, 1,085 m³/day (3.9%) is authorized for municipal purposes, 7,164 m³/day (25.8%) is authorized for fishery purposes, 3.4 m³/day is authorized for recreation, and the remaining 0.3 m³/day is allotted for commercial use, as shown below in Table 1. A figure showing the locations of the authorized non-exempt groundwater users is in Appendix A (page A-7) and on the CD-ROM. Table 1 also shows a breakdown of the 265 groundwater allocations by the aquifer in which the water well is completed. Approximately ninety-seven percent of the total authorized groundwater allocations are in the Lower Sand and Gravel Aquifer. The 27 users where an aquifer cannot be determined is because there is no completion information available.

| Aquifer ** | No. of Diversions | Registrations (m³/day) | Licensed Groundwater Users* (m³/day) Agricultural | Municipal | Dewatering | Fishery | Recreation | Commercial | Authorized Non-Exempt Total | Percentage |
|---|---|---|---|---|---|---|---|---|---|---|
| Upper Sand and Gravel | 21 | 36 | 7 | 0 | 0 | 0 | 0 | 0 | 43 | 0.2 |
| Lower Sand and Gravel | 78 | 98 | 165 | 926 | 18,587 | 7,164 | 0 | 0.3 | 26,940 | 97.1 |
| Disturbed Belt | 35 | 46 | 0 | 0 | 0 | 0 | 3.4 | 0 | 49 | 0.2 |
| Lower Lacombe | 1 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| Haynes | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 4.0 | 0.0 |
| Upper Scollard | 4 | 4 | 0 | 18 | 0 | 0 | 0 | 0 | 22 | 0.1 |
| Lower Scollard | 16 | 15 | 22 | 12 | 0 | 0 | 0 | 0 | 49 | 0.2 |
| Upper Horseshoe Canyon | 19 | 16 | 81 | 30 | 0 | 0 | 0 | 0 | 127 | 0.5 |
| Middle Horseshoe Canyon | 20 | 20 | 179 | 77 | 0 | 0 | 0 | 0 | 276 | 1.0 |
| Lower Horseshoe Canyon | 9 | 19 | 68 | 0 | 0 | 0 | 0 | 0 | 87 | 0.3 |
| Bearpaw | 22 | 26 | 47 | 22 | 0 | 0 | 0 | 0 | 95 | 0.3 |
| Oldman | 12 | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 27 | 0.1 |
| Unknown | 27 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 24 | 0.1 |
| Total | 265 | 335 | 569 | 1,085 | 18,587 | 7,164 | 3.4 | 0.3 | 27,744 | 100 |
| Percentage | | 1.2 | 2.1 | 3.9 | 67.0 | 25.8 | 0.0 | 0.0 | 100 | |

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

***Table 1. Authorized Non-Exempt Groundwater Diversions***

Based on the 2001 Agriculture Census (Statistics Canada), the calculated water requirement for 478,740 livestock for the County (including the Blood First Nation lands) is in the order of 10,207 m³/day. This value includes intensive livestock use but not domestic animals. Of the 10,207 m³/day average calculated livestock

7 see conversion table on page 65

use, AENV has authorized a groundwater diversion of 904 m³/day (agricultural and registration) (9%) and licensed a surface-water diversion based on consumptive use of 9,953 m³/day (98%). AENV may have authorized seven percent more than is required for calculated livestock use.

### 2.3.6 Groundwater Chemistry and Base of Groundwater Protection

Groundwaters from an aquifer in the surficial deposits can be expected to be chemically hard, having a total 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. High nitrate + nitrite (as N) concentrations were evident in 12% of the available chemical data for the surficial aquifers and 8% 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 2,000 mg/L (page A-30). 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. More than 11% of the chemical analyses for upper bedrock water wells indicate a fluoride concentration above 1.5 mg/L, with most of the exceedances occurring outside the disturbed belt of the County (page A-31).

| Constituent | No. of Analyses | Range for County in mg/L Minimum | Maximum | Median | Recommended Maximum Concentration SGCDWQ |
|---|---|---|---|---|---|
| Total Dissolved Solids | 455 | 4 | 7,858 | 998 | 500 |
| Sodium | 328 | 7 | 2,218 | 265 | 200 |
| Sulfate | 458 | 0 | 4,370 | 278 | 500 |
| Chloride | 455 | 0 | 1,444 | 10 | 250 |
| Fluoride | 318 | 0 | 4.9 | 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)

**SGCDWQ** - Summary of Guidelines for Canadian Drinking Water Quality Federal-Provincial Subcommittee on Drinking Water, March 2001

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

The minimum, maximum and median[8] 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 Summary of Guidelines for Canadian Drinking Water Quality (SGCDWQ) in Table 2. Of the five constituents compared to the SGCDWQ, median concentrations of TDS and sodium exceed the guidelines; maximum values of all five constituents exceed the guidelines.

In general, Alberta Environment defines the Base of Groundwater Protection as the elevation below which the groundwater will have more than 4,000 mg/L of total dissolved solids. By using the ground elevation, formation elevations, and Alberta Energy and Utilities Board (EUB) information indicating the formations containing the deepest useable water for agricultural needs, a value for the depth to the Base of Groundwater Protection can be determined. These values are gridded using the Kriging[9] 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 the Base of Groundwater Protection ranges from less than 100 metres along parts of the St. Mary River, to more than 1,100 metres in the southwestern parts of the County, as shown on Figure 4, on some cross-sections presented in Appendix A, and on the CD-ROM.

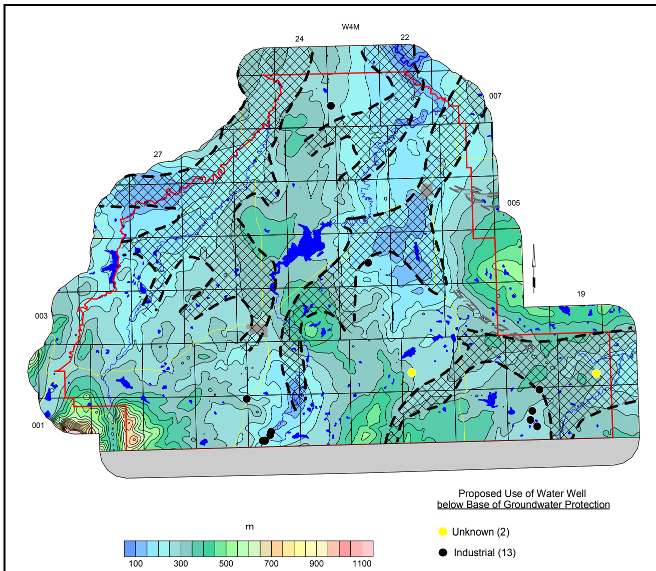


***Figure 4. Depth to Base of Groundwater Protection (after EUB, 1995)***

[8] see glossary
[9] See glossary

There are 2,511 water wells with completed depth data, of which 15 are completed below the Base of Groundwater Protection. Most of these water wells are located within or adjacent to buried bedrock valleys. Of the 15 water wells completed below the Base of Groundwater Protection, 13 are/were used for industrial purposes, and two water wells do not have a proposed use. Chemistry data are available for three water wells, which provided groundwaters with TDS of more than 4,000 mg/L. In the County, the Base of Groundwater Protection passes through parts of all the bedrock formations (see pages A-12 to A-16).

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

Even with the available sources of data, the number of water-level data points relative to the size of the County is too few to provide a reliable groundwater budget (see section 6.0 of this report). The most cost-efficient method to collect additional groundwater monitoring data would be to have the water well owners measuring the water level in their own water well on a regular basis, as has been the case in the Wildrose Country Ground Water Monitoring Association and Flagstaff County.

# 3. Terms

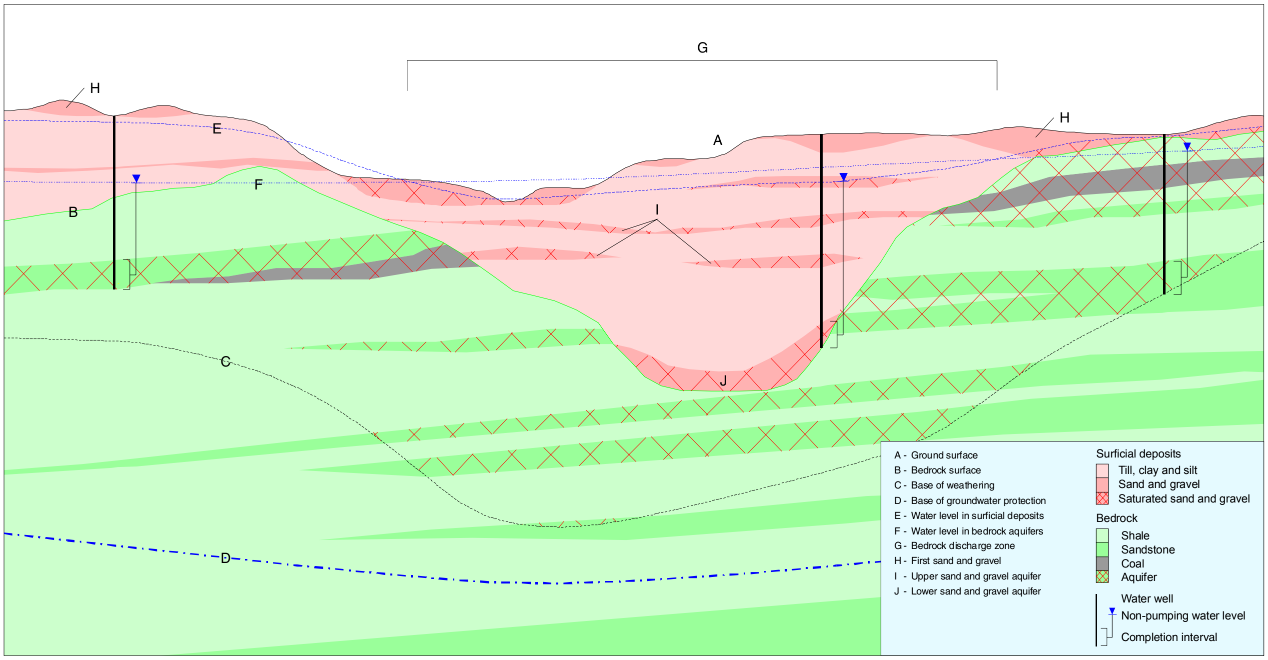


***Figure 5. Generalized Cross-Section (for terminology only)***


***Figure 6. Geologic Column***

# 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
5) chemical analyses for some groundwaters[10]
6) location of some flowing shot holes
7) location of some structure test holes
8) a variety of data related to the groundwater resource.

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

The present project uses the 10TM coordinate system based on the NAD27 datum. This means that a record for the NW ¼ of section 28, township 001, range 23, W4M, would have a horizontal coordinate with an Easting of 144,077 metres and a Northing of 5,434,538 metres, the centre of the quarter section. If the water well has been repositioned by AAFC-PFRA using orthorectified aerial photos, the location will be more accurate, possibly within several tens of metres of the actual location. Once the horizontal coordinates are determined for a record, a ground elevation for that record is obtained from the 1:20,000 Digital Elevation Model (DEM); AltaLIS Ltd. provides the DEM.

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

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

[10] 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.

Where possible, determinations are made from individual records in order to assign water wells to aquifers and to obtain values 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[11].

Also, where sufficient information is available, values for apparent transmissivity[12] and apparent yield[13] are calculated, based on the aquifer test summary data supplied on the water well drilling reports. Where valid detailed aquifer test results exist, the interpreted data provide values for aquifer transmissivity and effective transmissivity. Since the last regional hydrogeological map covering at least a part of the County was published in 1974 (Tokarsky, 1974), 587 values for apparent transmissivity and 456 values for apparent yield have been added to the groundwater database. The median apparent yield of the water wells with apparent yield values is 32 m³/day. Approximately 20% of the apparent yield values for these water wells are less than 6.5 m³/day. With the addition of the apparent yield values, including a 0.1-m³/day value assigned to "dry" water wells and water test holes, a hydrogeological map has been prepared to help illustrate the general groundwater availability across the County (Figure 7). 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.

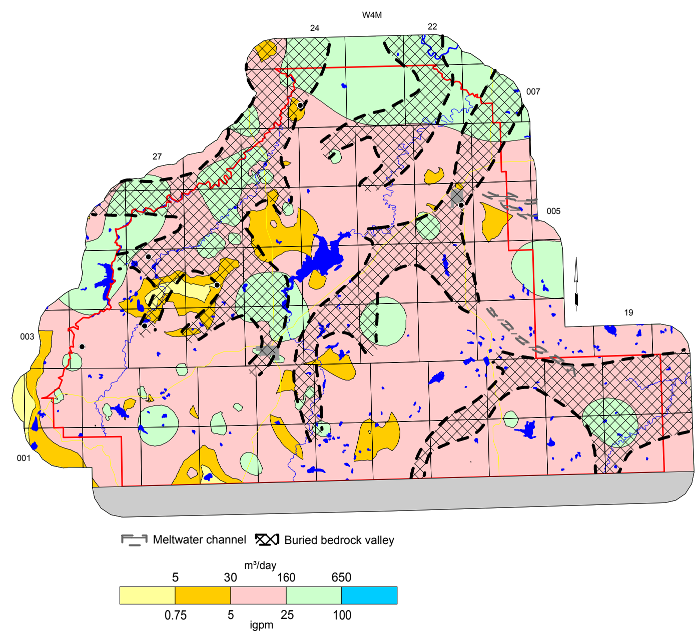


***Figure 7. Hydrogeological Map***

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 and apparent yield 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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11 See glossary
12 For definitions of Transmissivity, see glossary
13 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.

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 depth of a water well cannot be established, the data from that water well are not used in determining the distribution of hydraulic parameters.

After the water wells are assigned to a specific aquifer, the parameters from the water well records are assigned to the individual aquifers. The parameters include non-pumping (static) water level (NPWL), apparent transmissivity, and apparent water well yield. The NPWL given on the water well record is usually the water level recorded when the water well was drilled, measured prior to the initial aquifer test. In areas where groundwater levels have since fallen, the NPWL may now be lower and accordingly, potential apparent yield would be reduced. 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).

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 007, ranges 19 to 29, W4M, plus a buffer area of at least 5,000 metres. 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; for the maps, the areas with little or no data are identified.

## 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. For the upper bedrock aquifer(s) where areas of insufficient data are available from the groundwater database, prepared maps have been masked with a solid faded pink color to indicate these areas. These masks have been added to the Scollard, Horseshoe Canyon, Bearpaw and Oldman 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. Five cross-sections are presented in Appendix A of this report and as poster-size drawings forwarded with this report; only two (A-A’ and B-B’) 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 5.0
- ArcView 3.2
- AutoCAD 2002
- CorelDraw! 10.0
- Microsoft Office XP
- Surfer 8

# 5. Aquifers

## 5.1 Background

An aquifer is a permeable rock unit that is saturated. In this context, rock refers to subsurface materials, such as sand, gravel, sandstone and coal. If the non-pumping water level is above the top of the rock unit, this type of aquifer is a confined or artesian aquifer. If the rock unit is not entirely saturated and the water level is below the top of the rock unit, this type of aquifer is a water-table or unconfined 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.

## 5.2 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[14] and lacustrine[15] deposits. The lacustrine deposits include clay, silt and fine-grained sand. The *upper surficial deposits* include the traditional glacial sediments of till[16] and ice-contact deposits. Pre-glacial materials are expected to be mainly present in the eastern two-thirds of the County, and in association with the buried bedrock valleys. Meltwater channels are associated with glaciation.

### 5.2.1 Geological Characteristics of Surficial Deposits

While the surficial deposits are treated as one hydrogeologic unit, they consist of three hydraulic units. The first unit is the sand and gravel deposits of the lower surficial deposits, when present. These deposits are mainly saturated. 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 5, page 9. While the unsaturated deposits are not technically an aquifer, they are significant as they provide a pathway for soluble contaminants to move downward into the groundwater.

14 See glossary
15 See glossary
16 See glossary

The base of the surficial deposits is the bedrock surface, represented by the bedrock topography as shown on the adjacent map. Regionally, the bedrock surface varies between 820 and 1,460 metres AMSL. The lowest elevations occur mainly in the northern parts of the County in the Waterton and St. Mary river valleys, and the highest within the Disturbed Belt in the southwestern part of the County and along the Milk River Ridge in the southeastern part of the County, as shown on Figure 8 and page A-17.

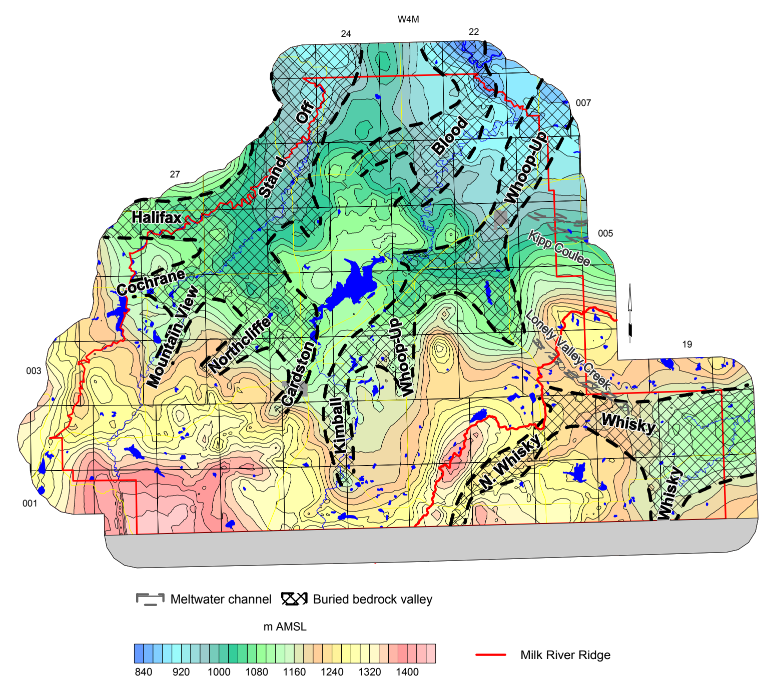



*Figure 8. Bedrock Topography*

Over the majority of the County, the surficial deposits are less than 45 metres thick (see CD-ROM). The exceptions are mainly in association with areas where buried bedrock valleys are present, within the Disturbed Belt, and between the Milk River Ridge and the Buried Whoop-Up Valley, where the deposits can have a thickness of more than 45 metres.

The main linear bedrock lows in the northern part of the County are the Buried Stand Off Valley and the Buried Whoop-Up Valley, and of minor importance is the Buried Blood Valley. These three bedrock valleys are tributaries to the Buried Lethbridge Valley immediately north of the County study area. The Halifax, Cochrane, Mountain View, Northcliffe and Cardston bedrock valleys are tributaries to the Buried Stand Off Valley. In the County, the Buried Kimball Valley is the main tributary to the Buried Whoop-Up Valley (Geiger, 1965).

The Buried Whisky Valley, the main linear bedrock low in the southeastern part of the County, lies south and east of the Milk River Ridge. The Buried N. Whisky Valley is the main tributary to the Buried Whisky Valley. A second tributary valley is the Buried Ross Valley but has not been labelled due to its indefinite contours.

The Buried Stand Off Valley is coincidental with the present-day Belly River. The Valley is nine to fourteen kilometres wide within the map boundary, with local bedrock relief being up to 80 metres. The tributaries are less than five kilometres wide, with local bedrock relief being in the order of 40 metres. Sand and gravel deposits can be expected in association with the Buried Stand Off Valley and its tributaries, with the sand and gravel deposits expected to be mainly less than five metres thick.

The Buried Whoop-Up Valley is four to seven kilometres wide within the map boundary, with local bedrock relief being up to 60 metres. The tributaries are less than five kilometres wide, with local bedrock relief being in the order of 40 metres. Sand and gravel deposits can be expected in association with the Buried Whoop-Up Valley and its tributaries, with the sand and gravel deposits expected to be mainly less than five metres thick. Thicknesses of sand and gravel deposits of more than five metres are more apparent in the Buried Whoop-Up Valley than in the Buried Stand Off Valley.

The extent of the Buried Blood Valley is not clearly defined based on the available bedrock elevations, and has been approximated on Figure 8 based on Geiger's interpretation (Geiger, 1965). The Buried Blood Valley is four to ten kilometres wide, with local bedrock relief being in the order of 60 metres, and sand and gravel deposits expected to be more than two metres thick.

The Buried Whisky Valley is five to fifteen kilometres wide within the map boundary, with local bedrock relief being up to 80 metres. The North Whisky tributary is less than five kilometres wide, with local bedrock relief being in the order of 40 metres. Sand and gravel deposits can be expected in parts of the Buried Whisky Valley and its tributaries, with the sand and gravel deposits expected to be mainly less than five metres thick.

The lower surficial deposits are composed mostly of fluvial and lacustrine deposits. Lower surficial deposits occur mainly east of the Disturbed Belt (see Figure 9). The total thickness of the lower surficial deposits is mainly less than 45 metres, but can be more than 45 metres in the buried bedrock valleys and west of the Milk River Ridge (see CD-ROM). 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 (see CD-ROM).

In the County, there are two glacial meltwater channels (Shetsen, 1987) that overlie the linear bedrock lows: the Kip Coulee Meltwater Channel in association with the Buried Whoop-Up Valley and the Lonely Valley Creek Meltwater Channel in association with the Buried Whisky Valley (see Figure 8). Because sediments associated with the lower surficial deposits are indicated as being present in parts of the meltwater channels, it is possible that the meltwater channels originally were tributaries to the buried bedrock valleys (see CD-ROM).

The upper surficial deposits are either directly or indirectly a result of glacial activity. The deposits include till, with minor sand and gravel deposits of meltwater origin, which are expected to occur mainly as isolated pockets. The thickness of the upper surficial deposits is mainly less than 50 metres. Upper surficial deposits are present mainly in the southwestern part of the County and are absent from the buried bedrock valleys (see CD-ROM). 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 upper sand and gravel deposits are usually less than five metres thick (see CD-ROM). Upper sand and gravel deposits are present mainly in the southwestern part of the County and are absent from the buried bedrock valleys (see CD-ROM).

The west-east cross-section A-A', Figure 9 shown below, passes across the Buried Kimball Valley, the Milk River Ridge and the Buried Whisky Valley and shows the surficial deposits being in the order of 50 metres thick between the Milk River Ridge and the Buried Kimball Valley, and in parts of the Buried Whisky Valley.

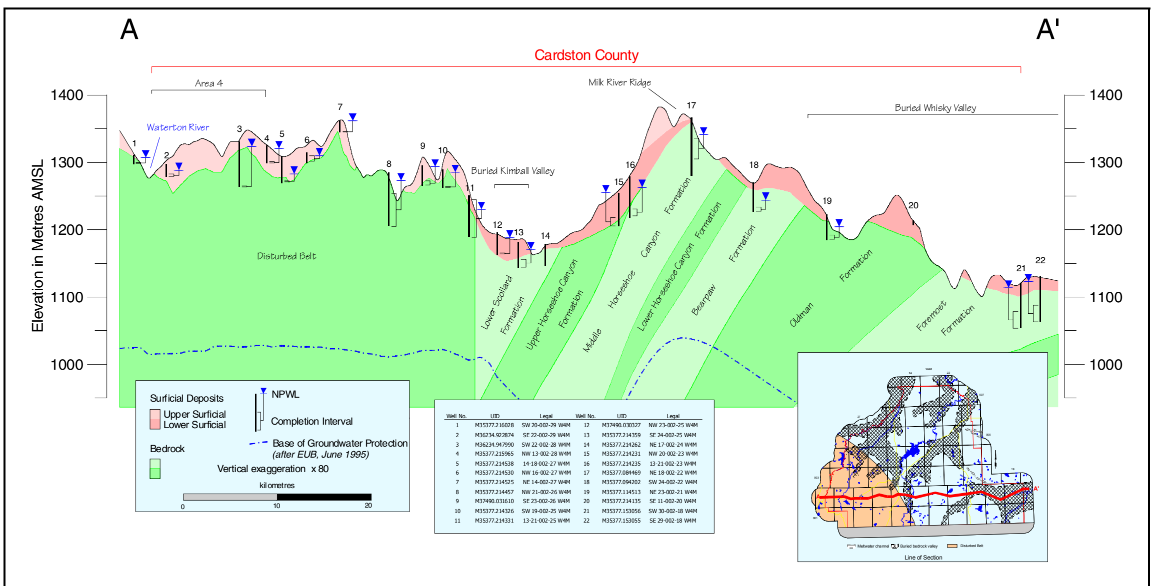



*Figure 9. Cross-Section A - A'*

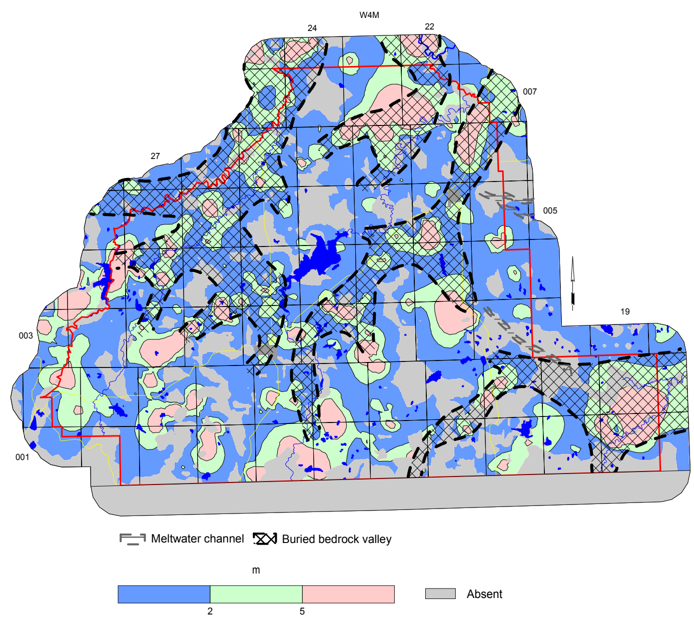



*Figure 10. Thickness of Sand and Gravel Deposits*

Sand and gravel deposits (Figure 10) can occur throughout the surficial deposits. The total thickness of sand and gravel deposits is generally less than two metres but can be more than five metres in association with buried bedrock valleys and within the Disturbed Belt.

The combined thickness of all sand and gravel deposits has been determined as a function of the total thickness of the surficial deposits. Over approximately 5% 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-20). The areas where sand and gravel deposits constitute more than 30% of the total thickness of the surficial deposits are mainly in the areas associated with linear bedrock lows.

### 5.2.2 Sand and Gravel Aquifer(s)

The main source of groundwater in the County is aquifers in the surficial deposits. 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.

Since the sand and gravel aquifer(s) are not present everywhere, the actual aquifer that is developed at a given location is usually dictated by the aquifer that is present. Over approximately 40% of the County, the sand and gravel deposits are not present, or if present, are not saturated; these areas are designated as grey on the adjacent map. In the County, the thickness of the sand and gravel aquifer(s) is generally less than five metres, but can be more than five metres mainly in areas of, or near, linear bedrock lows, and within the Disturbed Belt, as shown in Figure 11, in Appendix A and on the CD-ROM.

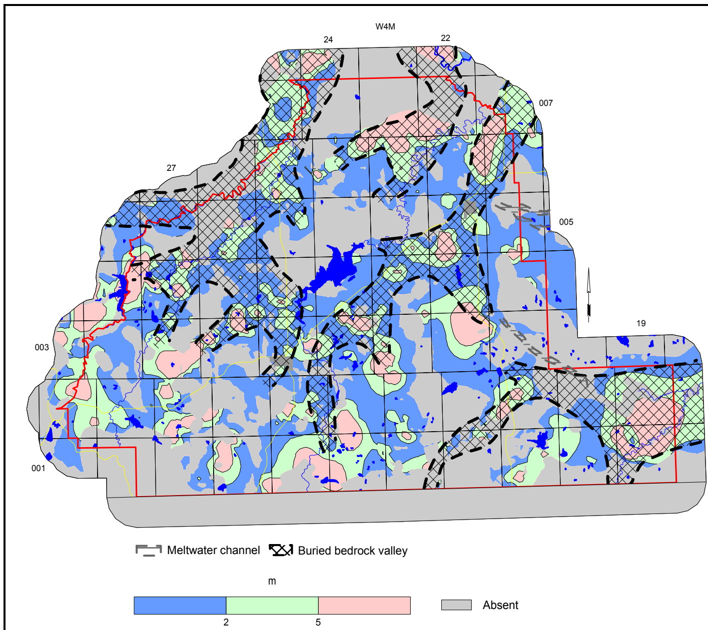



*Figure 11. Thickness of Sand and Gravel Aquifer(s)*

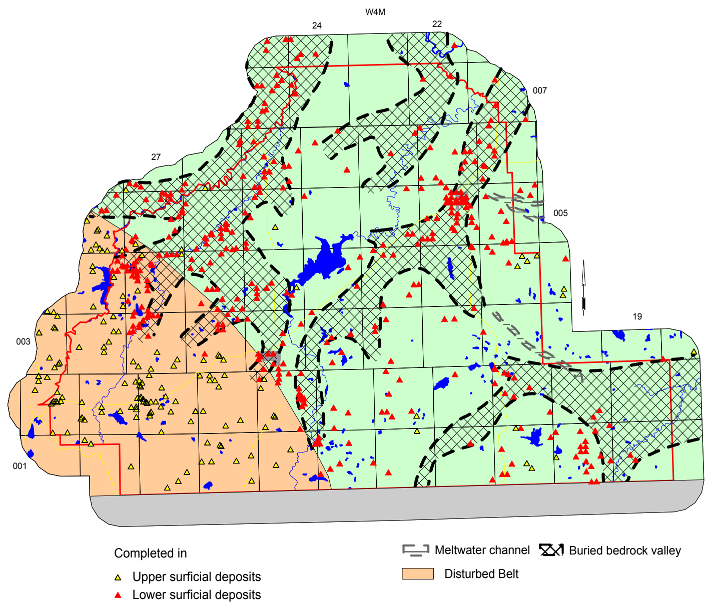



***Figure 12. Water Wells Completed in Upper and Lower Surficial Deposits***

Of the 2,671 water wells in the database, 427 were defined as being completed in surficial aquifers, based on lithologic information and water well completion details. From the present hydrogeological analysis, 1,107 water wells are completed in aquifers in the surficial deposits. Of the 1,107 water wells, 135 are completed in aquifers in the upper surficial deposits, 418 are completed in aquifers in the lower surficial deposits, and 553 water wells are completed in multiple surficial aquifers. This number of water wells (1,107) is 2.6 times the number (427) 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 within the Disturbed Belt; water wells completed in the lower surficial deposits occur mainly in buried bedrock valleys (Figure 12). Even though only about 41% of water wells in the County are completed in surficial aquifers, 13 of the 20 highest yielding water wells in the County are completed in surficial deposits (and 55 of the 100 highest yielding water wells).

Most of the high-volume authorized non-exempt water wells in the County (e.g. for dewatering or fisheries operations) are completed in surficial aquifers. In some cases, it is suspected that high apparent yields are possibly due to good aquifer connection with nearby rivers (e.g. adjacent to the Belly River). Ninety-nine authorized non-exempt diversions are from surficial aquifers but they represent 97.3% of groundwater use.

| 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 |
|---|---|---|---|---|
| Upper Surficial | 25 | 6 | 12 | 7 |
| Lower Surficial | 67 | 7 | 37 | 23 |
| Multiple Completions | 127 | 15 | 59 | 53 |
| Totals | 219 | 28 | 108 | 83 |

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

In the County, there are 219 records for surficial water wells with apparent yield data, which is 20% of the 1,107 surficial water wells. Of the 219 water well records with apparent yield values, 92 have been assigned to aquifers associated with specific geologic units. Thirteen percent (28) of the 219 water wells completed in the sand and gravel aquifer(s) have apparent yields that are less than ten m³/day, 49% (108) have apparent yield values that range from 10 to 100 m³/day, and 38% (83) have apparent yields that are greater than 100 m³/day, as shown in Table 3. In addition to the 219 records for surficial water wells, there are six records that indicate that the water well is dry[17], 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 each of the six dry holes prior to gridding. The majority of the dry holes are in multiple surficial completions.

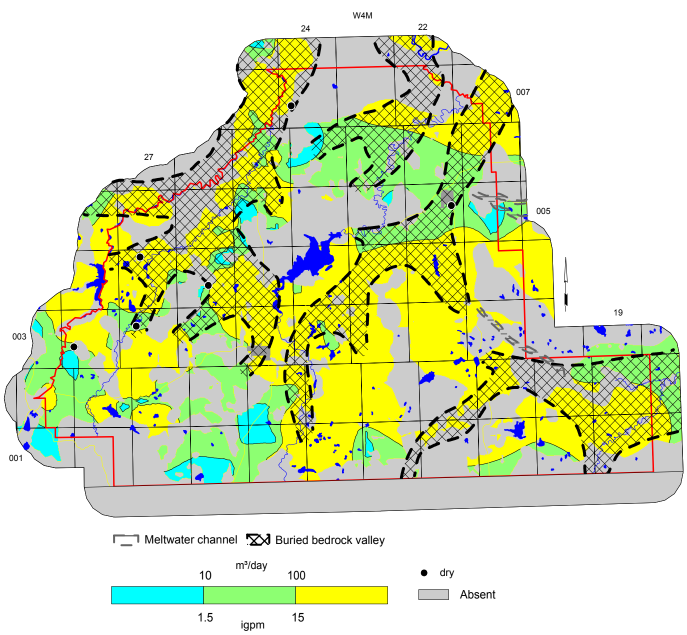



***Figure 13. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)***

The adjacent map shows expected yields for water wells completed in sand and gravel aquifer(s).

Based on the aquifers that have been developed by existing water wells, these data show that water wells with yields of more than 100 m³/day from sand and gravel aquifer(s) can be expected in most of the County where sand and gravel aquifer(s) are present.

17 "dry" can be due to a variety of reasons: skill of driller, type of drilling rig/method used, the geology

#### *5.2.2.1 Chemical Quality of Groundwater from Surficial Deposits*

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

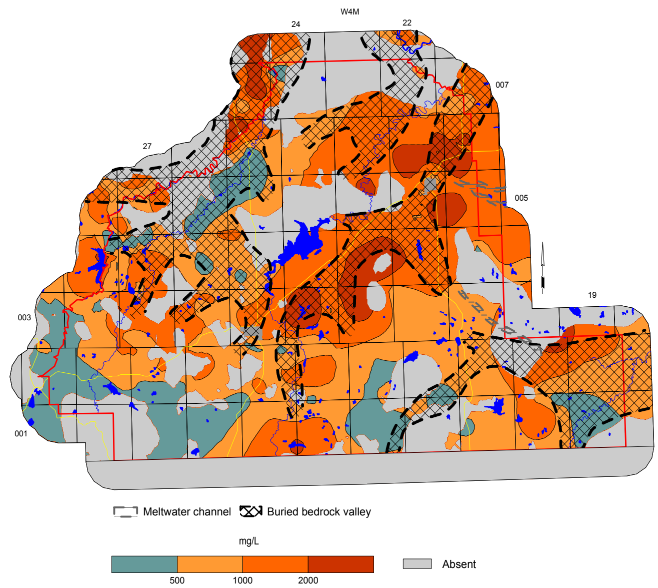



***Figure 14. Total Dissolved Solids in Groundwater from Surficial Deposits***

The Piper tri-linear diagram[18] for surficial deposits (page A-28) shows that the groundwaters have no dominant cation or anion. Seventy-five percent of the groundwaters from the surficial deposits have a TDS concentration of more than 500 mg/L. Groundwaters having TDS concentrations of less than 500 mg/L occur mainly along parts of the Belly River and the Milk River, and in association with the Disturbed Belt. Sixty-one percent of the groundwaters from the surficial deposits are reported to have dissolved iron concentrations of less than or equal to the aesthetic objective (AO) of 0.3 mg/L. However, many iron analysis results are questionable due to varying sampling and analytical methodologies.

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 more than 90% of the samples analyzed for surficial deposits in the County, the chloride ion concentration is less than 50 mg/L (see CD-ROM).

| Constituent | No. of Analyses | Range for County in mg/L Minimum | Maximum | Median | Recommended Maximum Concentration SGCDWQ |
|---|---|---|---|---|---|
| Total Dissolved Solids | 486 | 120 | 5,526 | 878 | 500 |
| Sodium | 344 | 0 | 990 | 121 | 200 |
| Sulfate | 486 | 0 | 3,500 | 250 | 500 |
| Chloride | 473 | 0 | 360 | 9 | 250 |
| Nitrate + Nitrite (as N) | 267 | 0 | 116 | 0.0 | 10 |

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

***Table 4. Concentrations of Constituents in Groundwaters from Surficial Deposits***

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 32 of the 267 groundwater samples analyzed (up to about 1986).

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

[18] 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 over large areas but are expected over approximately 15% 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 the depth to the top of the lower surficial deposits when present. In the County, the thickness of the Upper Sand and Gravel Aquifer is generally less than five metres, but can be more than five metres in association with the Disturbed Belt in the southwestern part of the County.

#### *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 long-term yields of the water wells are expected to be less than the apparent yields. The long-term yields for water wells completed through this Aquifer are expected to be mainly less than those shown on the adjacent figure.

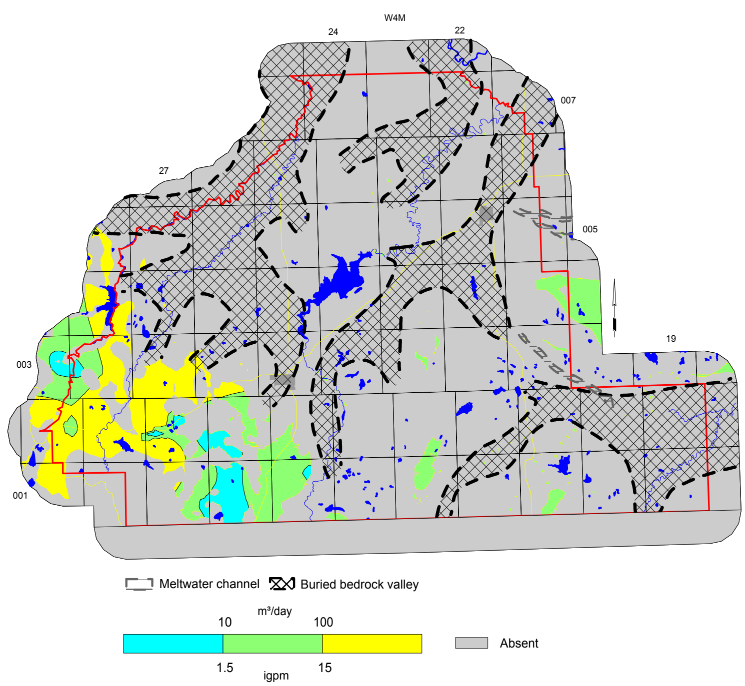



**_Figure 15. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer_**

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 twenty-one authorized non-exempt water wells that are completed through the Upper Sand and Gravel Aquifer, for a total authorized diversion of 43 $m^3$/day (Table 1, page 6). Twenty of the twenty-one non-exempt authorizations are for registrations for traditional agriculture use under the *Water Act*. Six of the twenty-one authorized non-exempt 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, including 22 in the County that are provided by Moran (1986) and Shetsen (1991).

#### *5.2.4.1 Aquifer Thickness*

The thickness of the Lower Sand and Gravel deposits is mainly less than five metres, but can be up to ten metres in the buried bedrock valleys (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. The most notable areas where yields of more than 100 m³/day are expected are mainly in association with the Buried Stand Off Valley. In the County, the highest yielding water wells are completed in the Lower Sand and Gravel Aquifer, which tends to support a large proportion of the high consumption authorized non-exempt water wells.

In the County, there are 78 non-exempt authorizations for water wells that are completed through the Lower Sand and Gravel Aquifer, for a total authorized diversion of 26,940 m³/day, of which 96% is used for dewatering and fishery purposes.

Twenty-nine of the 78 authorized non-exempt water wells completed through the Lower Sand and Gravel Aquifer could be linked to a water well in the AENV groundwater database.

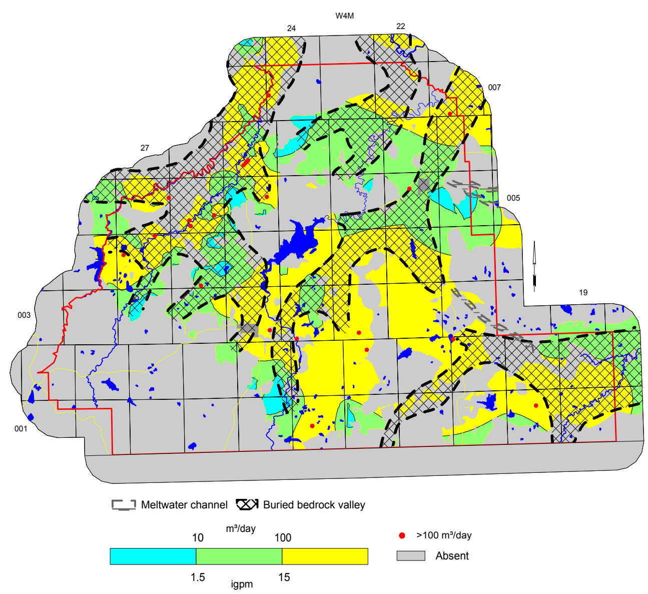



***Figure 16. Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer***

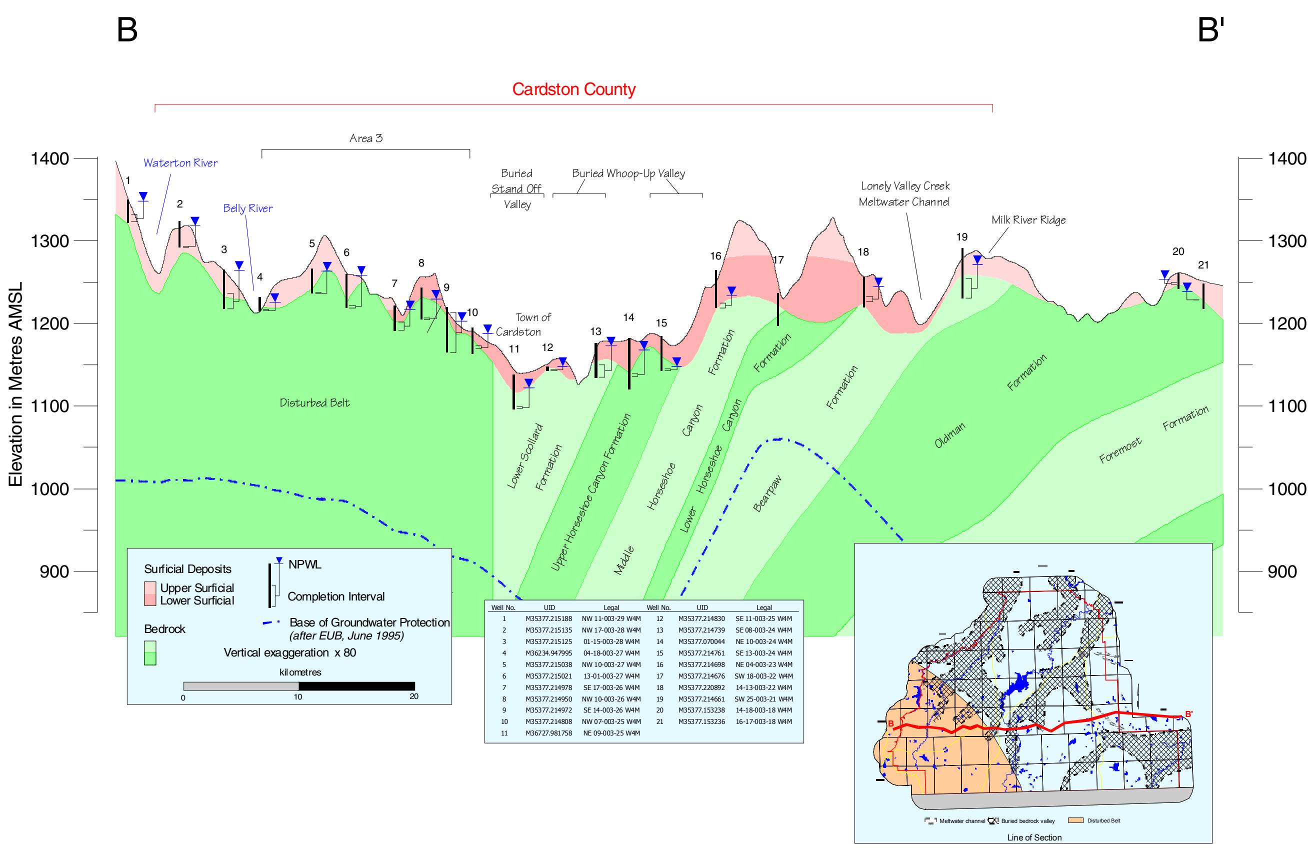
A groundwater study conducted for the Town of Cardston indicated a water supply well in 09-09-003-25 W4M, and completed in the Lower Sand and Gravel Aquifer in association with the Buried Cardston Valley, had a safe yield of 160 m³/day (HCL, July 1975). The Town of Cardston is currently licensed to divert 111 m³/day from a water supply well completed in the Lower Sand and Gravel Aquifer in 12-05-003-25 W4M.

A preliminary groundwater study was conducted for the Blood First Nation lands in 1997 with the existing St. Paul School Water Supply Well (Dash, November 1997). The St. Paul School WSW in NW 22-003-25 W4M is completed in the Lower Sand and Gravel Aquifer in association with the Buried Cardston Aquifer. The St. Paul WSW is used to divert groundwater to a pipeline, at a maximum pumping rate of 58 m³/day, which supplies the St. Paul School. The Blood First Nation wanted to determine if the groundwater diversion rate from the St. Paul School WSW could be increased to 190 m³/day in order to supply groundwater to a proposed rural pipeline. An extended aquifer test consisting of pumping the St. Paul School WSW for seven days at a rate of 1,020 lpm and a two-hour recovery period (at the request of the Blood First Nation) indicated a maximum long-term yield may be in the order of 525 m³/day; however, PFRA strongly recommended that the Blood First Nation initiate a conscientious groundwater monitoring program in order to determine the impact the increased groundwater diversion may have in the Lower Sand and Gravel Aquifer. Unfortunately, if a groundwater monitoring program was ever initiated, the monitoring data have not been made available to AAFC-PFRA.

## 5.3 Bedrock

### 5.3.1 Bedrock Aquifers

The upper bedrock includes formations that are less than 200 metres below the bedrock surface. In the County, the upper bedrock includes the Disturbed Belt, parts of the Paskapoo Formation, the Edmonton Group, the Bearpaw Formation, and the Belly River Group[19] as shown below on cross-section B-B' (see page A-13). 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[20] and water well screens are a necessity.




| Well No. | UID | Legal | Well No. | UID | Legal |
|---|---|---|---|---|---|
| 1 | M35377.215188 | NW 11-003-29 W4M | 12 | M35377.214830 | SE 11-003-25 W4M |
| 2 | M35377.215135 | NW 17-003-28 W4M | 13 | M35377.214739 | SE 08-003-24 W4M |
| 3 | M35377.215125 | 01-15-003-28 W4M | 14 | M35377.070044 | NE 10-003-24 W4M |
| 4 | M36234.947995 | 04-18-003-27 W4M | 15 | M35377.214761 | SE 13-003-24 W4M |
| 5 | M35377.215038 | NW 10-003-27 W4M | 16 | M35377.214698 | NE 04-003-23 W4M |
| 6 | M35377.215021 | 13-01-003-27 W4M | 17 | M35377.214676 | SW 18-003-22 W4M |
| 7 | M35377.214978 | SE 17-003-26 W4M | 18 | M35377.220892 | 14-13-003-22 W4M |
| 8 | M35377.214950 | NW 10-003-26 W4M | 19 | M35377.214661 | SW 25-003-21 W4M |
| 9 | M35377.214972 | SE 14-003-26 W4M | 20 | M35377.153238 | 14-18-003-18 W4M |
| 10 | M35377.214808 | NW 07-003-25 W4M | 21 | M35377.153236 | 16-17-003-18 W4M |
| 11 | M36727.981758 | NE 09-003-25 W4M | | | |

***Figure 17. Cross-Section B - B'***

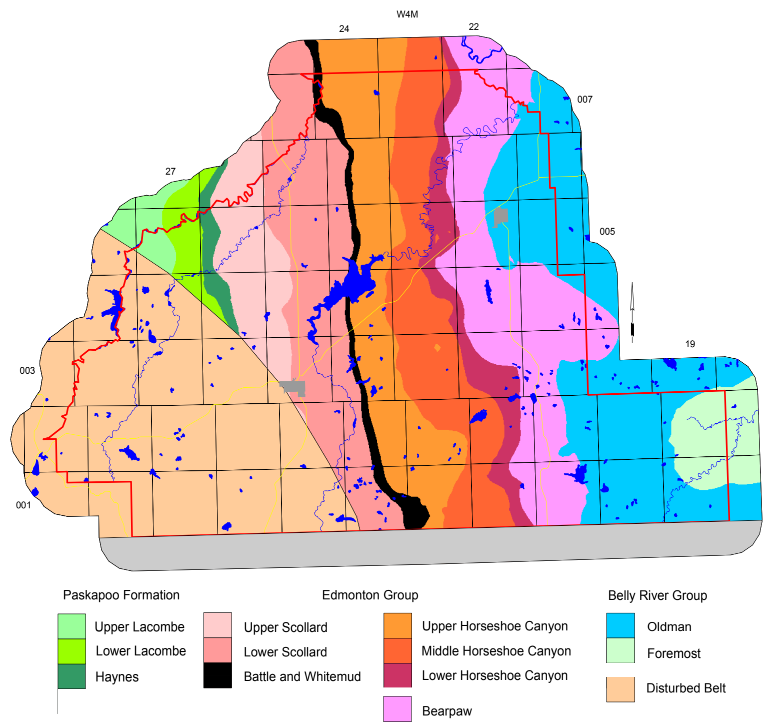
In the County, the Base of Groundwater Protection passes through parts of all the bedrock formations. A map showing the depth to the Base of Groundwater Protection is given on page 7 of this report, in Appendix A, and on the CD-ROM.

[19] The Scollard Formation is equivalent to the Willow Creek Formation, the Upper Horseshoe Canyon Formation is equivalent to the Upper St. Mary River Formation, the Middle Horseshoe Canyon Formation is equivalent to the Lower St. Mary River Formation, and the Lower Horseshoe Canyon Formation is equivalent to the Blood Reserve Formation.

[20] See glossary

### 5.3.2 Geological Characteristics

The Disturbed Belt is the upper bedrock in the western part of the County. The outline of the Disturbed Belt has been defined based on the Geological Map of Alberta (Hamilton et al, 1999, and Green, 1972). The Rocky Mountains and Foothills together form the Disturbed Belt in an area that has been deformed by folding and thrust faulting (Tokarsky, 1974). Water wells that were located within the Disturbed Belt boundary were defined as being completed in aquifers within the surficial deposits or in the Disturbed Belt Aquifer.




(for equivalent geological names, see footnote 19 on page 23)

***Figure 18. Bedrock Geology***

The Paskapoo Formation in central Alberta consists of the Dalehurst, Lacombe and Haynes members (Demchuk and Hills, 1991). The Edmonton Group, the Bearpaw Formation and the Belly River Group underlie the Paskapoo Formation. The Edmonton Group includes the Scollard, Battle, Whitemud and Horseshoe Canyon formations. The Belly River Group includes the Oldman and Foremost formations. A generalized geologic column is illustrated in Figure 6, in Appendix A, and on the CD-ROM.

The Paskapoo Formation consists of cycles of thick, tabular sandstone, siltstone and mudstone layers (Glass, 1990). The maximum thickness of the Paskapoo Formation is generally less than 800 metres. In the County, the Dalehurst Member is not present.

The Lacombe Member subcrops in parts of townships 004 to 006, ranges 26 to 28, W4M. The maximum thickness of the Lacombe Member is generally less than 320 metres. The upper part of the Lacombe Member is mostly composed of shale interbedded with sandstone and has a maximum thickness of 170 metres. The lower part of the Lacombe Member is composed of sandstone and coal layers. In the middle of the lower part of the Lacombe Member there is a coal zone, which can be up to five metres thick. In the County, the Lower Lacombe Member has a maximum thickness of 150 metres.

The Haynes Member underlies the Lacombe Member and is composed mainly of sandstone with some siltstone, shale and coal. In other parts of Alberta, the Haynes Member has a maximum thickness of 100 metres; in the County, the Haynes Member has a maximum thickness of 50 metres.

The Scollard Formation underlies the Haynes Member, generally has a maximum thickness of 160 metres and has two separate designations: Upper and Lower. The Upper Scollard consists mainly of sandstone, siltstone, shale and coal seams or zones. The Lower Scollard is composed mainly of shale and sandstone. In the County, the Scollard Formation has a maximum thickness of 500 metres.

Beneath the Scollard Formation are two formations having a maximum thickness of 30 metres; the two are the Battle and Whitemud formations. The Battle Formation is composed mainly of claystone, tuff, shale and bentonite, and includes the Kneehills Member, a 2.5- to 30-cm thick tuff bed. The Whitemud Formation is composed mainly of shale, siltstone, sandstone and bentonite. The Battle and Whitemud formations are significant geologic markers, and were used in the preparation of various geological surfaces within the bedrock. Because of the ubiquitous nature of the bentonite in the Battle and Whitemud formations, there is very little significant permeability within these two formations.

The Horseshoe Canyon Formation is the lower part of the Edmonton Group and is the upper bedrock in the central parts of the County. The Horseshoe Canyon Formation has a maximum thickness of 500 metres and has three separate designations: Upper, Middle and Lower. The Upper Horseshoe Canyon, which can be up to 100 metres thick in other parts of Alberta, has a maximum thickness of 180 metres in Cardston County. The Middle Horseshoe Canyon, which can be up to 70 metres thick in other parts of Alberta, has an average thickness of 200 metres in the County. The Lower Horseshoe Canyon, which is up to 170 metres thick in other parts of Alberta, has an average thickness of 100 metres in the County.

The Horseshoe Canyon Formation consists of deltaic[21] and fluvial sandstone, siltstone and shale with interbedded coal seams, bentonite and thin nodular beds of limestone and ironstone. Because of the low-energy environment in which deposition occurred, the sandstones, when present, tend to be finer grained. The lower 60 to 70 metres and the upper 30 to 50 metres of the Horseshoe Canyon Formation can include coarser grained sandstone deposits.

The Bearpaw Formation underlies the Horseshoe Canyon Formation and is in the order of 200 metres thick within the County. The Bearpaw Formation consists of marine shale, siltstone and minor sandstone layers except in some areas where the thickness of the sandstone layers can be significant. The Bearpaw Formation "represents the final widespread marine unit in the Western Canada Foreland Basin" (Catuneanu et al, 1997).

The Belly River Group includes the Oldman and Foremost formations. The Oldman Formation is present as the upper bedrock in the southeastern part of the County, and is mainly less than 250 metres thick. The Oldman Formation is composed of continental deposits, sandstone, siltsone, 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 along the Milk River. The Foremost Formation is mainly less than 200 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.

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.

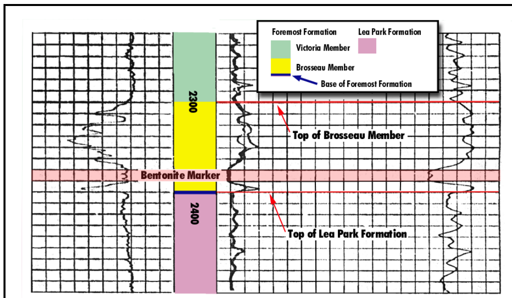



***Figure 19. E-Log showing Base of Foremost Formation***

[21] See glossary

There will be a limited review of the Lower Lacombe and Haynes members and the Foremost Formation in the text of this report because there are not sufficient hydrogeological data to create meaningful contour maps; the only maps associated with the Lower Lacombe and Haynes members and the Foremost Formation to be included on the CD-ROM will be structure-contour maps.

### 5.3.3 Upper Bedrock Completion Aquifer(s)

Of the 2,671 water wells in the database, 459 were defined as being completed below the top of bedrock, based on lithologic information and water well completion details. However, at least a reported completion depth is available for 1,394 water wells completed below the bedrock surface. Of these 1,394 water wells, eleven are completed below the upper bedrock, ten in saline formations and one in the Milk River Aquifer, giving a total of 1,383 water wells completed in upper bedrock aquifer(s). Assigning a water well to a specific geologic unit 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 the top of the completion interval was 80% of the total completed depth of a water well. With this assumption, it has been possible to designate the specific bedrock aquifer of completion for an additional 716 bedrock water wells, giving a total of 1,175 water wells. The remaining 208 of the total 1,383 bedrock water wells are identified as being completed in more than one bedrock aquifer as shown in Table 5. The bedrock water wells are mainly completed in the Disturbed Belt and the Lower Scollard aquifers.

| Geologic Unit | No. of Bedrock Water Wells |
|---|---|
| Disturbed Belt | 344 |
| Upper Lacombe | 9 |
| Lower Lacombe | 5 |
| Haynes | 6 |
| Upper Scollard | 61 |
| Lower Scollard | 194 |
| Upper Horseshoe Canyon | 124 |
| Middle Horseshoe Canyon | 98 |
| Lower Horseshoe Canyon | 28 |
| Bearpaw | 168 |
| Oldman | 136 |
| Foremost | 2 |
| Multiple Completions | 208 |
| Total | 1,383 |

***Table 5. Completion Aquifer for Upper Bedrock Water Wells***

There are 294 records for bedrock water wells that have apparent yield values, which is 21% of the 1,383 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. The areas where higher yields are expected may identify locations of increased permeability resulting from the weathering process. In addition to the 1,383 records for bedrock water wells, there are 201 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 201 dry water test holes prior to gridding. One hundred and twenty-nine (64%) of the 201 dry water test holes are within the Blood First Nation lands, of which 64 (50%) are completed in Lower Scollard Aquifer. In the County, 74 (37%) of the 201 dry water test holes are completed in the Upper and Lower Scollard aquifers.

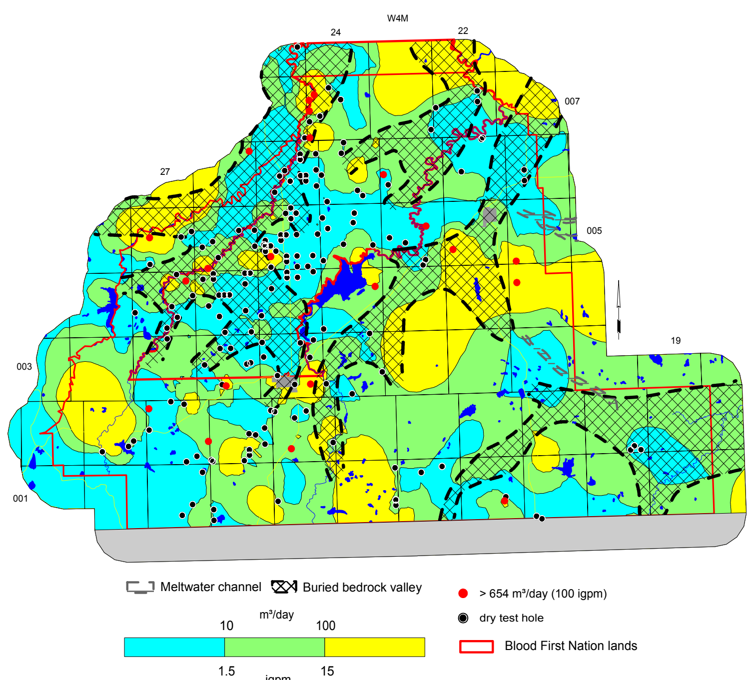



***Figure 20. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)***

Of the 294 water well records with apparent yield values, 244 have been assigned to aquifers associated with specific geologic units. Thirty-three percent (99) of the 297 water wells completed in bedrock aquifers have apparent yields that are less than ten m³/day, 44% (128) have apparent yield values that range from 10 to 100 m³/day, and 23% (67) have apparent yields that are greater than 100 m³/day, as shown in Table 6. The water well records having higher apparent yield values are expected to be in areas of increased permeability resulting from the weathering process.

| 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 |
|---|---|---|---|---|
| Disturbed Belt | 90 | 32 | 37 | 21 |
| Upper Lacombe | 3 | 2 | 0 | 1 |
| Lower Lacombe | 1 | 0 | 0 | 1 |
| Haynes | 0 | 0 | 0 | 0 |
| Upper Scollard | 14 | 5 | 5 | 4 |
| Lower Scollard | 40 | 13 | 19 | 8 |
| Upper Horseshoe Canyon | 24 | 7 | 11 | 6 |
| Middle Horseshoe Canyon | 20 | 9 | 7 | 4 |
| Lower Horseshoe Canyon | 5 | 1 | 2 | 2 |
| Bearpaw | 29 | 5 | 16 | 8 |
| Oldman | 17 | 3 | 12 | 2 |
| Foremost | 0 | 0 | 0 | 0 |
| Multiple Completions | 51 | 22 | 19 | 10 |
| Totals | 294 | 99 | 128 | 67 |

* - does not include dry test holes

***Table 6. Apparent Yields of Bedrock Aquifers***

### 5.3.4 Chemical Quality of Groundwater

The Piper tri-linear diagram for bedrock aquifers (page A-28) 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.

The TDS concentrations in the groundwaters from the upper bedrock aquifer(s) range from less than 500 mg/L to more than 2,000 mg/L, with the lower TDS values being in the Disturbed Belt Aquifer and the highest TDS values being in the central part of the County (page A-30). 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.

In the County, 95% of the chloride concentrations in the groundwaters from the upper bedrock aquifer(s) are less than 100 mg/L. Chloride concentrations of greater than 100 mg/L are mainly associated with groundwaters from the Oldman Aquifer.

The nitrate + nitrite (as N) concentrations are less than 1.0 mg/L in 75% of the chemical analyses and greater than 10.0 mg/L in eight percent for upper bedrock water wells. Eighty percent of the total hardness values in the groundwaters from the upper bedrock aquifer(s) are less than 200 mg/L.

In the County, approximately 35% 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 35% of the groundwater samples from the entire County are between 0.5 and 1.5 mg/L and approximately 30% exceed the maximum acceptable concentration for fluoride of 1.5 mg/L.

A comparison was made of fluoride concentrations in the groundwaters from water wells in the County completed in different aquifers in the upper bedrock. The comparison was made to determine if there was a relationship between fluoride concentrations and the aquifer of completion. In addition, the comparisons were extended to compare the trends established within the County to trends throughout Alberta. The comparisons are summarized below in Table 7.

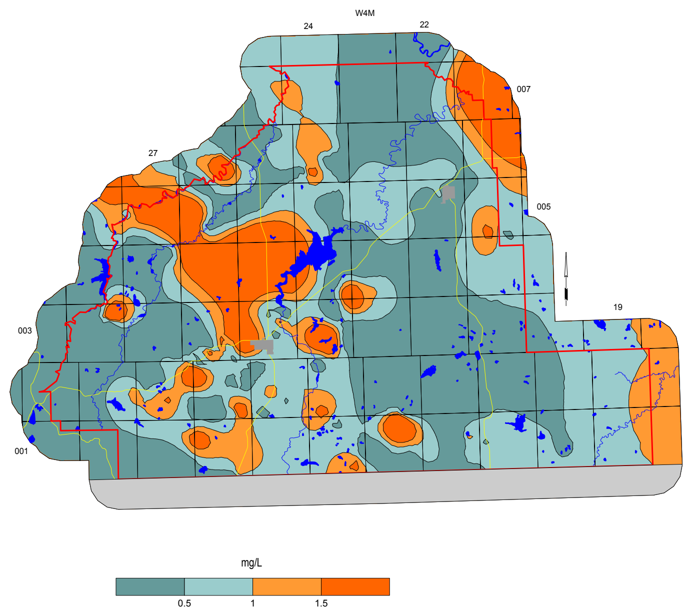



***Figure 21. Fluoride in Groundwater from Upper Bedrock Aquifer(s)***

Throughout Alberta, the median fluoride concentrations in groundwaters increase consistently in water wells completed in aquifers above the Upper Scollard Aquifer. In the County, there were insufficient data in the Lacombe and Haynes aquifers to determine if this trend would be replicated. In both the County and throughout Alberta, median fluoride concentrations decrease consistently in water wells completed below the Lower Scollard Aquifer, with the exception of the Oldman Aquifer. The percentages of analyses with fluoride concentrations of greater than 1.5 mg/L and greater than 2.5 mg/L exhibit a similar trend.

| | Fluoride | | | | Percentage of Analyses Greater than the SGCDWQ (1.5 mg/L) | | Percentage of Analyses Greater than 2.5 mg/L | |
|---|---|---|---|---|---|---|---|---|
| | No. of Analyses | | Median | | | | | |
| Aquifer Name | County | All Alberta | County | All Alberta | County | All Alberta | County | All Alberta |
| Disturbed Belt | 100 | 616 | 0.4 | 0.27 | 11.0 | 8.0 | 6.0 | 3.7 |
| Upper Lacombe | 3 | 1,171 | #N/A | 0.42 | #N/A | 19.7 | #N/A | 10.1 |
| Lower Lacombe | 0 | 1,100 | #N/A | 0.43 | #N/A | 22.5 | #N/A | 12.0 |
| Haynes | 1 | 717 | #N/A | 0.53 | #N/A | 22.7 | #N/A | 13.8 |
| Upper Scollard | 7 | 695 | 2.4 | 0.47 | 57.1 | 20.1 | 42.9 | 6.6 |
| Lower Scollard | 37 | 861 | 0.8 | 0.56 | 13.5 | 16.7 | 5.4 | 3.1 |
| Upper Horseshoe Canyon | 37 | 4,546 | 0.8 | 0.65 | 13.5 | 24.4 | 13.5 | 6.0 |
| Middle Horseshoe Canyon | 22 | 2,179 | 0.6 | 0.50 | 4.5 | 16.0 | 4.5 | 2.2 |
| Lower Horseshoe Canyon | 6 | 6,350 | 0.5 | 0.43 | 0.0 | 7.0 | 0 | 0.8 |
| Bearpaw | 30 | 2,683 | 0.4 | 0.42 | 0.0 | 4.6 | 0 | 0.4 |
| Oldman | 31 | 3,793 | 0.5 | 0.70 | 12.9 | 16.8 | 9.7 | 2.3 |

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#N/A - fewer than five analyses

***Table 7. Fluoride Concentrations in Groundwaters from Upper Bedrock Aquifer(s)***

### 5.3.5 Disturbed Belt Aquifer

The Disturbed Belt Aquifer comprises the permeable parts of the Disturbed Belt, as defined for the present program. Structure contours have not been prepared for the top and bottom of the Disturbed Belt, which is the bedrock in the extreme southwestern part of the County. The regional groundwater flow direction in the Disturbed Belt Aquifer is toward the Belly River (see CD-ROM).

#### *5.3.5.1 Depth to Top*

The depth to the top of the Disturbed Belt is mainly less than 50 metres and is a reflection of the thickness of the surficial deposits.

#### *5.3.5.2 Apparent Yield*

The apparent yields for individual water wells completed through the Disturbed Belt Aquifer are mainly in the range of 10 to 100 m³/day. Also shown on the adjacent map are the locations of the 43 dry water test holes. The areas showing water wells with yields of greater than 100 m³/day are mainly associated with the edge of the Disturbed Belt.

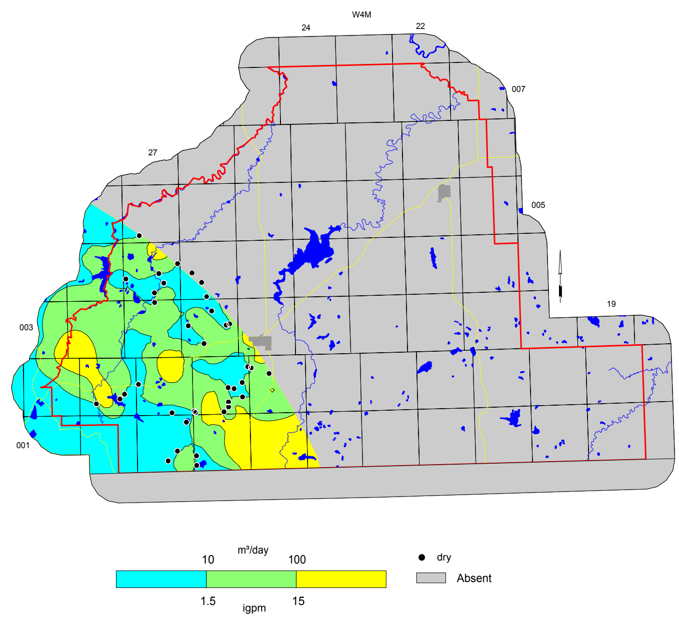


***Figure 22. Apparent Yield for Water Wells Completed through Disturbed Belt Aquifer***

There are 35 authorized non-exempt water wells completed through the Disturbed Belt Aquifer, for a total of 49 m³/day. Thirty-four have been for registrations and are expected to be used for stock and/or crop spraying purposes. Twenty of the 35 authorized non-exempt water wells could be linked to a water well in the AENV groundwater database.

#### *5.3.5.3 Quality*

The groundwaters from the Disturbed Belt Aquifer are mainly a sodium-bicarbonate-type (see Piper diagram on CD-ROM), with 65% of the groundwater samples having TDS concentrations of less than 1,000 mg/L (page A-33). The sulfate concentrations are mainly less than 500 mg/L. Chloride concentrations from the Disturbed Belt Aquifer are mainly less than 100 mg/L.

| Constituent | No. of Analyses | Range for County in mg/L Minimum | Maximum | Median | All Bedrock Median | Recommended Maximum Concentration SGCDWQ |
|---|---|---|---|---|---|---|
| Total Dissolved Solids | 133 | 4.2 | 4238 | 828 | 998 | 500 |
| Sodium | 109 | 3 | 820 | 214 | 265 | 200 |
| Sulfate | 132 | 0 | 2429 | 165 | 278 | 500 |
| Chloride | 133 | 0 | 175 | 7 | 10 | 250 |
| Fluoride | 100 | 0 | 4 | 0.4 | 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)
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***Table 8. Apparent Concentrations of Constituents in Groundwaters from Disturbed Belt Aquifer***

The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and fluoride in the groundwaters from water wells completed in the Disturbed Belt Aquifer in the County have been compared to the SGCDWQ and median concentrations from all upper bedrock aquifer(s) in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines in all upper bedrock aquifer(s) and the Disturbed Belt Aquifer. The median concentrations in the Aquifer are all below the median concentrations from water wells completed in all upper bedrock aquifer(s).

### 5.3.6 Upper Lacombe Aquifer (Paskapoo)

The Upper Lacombe Aquifer comprises the permeable parts of the Lower Lacombe Member, as defined for the present program. Structure contours have been prepared for the top of the Upper Lacombe Member. The structure contours show that the Upper Lacombe Member ranges in elevation from less than 1,070 to more than 1,130 metres AMSL and has a maximum thickness of 170 metres. The non-pumping water level in the Upper Lacombe Aquifer is downgradient to the northeast toward the Waterton River (see CD-ROM).

#### *5.3.6.1 Depth to Top*

The depth to the top of the Upper Lacombe Member is mainly less than 50 metres and is a reflection of the thickness of the surficial deposits (page A-34).

#### *5.3.6.2 Apparent Yield*

There are four available control points within the buffer area for individual water wells completed through the Upper Lacombe Aquifer, of which three values have an apparent yield of less than 100 m³/day.

In the County, there are no authorized non-exempt water wells completed through the Upper Lacombe.

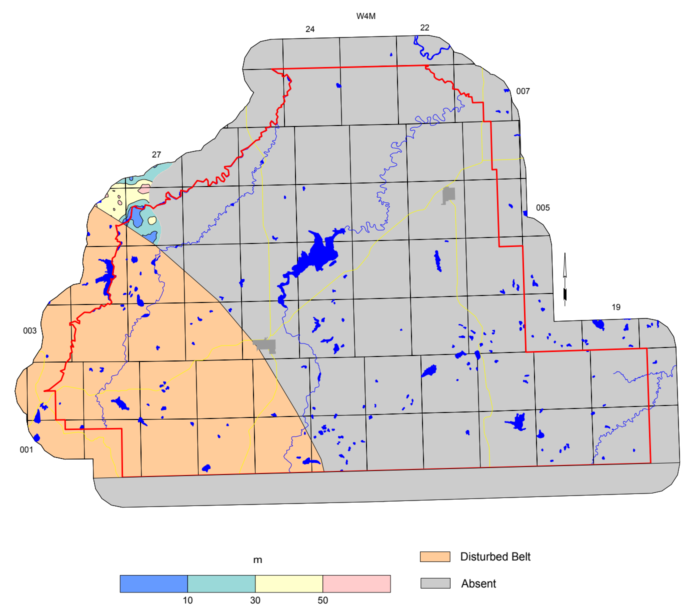


***Figure 23. Apparent Yield for Water Wells Completed through Upper Lacombe Aquifer***

#### *5.3.6.3 Quality*

There were sufficient data to determine the groundwater type for two water wells completed in the Upper Lacombe Aquifer. The data indicated that the groundwaters from the Upper Lacombe Aquifer are a bicarbonate type, with no dominant cation (see Piper diagram on CD-ROM).

The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and fluoride in the groundwaters from water wells completed in the Upper Lacombe Aquifer in the County have been compared to the SGCDWQ and median concentrations from all upper bedrock aquifer(s) in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines in all upper bedrock aquifer(s) and the Lower Lacombe Aquifer. The median concentrations of chloride and fluoride from water wells completed in the Upper Lacombe Aquifer are greater than the median concentrations from water wells completed in all upper bedrock aquifer(s).

| Constituent | No. of Analyses | Range for County in mg/L | | | All Bedrock Median | Recommended Maximum Concentration SGCDWQ |
|---|---|---|---|---|---|---|
| | | Minimum | Maximum | Median | | |
| Total Dissolved Solids | 4 | 564 | 1196 | 899 | 998 | 500 |
| Sodium | 3 | 91 | 269 | 225 | 265 | 200 |
| Sulfate | 4 | 96 | 253 | 118 | 278 | 500 |
| Chloride | 4 | 20 | 32 | 27 | 10 | 250 |
| Fluoride | 3 | 1 | 3 | 0.7 | 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)
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***Table 9. Apparent Concentrations of Constituents in Groundwaters from Upper Lacombe Aquifer***

### 5.3.7 Lower Lacombe Aquifer (Paskapoo)

The Lower Lacombe Aquifer comprises the permeable parts of the Lower Lacombe Member, as defined for the present program. Structure contours have been prepared for the top of the Lower Lacombe Member. The structure contours show that the Lower Lacombe Member ranges in elevation from less than 925 to more than 1,100 metres AMSL and has a maximum thickness of 150 metres.

#### *5.3.7.1 Depth to Top*

The depth to the top of the Lower Lacombe Member ranges from less than ten metres below ground level where the Member subcrops to more than 100 metres at the western edge of the County. The greatest depth is in areas where the Upper Lacombe Member is also present (page A-37).

#### *5.3.7.2 Apparent Yield*

There is only one available apparent yield value for a water well completed through the Lower Lacombe Aquifer (see Table 6 on page 27). In addition, there are two dry water test holes that were completed in the Lower Lacombe Aquifer.

There is one registered water well completed through the Lower Lacombe Aquifer that has been authorized to divert 0.2 m³/day. This water well is in SE 05-008-21 W4M and could be linked to a specific water well in the AENV groundwater database.

#### *5.3.7.3 Quality*

There are no chemistry values available for groundwater from water wells completed through the Lower Lacombe Aquifer. There is one dry water test hole that was completed in the Haynes Aquifer.

### 5.3.8 Haynes Aquifer (Paskapoo)

The Haynes Aquifer comprises the permeable parts of the Haynes Member, as defined for the present program. Structure contours have been prepared for the top of the Haynes Member. The structure contours show that the Haynes Member ranges in elevation from less than 825 to more than 1,100 metres AMSL and has a maximum thickness of 50 metres.

#### *5.3.8.1 Depth to Top*

The depth to the top of the Haynes Member ranges from less than 25 metres below ground surface at the eastern extent to more than 200 metres in the western part of the County (page A-38).

#### *5.3.8.2 Apparent Yield*

There are no apparent yield values available for water wells completed through the Haynes Aquifer.

There is one registered water well completed through the Haynes Aquifer that has been authorized to divert 4.0 m³/day. This water well is in NW 30-005-26 W4M and could not be linked to a specific water well in the AENV groundwater database.

#### *5.3.8.3 Quality*

There were sufficient data to determine the groundwater type for one water well completed through the Haynes Aquifer. The data indicated that the groundwater from the water well is a sodium-bicarbonate type.

### 5.3.9 Upper Scollard Aquifer (Upper Part of Willow Creek)

The Upper Scollard Aquifer comprises the permeable parts of the Upper Scollard Formation that underlie the Haynes Member, and subcrops under the surficial deposits in the western quarter of the County. Structure contours have been prepared for the top of the Formation. The structure contours show that the Upper Scollard Formation ranges in elevation from less than 785 to more than 1,160 metres AMSL and has a thickness of in the order of 240 metres. The non-pumping water level in the Upper Scollard Aquifer slopes north toward the Waterton and Belly rivers.

#### *5.3.9.1 Depth to Top*

The depth to the top of the Upper Scollard Formation ranges from less than ten metres below ground surface at the eastern extent to more than 250 metres in the western part of the County (page A-39).

#### *5.3.9.2 Apparent Yield*

Of the 201 dry water test holes completed in bedrock, 23 (11%) are completed in the Upper Scollard Aquifer. Without the inclusion of the 23 dry water test holes, there are equal percentages of apparent yield values in each contour interval (see Table 6 on page 27) for individual water wells completed through the Upper Scollard Aquifer. With the inclusion of the 23 dry water test holes shown on the adjacent map, the apparent yields for water wells completed in the Upper Scollard Aquifer are mainly less than ten m³/day.

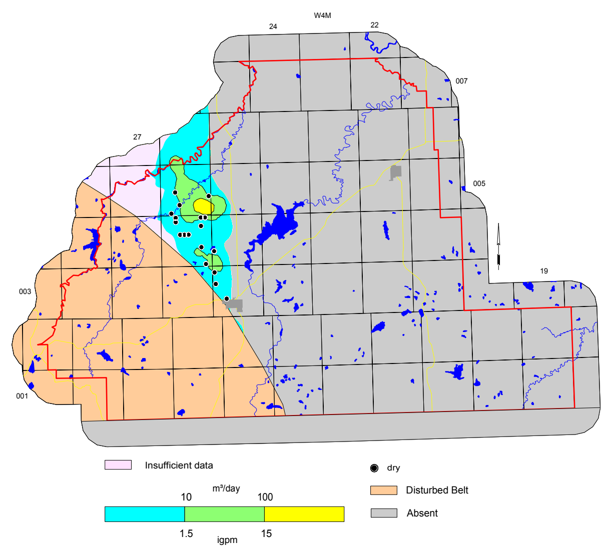


***Figure 24. Apparent Yield for Water Wells Completed through Upper Scollard Aquifer***

In the County, there are four non-exempt water wells completed in the Upper Scollard Aquifer, authorized to divert a total of 22.2 m³/day. Of the four water wells, three are licensed for municipal purposes and the fourth is a registration. Only one authorized non-exempt water well could be linked to a water well in the AENV groundwater database.

#### *5.3.9.3 Quality*

The groundwaters from the Upper Scollard Aquifer are mainly a bicarbonate type, with no dominant cation (see Piper diagram on CD-ROM). Total dissolved solids concentrations range mainly between 500 and 2,000 mg/L (page A-41), with more than 65% of the groundwater samples having TDS concentrations of greater than 500 mg/L. The TDS concentrations of less than 500 mg/L may be a result of more active flow systems and shorter flow paths. The sulfate concentrations are mainly less than 500 mg/L. All of the chloride concentrations from the water wells completed in the Upper Scollard Aquifer are less than 100 mg/L.

| Constituent | No. of Analyses | Range for County in mg/L | | | All Bedrock Median | Recommended Maximum Concentration SGCDWQ |
|---|---|---|---|---|---|---|
| | | Minimum | Maximum | Median | | |
| Total Dissolved Solids | 9 | 240 | 1677 | 729 | 998 | 500 |
| Sodium | 8 | 16 | 601 | 164 | 265 | 200 |
| Sulfate | 9 | 43 | 770 | 167 | 278 | 500 |
| Chloride | 9 | 2 | 35 | 7 | 10 | 250 |
| Fluoride | 7 | 0 | 4 | 2.4 | 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)
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***Table 10. Apparent Concentrations of Constituents in Groundwaters from Upper Scollard Aquifer***

Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and fluoride exceed the guidelines. Only the median concentrations of fluoride from water wells completed in the Upper Scollard Aquifer are greater than the median concentrations from water wells completed in all upper bedrock aquifer(s).

### 5.3.10 Lower Scollard Aquifer (Lower Part of Willow Creek)

The Lower Scollard Aquifer comprises the porous and permeable parts of the Lower Scollard Formation that underlie the Upper Scollard Formation, and subcrop under the surficial deposits mainly in the western third of the County. Structure contours have been prepared for the top of the Formation. The structure contours show that the Lower Scollard Formation ranges in elevation from less than 625 to more than 1,275 metres AMSL and has a maximum thickness of 275 metres. The non-pumping water level in the Lower Scollard Aquifer is downgradient to the northwest toward the Waterton, Belly and St. Mary rivers.

#### *5.3.10.1 Depth to Top*

The depth to the top of the Lower Scollard Formation ranges from less than ten metres below ground surface at the eastern extent to more than 500 metres in the western part of the County (page A-42).

#### *5.3.10.2 Apparent Yield*

The apparent yields for individual water wells completed through the Lower Scollard Aquifer range mainly from 10 to 100 m³/day, having a median apparent yield of 12.5 m³/day). Of the 201 dry water test holes completed in bedrock, 74 (38%) are completed in the Lower Scollard Aquifer.

In the County, there are 16 authorized non-exempt water wells that are completed in the Lower Scollard Aquifer, for a total authorized diversion of 49 m³/day. Four of the 16 authorized non-exempt water wells could be linked to a water well in the AENV groundwater database.

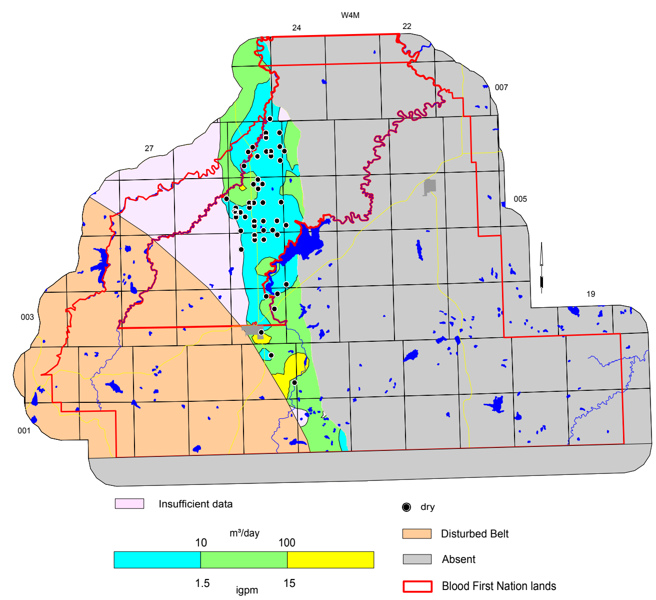


***Figure 25. Apparent Yield for Water Wells Completed through Lower Scollard Aquifer***

#### *5.3.10.3 Quality*

The groundwaters from the Lower Scollard Aquifer are mainly a bicarbonate-to-sulfate type, with sodium as the main cation (see Piper diagram on CD-ROM). Total dissolved solids concentrations are mainly less than 1,500 mg/L (page A-44), with more than 60% of the groundwater samples having TDS concentrations of greater than 1,000 mg/L. The sulfate concentrations are mainly less than 1,000 mg/L, with more than 73% of the groundwater samples having sulfate concentrations of less than 500 mg/L. More than 90% of the chloride concentrations from the Lower Scollard Aquifer are less than 50 mg/L.

| Constituent | No. of Analyses | Range for County in mg/L Minimum | Maximum | Median | All Bedrock Median | Recommended Maximum Concentration SGCDWQ |
|---|---|---|---|---|---|---|
| Total Dissolved Solids | 45 | 180 | 2433 | 1097 | 998 | 500 |
| Sodium | 37 | 14 | 740 | 308 | 265 | 200 |
| Sulfate | 45 | 10 | 1300 | 324 | 278 | 500 |
| Chloride | 42 | 0 | 88 | 14 | 10 | 250 |
| Fluoride | 34 | 0 | 3 | 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)
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***Table 11. Apparent Concentrations of Constituents in Groundwaters from Lower Scollard Aquifer***

Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines. The median concentrations of TDS, sodium, sulfate, chloride, and fluoride from water wells completed in the Lower Scollard Aquifer are greater than the median concentrations from water wells completed in all upper bedrock aquifer(s).

### 5.3.11 Upper Horseshoe Canyon Aquifer (Upper St. Mary River)

The Upper Horseshoe Canyon Aquifer comprises the permeable parts of the Upper Horseshoe Canyon Formation that underlie the Lower Scollard Formation. The Upper Horseshoe Canyon Formation subcrops under the surficial deposits in the western half of the County. Structure contours have been prepared for the top of the Formation. The structure contours show that the Upper Horseshoe Canyon Formation ranges in elevation from less than 925 to more than 1,250 metres AMSL and has a thickness of up to 180 metres. The non-pumping water level in the Upper Horseshoe Canyon Aquifer is downgradient to the north toward the Waterton, Belly and St. Mary rivers.

#### *5.3.11.1 Depth to Top*

The depth to the top of the Upper Horseshoe Canyon Formation is variable, ranging from less than ten metres at the eastern extent to more than 700 metres in the western part of the County (page A-45).

#### *5.3.11.2 Apparent Yield*

The apparent yields for individual water wells completed through the Upper Horseshoe Canyon Aquifer range mainly from 10 to 100 m³/day, and having a median apparent yield value of 19 m³/day. There are 25 (12%) dry water test holes completed in the Upper Horseshoe Canyon Aquifer.

In the County, there are 19 authorized non-exempt water wells completed in the Upper Horseshoe Canyon Aquifer, for a total authorized diversion of 127 m³/day; the highest single diversion of 44 m³/day is licensed for agricultural purposes. Four of the 19 authorized non-exempt water wells could be linked to a water well in the AENV groundwater database.

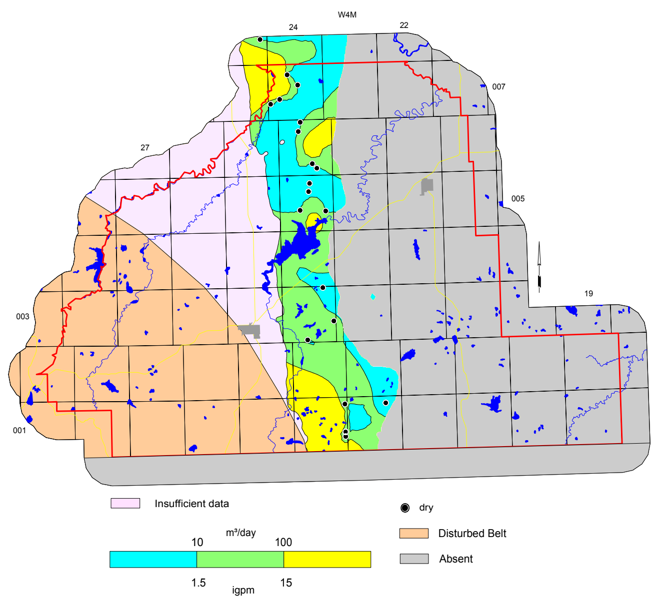


***Figure 26. Apparent Yield for Water Wells Completed through Upper Horseshoe Canyon Aquifer***

#### *5.3.11.3 Quality*

The groundwaters from the Upper Horseshoe Canyon Aquifer are mainly a bicarbonate-to-sulfate type, with sodium as the main cation (see Piper diagram on CD-ROM). Total dissolved solids concentrations range from less than 500 to more than 3,000 mg/L (page A-47), with more than 50% of the groundwater samples having TDS concentrations of greater than 1,000 mg/L. The sulfate concentrations range from less than 150 to more than 1,500 mg/L, with 47% of the groundwater samples having sulfate concentrations of more than 500 mg/L. Of the 49 chloride analyses available for water wells completed in the Upper Horseshoe Canyon Aquifer, only one has a chloride concentration that exceeds 50 mg/L.

Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines. The median concentrations of TDS, sulfate, chloride and fluoride from water wells completed in the Upper Horseshoe Canyon Aquifer are greater than the median concentrations from water wells completed in all upper bedrock aquifer(s).

| Constituent | No. of Analyses | Range for County in mg/L Minimum | Maximum | Median | All Bedrock Median | Recommended Maximum Concentration SGCDWQ |
|---|---|---|---|---|---|---|
| Total Dissolved Solids | 49 | 347 | 5066 | 1109 | 998 | 500 |
| Sodium | 35 | 1.3 | 1070 | 240 | 265 | 200 |
| Sulfate | 49 | 3 | 2859 | 385 | 278 | 500 |
| Chloride | 49 | 0 | 56 | 11 | 10 | 250 |
| Fluoride | 37 | 0 | 5 | 0.5 | 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)
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***Table 12. Apparent Concentrations of Constituents in Groundwaters from Upper Horseshoe Canyon Aquifer***

### 5.3.12 Middle Horseshoe Canyon Aquifer (Lower St. Mary River)

The Middle Horseshoe Canyon Aquifer comprises the permeable parts of the Middle Horseshoe Formation that underlie the Upper Horseshoe Canyon Formation, and subcrop under the surficial deposits. Structure contours have been prepared for the top of the Formation, which underlies the western half of the County. The structure contours show that the Middle Horseshoe Canyon Formation ranges in elevation from less than 200 to more than 1,300 metres AMSL and has a maximum thickness of 200 metres. The non-pumping water level in the Middle Horseshoe Canyon Aquifer is downgradient to the north toward the Waterton, Belly and St. Mary rivers.

#### *5.3.12.1 Depth to Top*

The depth to the top of the Middle Horseshoe Canyon Formation is variable, ranging from less than ten metres at the eastern extent to more than 900 metres in the western part of the County (page A-48).

#### *5.3.12.2 Apparent Yield*

The apparent yields for individual water wells completed through the Middle Horseshoe Canyon Aquifer range mainly from 10 to 100 m³/day, with 57% of the values being greater than ten m³/day. There are four (2%) dry water test holes completed in the Middle Horseshoe Canyon Aquifer.

In the County, there are 20 authorized non-exempt water wells completed in the Middle Horseshoe Canyon Aquifer, for a total authorized diversion of 277 m³/day; the highest single diversion of 115 m³/day is for a water supply well in 01-01-004-24 W4M used for agricultural purposes. Five of the 20 authorized non-exempt water wells could be linked to a water well in the AENV groundwater database.

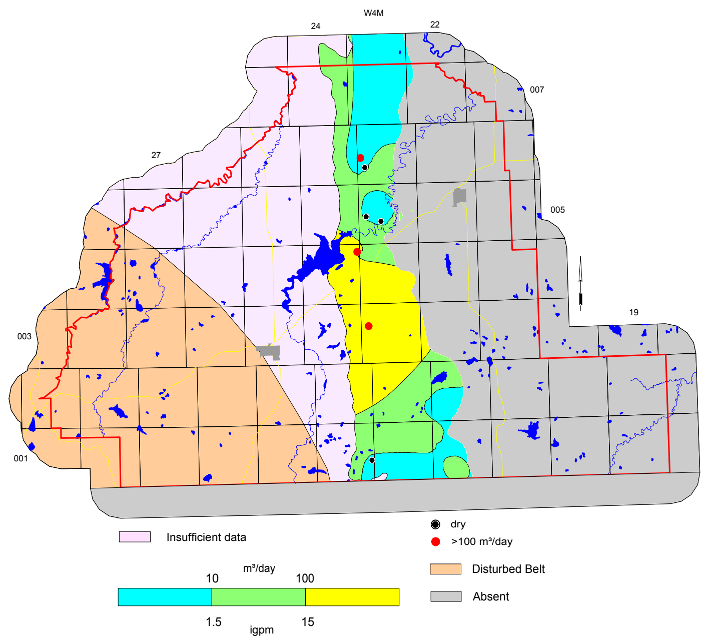


***Figure 27. Apparent Yield for Water Wells Completed through Middle Horseshoe Canyon Aquifer***

#### *5.3.12.3 Quality*

The groundwaters from the Middle Horseshoe Canyon Aquifer are mainly a sodium-bicarbonate or sulfate type (see Piper diagram on CD-ROM). Total dissolved solids concentrations range mainly between 500 and 2,000 mg/L, with only two values of TDS being less than 500 mg/L (page A-50). The sulfate concentrations are mainly less than 500 mg/L. Of the 27 chloride analyses available for the water wells completed in the Middle Horseshoe Canyon Aquifer, 26 have chloride concentrations of less than 50 mg/L.

| Constituent | No. of Analyses | Range for County in mg/L Minimum | Maximum | Median | All Bedrock Median | Maximum Concentration SGCDWQ |
|---|---|---|---|---|---|---|
| Total Dissolved Solids | 27 | 392 | 3830 | 1152 | 998 | 500 |
| Sodium | 19 | 101 | 623 | 290 | 265 | 200 |
| Sulfate | 27 | 54 | 2330 | 490 | 278 | 500 |
| Chloride | 27 | 4 | 78 | 9 | 10 | 250 |
| Fluoride | 21 | 0 | 4 | 0.3 | 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)

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***Table 13. Apparent Concentrations of Constituents in Groundwaters from Middle Horseshoe Canyon Aquifer***

Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines. The median concentrations of TDS, sodium and sulfate from water wells completed in the Middle Horseshoe Canyon Aquifer are greater than the median concentrations from water wells completed in all upper bedrock aquifer(s).

#### 5.3.13 Lower Horseshoe Canyon Aquifer (Blood Reserve)

The Lower Horseshoe Canyon Aquifer comprises the permeable parts of the Lower Horseshoe Canyon Formation that underlie the Middle Horseshoe Canyon Formation, and subcrop under the surficial deposits. Structure contours have been prepared for the top of the Formation. The structure contours show that the Lower Horseshoe Canyon Formation ranges in elevation from below 0 to more than 1,300 metres AMSL and has an average thickness of 100 metres. The non-pumping water level in the Lower Horseshoe Canyon Aquifer is downgradient to the north toward the Oldman River.

##### *5.3.13.1 Depth to Top*

The depth to the top of the Lower Horseshoe Canyon Formation is variable, ranging from less than ten metres at the eastern extent, to more than 1,100 metres in the western part of the County (page A-51).

##### *5.3.13.2 Apparent Yield*

The apparent yields for individual water wells completed through the Lower Horseshoe Canyon Aquifer range mainly from 10 to 100 m³/day, with four of the five water wells having an apparent yield value of more than ten m³/day. There are no dry water test holes completed in the Lower Horseshoe Canyon Aquifer.

In the County, there are nine authorized non-exempt water wells completed in the Lower Horseshoe Canyon Aquifer, for a total of 88 m³/day; the highest single diversion of 64 m³/day is for a water supply well in 14-23-005-23 W4M used for agricultural purposes. One of the nine authorized non-exempt water wells could be linked to a water well in the AENV groundwater database.

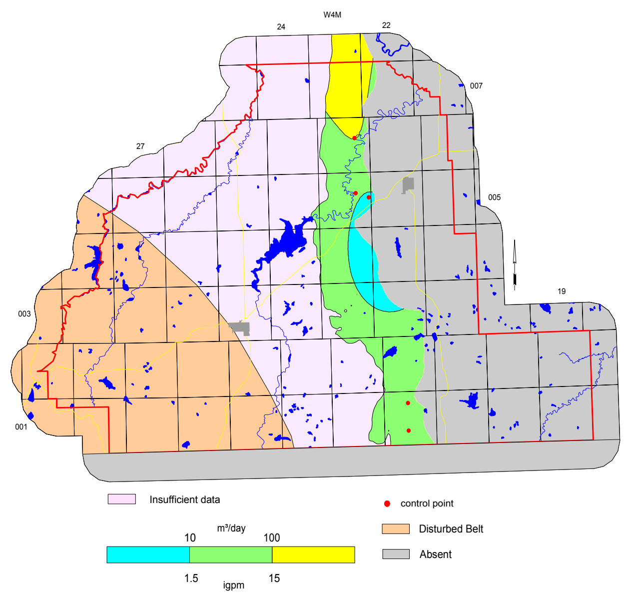


***Figure 28. Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer***

##### *5.3.13.3 Quality*

The groundwaters from the Lower Horseshoe Canyon Aquifer are mainly a sodium-bicarbonate or sulfate type (see Piper diagram on CD-ROM). Total dissolved solids concentrations are mainly greater 500 mg/L (page A-53), with only one TDS concentration being less than 500 mg/L. The sulfate concentrations are mainly less that 500 mg/L. Only one of the nine chloride values is greater than ten mg/L.

| Constituent | No. of Analyses | Range for County in mg/L Minimum | Maximum | Median | All Bedrock Median | Recommended Maximum Concentration SGCDWQ |
|---|---|---|---|---|---|---|
| Total Dissolved Solids | 9 | 446 | 1575 | 965 | 998 | 500 |
| Sodium | 5 | 65 | 449 | 202 | 265 | 200 |
| Sulfate | 9 | 88 | 806 | 413 | 278 | 500 |
| Chloride | 9 | 3.0 | 33 | 6.0 | 10 | 250 |
| Fluoride | 6 | 0.1 | 1.1 | 0.5 | 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)
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***Table 14. Apparent Concentrations of Constituents in Groundwaters from Lower Horseshoe Canyon Aquifer***

Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines. The median concentrations of TDS, sulfate and fluoride from water wells completed in the Lower Horseshoe Canyon Aquifer are greater than the median concentrations from water wells completed in all upper bedrock aquifer(s).

### 5.3.14 Bearpaw Aquifer

The Bearpaw Aquifer comprises the permeable parts of the Bearpaw Formation that underlie the Lower Horseshoe Canyon Formation, and subcrops under the surficial deposits in most of the County. Structure contours have been prepared for the top of the Formation. The structure contours show that the Bearpaw Formation ranges in elevation from below -100 to more than 1,300 metres AMSL and has an average thickness of 200 metres. The non-pumping water level in the Bearpaw Aquifer is downgradient to the north toward the Oldman River.

#### *5.3.14.1 Depth to Top*

The depth to the top of the Bearpaw Formation is variable, ranging from less than ten metres at the eastern extent, to more than 1,100 metres in the western part of the County (page A-54).

#### *5.3.14.2 Apparent Yield*

The apparent yields for individual water wells completed through the Bearpaw Aquifer range mainly from 10 to 100 m³/day, with more than 80% of the values being greater than ten m³/day. There are five (2.5%) dry water test holes completed in the Bearpaw Aquifer.

In the County, there are 22 authorized non-exempt water wells completed in the Bearpaw Aquifer, for a total of 94 m³/day; the highest single diversion of 16 m³/day is for a water supply well in 13-21-004-21 W4M licensed to the Hutterian Rockport Colony for municipal purposes. Fifteen of the 22 authorized non-exempt water wells could be linked to a water well in the AENV groundwater database.

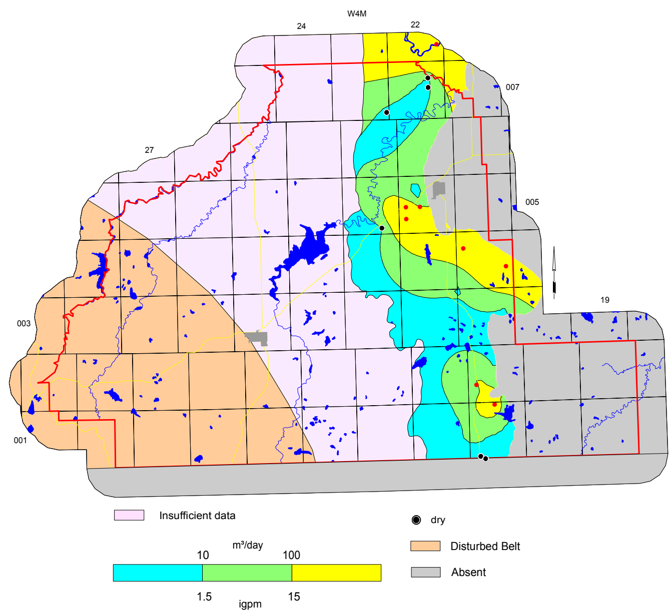


***Figure 29. Apparent Yield for Water Wells Completed through Bearpaw Aquifer***

#### *5.3.14.3 Quality*

The groundwaters from the Bearpaw Aquifer are mainly a sodium-bicarbonate or sulfate type (see Piper diagram on CD-ROM). Total dissolved solids concentrations range from less than 500 to more than 3,000 mg/L (page A-56), with 80% of the TDS concentrations being greater than 500 mg/L. The sulfate concentrations are mainly less than 500 mg/L. Ninety percent of the chloride concentrations from the Bearpaw Aquifer are less than 100 mg/L.

| Constituent | No. of Analyses | Range for County in mg/L Minimum | Maximum | Median | All Bedrock Median | Recommended Maximum Concentration SGCDWQ |
|---|---|---|---|---|---|---|
| Total Dissolved Solids | 48 | 277 | 7248 | 933 | 998 | 500 |
| Sodium | 35 | 33 | 704 | 223 | 265 | 200 |
| Sulfate | 50 | 7 | 4165 | 269 | 278 | 500 |
| Chloride | 50 | 0.0 | 89 | 7.9 | 10 | 250 |
| Fluoride | 30 | 0.1 | 1.3 | 0.4 | 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)
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***Table 15. Apparent Concentrations of Constituents in Groundwaters from Bearpaw Aquifer***

Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines. None of the mean values from water wells completed in the Bearpaw Aquifer are greater than the median concentrations from water wells completed in all upper bedrock aquifer(s).

#### 5.3.15 Oldman Aquifer

The Oldman Aquifer comprises the permeable parts of the Oldman Formation that underlie the Bearpaw Formation, and subcrop under the surficial deposits in most of the County. Structure contours have been prepared for the top of the Formation. The structure contours show that the Oldman Formation ranges in elevation from below -200 to more than 1,400 metres AMSL and has an average thickness of 250 metres. The non-pumping water level in the Oldman Aquifer is downgradient to the northwest toward the Oldman River and southeast toward the Milk River.

##### *5.3.15.1 Depth to Top*

The depth to the top of the Oldman Formation is variable, ranging from less than ten metres at the eastern extent, to more than 1,300 metres in the western part of the County (page A-57).

##### *5.3.15.2 Apparent Yield*

The apparent yields for individual water wells completed through the Oldman Aquifer range mainly from 10 to 100 m³/day, with more than 80% of the values being greater than ten m³/day. There are four (2%) dry water test holes completed in the Oldman Aquifer.

In the County, there are 12 authorized non-exempt water wells completed in the Oldman Aquifer, for a total of 26 m³/day; the highest single diversion of 6.9 m³/day is for a water supply well in NW 15-001-21 W4M authorized as a registration. Six of the eight authorized water wells could be linked to a water well in the AENV groundwater database.

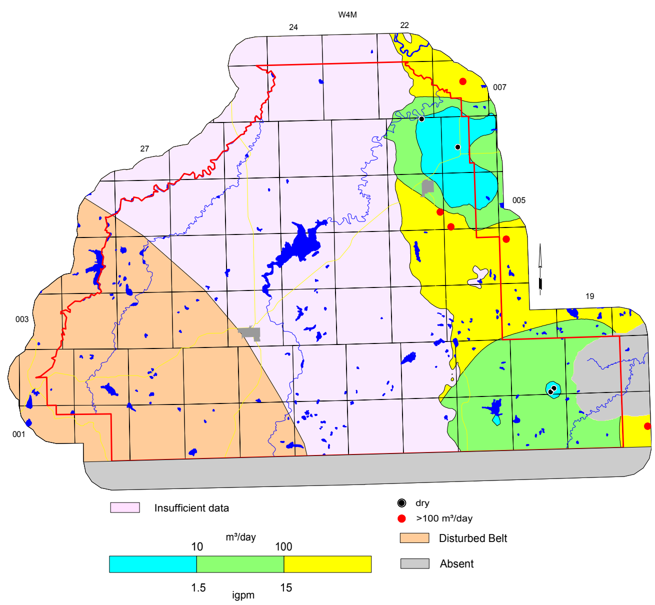


***Figure 30. Apparent Yield for Water Wells Completed through Oldman Aquifer***

##### *5.3.15.3 Quality*

The groundwaters from the Oldman Aquifer are mainly a sodium-bicarbonate or sulfate type (see Piper diagram on CD-ROM). Total dissolved solids concentrations range mainly from greater than 500 to less than 2,000 mg/L (page A-59), with only two TDS concentrations being less than 500 mg/L. The sulfate concentrations range mainly between 100 and 1,000 mg/L. Seventy-seven percent of the chloride concentrations from the Oldman Aquifer are less than 100 mg/L. The fluoride concentrations in the Oldman Aquifer are expected to be more than 1.5 mg/L where the depth to top of the Oldman Aquifer is mainly less than ten metres below ground surface.

| Constituent | No. of Analyses | Range for County in mg/L Minimum | Maximum | Median | All Bedrock Median | Recommended Maximum Concentration SGCDWQ |
|---|---|---|---|---|---|---|
| Total Dissolved Solids | 35 | 456 | 3320 | 1420 | 998 | 500 |
| Sodium | 32 | 154 | 1265 | 322 | 265 | 200 |
| Sulfate | 35 | 28 | 1785 | 522 | 278 | 500 |
| Chloride | 35 | 7.0 | 135 | 20.0 | 10 | 250 |
| Fluoride | 21 | 0.0 | 3.6 | 0.4 | 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)
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***Table 16. Apparent Concentrations of Constituents in Groundwaters from Oldman Aquifer***

Of the five constituents that have been compared to the SGCDWQ, the median values of TDS, sodium and sulfate exceed the guidelines. The median concentrations of TDS, sodium, sulfate and chloride from water wells completed in the Oldman Aquifer are greater than the median concentrations, and fluoride is equal to the median concentrations, from water wells completed in all upper bedrock aquifer(s).

### 5.3.16 Foremost Aquifer

The Foremost Aquifer comprises the permeable parts of the Foremost Formation, as defined for the present program. Structure contours have been prepared for the top of the Foremost Formation. The structure contours show that the Foremost Formation ranges in elevation from below -400 to more than 1,100 metres AMSL and is mainly less than 200 metres thick. The Foremost Formation is underlain by the Lea Park Formation, a regional aquitard.

#### *5.3.16.1 Depth to Top*

The depth to the top of the Foremost Formation ranges from less than ten metres below ground surface at the eastern extent to more than 1,500 metres in the western part of the County (page A-60).

#### *5.3.16.2 Apparent Yield*

There are no apparent yield values available for water wells completed through the Foremost Aquifer.

#### *5.3.16.3 Quality*

There are three values for TDS concentrations for water wells completed through the Foremost Aquifer. All three values are greater than 1,000 mg/L. The four values for sulfate for water wells completed through the Foremost Aquifer are less than 1,000 mg/L. The three values for chloride for water wells completed through the Foremost Aquifer are less than 50 mg/L.

# 6. Groundwater Budget

## 6.1 Hydrographs

In the County, there are two observation water wells that are part of the AENV regional groundwater-monitoring network. These are locations where water levels are being measured and recorded as a function of time: AENV Obs Water Well No. 105 in 13-19-004-27 W4M, approximately two kilometres east of the Waterton Reservoir and one kilometre southwest of Cochrane Lake, and AENV Obs WW No. 101 in 13-11-001-22 W4M, approximately four kilometres northeast of the Hamlet of Del Bonita. The water level in AENV Obs WW No. 105 was measured from April 27, 1965 to October 21, 1993, and the water level in AENV Obs WW No. 101 has been measured since June 19, 1985 (see page A-63).

AENV Obs WW No. 105 is drilled to a depth of 12.2 metres below ground surface and completed open hole in the upper part of the Lower Sand and Gravel Aquifer in association with the Buried Cochrane Valley. The upper part of the Buried Cochrane Valley consists primarily of silt and clay. AENV Obs WW No. 105 encountered only till from surface to its completed depth of 12.2 metres. This observation water well was drilled by the Groundwater Division of the Alberta Research Council (ARC) on October 23, 1964. The filling of the Waterton Reservoir began on March 18, 1965, and with the combined efforts of ARC and PFRA, a study was conducted in order to determine the effects that the reservoir would have on the Lower Sand and Gravel Aquifer in association with the Buried Cochrane Valley (Vanden Berg and Geiger, 1973). During 1964, as part of the study, the Alberta Research Council installed five piezometer nests, each nest consisting of a shallow water well and a deep water well, in order to observe any changes the Waterton Reservoir would have on the groundwater. All ten water wells were completed in the lower surficial deposits associated with the Lower Sand and Gravel Aquifer. AENV Obs WW No. 105, one of the shallow water wells, was completed to observe any changes on the depth of the water table. The deep water wells were completed at the base of the lower sand and gravel deposits in order to measure the hydraulic pressure in the Lower Sand and Gravel Aquifer in association with the Buried Cochrane Valley.

The Waterton Reservoir was initially filled from March 18, 1965 to June 18, 1965 and, during this period, the surface water level in the reservoir rose in the order of 40 metres. On March 18, 1965 when the Waterton Reservoir began to fill, there was a rapid rise in the groundwater levels in the five deep water wells, causing the water levels to flow in three of the deep water wells, creating a spring, and forcing up the surface casing of a farmer's water well until the groundwater flowed without control. It was determined that the lower sand and gravel deposits of the Lower Sand and Gravel Aquifer are hydraulically associated with the water level in the Waterton Reservoir. In order to prevent further farm water wells from flowing, PFRA installed a series of pressure-relief water wells.

The non-pumping water level in AENV Obs WW No. 105 on October 23, 1964 was 3.51 metres below ground surface as shown on the figure on the following page. The next water level measured in AENV Obs WW No. 105 was on April 27, 1965, approximately six weeks after the filling of the Waterton Reservoir began. Between October 23, 1964 and April 27, 1965, the water level in AENV Obs WW No. 105 rose 0.62 metres. On May 22, 1965, the last measured water level recorded prior to the completion of the filled reservoir was 2.89 metres below ground surface. The first measured water level following the filling of the reservoir was on June 17, 1965 and the measured water level rose to a depth of 2.08 metres below ground surface, a rise of 0.81 metres.

The water-level fluctuations in AENV Obs WW No. 105 from 1964 to 1970 have been compared to the monthly precipitation measured at the Cardston weather station. A six-year interval was chosen in order to make an easier visual comparison between the water-level fluctuation in AENV Obs WW No. 105 and the monthly precipitation recorded at the Cardston weather station. The change in precipitation would give an indication of changes that would be reflected in the water level in the Waterton Reservoir.

The water levels in water wells that do not flow follow the reservoir level closely and instantaneously (Vanden Berg and Geiger, 1973). This trend is shown on the adjacent figure. There is a reasonable relationship between the monthly precipitation recorded at the Cardston weather station and the water levels measured in AENV Obs WW No. 105.

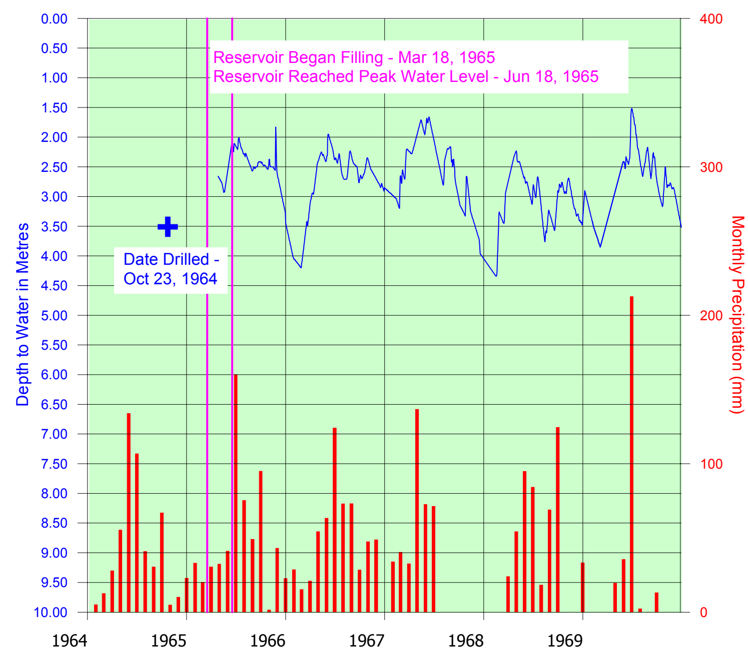


*Figure 31. Precipitation vs Water Levels in AENV Obs WW No. 105*

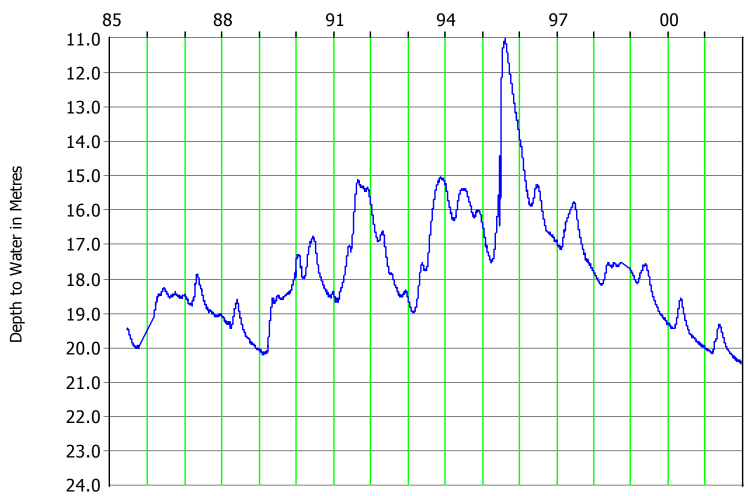


*Figure 32. Water-Level Measurements in AENV Obs WW No. 101*

AENV Obs WW No. 101 is completed open hole from 26.5 to 73.2 metres in the Lower Horseshoe Canyon and the Bearpaw aquifers.

The water level has been measured in AENV Obs WW No. 101 since mid-1985. The adjacent hydrograph shows annual cycles of recharge and decline throughout the year. In an area where there are no expected seasonal uses of groundwater, the highest water level will usually occur in late spring/early summer and the lowest water level will be in late winter/early spring. From 1986 to 1990, the highest water level in AENV Obs WW No. 101 generally occurs in late spring/early summer. The rise in water level in late spring/early summer could be associated with recharge when the frost leaves the ground. From 1991 to 1995, the highest water level in AENV Obs WW No. 101 occurs in late fall/early winter. The rise in water level late in the year could be associated with excess precipitation after most vegetation has been killed by frost and before the ground has frozen. From 1996 to the end of 2001, the highest water level occurs again in late spring/early summer and the lowest water level generally occurs in late winter/early spring. Overall annual fluctuations in AENV Obs WW No. 101 mainly range from two to four metres. In 1995, the water level rose from a low of 17.4 metres on April 14 to a high of 11.2 metres below ground surface on August 24. From 1985 to the end of 1995, there was a net rise in the water level of approximately nine metres, and from 1995 to the end of 2001, there has been a net decline in the water level of approximately 9.4 metres.

The water-level fluctuations in AENV Obs WW No. 101 have been compared to the precipitation measured at the Del Bonita weather station. Recorded precipitation is available from May 1985 to February 1990. From 1986 to 1990, there were no annual cycles of recharge in response to a decrease in precipitation. In 1989 and 1990, the rise in water level in late spring/early summer could be associated with recharge when the frost leaves the ground. From 1991 to 1996, the rise in water level late in the year could be associated with excess precipitation after most vegetation has been killed by frost and before the ground has frozen.

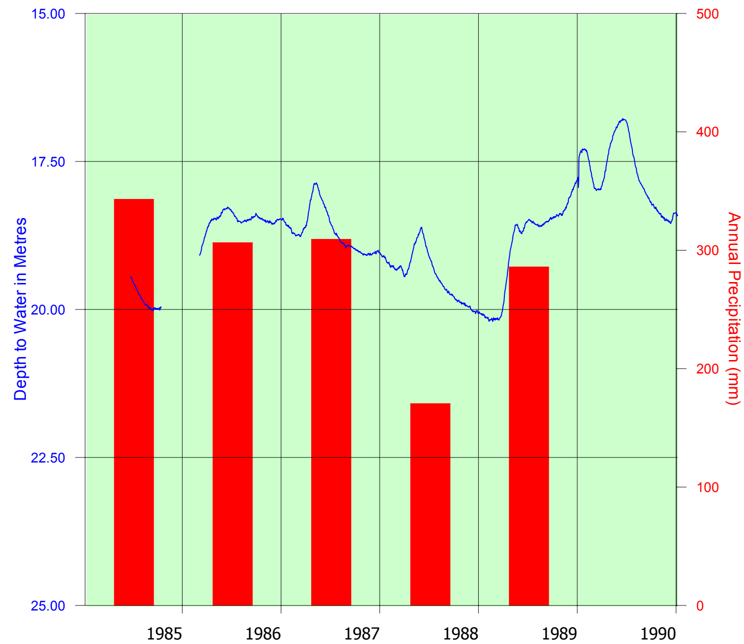


***Figure 33. Annual Groundwater Precipitation vs Water Levels in AENV Obs WW No. 101***

The closest authorized non-exempt water well to AENV Obs WW No. 101, completed in the Bearpaw Aquifer, is 1.3 kilometres east of AENV Obs WW No. 101 in NE 11-001-22 W4M and is authorized to divert 2.2 m³/day. Within a 5,000-metre radius of AENV Obs WW No. 101, there are eleven non-exempt groundwater users that are authorized to divert a total of 26.1 m³/day. Of these eleven authorized non-exempt water wells, five are completed in the Bearpaw Aquifer.

It does not appear that groundwater diversion from authorized non-exempt water wells within a 5,000-metre radius of AENV Obs WW No. 101 is having an effect on the water-level fluctuations in AENV Obs WW No. 101.

## 6.2 Estimated Groundwater Use in Cardston County

An estimate of the quantity of groundwater removed from each geologic unit in Cardston County must include both the authorized non-exempt and the exempt groundwater diversions. As stated previously on page 6 of this report, the daily water requirement for livestock for the County based on the 2001 census is estimated to be 10,207 cubic metres. As of January 2003, AENV has licensed the use of 10,857 m³/day for livestock, which includes both surface water (based on consumptive use) and groundwater. Based on these figures, it would appear that there would not be any livestock watering from exempt groundwater use.

In the groundwater database for the County, there are records for 2,264 water wells that are used for domestic (1,454), domestic/stock (563) and stock (247) purposes.

Groundwater for household use requires a non-exempt authorization if the use is more than 1,250 m³/year. Under the *Water Act*, a residence is protected for up to 3.4 m³/day. However, the standard groundwater use for household purposes (a family of four) is 1.1 m³/day. Since there are 2,017 domestic water wells in Cardston County serving a population of 4,565, the domestic use per water well is 0.6 m³/day. Because it does not statistically appear that there any authorized non-exempt stock users, 0.6 m³/day was also assigned for domestic/stock water wells, and no value was assigned for stock water wells. Because of the limitations of the data, no attempt has been made to compensate for dugouts, springs or inactive water wells.

Based on using 0.6 m³/day for all available domestic or domestic/stock water wells, and the authorized amount for all non-exempt water wells, an estimate of the groundwater use from each geologic unit was prepared as shown below in Table 17. The data provided in Table 17 indicate that most of the 1,210 m³/day, estimated to be diverted from domestic or domestic/stock water wells, is from aquifers in the surficial deposits or the Disturbed Belt Aquifer. The total estimated groundwater use is mainly from the Lower Sand and Gravel Aquifer.

| | ***Domestic and Domestic/Stock Diversions*** | | | | | ***Authorized Non-Exempt Groundwater Diversions*** | ***Total Groundwater Diversions*** |
|---|---|---|---|---|---|---|---|
| Aquifer Designation | Number of Domestic | Daily Use (0.6 m³/day) | Number of Domestic and Stock | Daily Use (0.6 m³/day) | Totals m³/day | Totals (m³/day) | Totals m³/day |
| Multiple Surficial Completions | 329 | 197 | 106 | 64 | 261 | 0 | 261 |
| Upper Sand/Gravel | 78 | 47 | 27 | 16 | 63 | 43 | 106 |
| Lower Sand/Gravel | 226 | 136 | 103 | 62 | 197 | 26,940 (1) | 27,127 |
| Multiple Bedrock Completions | 101 | 61 | 59 | 35 | 96 | 0 | 96 |
| Disturbed Belt | 184 | 110 | 65 | 39 | 149 | 49 | 208 |
| Upper Lacombe | 3 | 2 | 3 | 2 | 4 | 0 | 4 |
| Lower Lacombe | 2 | 1 | 2 | 1 | 2 | 0.6 | 3 |
| Haynes | 5 | 3 | 0 | 0 | 3 | 4 | 7 |
| Upper Scollard | 43 | 26 | 9 | 5 | 31 | 22 | 53 |
| Lower Scollard | 138 | 83 | 18 | 11 | 94 | 49 | 143 |
| Upper Horseshoe Canyon | 84 | 50 | 12 | 7 | 58 | 127 | 185 |
| Middle Horseshoe Canyon | 46 | 28 | 26 | 16 | 43 | 276 | 319 |
| Lower Horseshoe Canyon | 6 | 4 | 7 | 4 | 8 | 87 | 95 |
| Bearpaw | 46 | 28 | 58 | 35 | 62 | 95 | 157 |
| Oldman | 58 | 35 | 43 | 26 | 61 | 27 | 88 |
| Unknown | 105 | 63 | 25 | 15 | 78 | 24 | 102 |
| Totals (2) | 1,454 | 872 | 563 | 338 | 1,210 | 27,744 | 28,954 |

(1) 18,587 m³/day of the 26,940 m³/day is licensed for dewatering purposes

(2) The values given in the table have been rounded and, therefore, the columns and rows may not add up equally

***Table 17. Total Groundwater Diversions by Aquifer***

By assigning 0.6 m³/day for domestic use or domestic/stock use, and using the total maximum authorized diversion associated with any non-exempt water well, a map has been prepared that shows the estimated groundwater use in terms of volume per section per day for the County (not including springs).

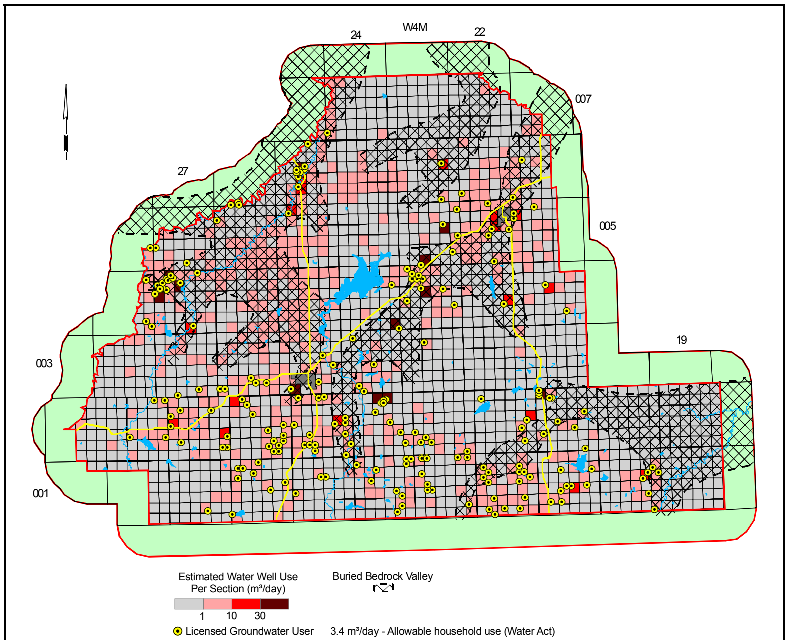


***Figure 34. Estimated Water Well Use Per Section***

There are 1,854 sections in the County. In 56% (1,043) of the sections in the County, there is no domestic, stock or authorized non-exempt groundwater user. The range in groundwater use for the remaining 811 sections is from 0.6 m³/day to nearly 22,000 m³/day (dewatering and fishery), with an average use per section of 16 m³/day (2.4 igpm). Without the inclusion of the dewatering wells in section 30, township 004, range 27, W4M, the average use per section is 3.8 m³/day (0.6 igpm). The estimated water well use per section can be more than 30 m³/day in 13 of the 811 sections. There are 49 of the total 265 authorized non-exempt groundwater users in areas of greater than 30 m³/day. The most notable areas where water well use of more than 30 m³/day is expected to occur is in the Buried Cochrane, Buried Cardston and Buried Whoop-Up valleys, as shown on Figure 34.

There are five dewatering water wells completed in the Lower Sand and Gravel Aquifer in section 30, township 004, range 27, W4M that are licensed by Alberta Environment to divert 14,800 m³/day. Rocky Mountain Broodstock Ltd. are licensed to divert 7,165 m³/day for fishery purposes from three water wells completed in the Lower Sand and Gravel Aquifer in 07-30-004-27 W4M. The combined authorized total of 21,965 m³/day from these eight water wells accounts for about 76% of the total groundwater use in the County.

| Groundwater Use within Cardston County (m³/day) | | % |
|---|---|---|
| Domestic/Stock (including agriculture and registrations) | 2,114 | 7 |
| Municipal (licensed) | 1,085 | 4 |
| Commercial/Dewatering/Fishery et al (licensed) | 25,755 | 89 |
| Total | 28,954 | 100 |

***Table 18. Total Groundwater Diversions***

In summary, the estimated total groundwater use within Cardston County is 28,954 m³/day, with the breakdown as shown in the adjacent table. An estimated 28,852 m³/day is being withdrawn from a specific aquifer. The remaining 102 m³/day or 11% is being withdrawn from unknown aquifer units. Approximately 96% of the total estimated groundwater use is from authorized non-exempt water wells. Of the 28,954 m³/day, 97% is being diverted from surficial aquifers and 3% from bedrock aquifers.

## 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 various parts of individual aquifers within the County.

The flow through each aquifer assumes that by taking a large enough area, an aquifer can be considered as homogeneous, the average gradient can be estimated from the non-pumping water-level surface, and flow takes place through the entire width of the aquifer; flow through the aquifers takes into consideration hydrogeological conditions outside the County border. Based on these assumptions, the estimated lateral groundwater flow through the individual aquifers has been summarized in Table 19.

Table 19 indicates that there is more groundwater flowing through the aquifers than has been authorized to be diverted from the individual aquifers, except for the Lower Sand and Gravel Aquifer. In some of the high-volume licensed water wells in the County (e.g. for dewatering or fisheries operations), it is suspected that the high groundwater use is a result of potential induced infiltration to the Lower Sand and Gravel Aquifer from the nearby rivers. However, even where use is less than the calculated aquifer flow, there can still be local impacts on water levels. The calculations of flow through individual aquifers as presented in the adjacent table are very approximate and are intended only as a guide; more detailed investigations are needed to better understand the groundwater flow.

| Aquifer/Area | Trans ($m^2$/day) | Gradient (m/m) | Width (m) | Flow ($m^3$/day) | Aquifer Flow ($m^3$/day) | Authorized Non-Exempt Diversion ($m^3$/day) | Exempted Diversion ($m^3$/day) | Total ($m^3$/day) |
|---|---|---|---|---|---|---|---|---|
| Upper Surficial | | | | | 10,100 | 43 | 0 | 43 |
| east | 15.3 | 0.0075 | 13,000 | 1492 | | | | |
| central - northeast | 15.3 | 0.0125 | 8,000 | 1530 | | | | |
| northwest | 15.3 | 0.0125 | 18,000 | 3443 | | | | |
| west - northeast | 15.3 | 0.0067 | 36,000 | 3672 | | | | |
| Lower Surficial | | | | | 3,700 | 26,940 | 0 | 26,940 |
| Stand Off | | | | | | | | |
| southwest to northeast | 37.6 | 0.0029 | 10,000 | 1074 | | | | |
| Whoop Up | | | | | | | | |
| south to north | 37.6 | 0.0034 | 6,000 | 769 | | | | |
| Whiskey | | | | | | | | |
| west to east | 37.6 | 0.0050 | 10,000 | 1880 | | | | |
| Upper Lacombe | | | | | 400 | 0 | 0 | 400 |
| *Northeast* | | | | | | | | |
| | 5.6 | 0.007 | 11,000 | 411 | | | | |
| Lower Lacombe | | | | | 400 | 0 | 0 | 0 |
| *Northern* | | | | | | | | |
| | 4.1 | 0.007 | 15,000 | 410 | | | | |
| Haynes | | | | | 1,000 | 4 | 0 | 4 |
| *Northern* | | | | | | | | |
| | 12.8 | 0.004 | 20,000 | 960 | | | | |
| Upper Scollard | | | | | 300 | 22 | 0 | 22 |
| *Northwest* | | | | | | | | |
| | 2.2 | 0.010 | 15,000 | 330 | | | | |
| Lower Scollard | | | | | 1,190 | 49 | 0 | 49 |
| *Northwest* | | | | | | | | |
| | 13 | 0.004 | 22,000 | 1192 | | | | |
| Upper Horseshoe Canyon | | | | | 430 | 127 | 0 | 127 |
| *Northwest* | | | | | | | | |
| | 5.4 | 0.004 | 20,000 | 432 | | | | |
| Middle Horseshoe Canyon | | | | | 750 | 276 | 0 | 276 |
| *Northwest* | | | | | | | | |
| | 5.5 | 0.005 | 30,000 | 750 | | | | |
| Lower Horseshoe Canyon | | | | | 1,380 | 87 | 0 | 87 |
| *Northwest* | | | | | | | | |
| | 8.3 | 0.006 | 30,000 | 1383 | | | | |
| Bearpaw | | | | | 1,120 | 95 | 0 | 95 |
| *Northwest* | | | | | | | | |
| | 7 | 0.004 | 40,000 | 1120 | | | | |
| Oldman | | | | | 3,380 | 27 | 0 | 27 |
| *Northwest* | | | | | | | | |
| | 8.8 | 0.008 | 50,000 | 3385 | | | | |
| Disturbed Belt | | | | | 3,700 | 49 | 0 | 49 |
| *South* | | | | | | | | |
| east | 7.8 | 0.008 | 13,000 | 811 | | | | |
| *West* | | | | | | | | |
| northeast | 7.8 | 0.008 | 16,000 | 998 | | | | |
| northwest | 7.8 | 0.011 | 8,000 | 672 | | | | |
| north-northeast | 7.8 | 0.012 | 13,000 | 1217 | | | | |

***Table 19. Groundwater Budget***

### 6.3.1 Quantity of Groundwater

An estimate of the volume of groundwater stored in the surficial deposits is 1.0 to 6.3 cubic kilometres. This volume is based on an areal extent of 4,150 square kilometres and a saturated thickness of five metres. The variation in the total volume is based on the value of porosity that is used for the surficial deposits. One estimate of porosity is 5%, which gives the low value of the total volume. The high estimate is based on a porosity of 30% (Ozoray, Dubord and Cowen, 1990).

The adjacent water-level map has been prepared from water levels associated with water wells completed to depths of less than 20 metres 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 flow direction north toward the Oldman River and southeast toward the Milk River.

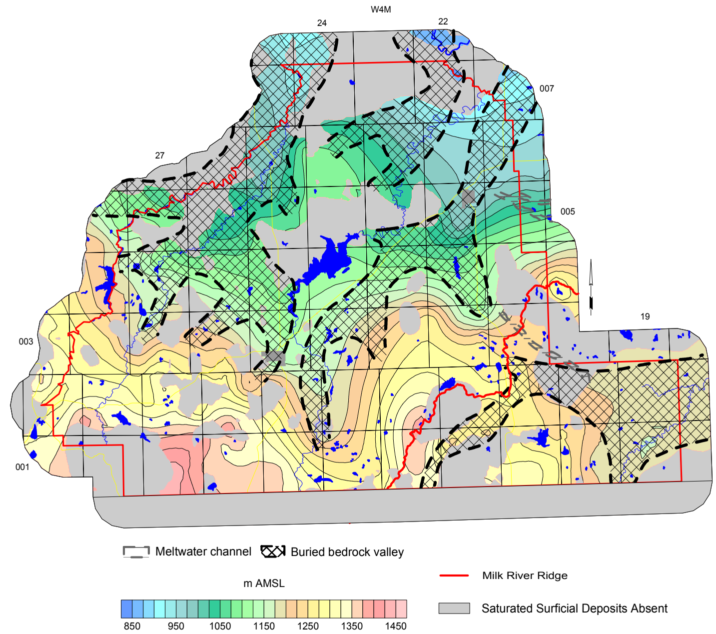


***Figure 35. Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep***

### 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 hydraulic unit. 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 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. 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.

In the absence of sufficient water-level data in the surficial deposits, a reasonable hydraulic gradient between the surficial deposits and the upper bedrock aquifer(s) could not be determined. Therefore, an alternative approach has been used to establish approximate recharge and discharge areas. The first objective was to determine the location of springs, flowing shot holes and any water wells that had a water level measurement depth of less than 0.1 metres. These locations would reflect where there is an upward hydraulic gradient from the bedrock to the surficial deposits (i. e. discharge). The depth to water level for water wells completed in the upper bedrock aquifer(s) has been determined by subtracting the non-pumping water-level surface associated with all water wells completed in the upper bedrock aquifer(s) from the bedrock surface. This resulting depth to water level grid was contoured to reflect the positioning of springs, flowing shot holes and flowing water wells (i. e. discharge). The recharge classification is used where the water level in the upper bedrock aquifer(s) is more than two metres below bedrock surface. The discharge areas are where the water level in the upper bedrock aquifer(s) is more than ten metres above the bedrock surface. When the depth to water level in the upper bedrock aquifer(s) is between two metres below and ten metres above the bedrock surface, the area is classified as a transition, that is, no recharge and no discharge.

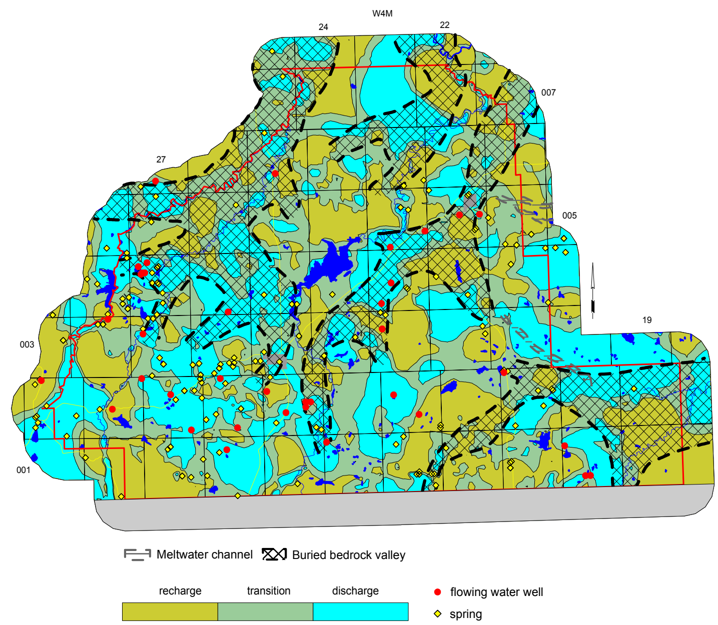


***Figure 36. Recharge/Discharge Areas in Upper Bedrock Aquifer(s)***

Figure 36 shows that, in more than 30% of the County, there is a downward hydraulic gradient from the bedrock surface toward the upper bedrock aquifer(s) (i. e. recharge). Areas where there is an upward hydraulic gradient from the bedrock to the bedrock surface (i. e. discharge) are mainly in the vicinity of creeks and river valleys and major meltwater channels. The remaining parts of the County are areas where there is a transition condition.

Because of the paucity of data, recharge/discharge maps for the individual bedrock aquifers have not been attempted.

With 30% of the County land area being one of recharge to the bedrock, and the average precipitation being 568 mm per year, one percent of the annual precipitation is sufficient to provide the total calculated quantity of groundwater flowing through the upper bedrock aquifer(s).

## 6.4 Areas of Groundwater Decline

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

The areas of groundwater decline in the sand and gravel aquifer(s) have been calculated by determining the frequency of non-pumping water level control points per five-year period. Of the 369 surficial water wells with a non-pumping water level and date in the County, 158 are from water wells completed before 1975 and 88 are from water wells completed after 1984.

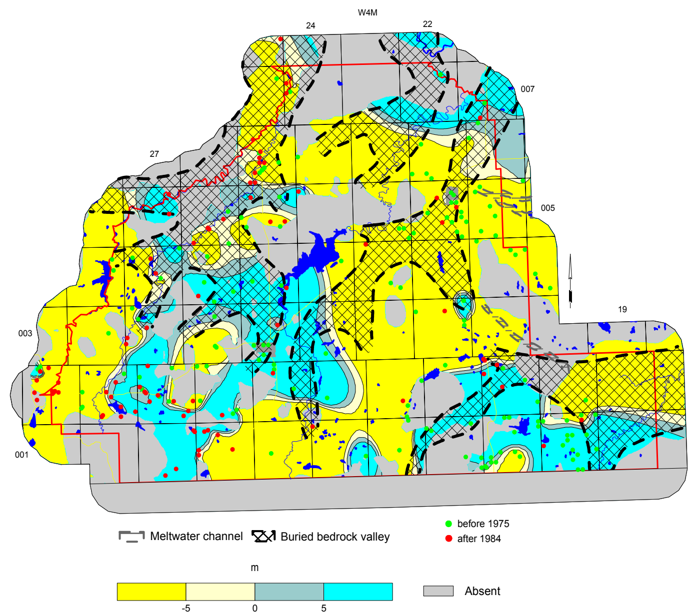


***Figure 37. Changes in Water Levels in Surficial Deposits***

Where the earliest water level (before 1975) is at a higher elevation than the latest water level (after 1984), there is the possibility that some groundwater decline has occurred. The interpretation of the adjacent map should be limited to areas where both earliest and latest water-level control points are present. Most of the areas in which the map suggests that there has been a decline in NPWL may reflect the nature of gridding a limited number of control points. The adjacent map, where sufficient control exists, indicates that there may have been a decline in the NPWL in parts of the Buried Stand Off, the Buried Cochrane, the Buried Mountain View, and the Buried Whoop-Up valleys.

Where the earliest water level is at a lower elevation than the latest water level, there is the possibility that the groundwater has risen at that location. The water level may have risen as a result of recharge in wetter years or may be a result of the water well being completed in a different surficial aquifer. Of the 16 groundwater users completed in surficial aquifers that are authorized to divert more than 50 m³/day, most occur in areas where a water-level decline exists.

| Estimated Water Well Use Per Section (m³/day) | *% of Area with More than a 5-Metre Projected Decline* |
|---|---|
| <10 | *62* |
| 10 to 30 | *1* |
| >30 | *1* |
| no use | *36* |

***Table 20. Water-Level Decline of More than 5 Metres in Sand and Gravel Aquifer(s)***

Figure 37 indicates that in 65% of the County where surficial deposits are present, it is possible that the non-pumping water level has declined. The areas of groundwater decline in the sand and gravel aquifer(s) where there is no estimated water well use suggest that groundwater diversion is not having an impact and that the decline may be due to variations in recharge to the aquifer.

In areas where a water-level decline of more than five metres is indicated on Figure 37, 36% of the areas has no estimated water well use; 62% of the use is less than ten m³/day; 1% of the use is between 10 and 30 m³/day per section; and the remaining 1% of the declines occurred where the estimated groundwater use per section is greater than 30 m³/day, as shown above in Table 20.

Of the 1,028 bedrock water wells with a NPWL and test date, 380 are from water wells completed before 1975 and 355 are from water wells completed after 1984. The adjacent map indicates that in more than 30% of the County, it is possible that the NPWL has declined. It appears that there has been a decline in the NPWL in areas of linear bedrock lows and near areas of discharge. Of the 165 groundwater users completed in upper bedrock aquifer(s), most occur in areas where a water-level rise exists.

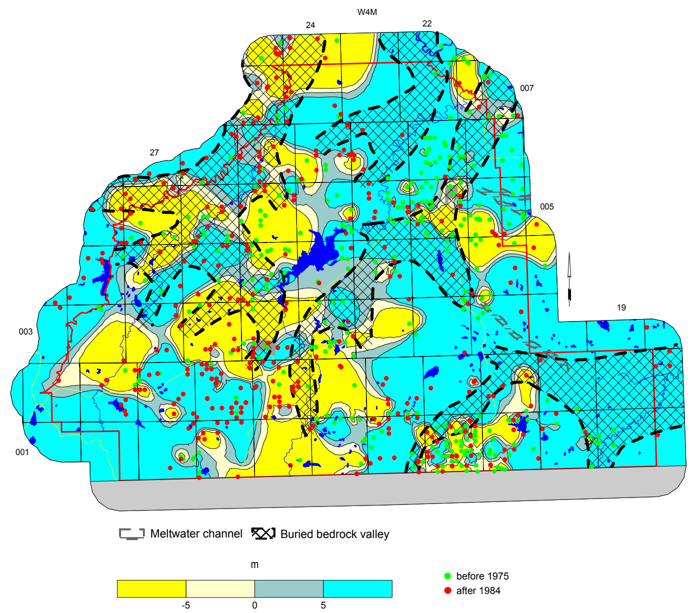


***Figure 38. Areas of Potential Groundwater Depletion - Upper Bedrock Aquifer(s)***

In areas where a water-level decline of more than five metres is indicated on Figure 38, 30% of the areas has no estimated water well use; 68% is less than ten m³/day; 1% is between 10 and 30 m³/day per section; the remaining 1% of the declines occurred where the estimated groundwater use per section is greater than 30 m³/day, as shown below in Table 21.

| Estimated Water Well Use (m³/day) | *% of Area with More than a 5-Metre Decline* |
|---|---|
| <10 | *68* |
| 10 to 30 | *1* |
| >30 | *1* |
| no use | *30* |

***Table 21. Water-Level Decline of More than 5 Metres in Upper Bedrock Aquifer(s)***

The areas of groundwater decline in the upper bedrock aquifer(s) where there is no estimated water well use suggest that groundwater production is not having an impact and that the decline may be due to variations in recharge to the aquifer.

## 6.5 Discussion of Specific Study Areas

As per the Request for Proposal, Cardston County requested that comments be made, where possible, on the following four study areas and issues. The issue is stated at the beginning of each of the following sections. Figure 39 shows the four specific study areas in the County; in Figure 40, the four specific study areas have been color outlined on the bedrock geology map; Figure 41 shows the apparent yield for water wells completed in the Sand and Gravel Aquifer(s); and Figure 42 shows the apparent yield for water wells completed in the Upper Bedrock Aquifer(s).

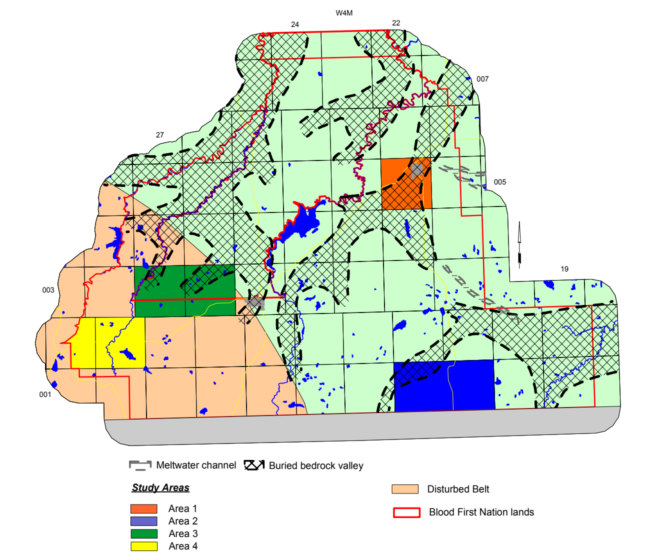


*Figure 39. Specific Study Areas*

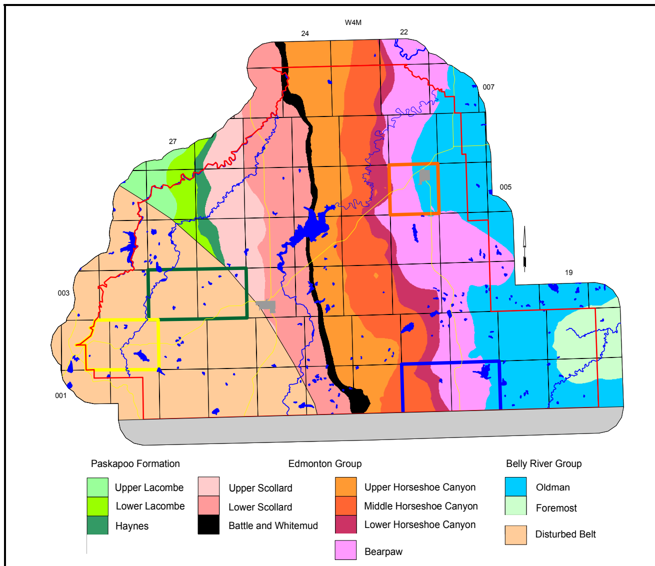


*Figure 40. Bedrock Geology of Specific Study Areas*

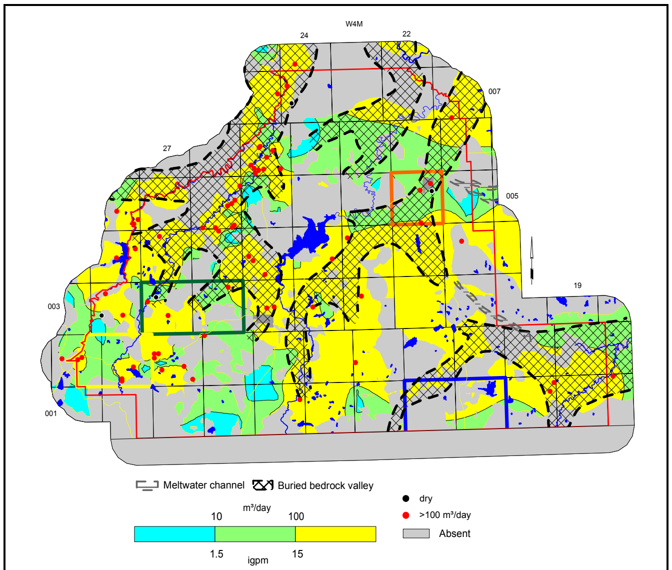


*Figure 41. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s) - Specific Study Areas*

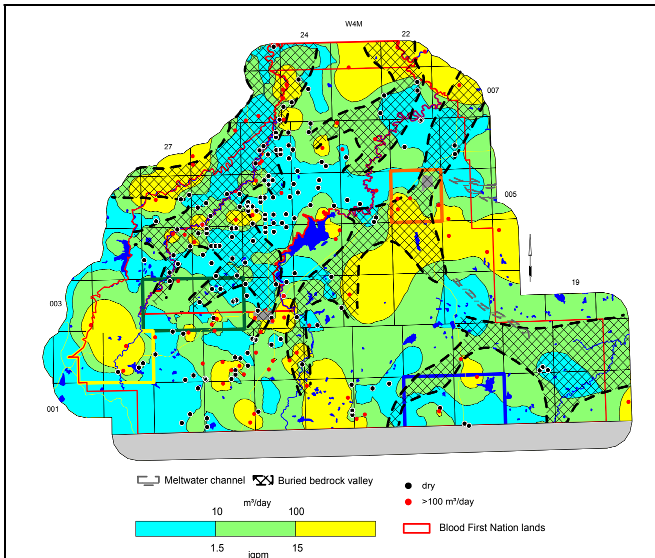


*Figure 42. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s) - Specific Study Areas*

### 6.5.1 Area 1 - Township 005, Range 22, W4M

What is the approximate extent and potential (yield and water quality) of the aquifers in this area? What are the trends in water levels over time in the underlying aquifers?

The Lower Sand and Gravel Aquifer is expected to be present in most of Area 1. The lower sand and gravel deposits are expected to be mainly less than five metres thick. In Area 1, the apparent yields in the Lower Sand and Gravel Aquifer(s) are mainly less than 100 m³/day, as shown on the adjacent map.

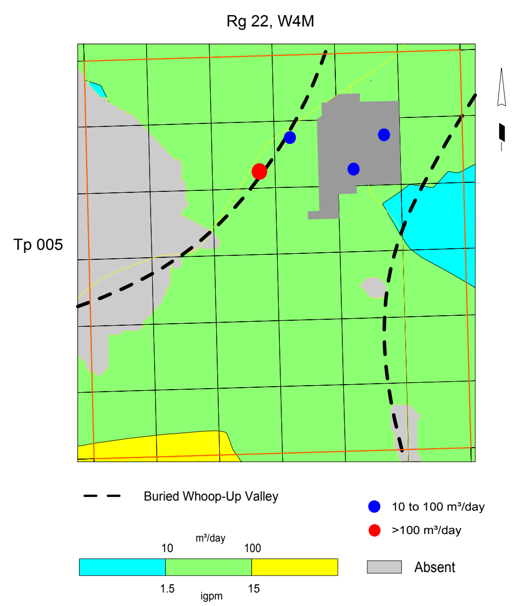


***Figure 43. Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer – Area 1***

There are indications that there has been a decline of more than five metres in the NPWL in Area 1 (see page A-76). However, the apparent decline is probably related to lack of spatial control rather than actual decline. In Area 1, there are five (two are at the same location) licensed water wells completed in the Lower Sand and Gravel Aquifer, of which the largest single potable groundwater allocation is for a water well licensed in 05-22-005-22 W4M that is authorized to divert 20.3 m³/day for agricultural purposes. It is unlikely that the decline in water level can be attributed to these licensed water wells.

Groundwaters from water wells completed in Area 1 in the surficial deposits are expected to have TDS concentrations of between 1,000 and 2,000 mg/L. There are 37 values for iron concentrations for water wells completed through the Lower Sand and Gravel Aquifer. Fourteen of the 37 values are greater than the SGCDWQ of 0.3 mg/L (see page A-77).

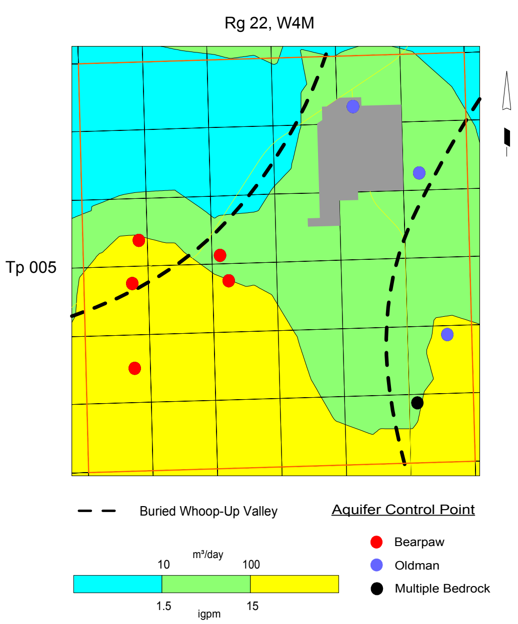


***Figure 44. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s) – Area 1***

The upper bedrock in Area 1 is comprised of the Bearpaw and Oldman formations (see page A-72). The higher apparent yields of greater than 100 m³/day tend to be in water wells completed in the Bearpaw Aquifer, southwest of the Town of Magrath.

There are indications that there has been a decline in the NPWL within the Buried Whoop-Up Valley (see page A-79). Most of the areas that indicate there has been a rise in the water level reflect the nature of gridding a limited number of control points. In Area 1, there are two authorized non-exempt water wells completed in the upper bedrock aquifer(s), for a total of 1.2 m³/day. Both water wells are registrations. It is unlikely that the decline in water levels can be attributed to these authorized non-exempt water wells.

Groundwaters from water wells completed in Area 1 in the upper bedrock aquifer(s) are expected to have TDS concentrations of more than 1,000 mg/L. There are 23 values for iron concentrations for water wells completed through the upper bedrock aquifer(s). Fifteen of the 23 values are greater than the SGCDWQ of 0.3 mg/L (see page A-77).

### 6.5.2 Area 2 – Township 001, Ranges 21 to 22, W4M

What is the approximate extent and potential (yield and water quality) of the aquifers in this area? What are the trends in water levels over time in the underlying aquifers?

The Lower Sand and Gravel Aquifer is present over 30% of Area 2. The lower sand and gravel deposits are expected to be mainly less than five metres thick. In Area 2, the apparent yields for water wells completed through the Lower Sand and Gravel Aquifer are expected to be greater than ten m³/day.

There are indications that there has been a rise in the NPWL in the northern part of Area 2, and a decline in the NPWL in township 001, range 21, W4M where the Aquifer is present (see page A-82). In Area 2, there are two authorized non-exempt water wells completed through the Lower Sand and Gravel Aquifer, for a total of 3.4 m³/day. Both authorized non-exempt water wells are registrations. It is unlikely that the decline in water levels can be attributed to these two water wells.

Groundwaters from water wells completed in Area 2 in the surficial deposits are expected to have TDS concentrations that are less than 1,000 mg/L.

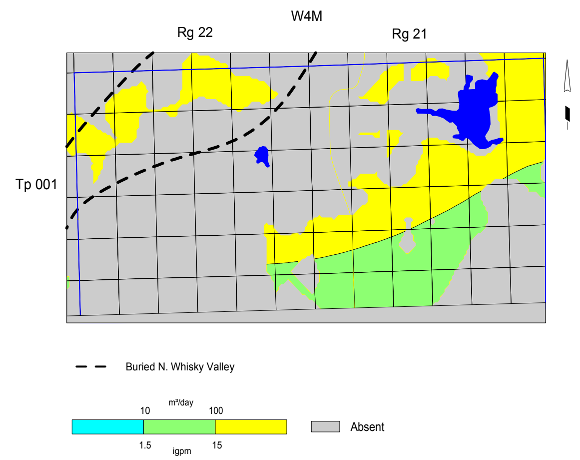


***Figure 45. Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer – Area 2***

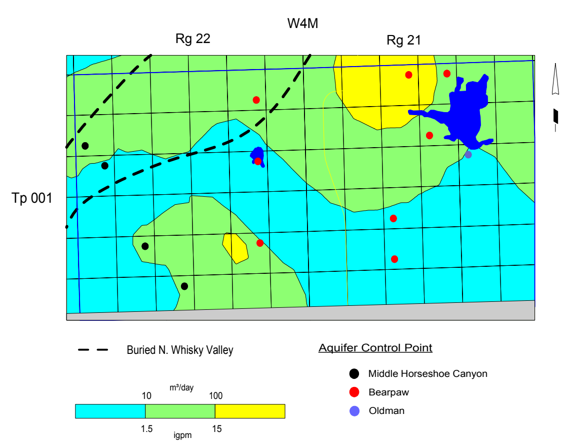


***Figure 46. Apparent Yield for Water Wells in Upper Bedrock Aquifer(s) – Area 2***

The upper bedrock in Area 2 is comprised of the Middle Horseshoe Canyon, Lower Horseshoe Canyon, Bearpaw and Oldman formations (see page A-72). In Area 2, there are no apparent yield values for water wells completed in the Lower Horseshoe Canyon Aquifer. The Bearpaw Aquifer is the main Aquifer present in Area 2. In Area 2, there are eight water wells completed in the Bearpaw Aquifer with apparent yield data. The apparent yields for water wells completed in the Bearpaw Aquifer are expected to be mainly less than 100 m³/day.

There are indications that there has been a NPWL decline over most of Area 2 (see page A-82). In Area 2, there are twenty bedrock water wells that are registered to divert up to 46.5 m³/day. It might be beneficial to the County to field-verify the water wells in Area 2. The level of verification should include obtaining meaningful horizontal coordinates for the water wells and verifying the water level and completed depth of the water wells.

Groundwaters from water wells completed in Area 2 in the upper bedrock aquifer(s) are expected to have TDS concentrations that are mainly less than 1,000 mg/L.

### 6.5.3 Area 3 – Township 003, Ranges 26 to 27, W4M

What is the approximate extent and potential (yield and water quality) of the aquifers in this area? What are the trends in water levels over time in the underlying aquifers?

The Sand and Gravel Aquifer(s) are present in approximately 75% of Area 3. The sand and gravel deposits are expected to be more than five metres thick in the Buried Northcliffe Valley within range 26, W4M. The apparent yields for water wells completed in the Sand and Gravel Aquifer(s) are greater than ten m³/day, as shown on the adjacent map.

In most of the buried bedrock valleys, there are indications that there has been a rise in the NPWL (see page A-88). In Area 3, there are two licences for water wells that are completed through the Upper Sand and Gravel Aquifer, for a total authorized diversion 0.6 m³day.

Groundwaters from water wells completed in Area 3 in the surficial deposits are expected to have TDS concentrations that range mainly between 500 and 2,000 mg/L.

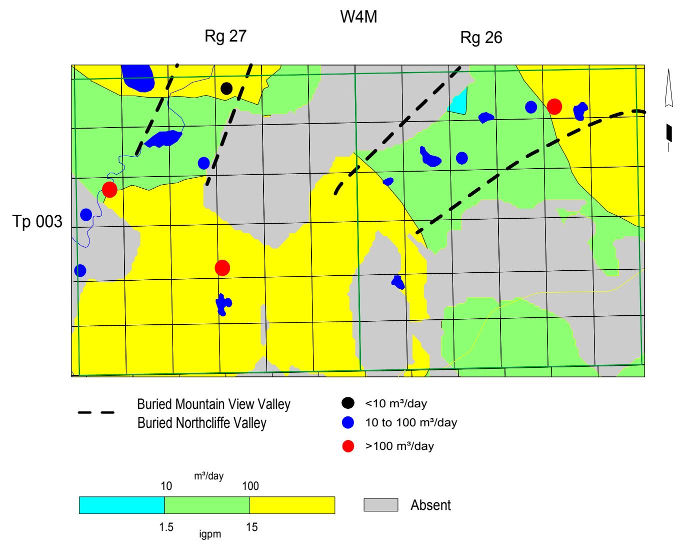


*Figure 47. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s) – Area 3*

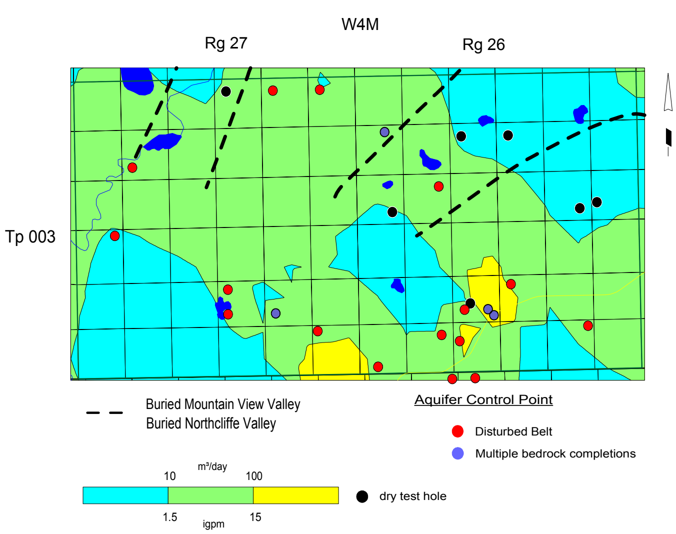


*Figure 48. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s) – Area 3*

The upper bedrock over most of Area 3 is the Disturbed Belt Formation. The apparent yields for water wells completed through the upper bedrock aquifer(s) are expected to range between ten and 100 m³/day.

The only part of Area 3 where there is sufficient data to determine if a NPWL change has occurred in the upper bedrock aquifer(s) is in the northwestern part of township 003, range 27, W4M. In this area, there are indications that a NPWL rise of less than five metres may have occurred. In Area 3, there are three licences for water wells that are completed through the Disturbed Belt Aquifer, for a total authorized diversion of 4.2 m³day.

Groundwaters from water wells completed in the upper bedrock aquifer(s) are expected to have TDS concentrations that range from less than 500 to more than 2,000 mg/L.

### 6.5.4 Area 4 – Township 002, Ranges 28 to 29, W4M

What is the approximate extent and potential (yield and water quality) of the aquifers in this area?

The Sand and Gravel Aquifer (s) are present in most of Area 4. The sand and gravel deposits are expected to be mainly less than five metres thick. In Area 4, the apparent yields in water wells completed in the Sand and Gravel Aquifer(s) are mainly less than 100 m³/day, as shown on the adjacent map.

There are indications that there has been a decline in the NPWL of more than five metres in the western two-thirds of Area 4 and a rise in the NPWL in the eastern third of Area 4 (see page A-94). In Area 4, there are three registrations for water wells that are completed through the Upper Sand and Gravel Aquifer, for a total authorized diversion 0.7 m³day. It is unlikely that the decline in water levels can be attributed to these three water wells.

Groundwaters from water wells completed in Area 4 in the surficial deposits are expected to have TDS concentrations that are mainly less than 500 mg/L.

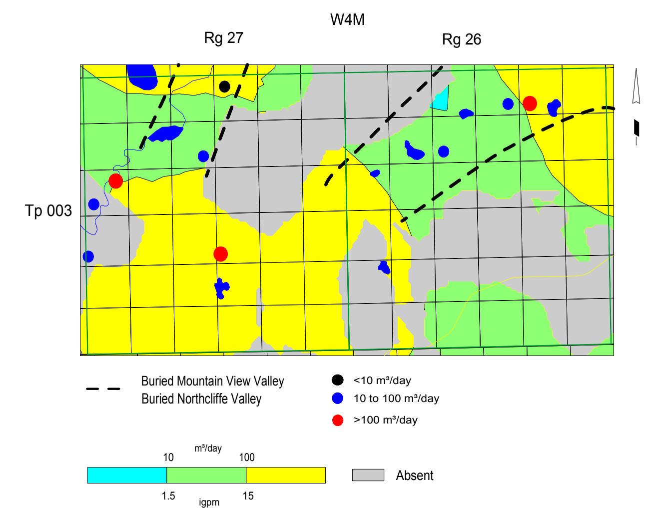


***Figure 49. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s) – Area 4***

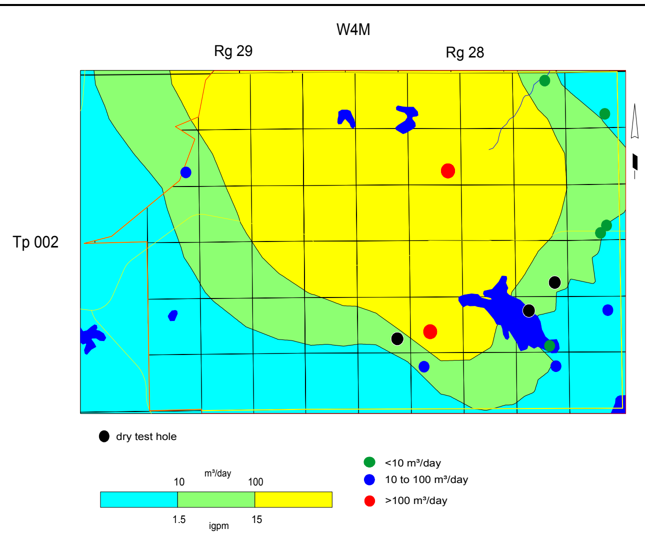


***Figure 50. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s) – Area 4***

The upper bedrock in Area 4 is the Disturbed Belt Formation (see page A-72). The apparent yields are mainly between 10 and 100 m³/day. In Area 4, there are three dry water test holes completed in the Disturbed Belt Aquifer.

There are indications that there has been a rise in the NPWL in the southwestern half of Area 4, and a decline in the NPWL in the northeastern half of Area 4. In Area 4, there are two authorized non-exempt water wells completed in the Disturbed Belt Aquifer, for a total 0.4 m³/day. Both water wells are registrations. It is unlikely that the decline in water levels can be attributed to these two water wells.

Groundwaters from water wells completed in the upper bedrock aquifer(s) are expected to have TDS concentrations that are mainly less 500 mg/L.

# 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 88 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 is one water well for which the County has responsibility; the County-operated water well is included in Appendix E. It is recommended that the County-operated water well plus the 88 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.

The results of the present study indicate that the main source of groundwater in the County is aquifers in the surficial deposits, which are the sand and gravel deposits associated with the lows in the bedrock surface. The median apparent yield value from all water wells completed in the Lower Sand and Gravel Aquifer that have an apparent yield, is in the order of 55 $m^3$/day (8.4 igpm). Fifty percent of the water wells completed in the Lower Sand and Gravel have an apparent yield of 52 $m^3$/day. The most noteworthy bedrock lows include the Buried Stand Off Valley and its tributary, the Buried Cochrane Valley; and the Buried Whoop-Up Valley and its tributary, the Buried Kimball Valley.

Of the 201 dry water test holes completed in bedrock, 48% of the dry water test holes are completed in the Scollard aquifers. The median apparent yield value of water wells completed in the Scollard aquifers is in the order of 15 $m^3$/day. The median value of fluoride concentrations (2.4 mg/L) from water wells completed in the Upper Scollard Aquifer is greater than the median concentrations (0.4 mg/L) from water wells completed in all upper bedrock aquifer(s). The areas underlain by the Scollard aquifers may need to investigate supplementing their present groundwater supply (e.g. rural pipeline).

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 88 water wells listed in Appendix E for which water well drilling reports are available, plus the County–operated water well, be subjected to the following actions (see pages C-2 to C-3):

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

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

A list of the 89 water wells that could be considered for the above program is given in Appendix E and on the CD-ROM.

An attempt to link the AENV groundwater and licensing databases was 35% successful in this study (see CD-ROM); sixty-five percent of authorized non-exempt 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 authorized non-exempt water wells are completed.

While there are a few areas where water-level data are available at different times, 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 (Buchanan, Bob (editor). Alberta Agriculture, Food and Rural Development, 1996).

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

**Communities that are concerned about apparent water-level declines in the aquifers in which their water supply wells are completed should implement a conscientious groundwater monitoring program.**

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.

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

**Groundwater is a renewable resource and it must be managed.**

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# 9. 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

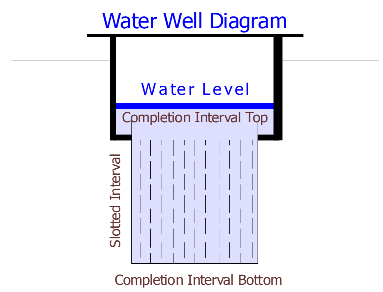
Aquitard — a confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer

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

Completion Interval — see diagram



**Completion Interval**

Deltaic — a depositional environment in standing water near the mouth of a river

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

Dfb — one of the Köppen climate classifications; a Dfb climate consists of warm to cool summers, severe winters, and no dry season. The mean monthly temperature drops below -3° C in the coolest month, and exceeds 10° C in the warmest month.

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

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

Fluvial — produced by the action of a stream or river

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

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

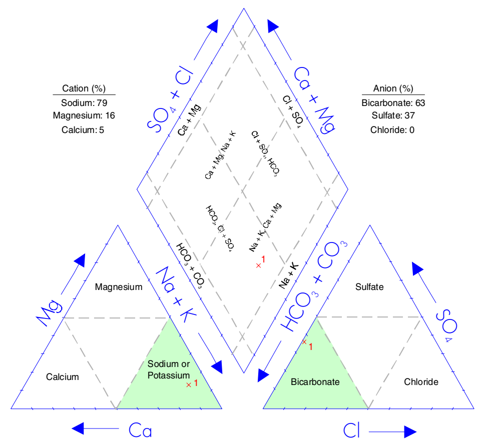
m³/day — cubic metres per day

mg/L — milligrams per litre

Median — the value at the centre of an ordered range of numbers

Obs WW — Observation Water Well

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




***Piper Tri-Linear Diagram***

Rock — earth material below the root zone

Surficial Deposits — includes all sediments above the bedrock

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

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

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

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

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

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

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

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

Apparent Yield: based mainly on apparent transmissivity

Long-Term Yield: based on effective transmissivity

| | |
|---|---|
| AAFC-PFRA | Prairie Farm Rehabilitation Administration Branch of Agriculture and Agri-Food Canada |
| 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 |
| IAAM | *Infinite Aquifer Artesian Model.* The mathematical model is used to calculate water levels at a given location. The model has been used for more than 17 years by HCL for several hundred groundwater monitoring projects. The model aquifer is based on a solution of the well function equation. The simulation calculates drawdown by solving the well function equation using standard approximation methods. The drawdown at any given point at any given time uses the method of superposition. |
| NPWL | non-pumping water level |
| TDS | Total Dissolved Solids |
| WSW | Water Source Well or Water Supply Well |

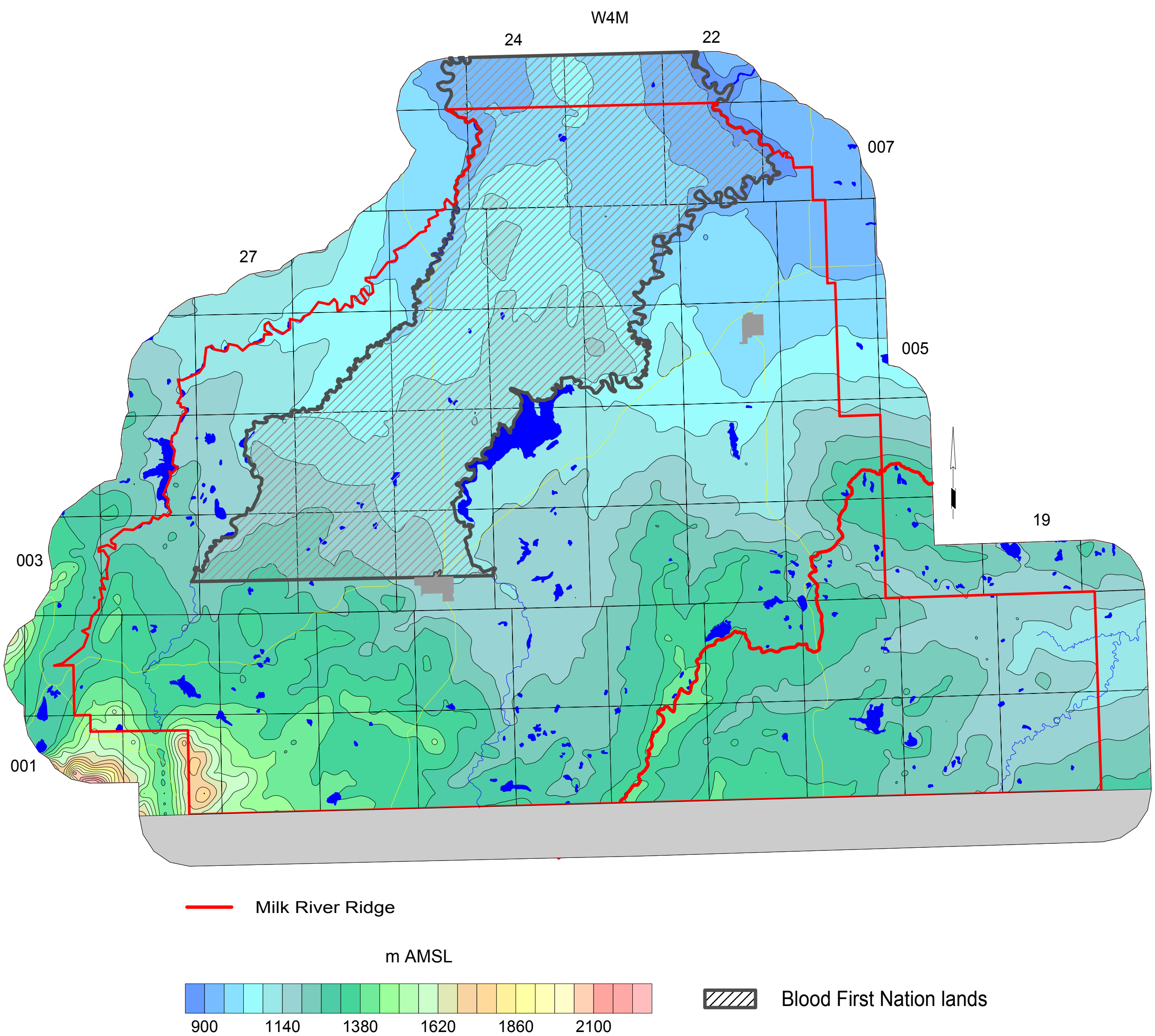
# 10. Conversions

| 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 | metres ($m^2$) |
| metres ($m^2$) | 10.763 910 | square feet ($ft^2$) |
| metres ($m^2$) | 0.000 001 | kilometres ($km^2$) |
| | | |
| **Concentration** | | |
| grains/gallon (UK) | 14.270 050 | ppm |
| ppm | 0.998 859 | mg/L |
| mg/L | 1.001 142 | ppm |
| | | |
| **Volume (capacity)** | | |
| acre feet | 1233.481 838 | cubic metres |
| cubic feet | 0.028 317 | cubic metres |
| cubic metres | 35.314 667 | cubic feet |
| cubic metres | 219.969 248 | gallons (UK) |
| cubic metres | 264.172 050 | gallons (US liquid) |
| cubic metres | 1000.000 000 | litres |
| gallons (UK) | 0.004 546 | cubic metres |
| imperial gallons | 4.546 000 | litres |
| | | |
| **Rate** | | |
| litres per minute | 0.219 974 | ipgm |
| litres per minute | 1.440 000 | cubic metres/day ($m^3$/day) |
| igpm | 6.546 300 | cubic metres/day ($m^3$/day) |
| cubic metres/day (m | 0.152 759 | igpm |
| | | |
| **Pressure** | | |
| psi | 6.894 757 | kpa |
| kpa | 0.145 038 | psi |
| | | |
| **Miscellaneous** | | |
| Celsius | F° = 9/5 (C° + 32) | Fahrenheit |
| Fahrenheit | C° = (F°- 32) * 5/9 | Celsius |
| degrees | 0.017 453 | radians |

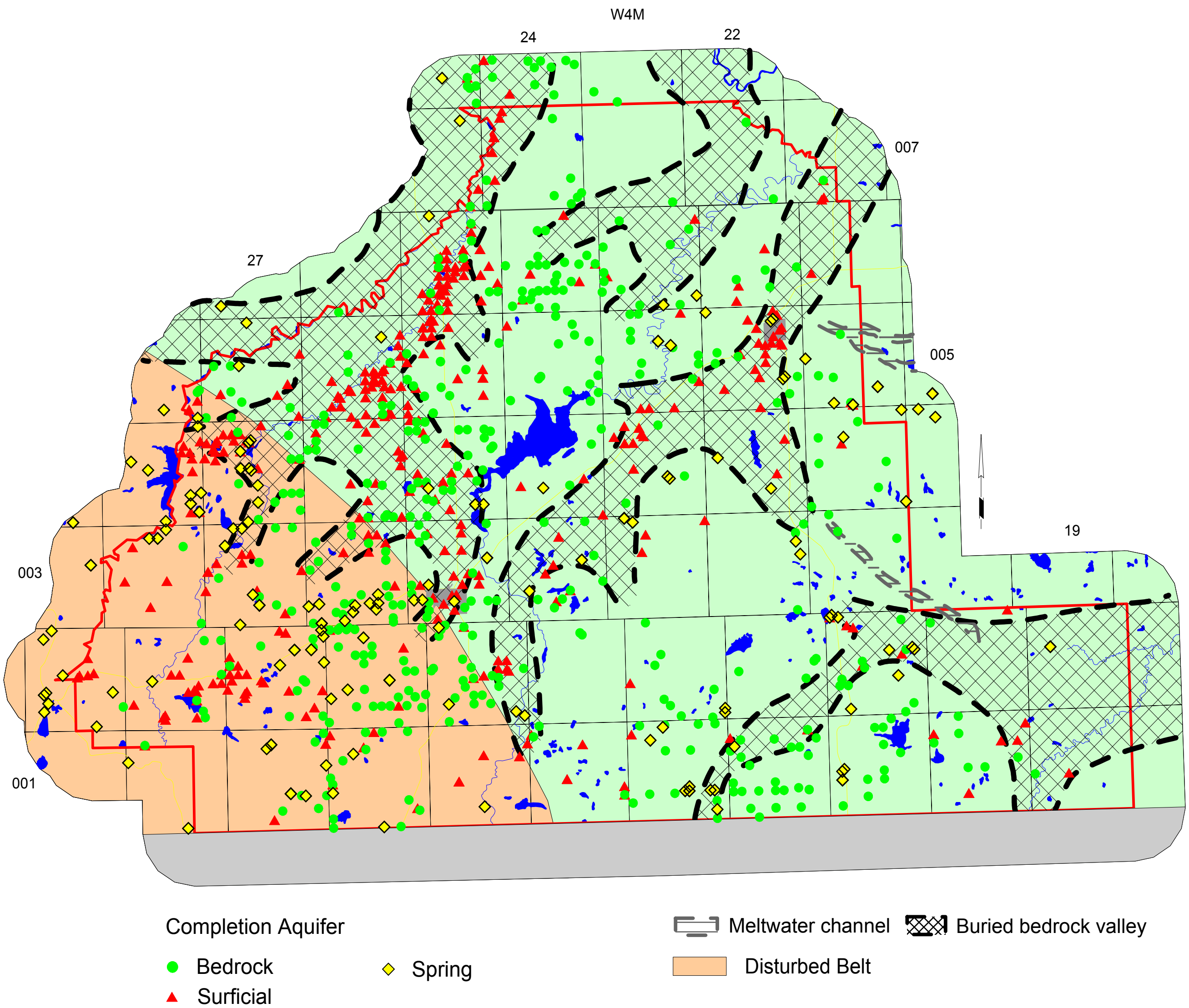
# CARDSTON COUNTY
## Appendix A

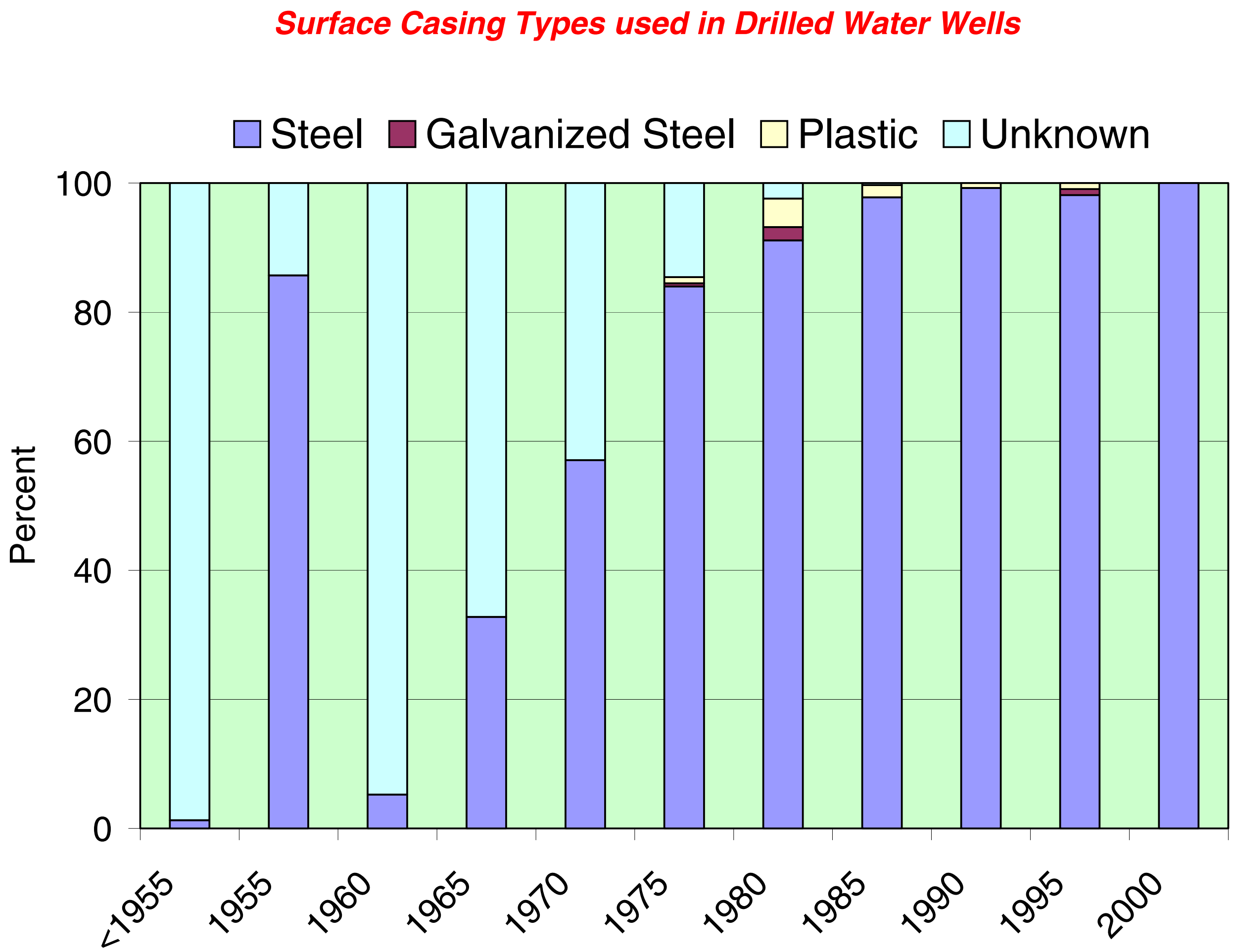
### Hydrogeological Maps and Figures

# Surface Topography

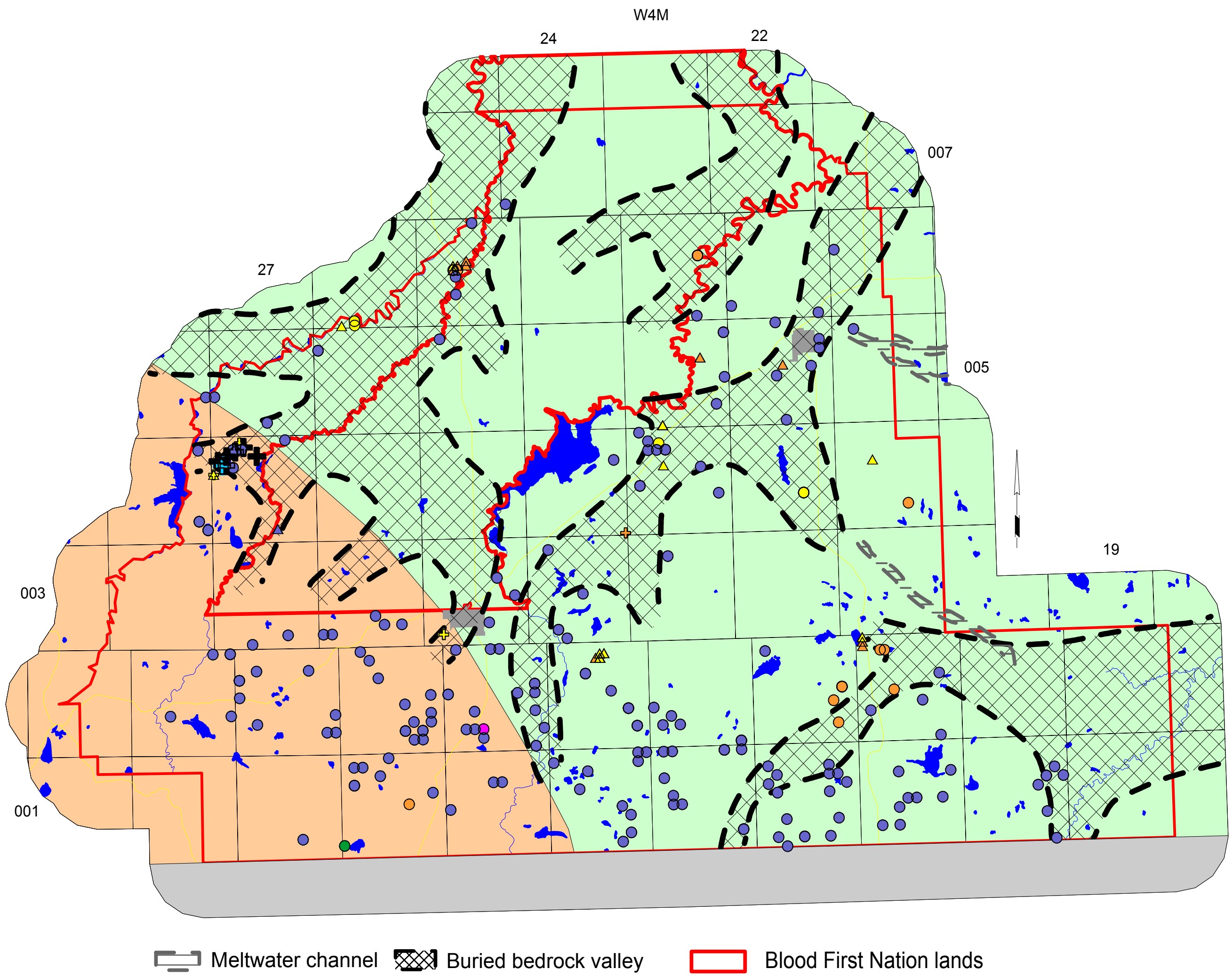


# Location of Water Wells and Springs




Surface Casing Types used in Drilled Water Wells
Steel
Galvanized Steel
Plastic
Unknown
Percent
100
80
60
40
20
0
<1955
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000

## Authorized Non-Exempt Groundwater Water Wells

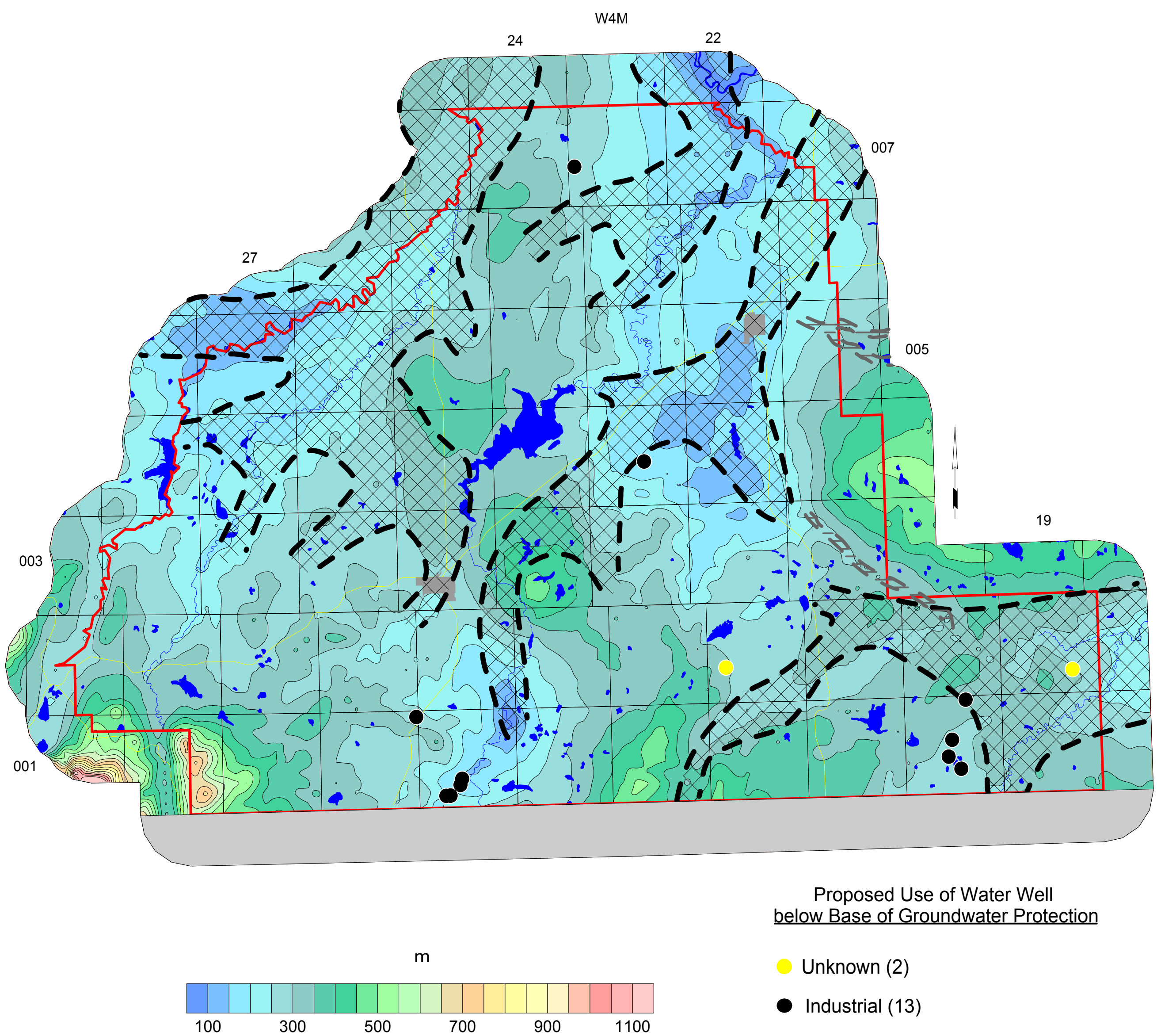



| | registration | agricultural | municipal | dewatering |
|---|---|---|---|---|
| < 10 | (192) | (20) | (5) | (2) |
| 10 to 100 | (1) | (15) | (11) | (0) |
| > 100 | (0) | (1) | (4) | (9) |

| | fishery | recreation | commercial |
|---|---|---|---|
| < 10 | (0) | (1) | (1) |
| 10 to 100 | (0) | (0) | (0) |
| > 100 | (3) | (0) | (0) |

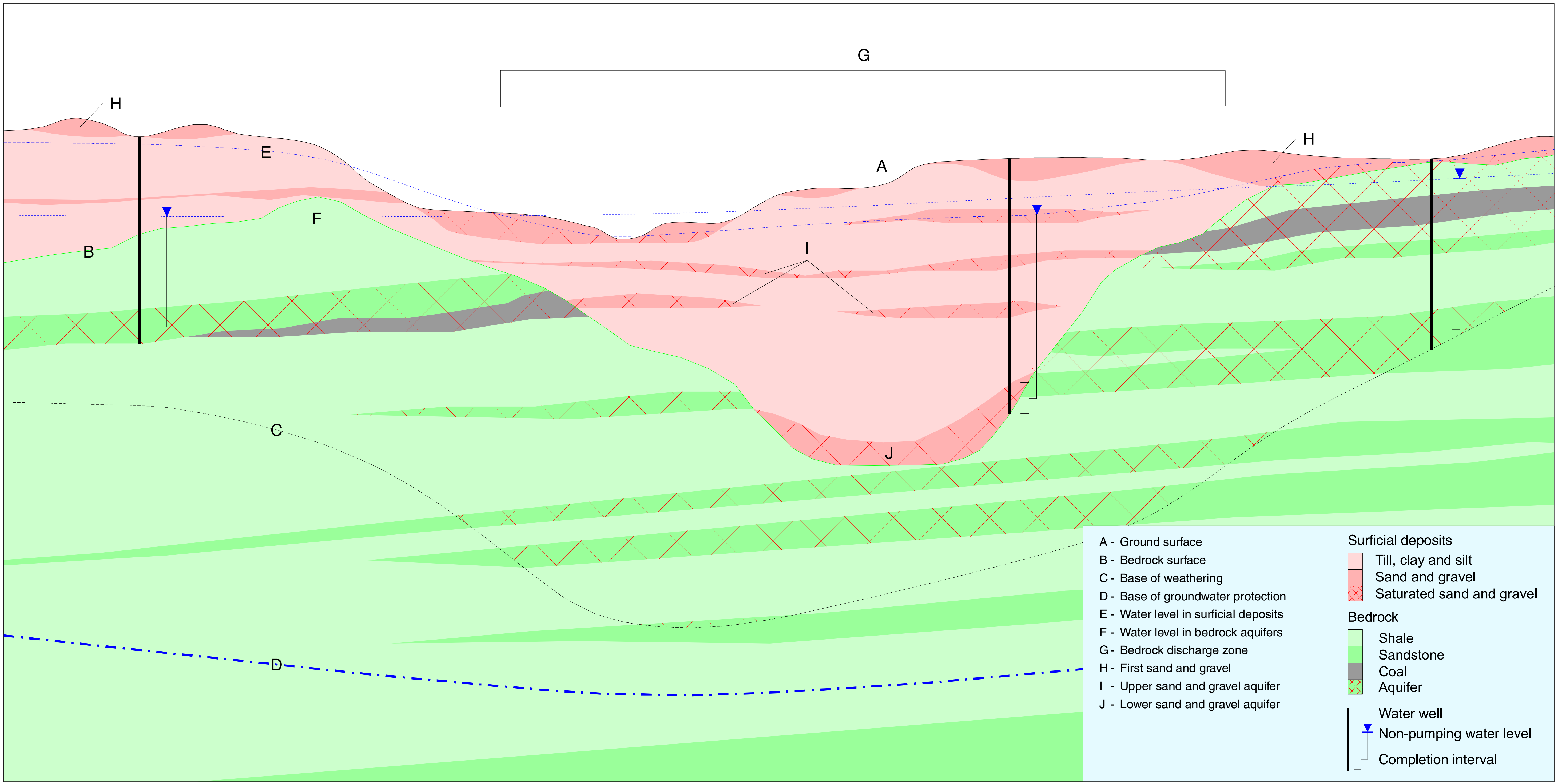
# Depth to Base of Groundwater Protection

*(modified after EUB, 1995)*



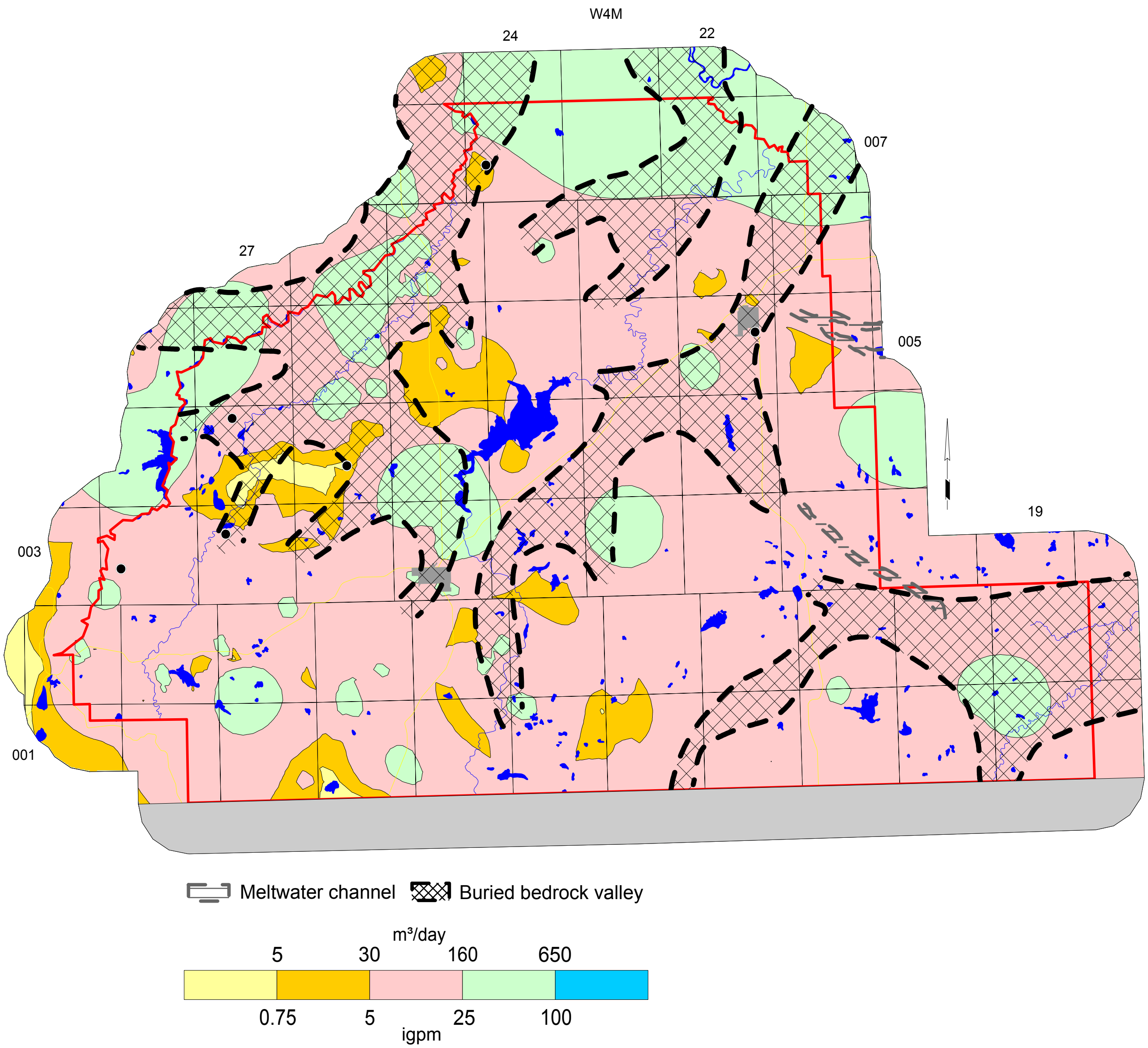
## *Generalized Cross-Section*

*(for terminology only)*

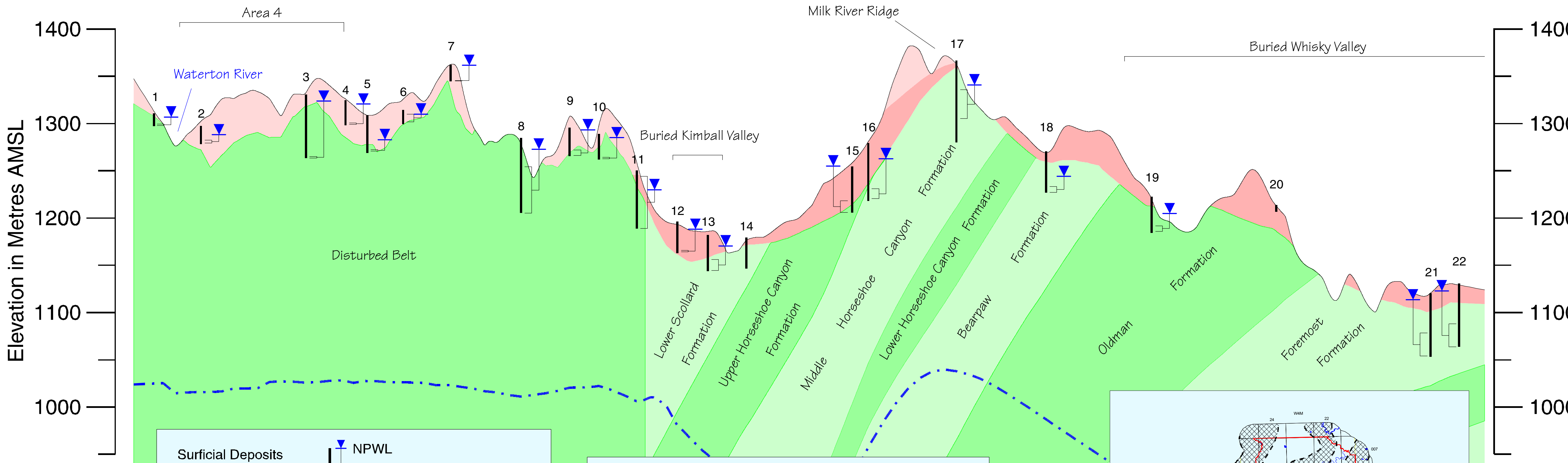


# Geologic Column

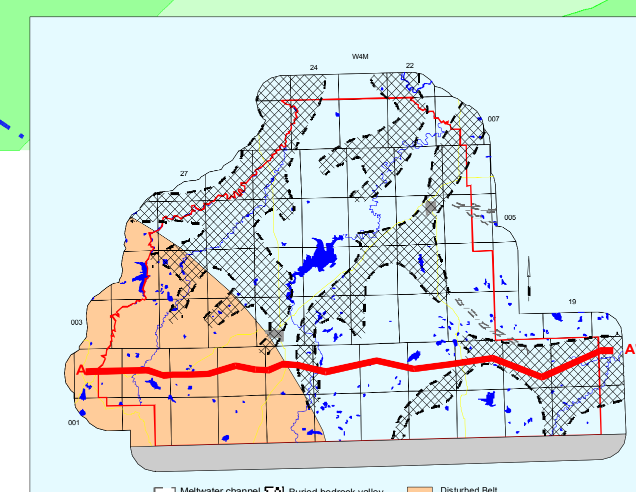
# Hydrogeological Map



## Cross-Section A - A'

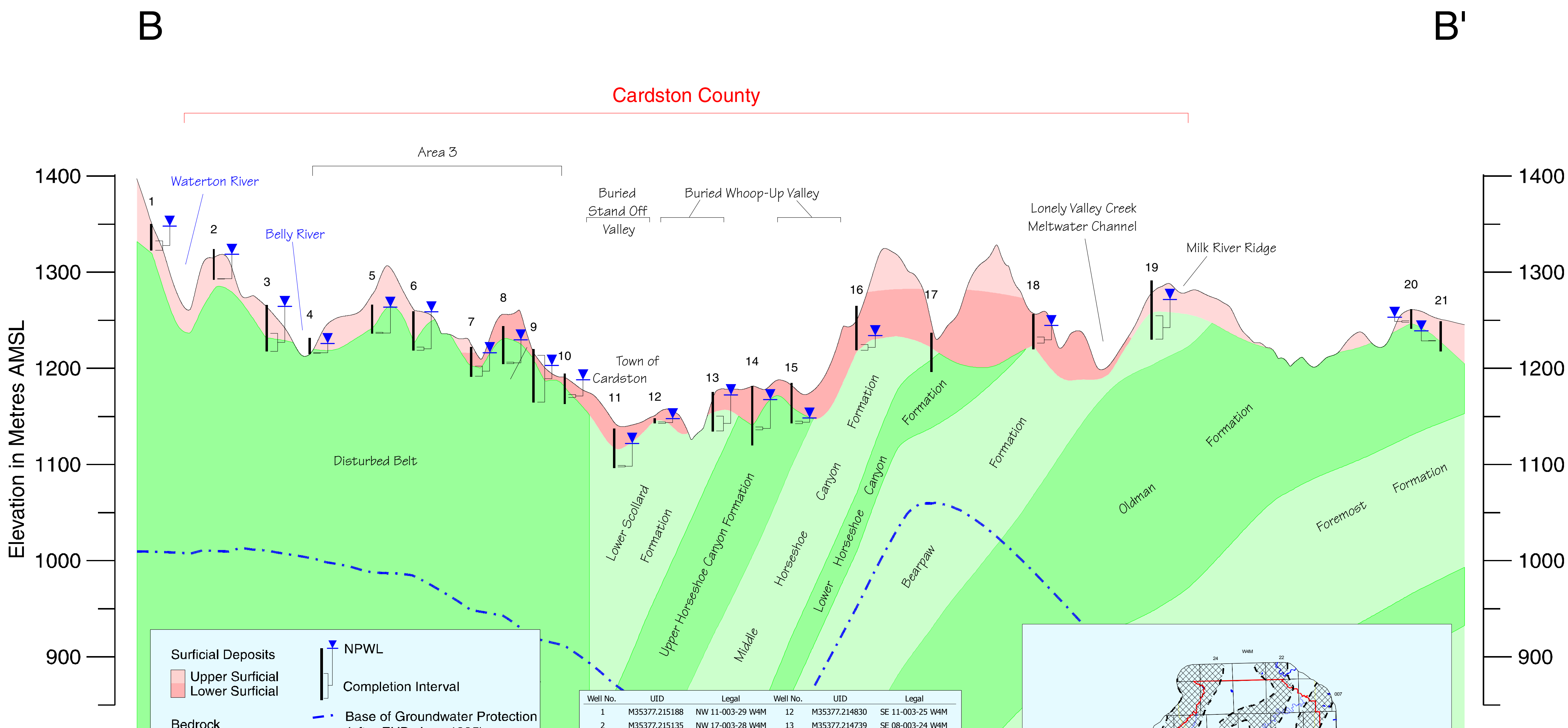



| Well No. | UID | Legal | Well No. | UID | Legal |
|---|---|---|---|---|---|
| 1 | M35377.216028 | SW 20-002-29 W4M | 12 | M37490.030327 | NW 23-002-25 W4M |
| 2 | M36234.922874 | SE 22-002-29 W4M | 13 | M35377.214359 | SE 24-002-25 W4M |
| 3 | M36234.947990 | SW 22-002-28 W4M | 14 | M35377.214262 | NE 17-002-24 W4M |
| 4 | M35377.215965 | NW 13-002-28 W4M | 15 | M35377.214231 | NW 20-002-23 W4M |
| 5 | M35377.214538 | 14-18-002-27 W4M | 16 | M35377.214235 | 13-21-002-23 W4M |
| 6 | M35377.214530 | NW 16-002-27 W4M | 17 | M35377.084469 | NE 18-002-22 W4M |
| 7 | M35377.214525 | NE 14-002-27 W4M | 18 | M35377.094202 | SW 24-002-22 W4M |
| 8 | M35377.214457 | NW 21-002-26 W4M | 19 | M35377.114513 | NE 23-002-21 W4M |
| 9 | M37490.031610 | SE 23-002-26 W4M | 20 | M35377.214135 | SE 11-002-20 W4M |
| 10 | M35377.214326 | SW 19-002-25 W4M | 21 | M35377.153056 | SW 30-002-18 W4M |
| 11 | M35377.214331 | 13-21-002-25 W4M | 22 | M35377.153055 | SE 29-002-18 W4M |

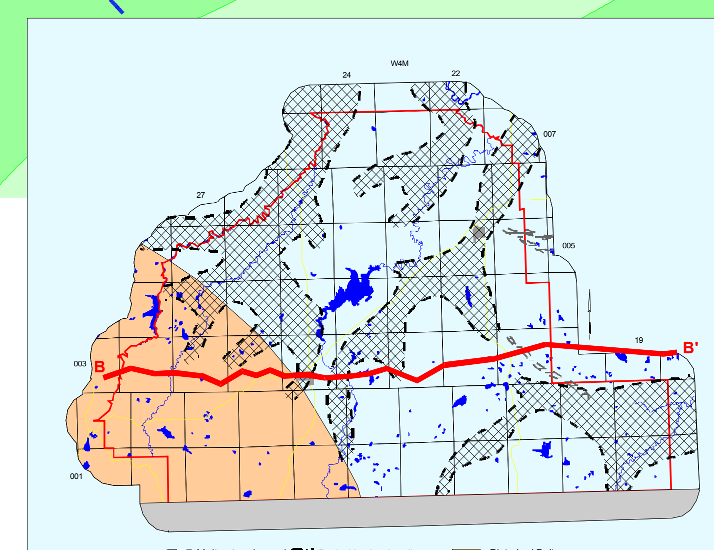



Line of Section

## Cross-Section B - B'

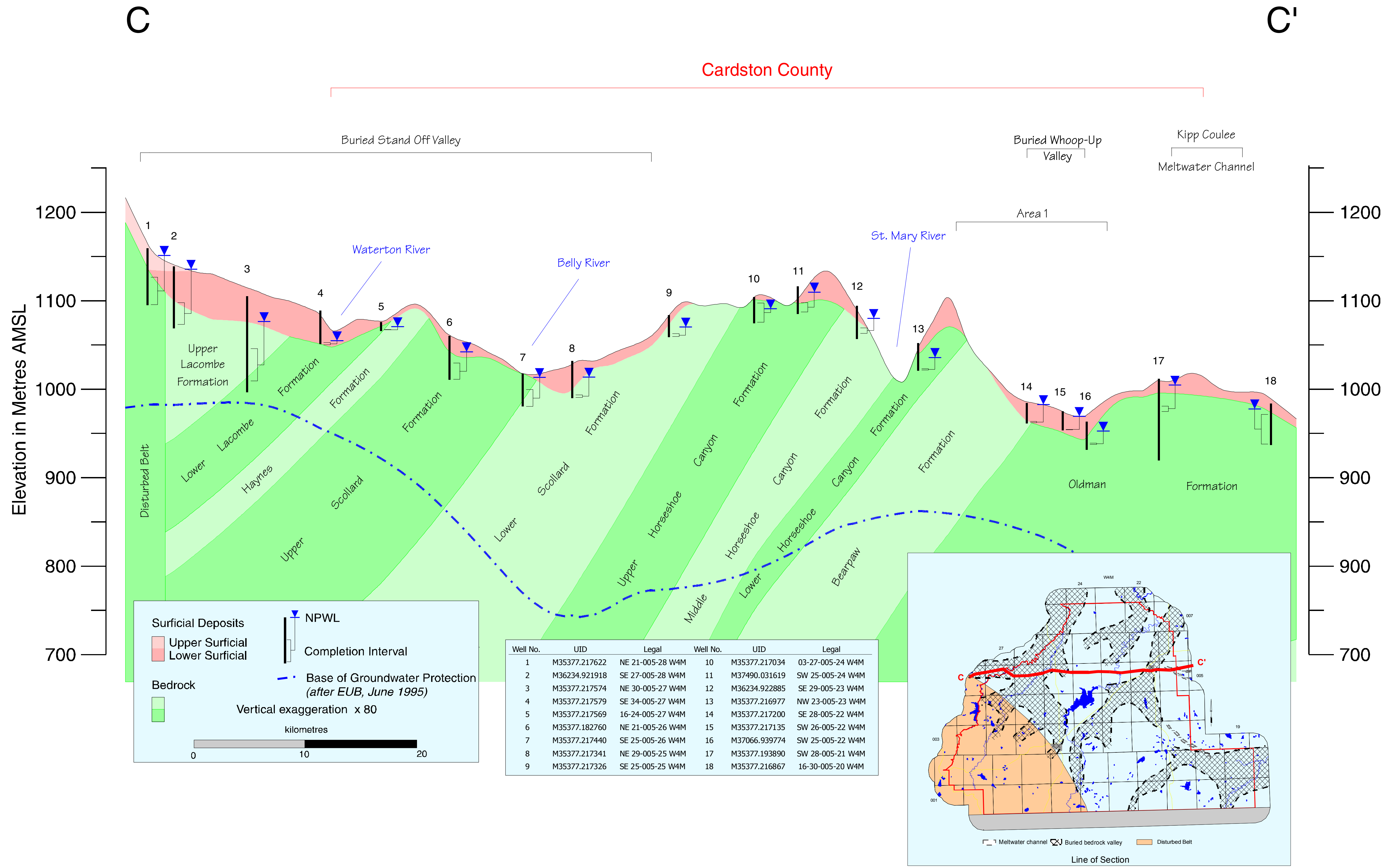



| Well No. | UID | Legal | Well No. | UID | Legal |
|---|---|---|---|---|---|
| 1 | M35377.215188 | NW 11-003-29 W4M | 12 | M35377.214830 | SE 11-003-25 W4M |
| 2 | M35377.215135 | NW 17-003-28 W4M | 13 | M35377.214739 | SE 08-003-24 W4M |
| 3 | M35377.215125 | 01-15-003-28 W4M | 14 | M35377.070044 | NE 10-003-24 W4M |
| 4 | M36234.947995 | 04-18-003-27 W4M | 15 | M35377.214761 | SE 13-003-24 W4M |
| 5 | M35377.215038 | NW 10-003-27 W4M | 16 | M35377.214698 | NE 04-003-23 W4M |
| 6 | M35377.215021 | 13-01-003-27 W4M | 17 | M35377.214676 | SW 18-003-22 W4M |
| 7 | M35377.214978 | SE 17-003-26 W4M | 18 | M35377.220892 | 14-13-003-22 W4M |
| 8 | M35377.214950 | NW 10-003-26 W4M | 19 | M35377.214661 | SW 25-003-21 W4M |
| 9 | M35377.214972 | SE 14-003-26 W4M | 20 | M35377.153238 | 14-18-003-18 W4M |
| 10 | M35377.214808 | NW 07-003-25 W4M | 21 | M35377.153236 | 16-17-003-18 W4M |
| 11 | M36727.981758 | NE 09-003-25 W4M | | | |



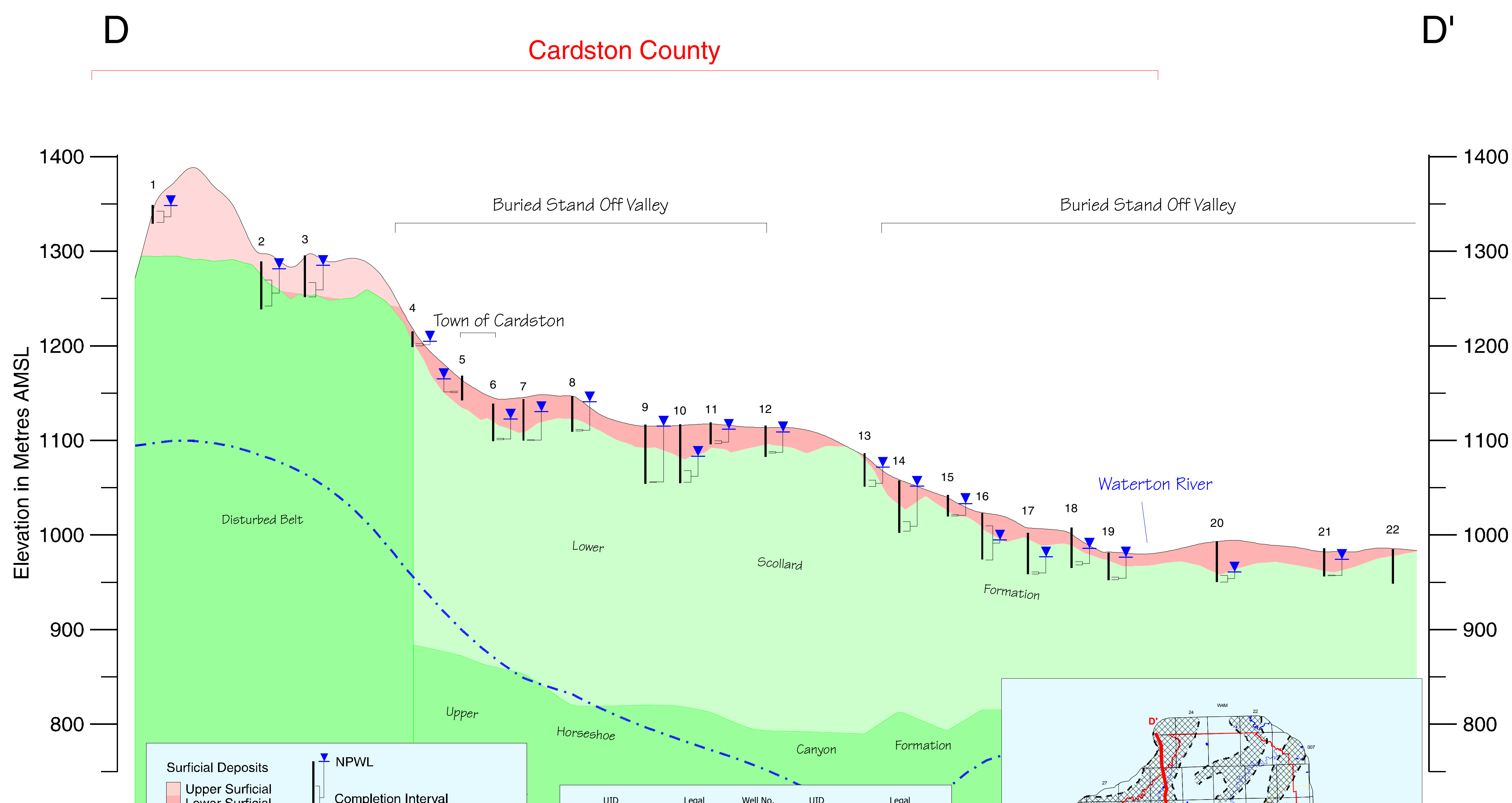

Line of Section

## Cross-Section C - C'

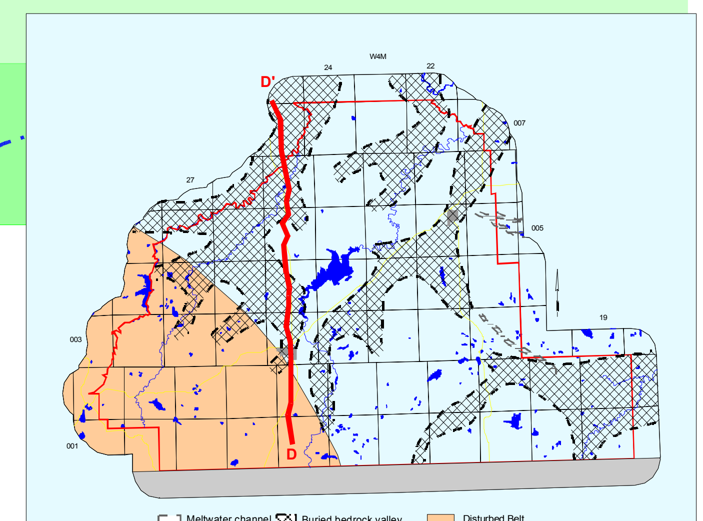



| Well No. | UID | Legal | Well No. | UID | Legal |
|---|---|---|---|---|---|
| 1 | M35377.217622 | NE 21-005-28 W4M | 10 | M35377.217034 | 03-27-005-24 W4M |
| 2 | M36234.921918 | SE 27-005-28 W4M | 11 | M37490.031619 | SW 25-005-24 W4M |
| 3 | M35377.217574 | NE 30-005-27 W4M | 12 | M36234.922885 | SE 29-005-23 W4M |
| 4 | M35377.217579 | SE 34-005-27 W4M | 13 | M35377.216977 | NW 23-005-23 W4M |
| 5 | M35377.217569 | 16-24-005-27 W4M | 14 | M35377.217200 | SE 28-005-22 W4M |
| 6 | M35377.182760 | NE 21-005-26 W4M | 15 | M35377.217135 | SW 26-005-22 W4M |
| 7 | M35377.217440 | SE 25-005-26 W4M | 16 | M37066.939774 | SW 25-005-22 W4M |
| 8 | M35377.217341 | NE 29-005-25 W4M | 17 | M35377.193890 | SW 28-005-21 W4M |
| 9 | M35377.217326 | SE 25-005-25 W4M | 18 | M35377.216867 | 16-30-005-20 W4M |

## Cross-Section D - D'

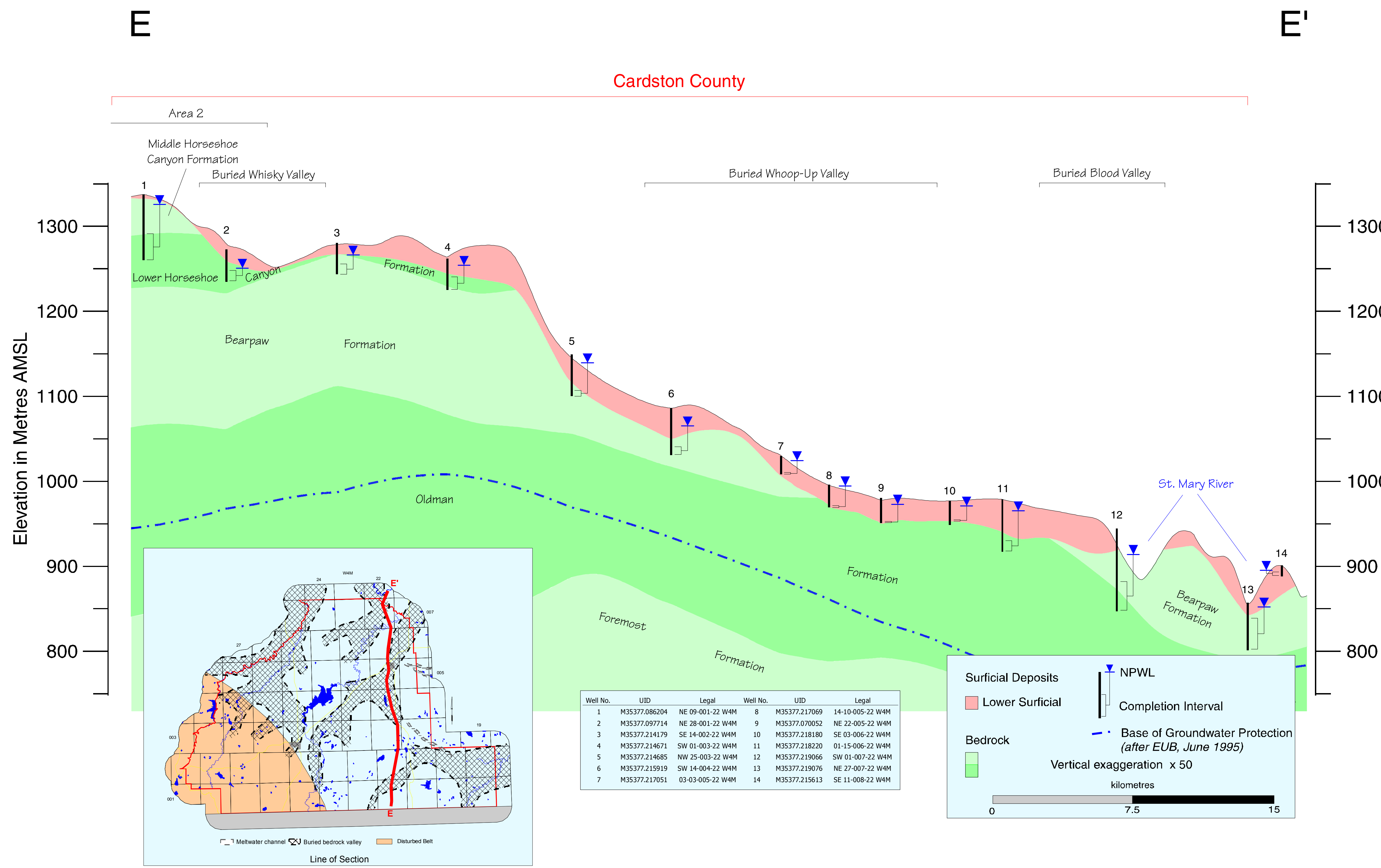



| UID | Legal | Well No. | UID | Legal |
|---|---|---|---|---|
| M35377.214024 | NE 17-001-25 W4M | 12 | M35377.216239 | ++ 28-004-25 W4M |
| M35377.145001 | SW 05-002-25 W4M | 13 | M35377.217283 | NW 09-005-25 W4M |
| M35377.214298 | 10-08-002-25 W4M | 14 | M35377.217298 | NE 16-005-25 W4M |
| M35377.214385 | 02-32-002-25 W4M | 15 | M35377.217333 | SW 28-005-25 W4M |
| M35377.214796 | NE 04-003-25 W4M | 16 | M35377.217352 | SE 33-005-25 W4M |
| M36727.981759 | NE 09-003-25 W4M | 17 | M35377.218355 | NE 04-006-25 W4M |
| M35377.214845 | NE 16-003-25 W4M | 18 | M35377.218420 | 04-15-006-25 W4M |
| M35377.214873 | SW 28-003-25 W4M | 19 | M35377.218451 | SE 21-006-25 W4M |
| M36234.947998 | 10-04-004-25 W4M | 20 | M35377.219161 | NE 03-007-25 W4M |
| M35377.216194 | NE 09-004-25 W4M | 21 | M35377.118012 | SW-27-007-25 W4M |
| M35377.216215 | NE 16-004-25 W4M | 22 | M36727.982585 | SW-04-008-25 W4M |



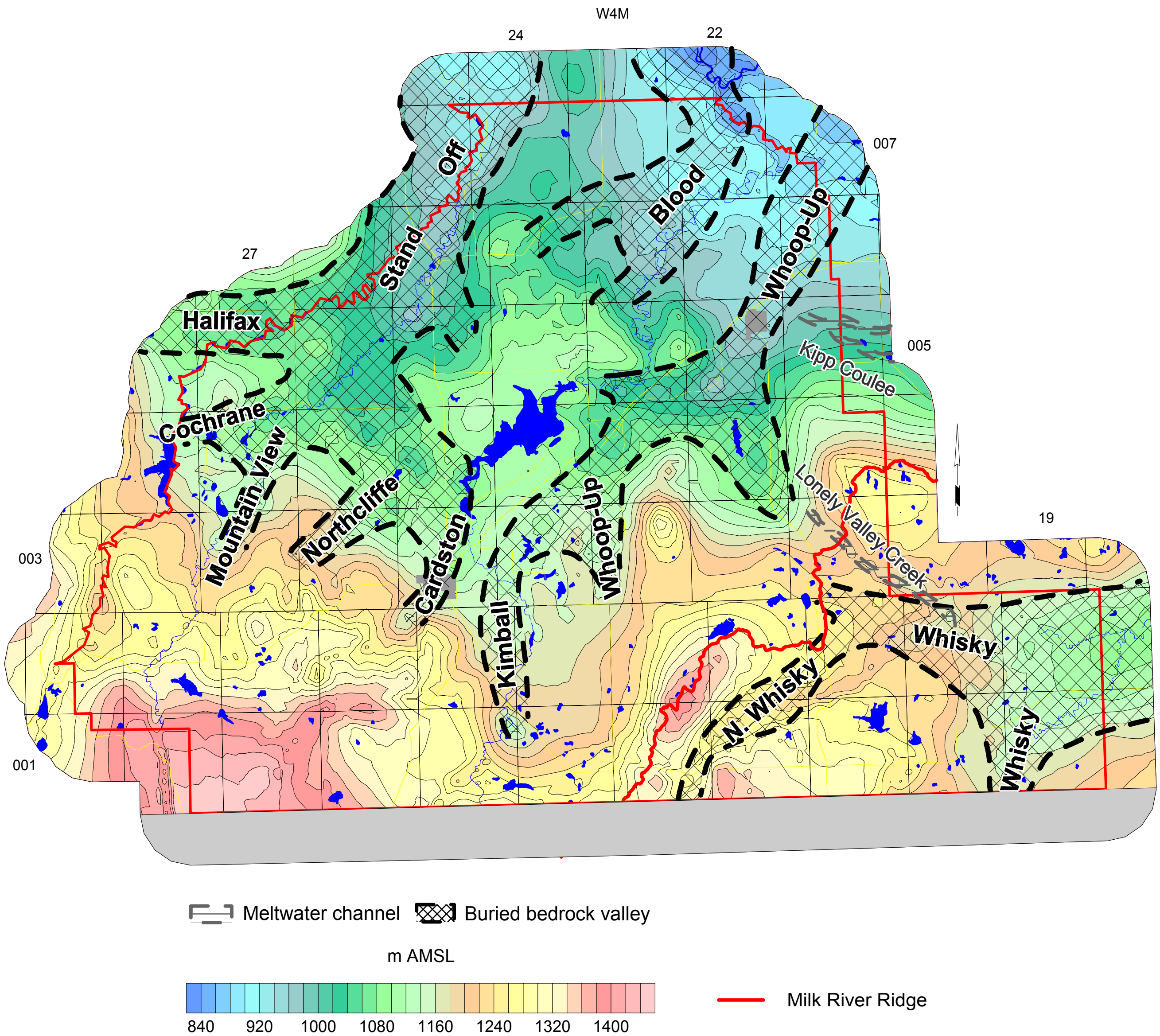

Line of Section

# Cross-Section E - E'

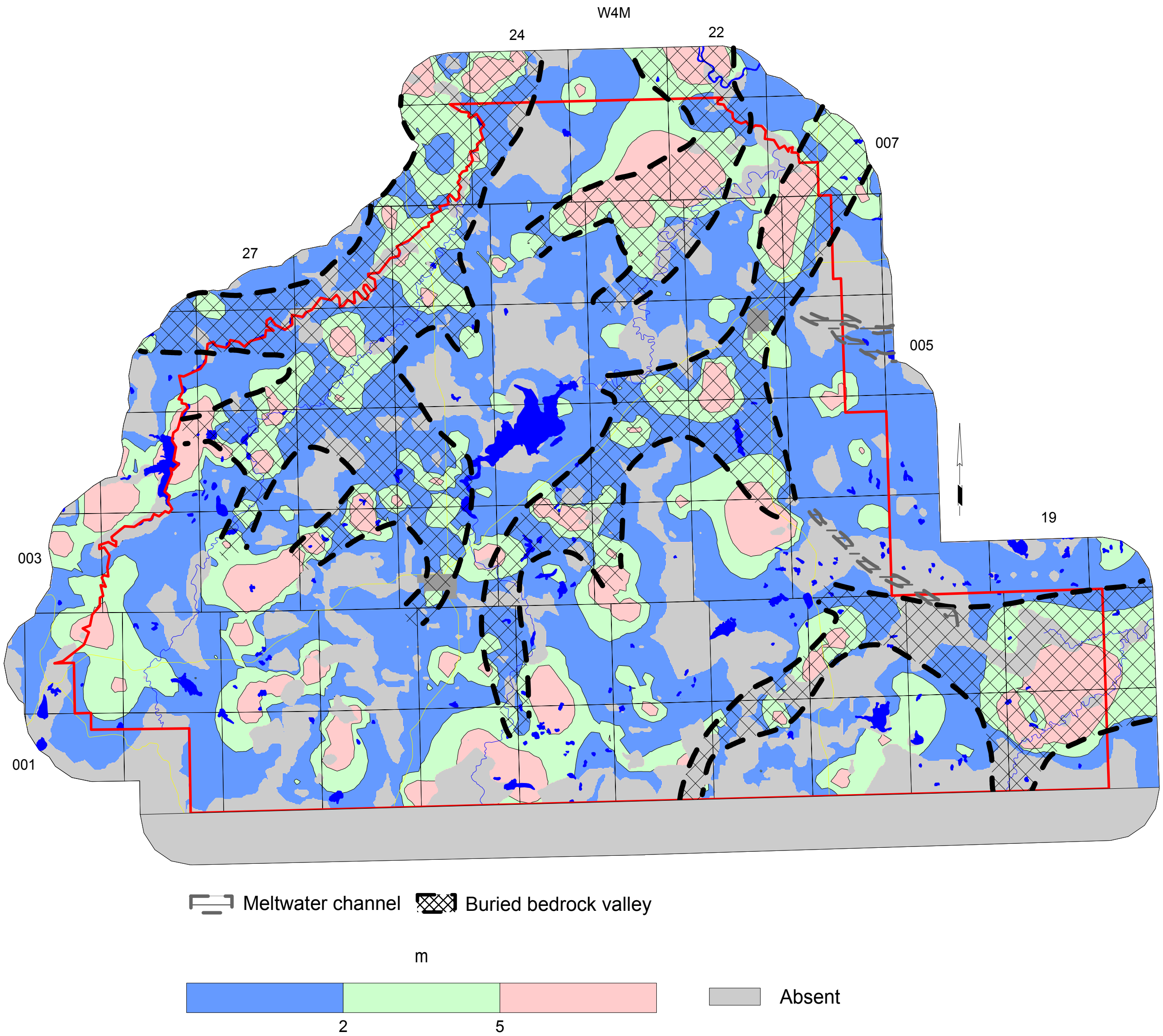



| Well No. | UID | Legal | Well No. | UID | Legal |
|---|---|---|---|---|---|
| 1 | M35377.086204 | NE 09-001-22 W4M | 8 | M35377.217069 | 14-10-005-22 W4M |
| 2 | M35377.097714 | NE 28-001-22 W4M | 9 | M35377.070052 | NE 22-005-22 W4M |
| 3 | M35377.214179 | SE 14-002-22 W4M | 10 | M35377.218180 | SE 03-006-22 W4M |
| 4 | M35377.214671 | SW 01-003-22 W4M | 11 | M35377.218220 | 01-15-006-22 W4M |
| 5 | M35377.214685 | NW 25-003-22 W4M | 12 | M35377.219066 | SW 01-007-22 W4M |
| 6 | M35377.215919 | SW 14-004-22 W4M | 13 | M35377.219076 | NE 27-007-22 W4M |
| 7 | M35377.217051 | 03-03-005-22 W4M | 14 | M35377.215613 | SE 11-008-22 W4M |

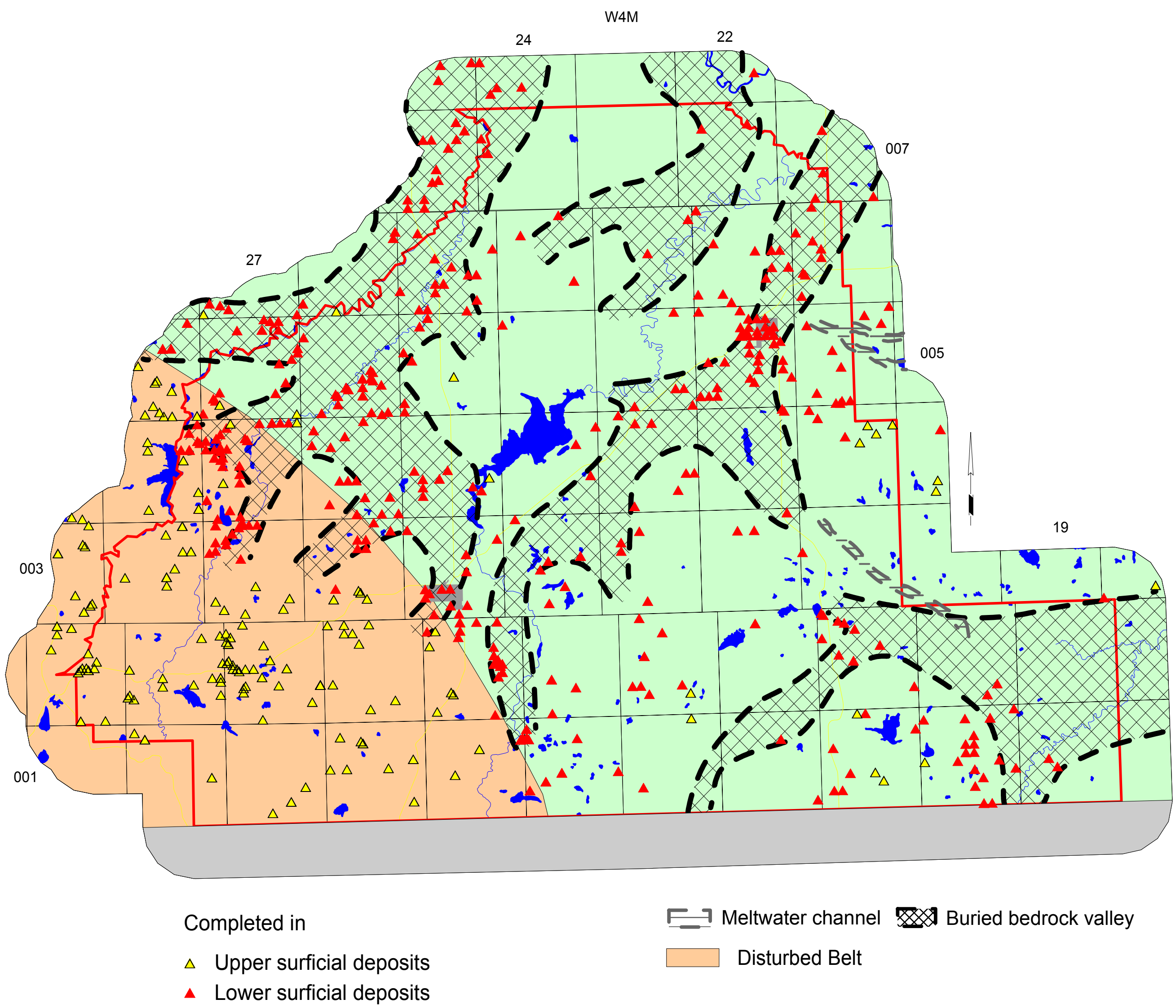
## Bedrock Topography



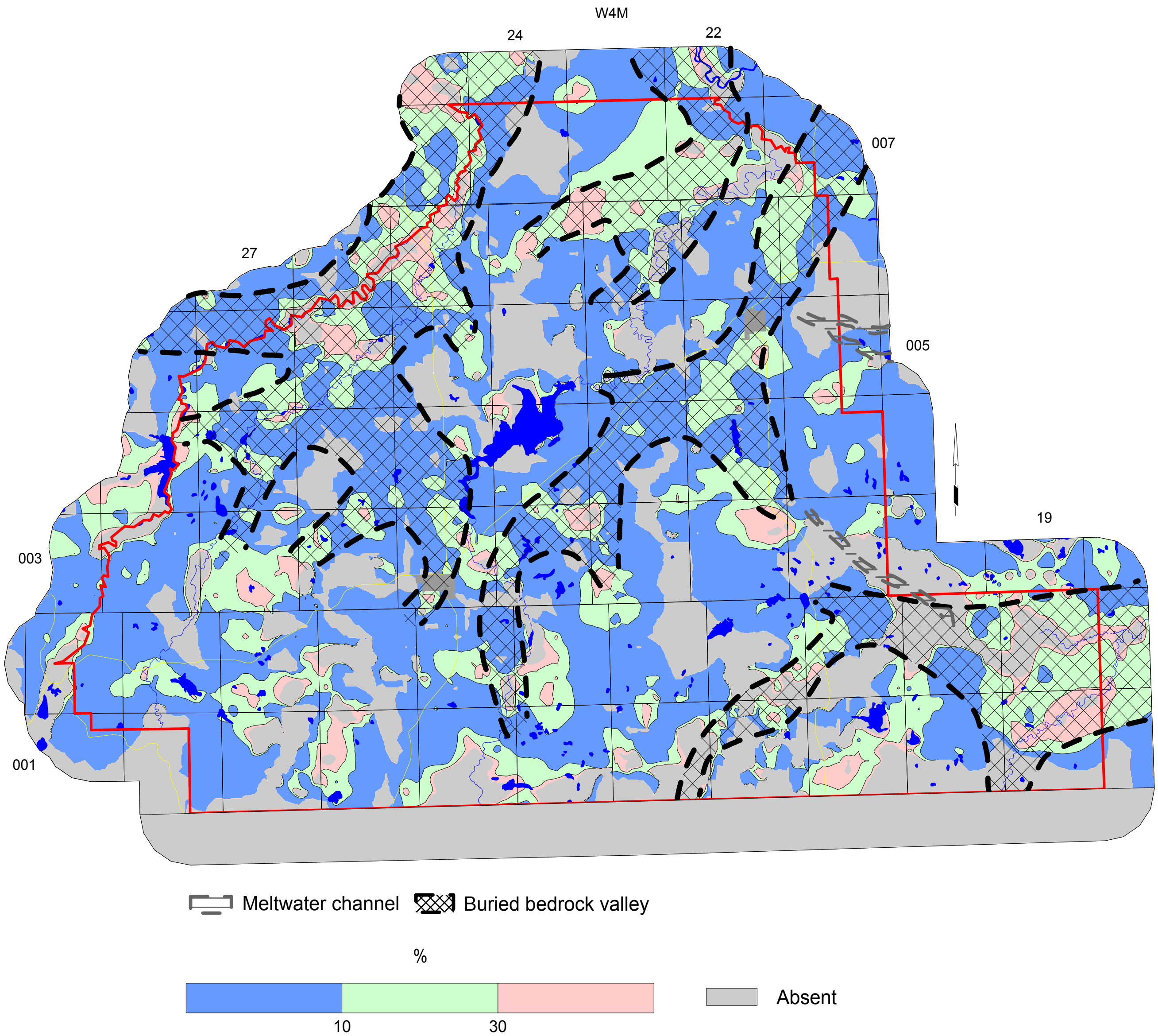
# Thickness of Sand and Gravel Deposits



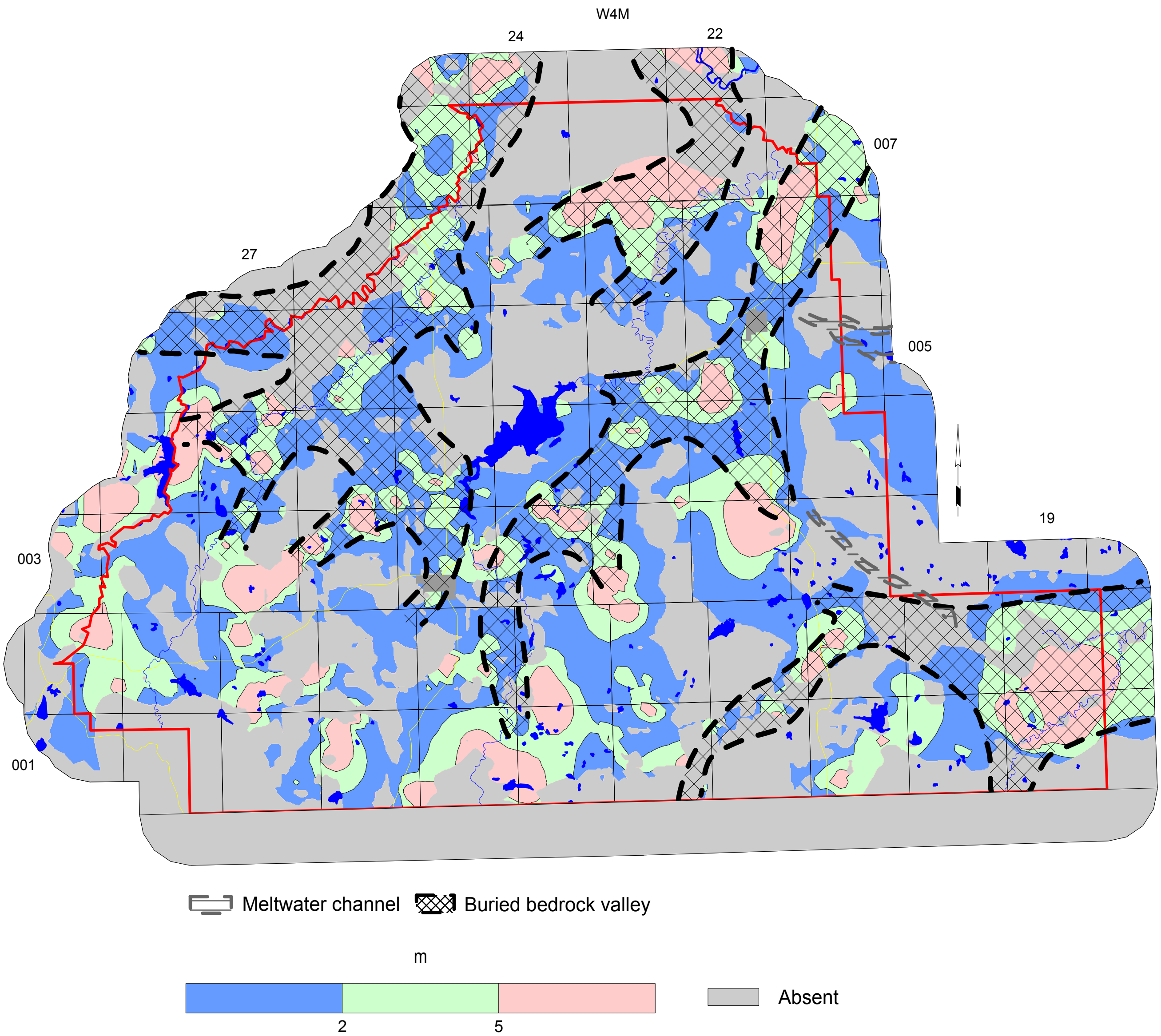
# Water Wells Completed In Upper and Lower Surficial Deposits



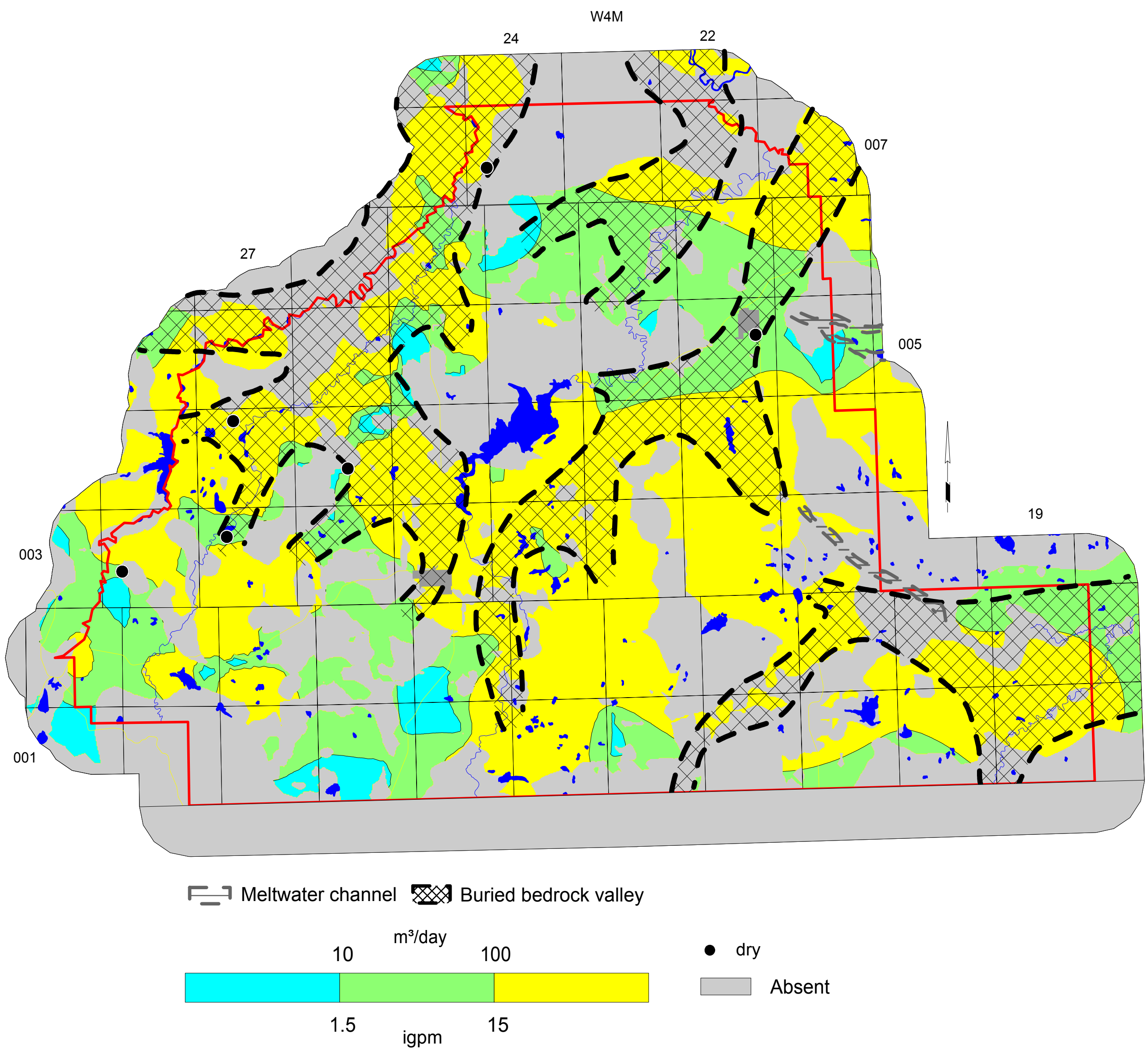
# Amount of Sand and Gravel in Surficial Deposits



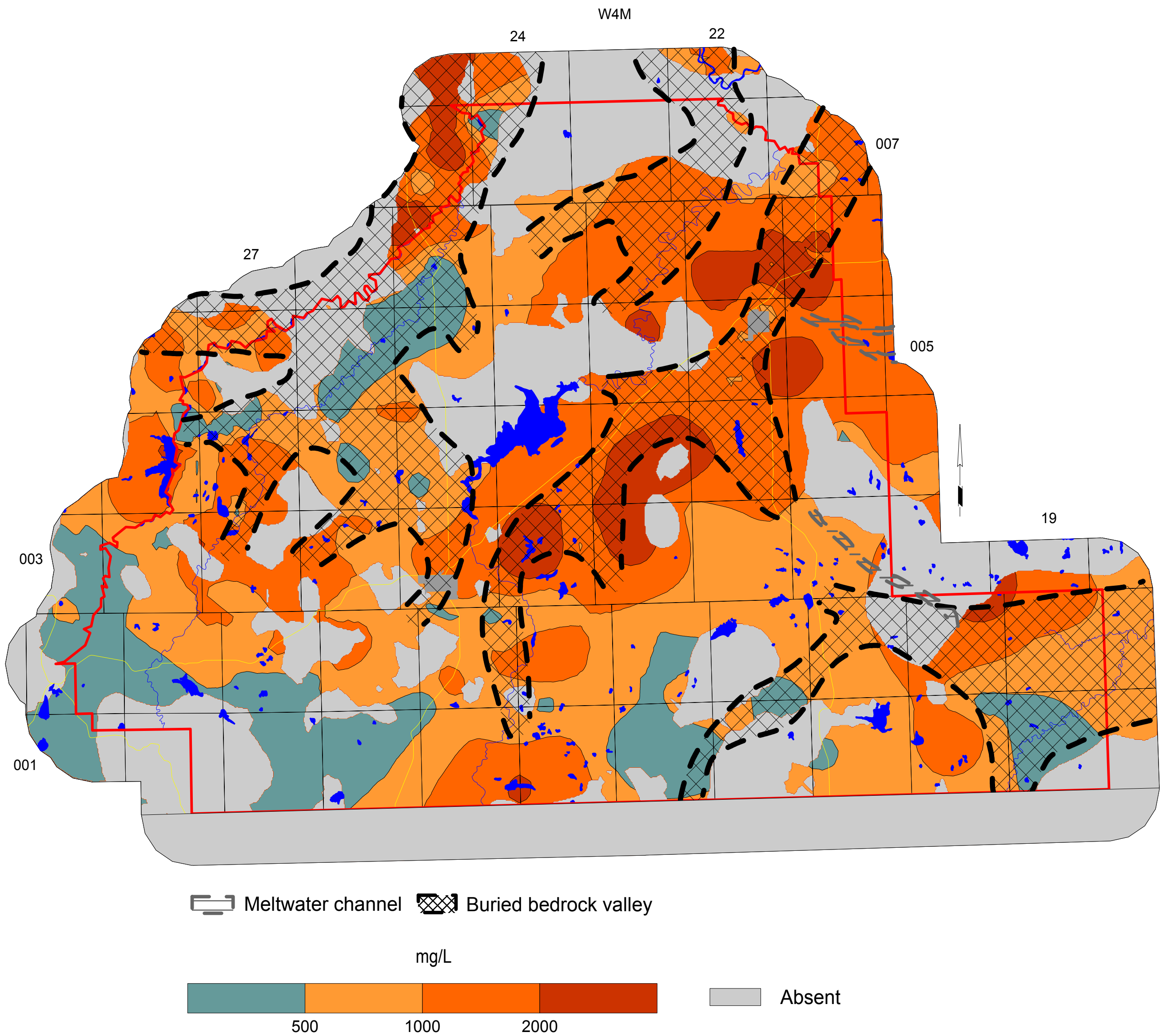
## Thickness of Sand and Gravel Aquifer(s)



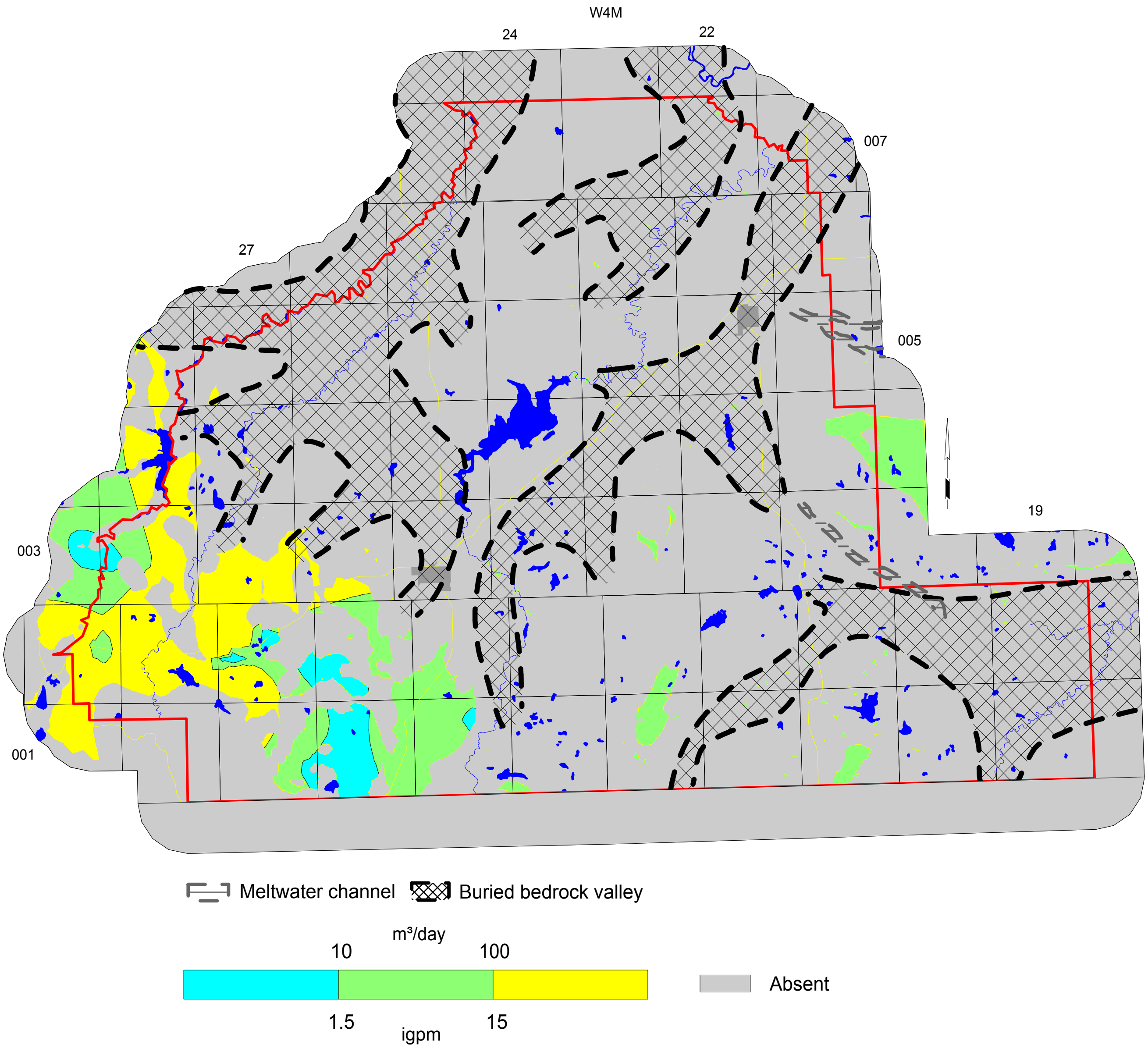
## Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)



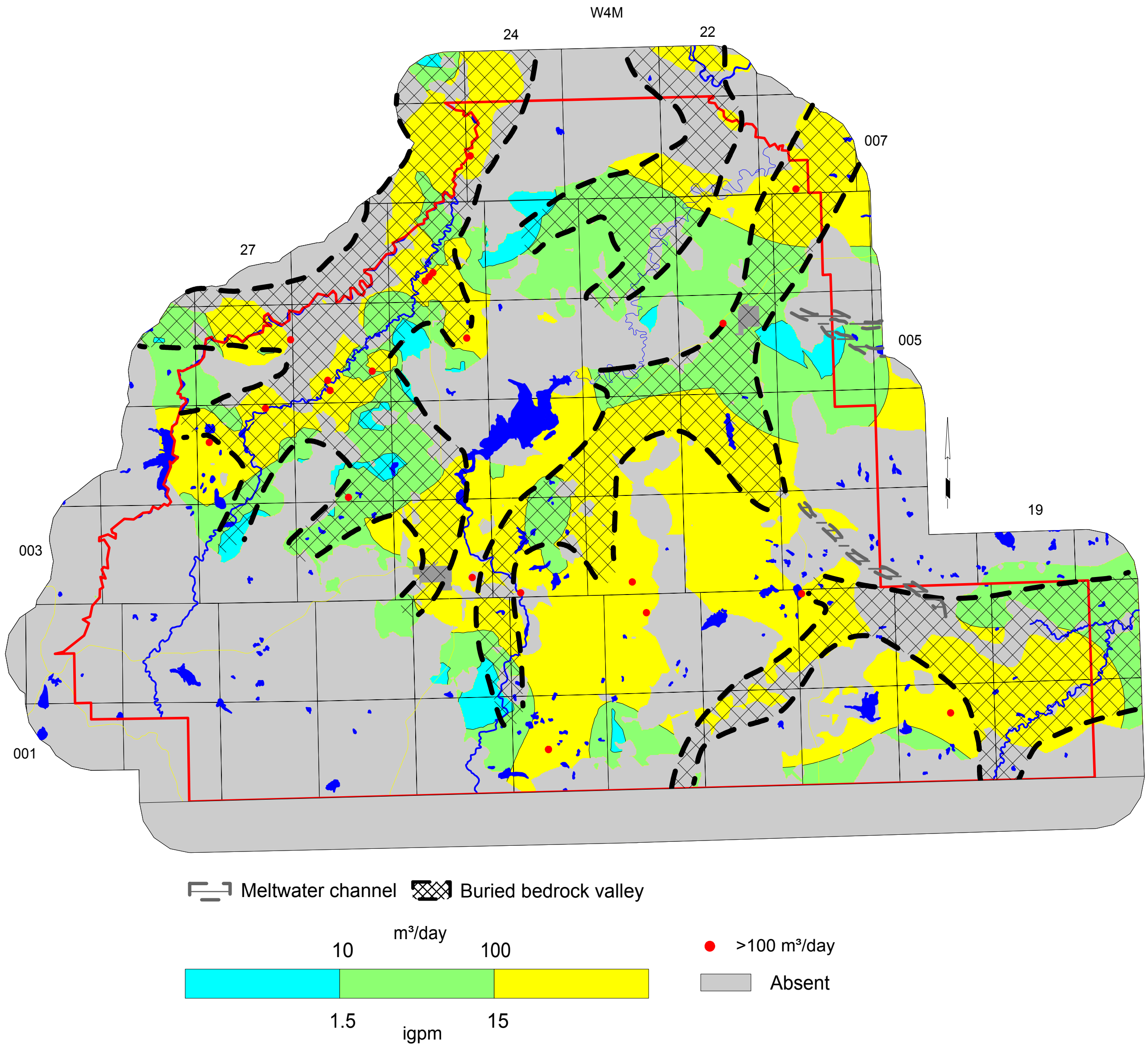
# Total Dissolved Solids in Groundwater from Surficial Deposits



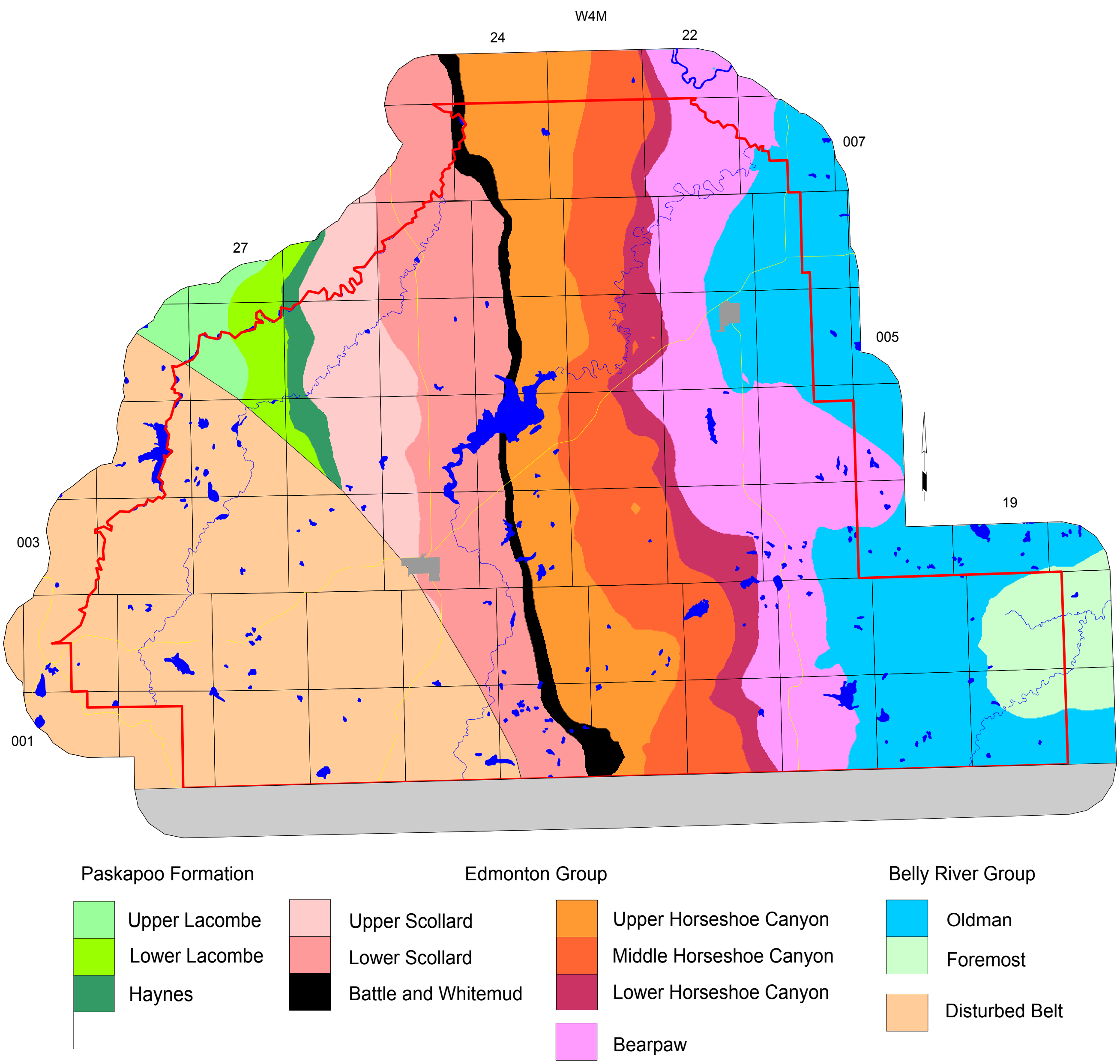
# Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer



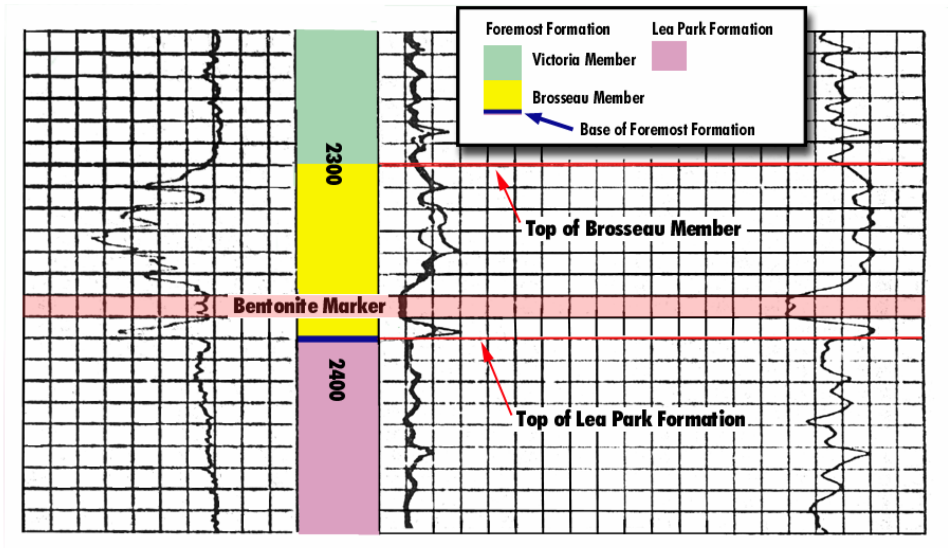
## Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer



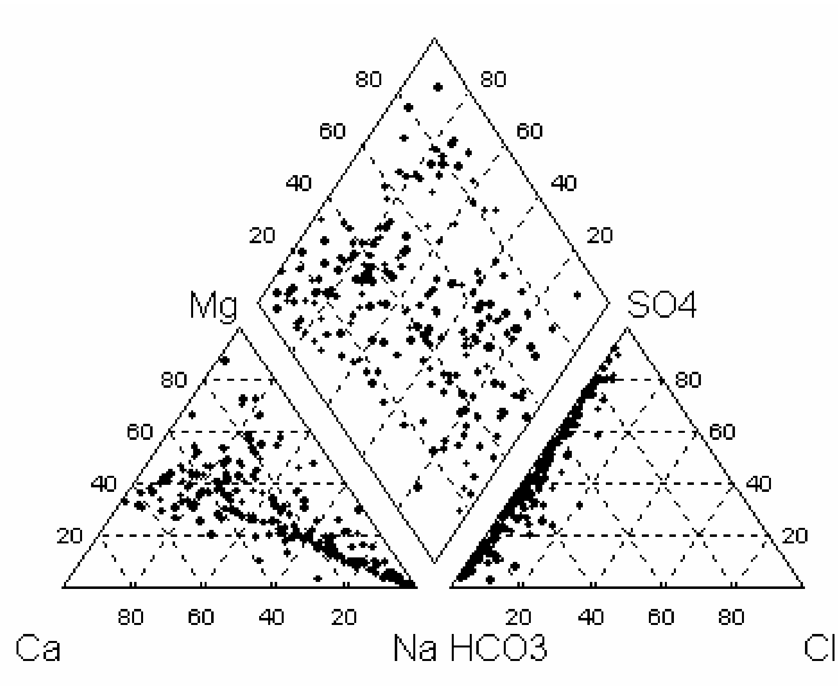
# Bedrock Geology



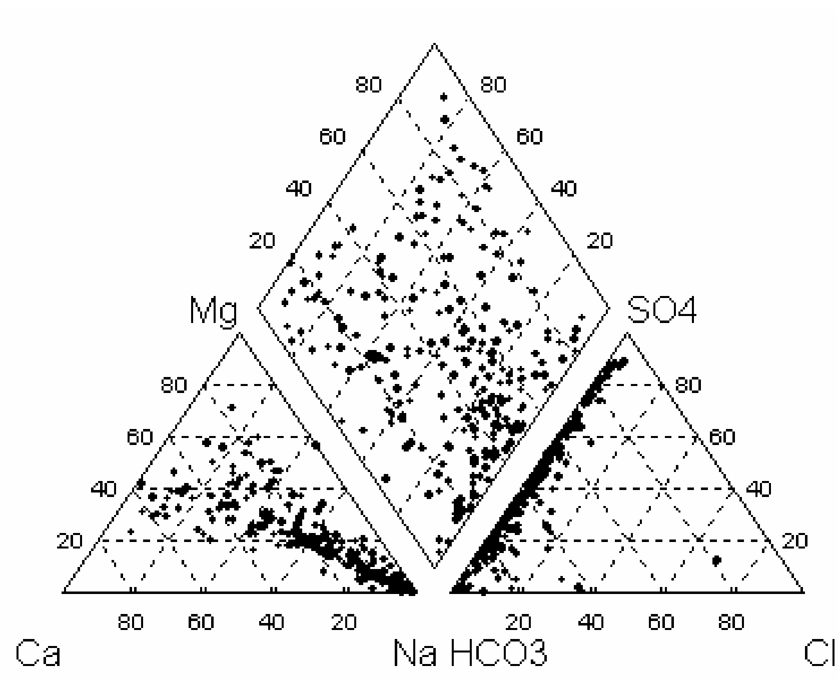
## E-Log Showing Base of Foremost Formation



## Piper Diagrams

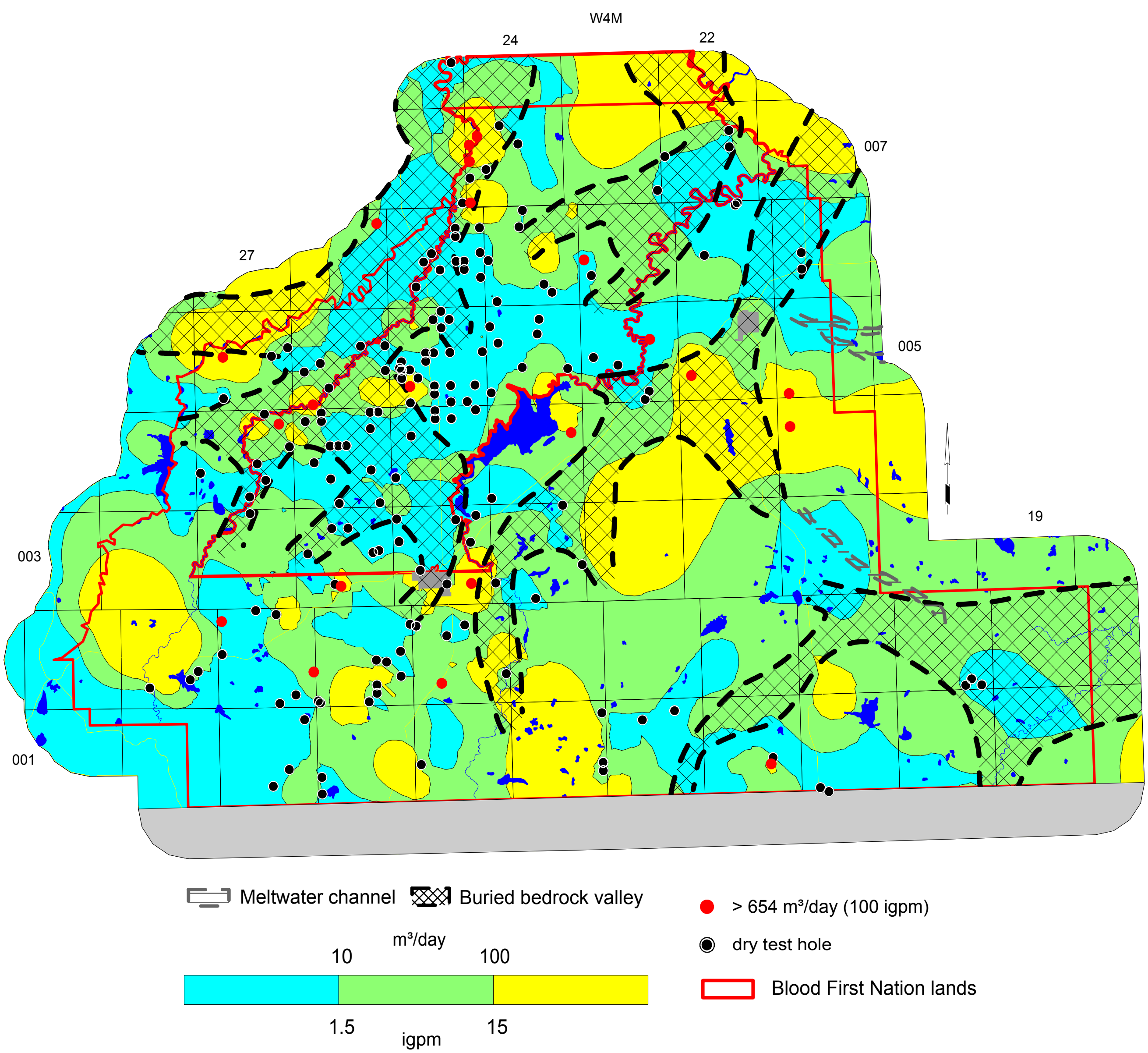



**Surficial Deposits**

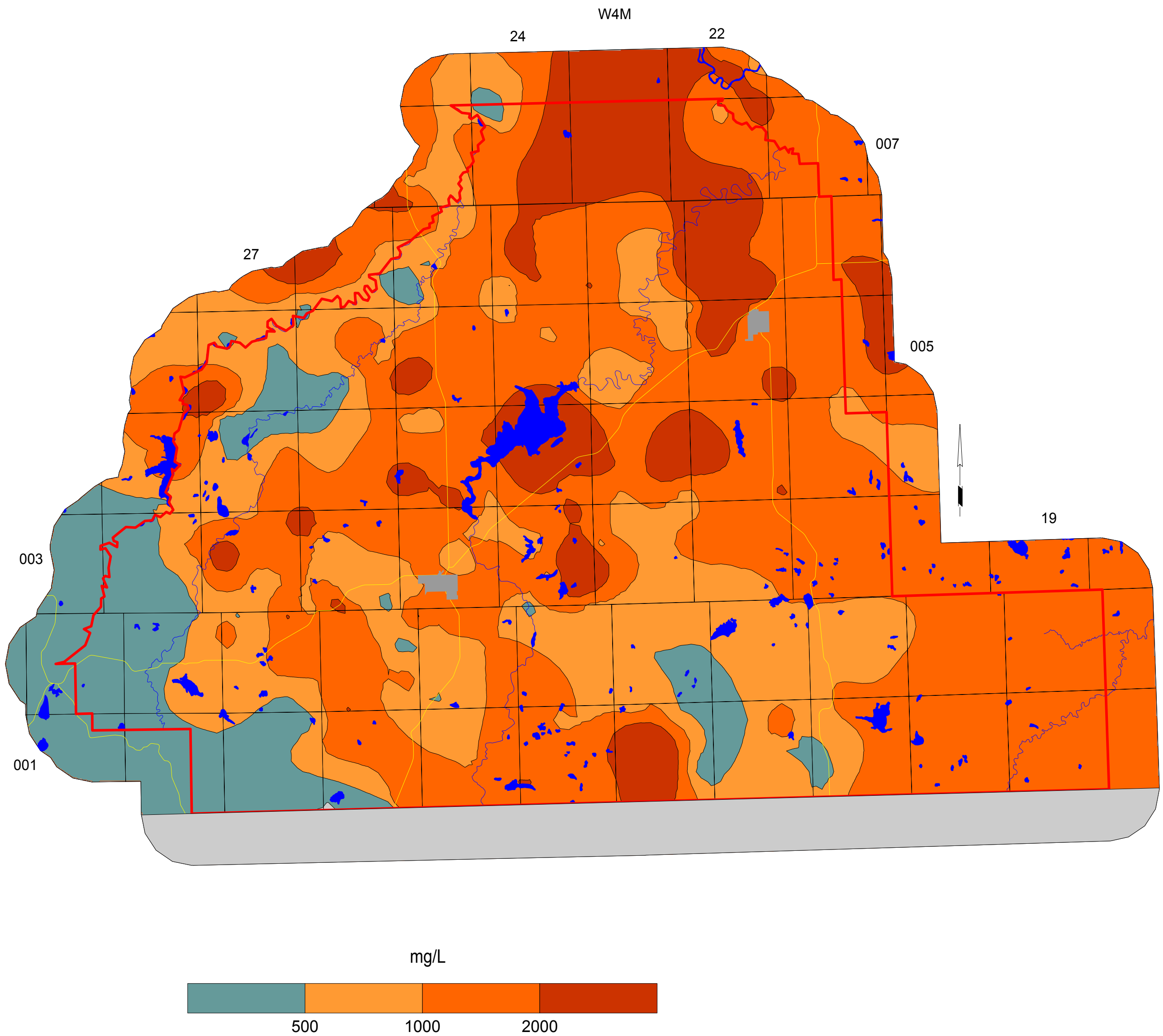



**Bedrock Aquifers**

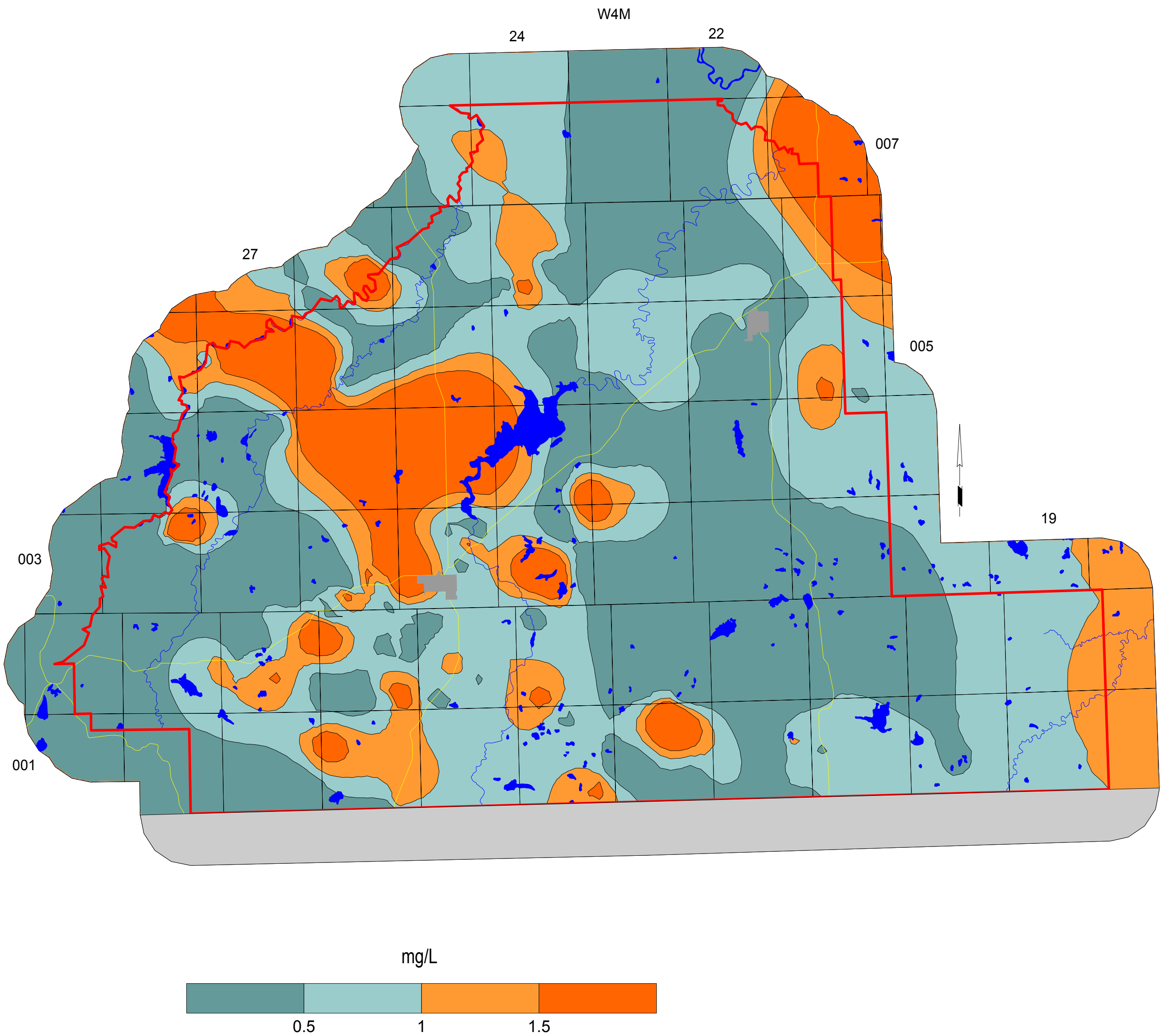
## Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



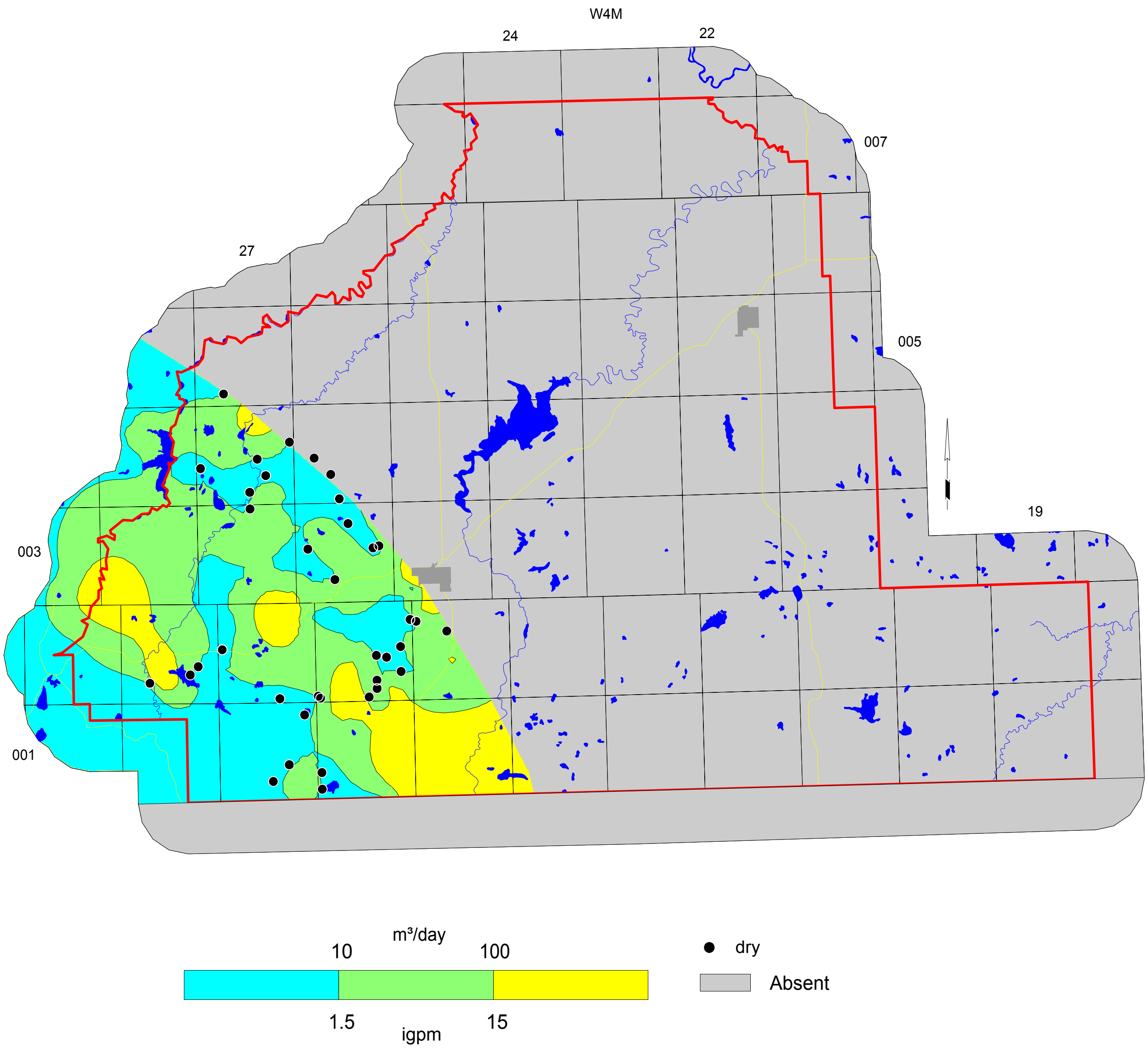
# Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



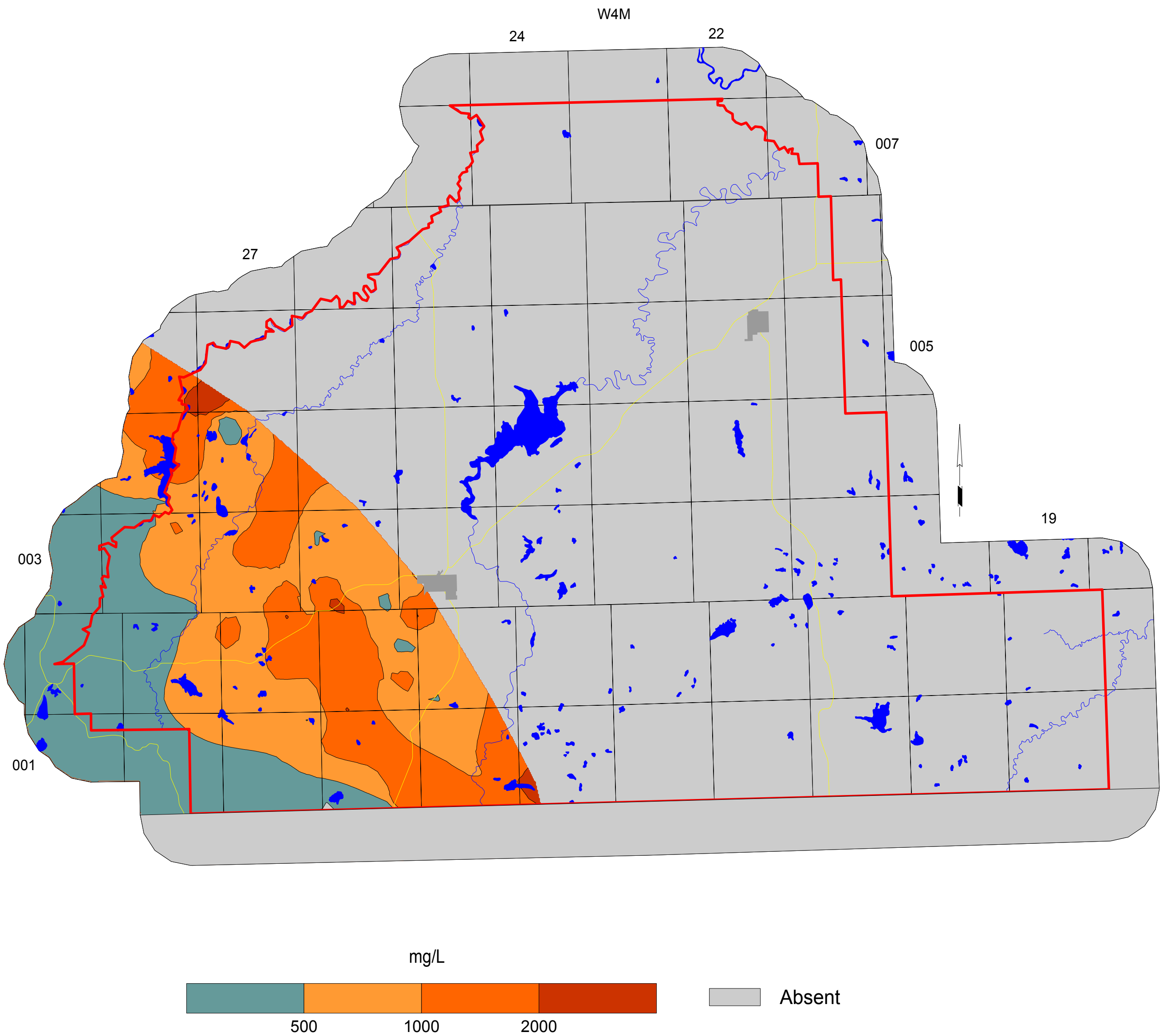
## Fluoride in Groundwater from Upper Bedrock Aquifer(s)



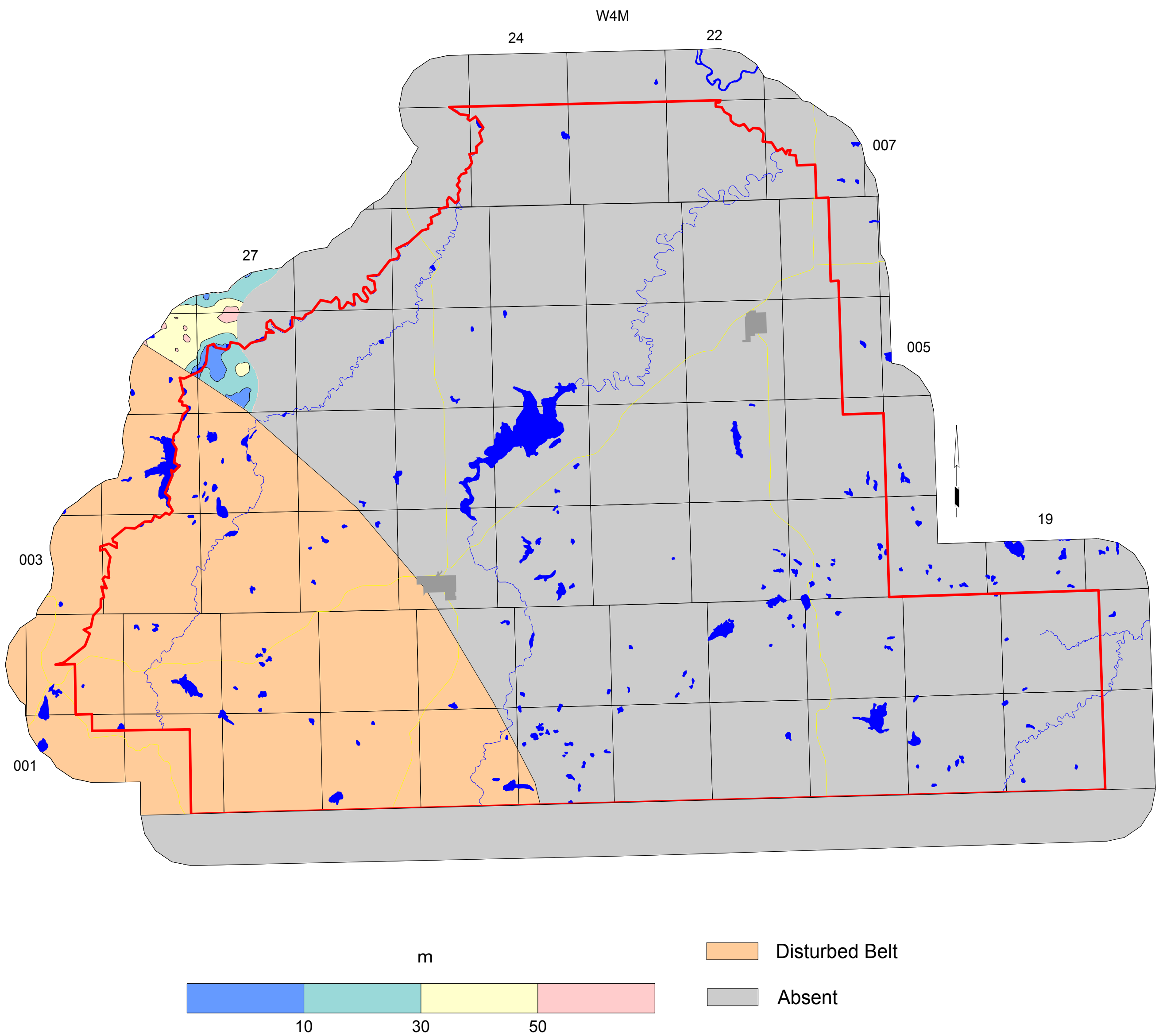
# Apparent Yield for Water Wells Completed through Disturbed Belt Aquifer



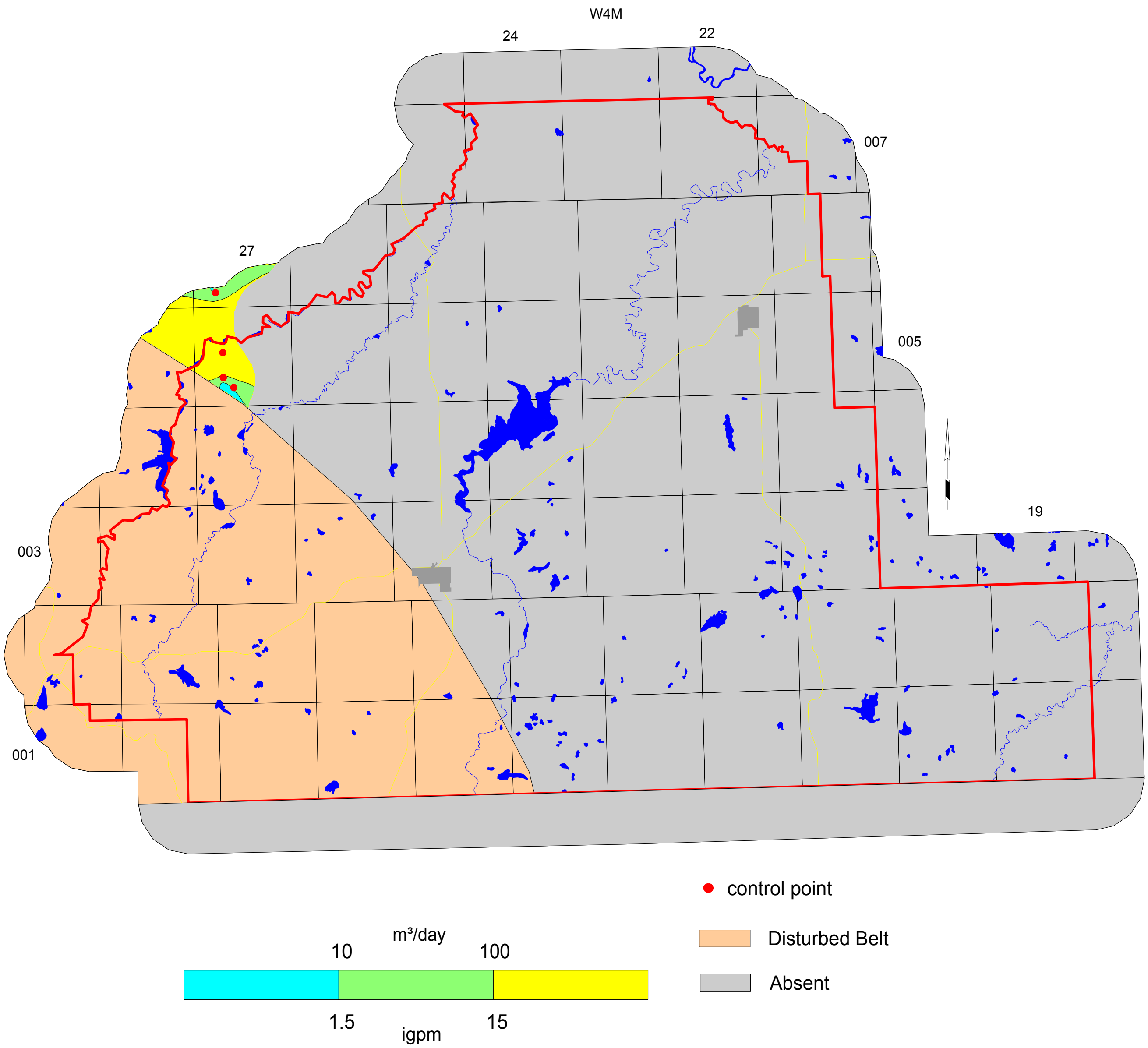
# Total Dissolved Solids in Groundwater from Disturbed Belt Aquifer



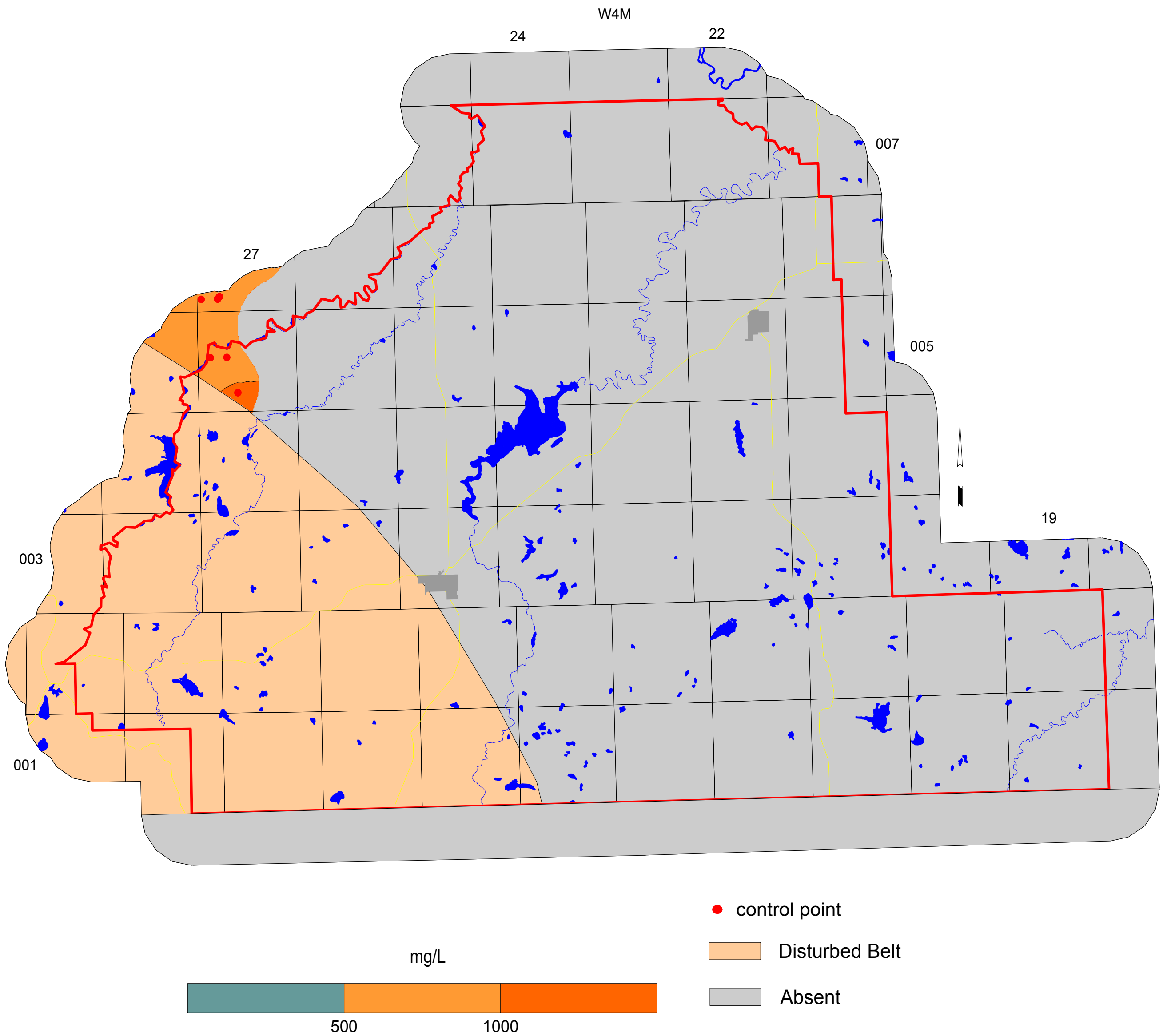
## Depth to Top of Upper Lacombe Member



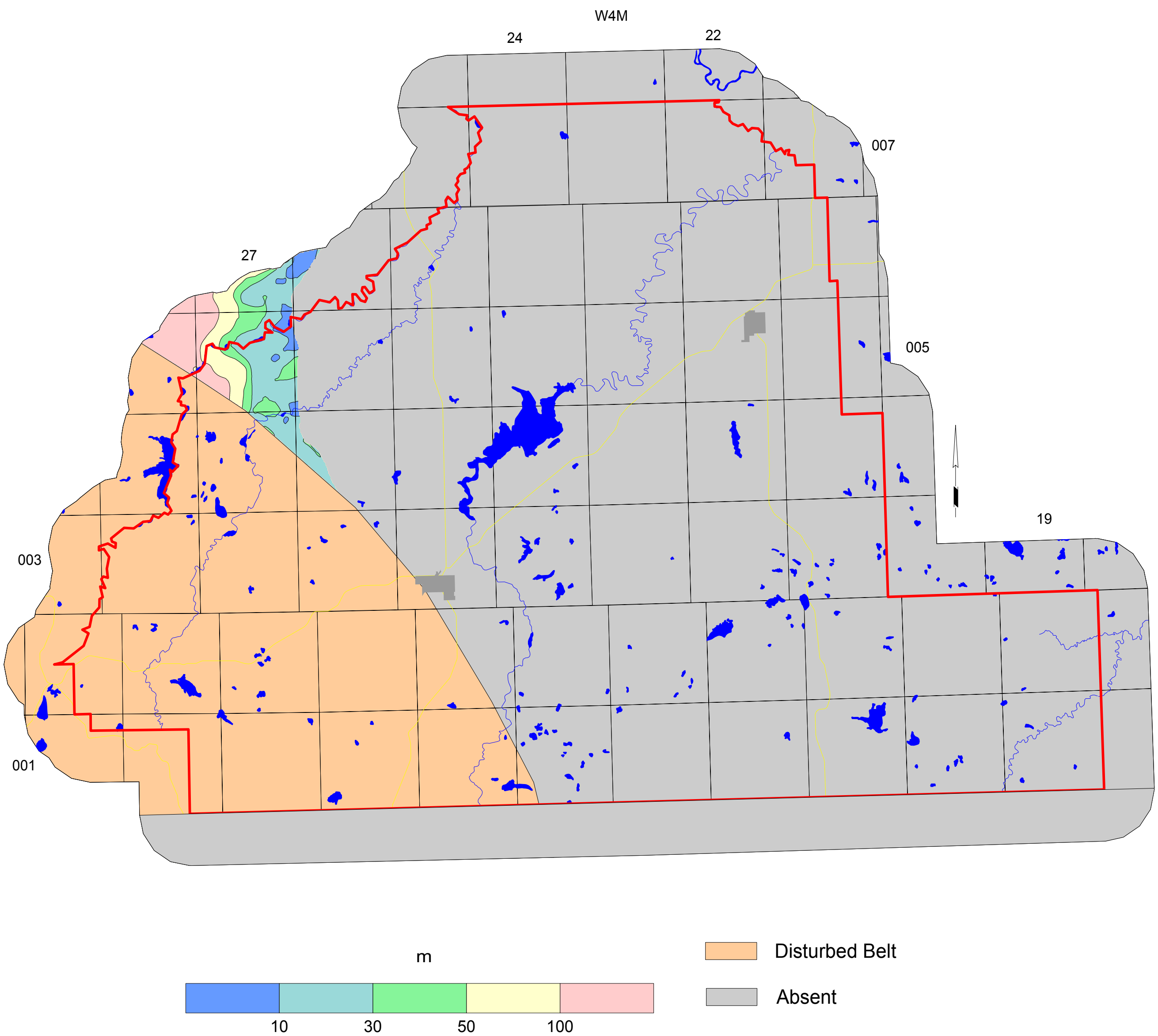
## Apparent Yield for Water Wells Completed through Upper Lacombe Aquifer



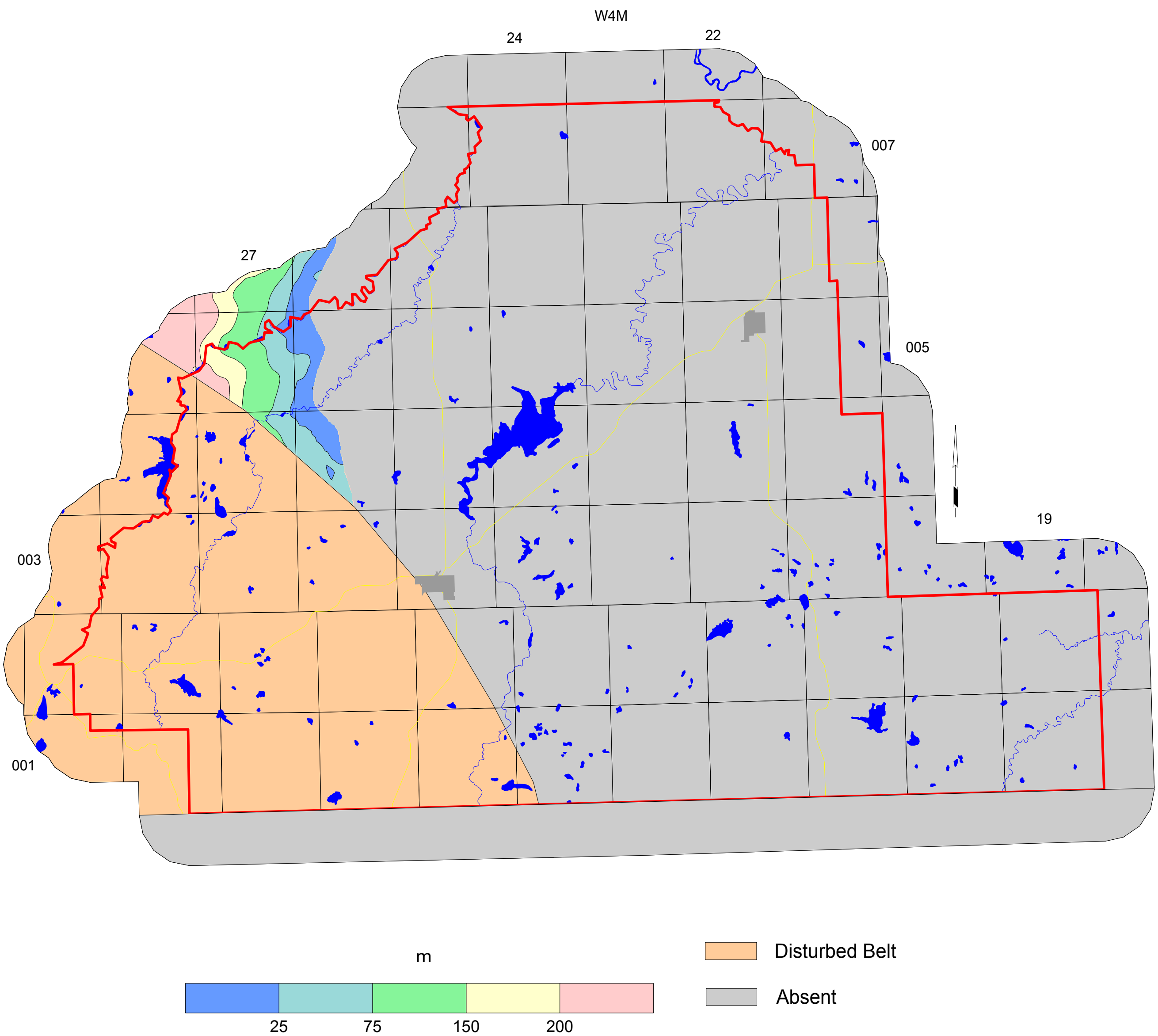
## Total Dissolved Solids in Groundwater from Upper Lacombe Aquifer



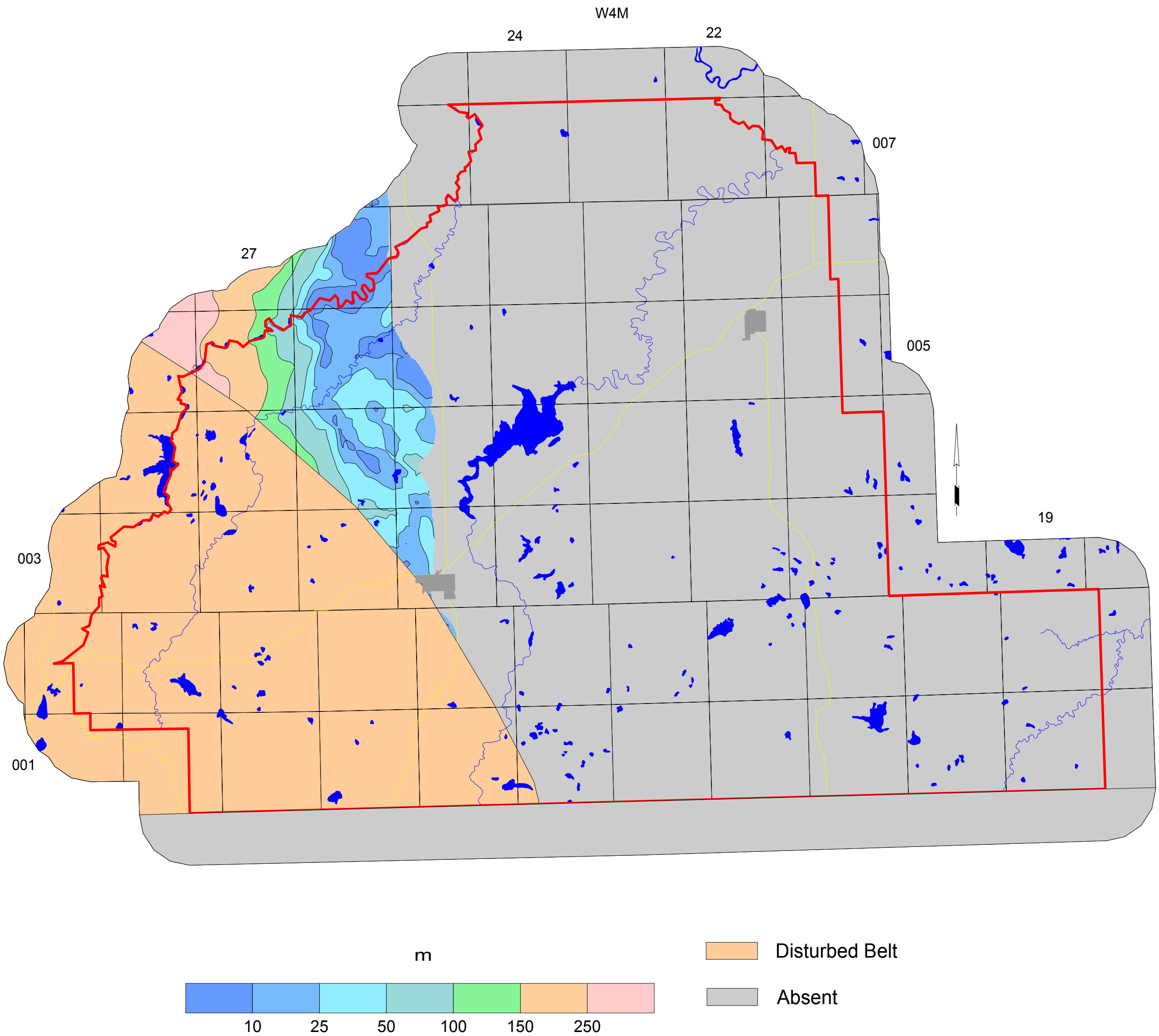
# Depth to Top of Lower Lacombe Member



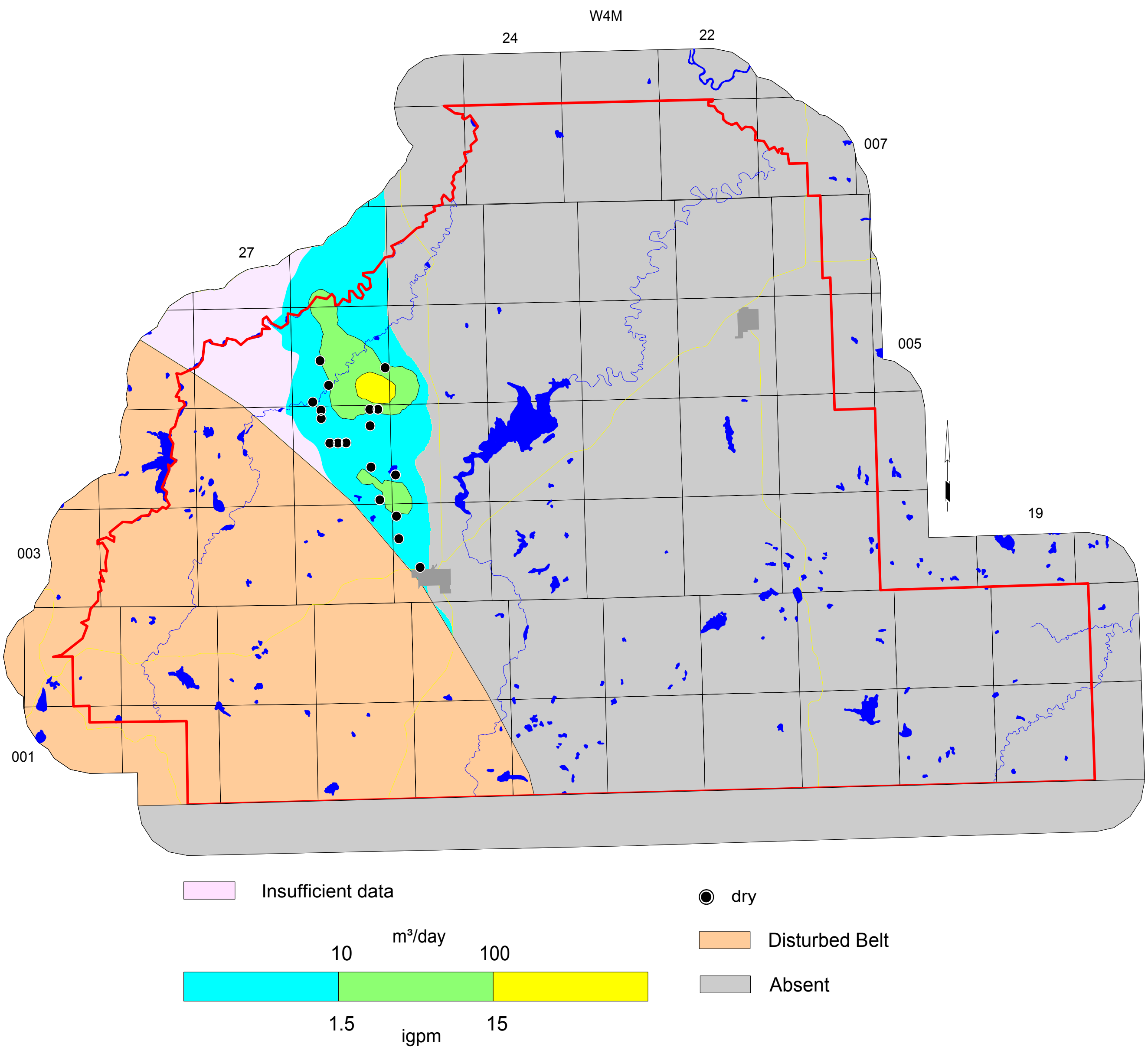
## Depth to Top of Haynes Member



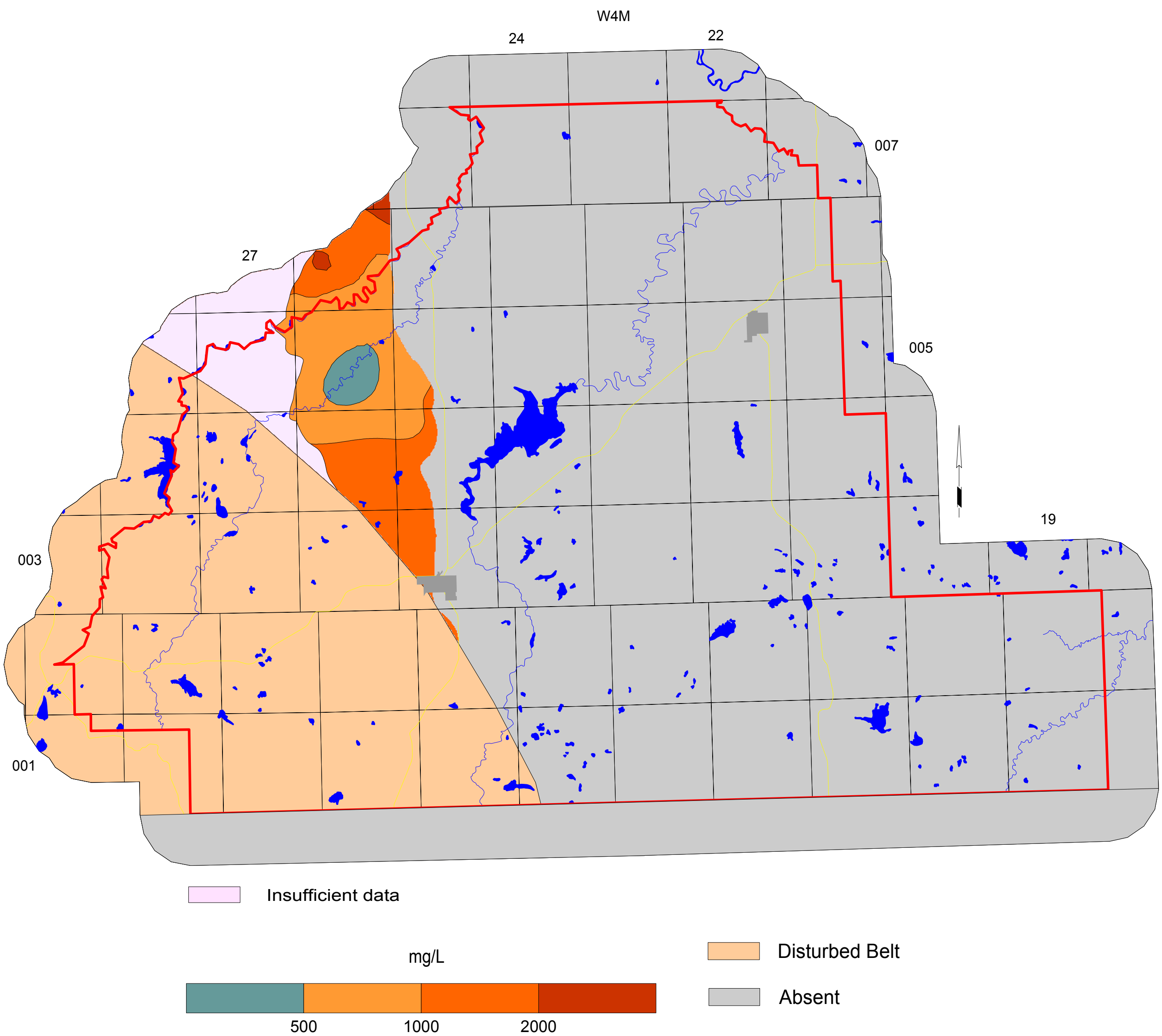
# Depth to Top of Upper Scollard Formation



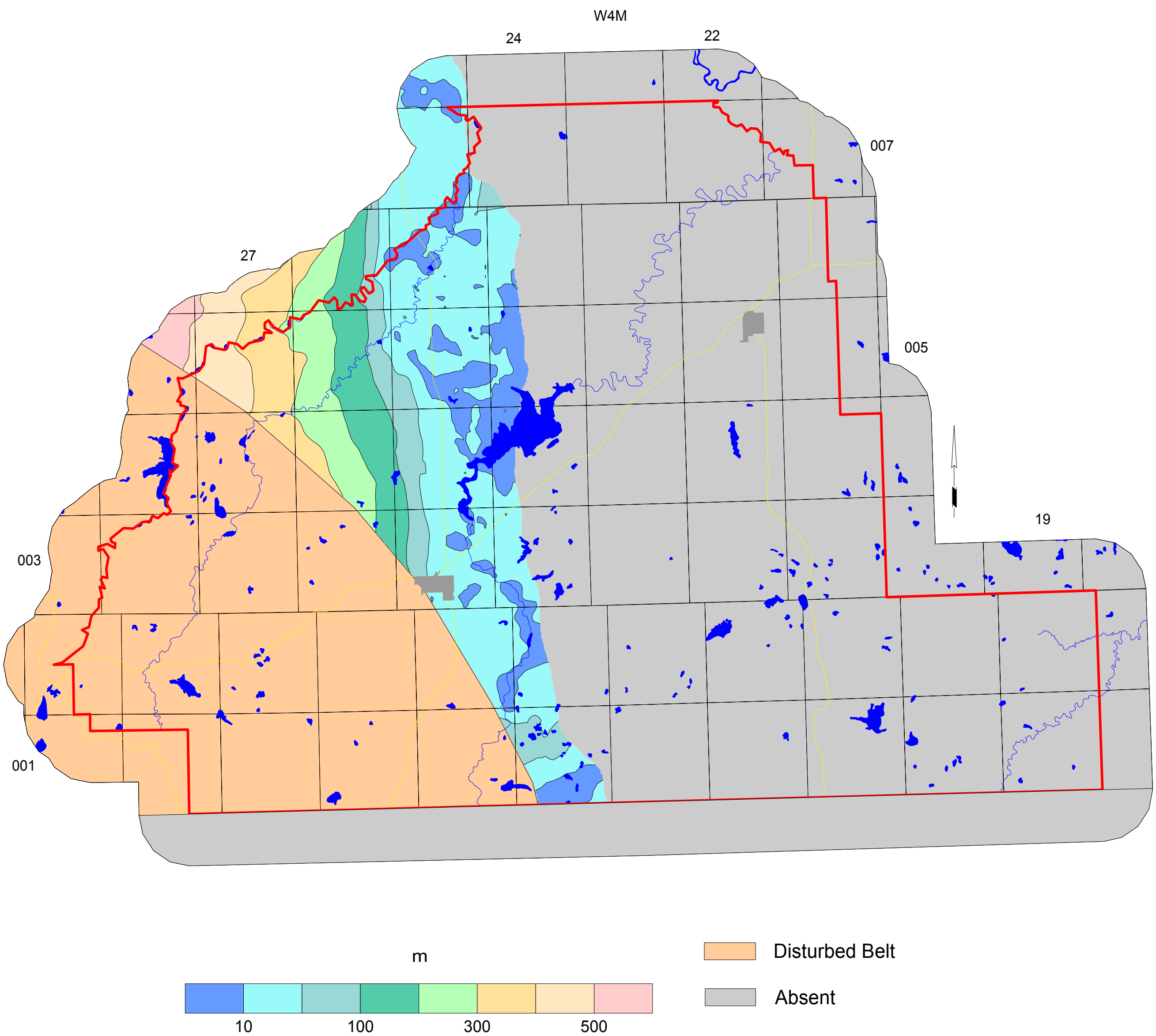
# Apparent Yield for Water Wells Completed through Upper Scollard Aquifer



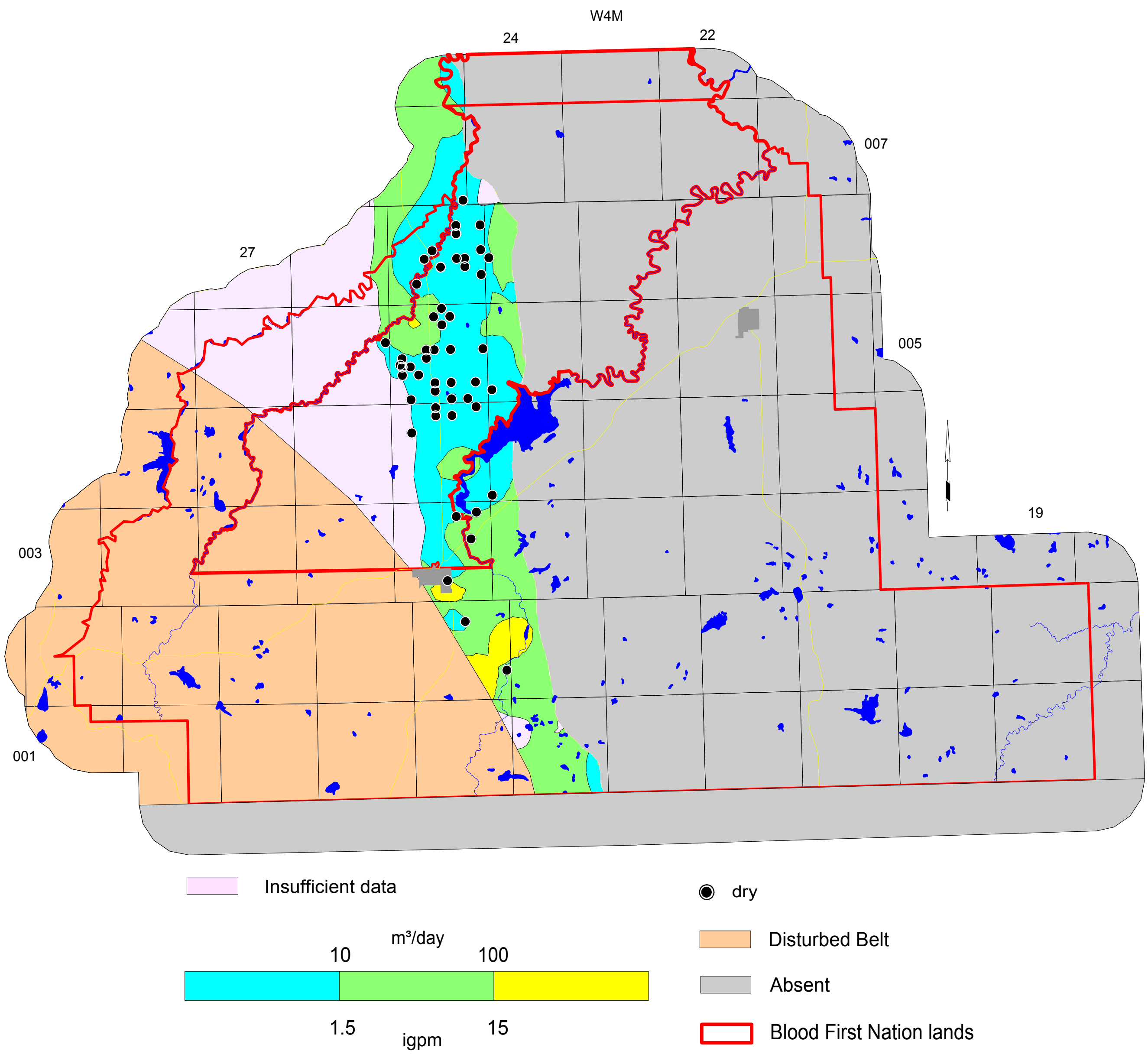
# Total Dissolved Solids in Groundwater from Upper Scollard Aquifer



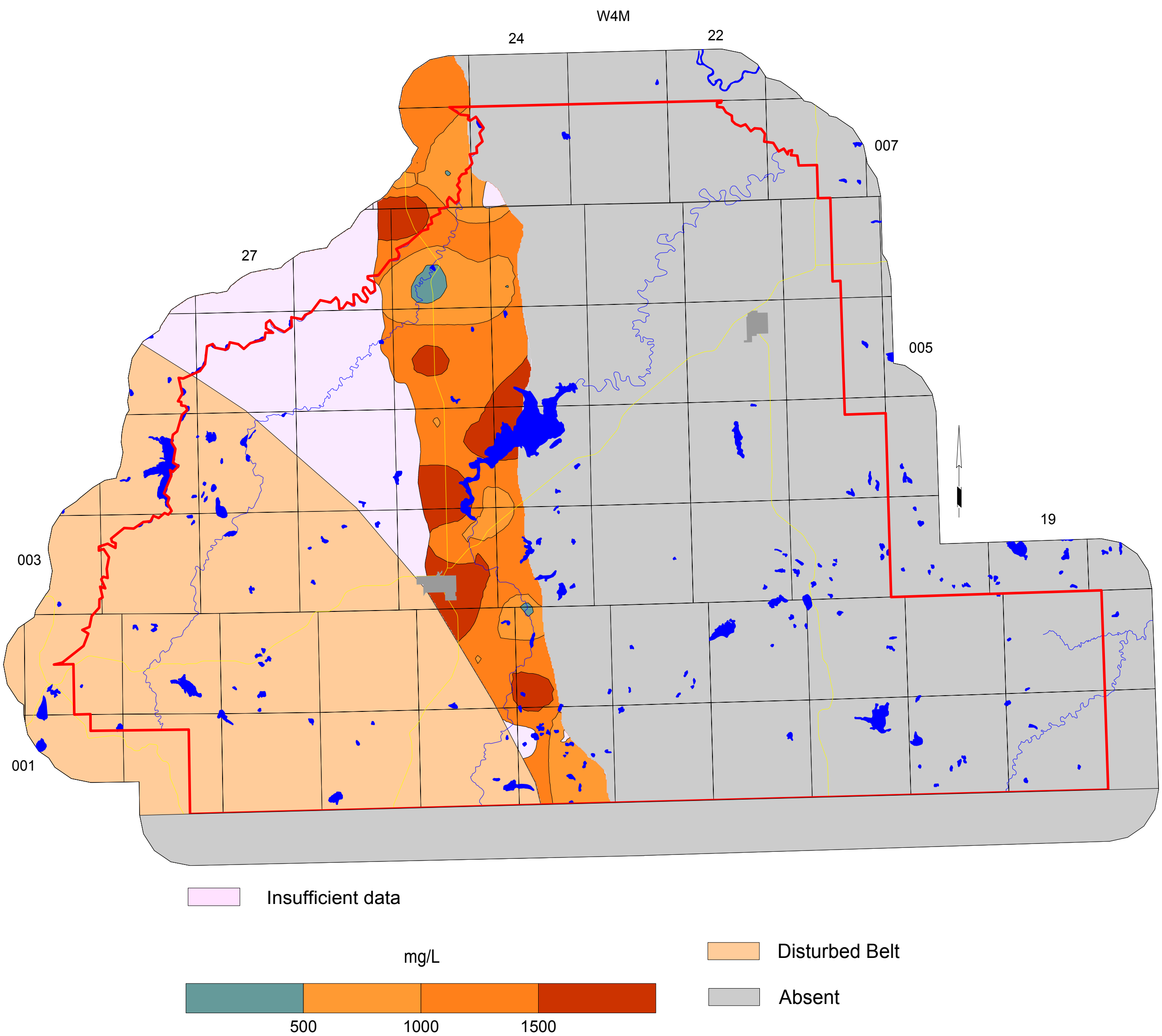
## Depth to Top of Lower Scollard Formation



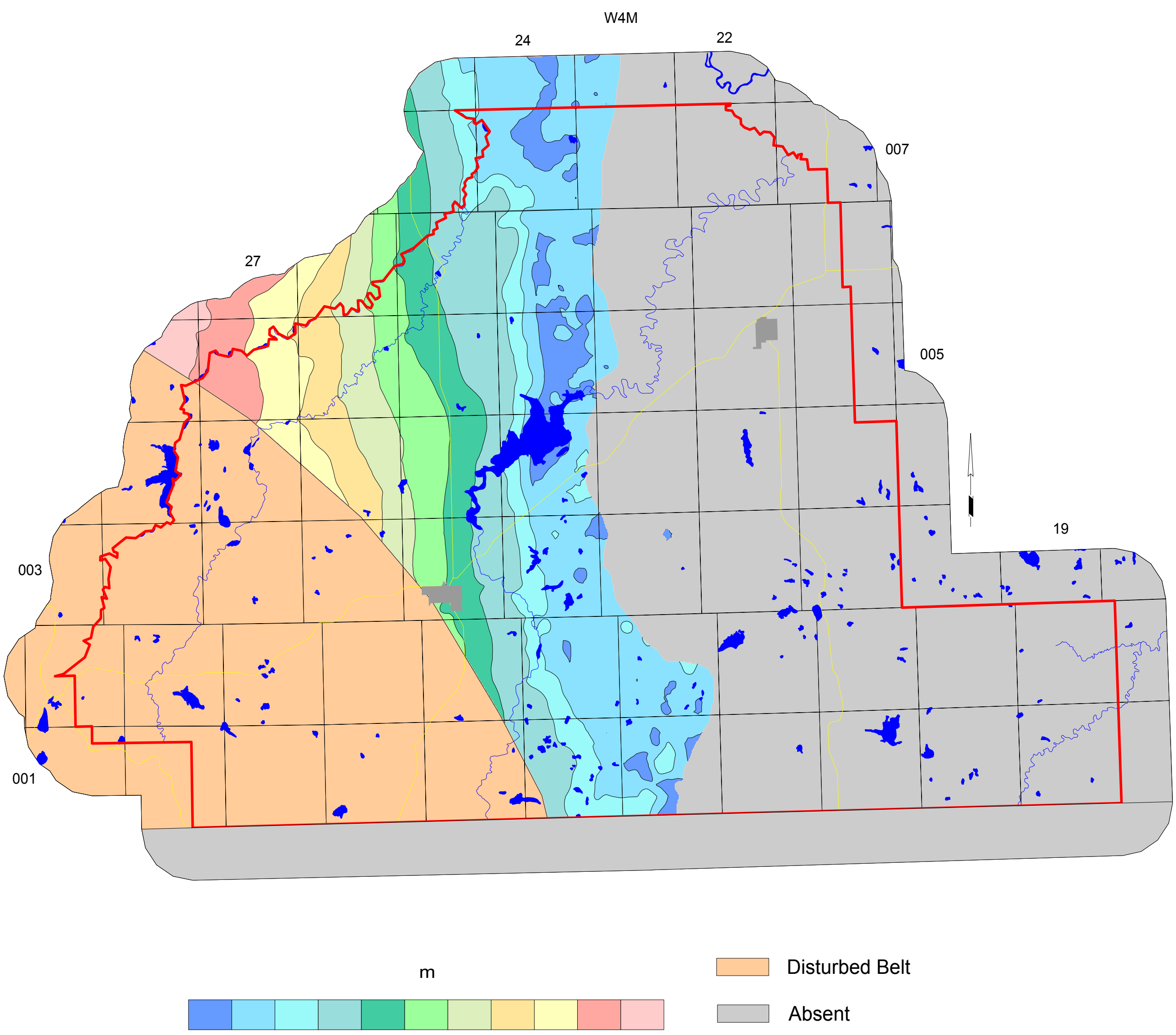
# Apparent Yield for Water Wells Completed through Lower Scollard Aquifer



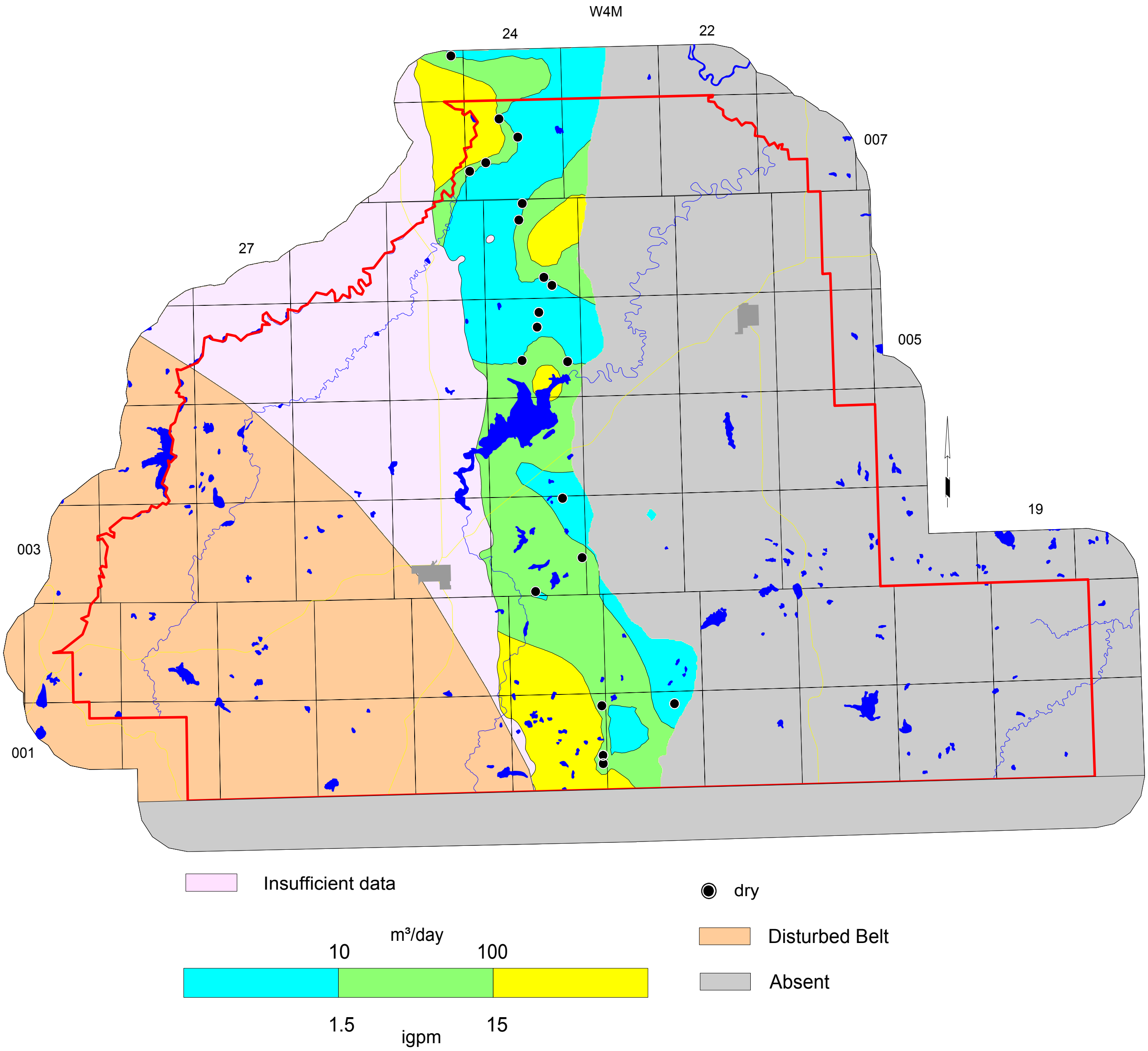
# Total Dissolved Solids in Groundwater from Lower Scollard Aquifer



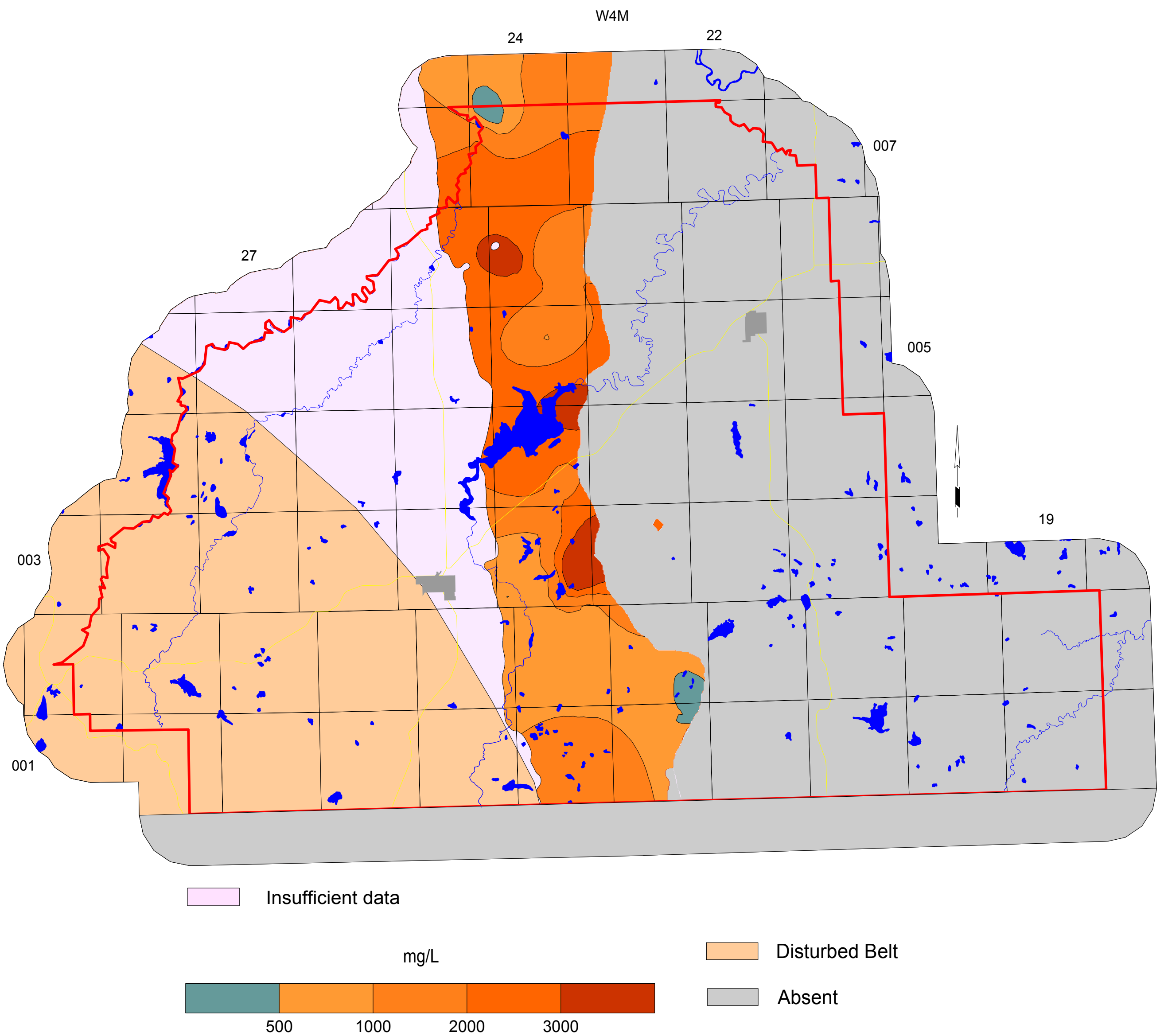
## Depth to Top of Upper Horseshoe Canyon Formation



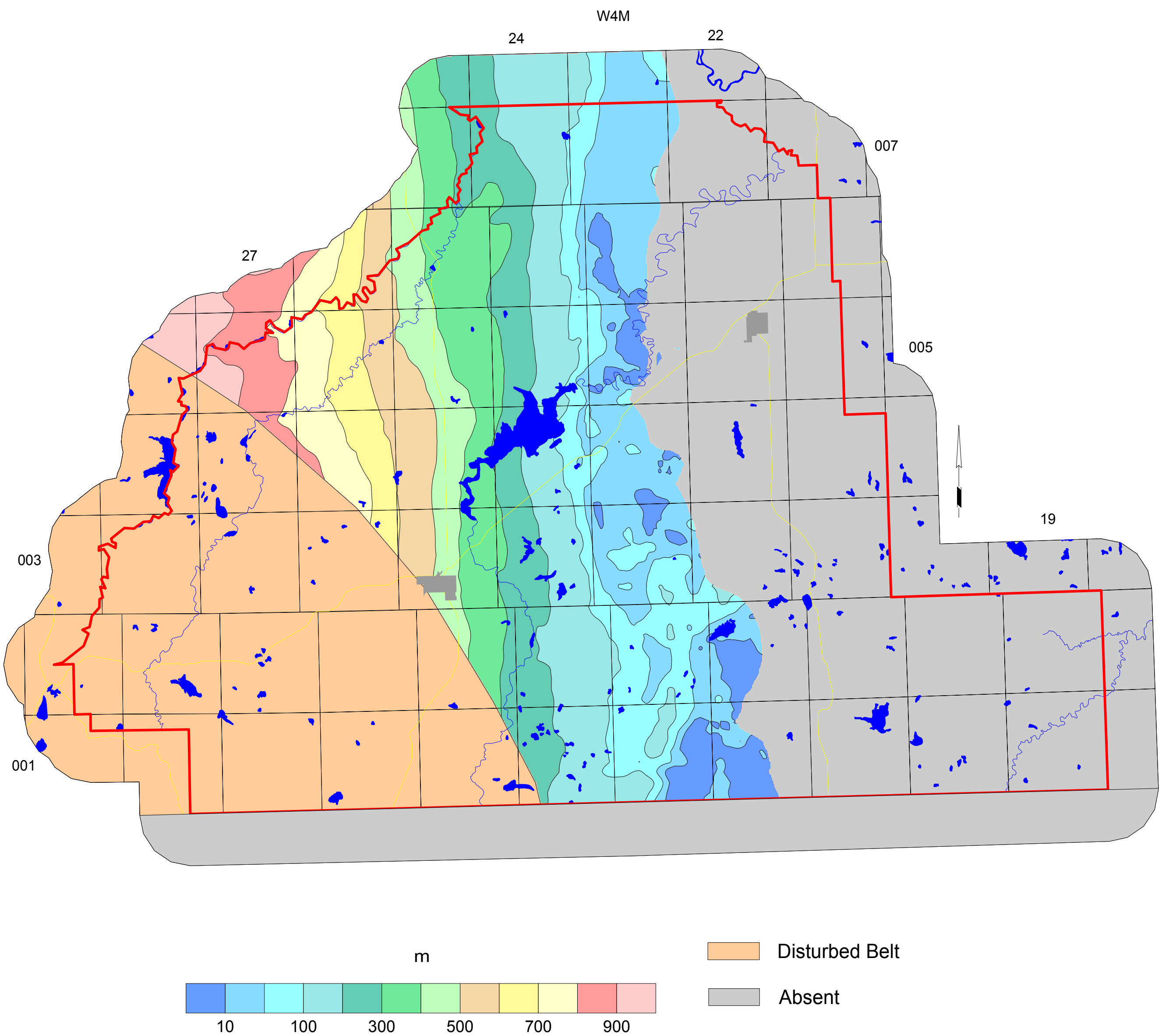
## Apparent Yield for Water Wells Completed through Upper Horseshoe Canyon Aquifer



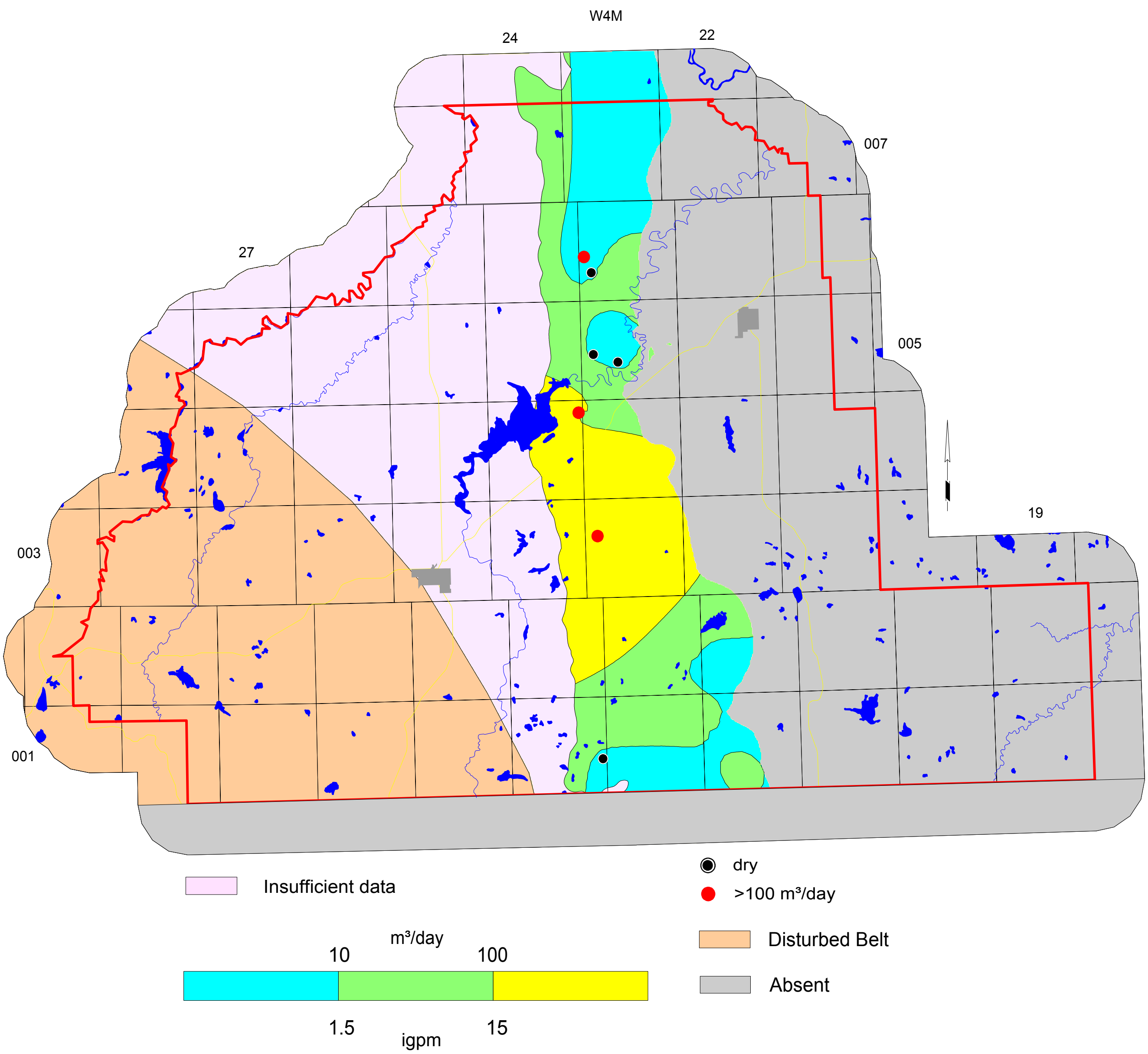
## Total Dissolved Solids in Groundwater from Upper Horseshoe Canyon Aquifer



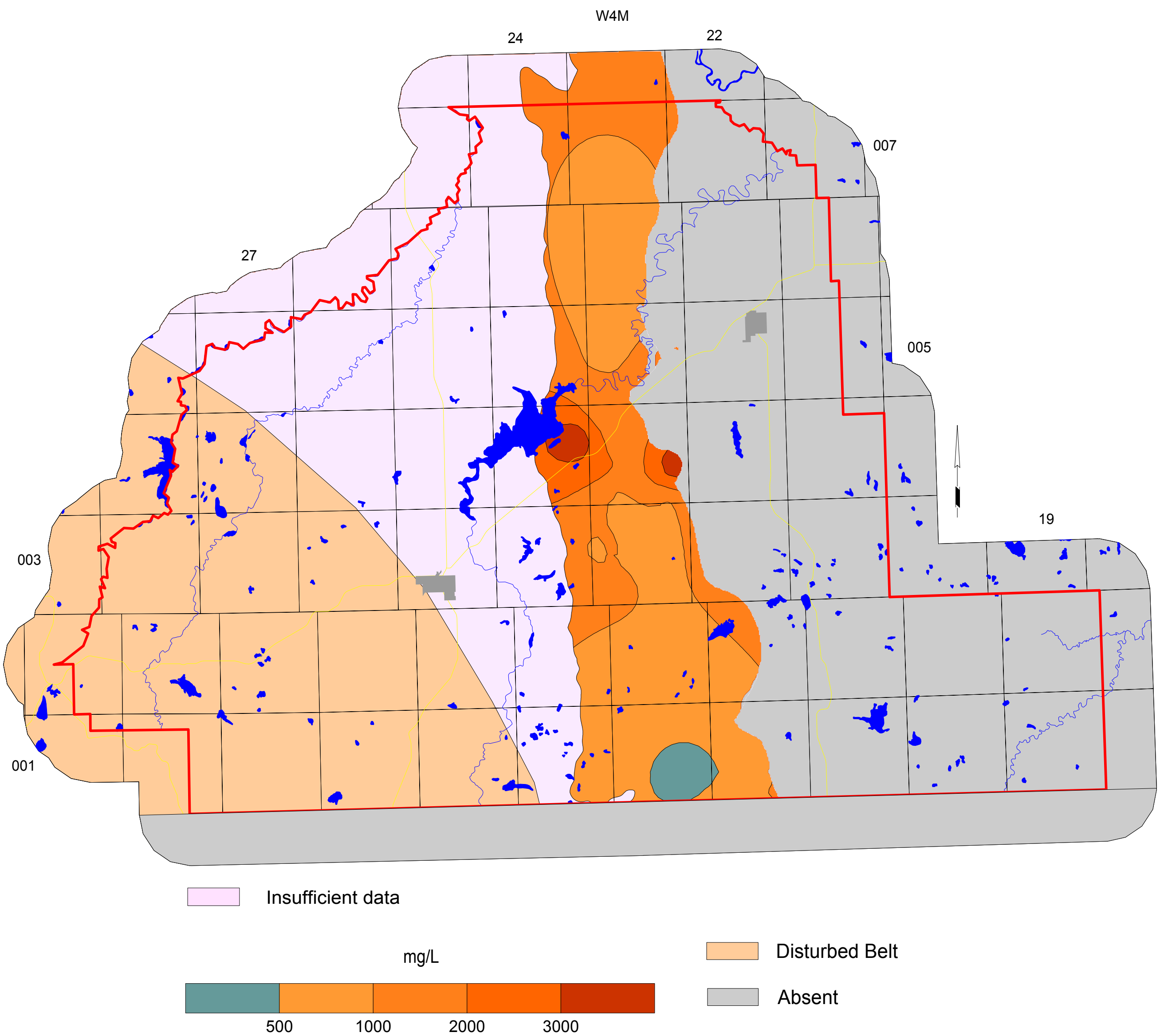
## Depth to Top of Middle Horseshoe Canyon Formation



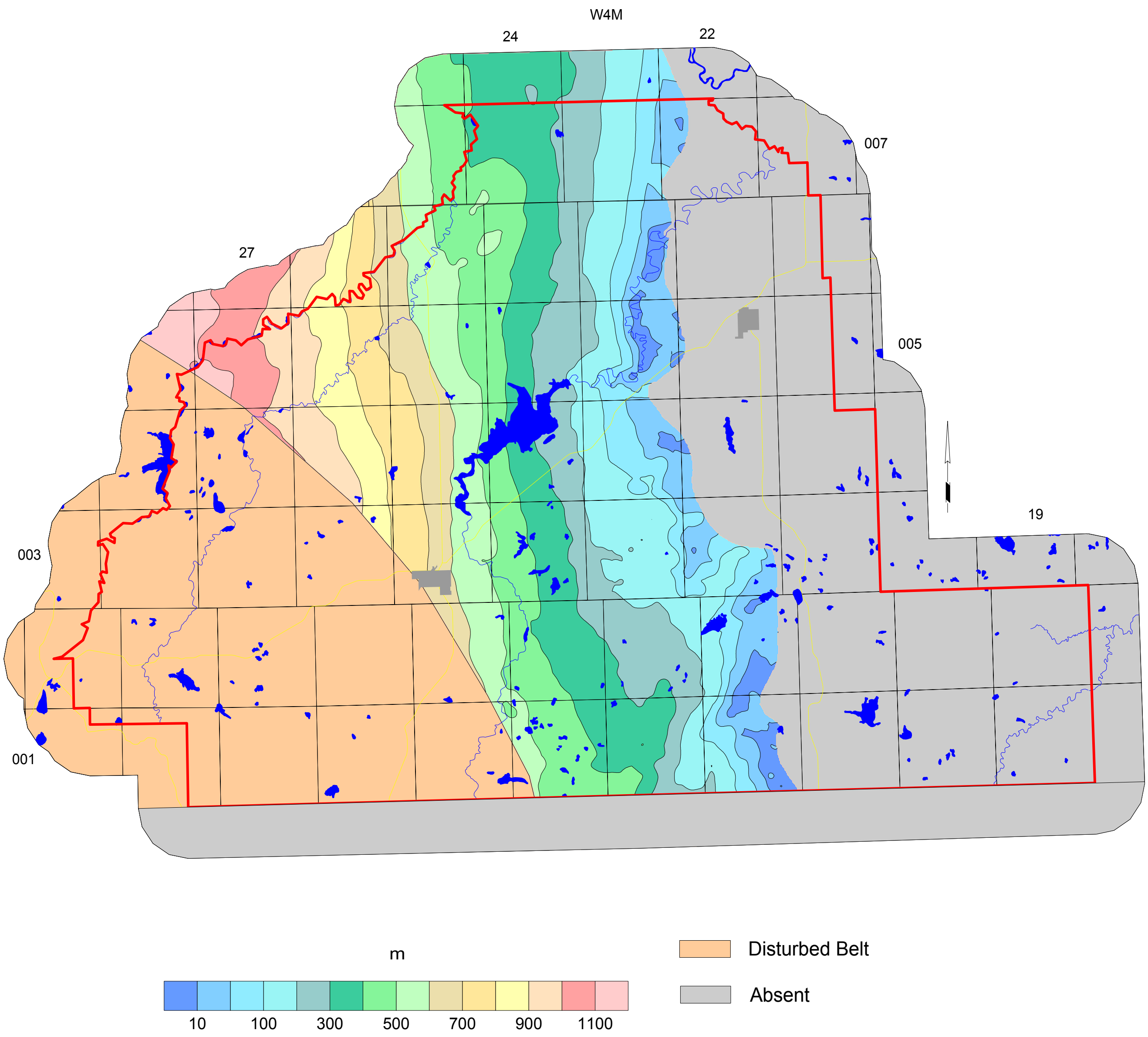
## Apparent Yield for Water Wells Completed through Middle Horseshoe Canyon Aquifer



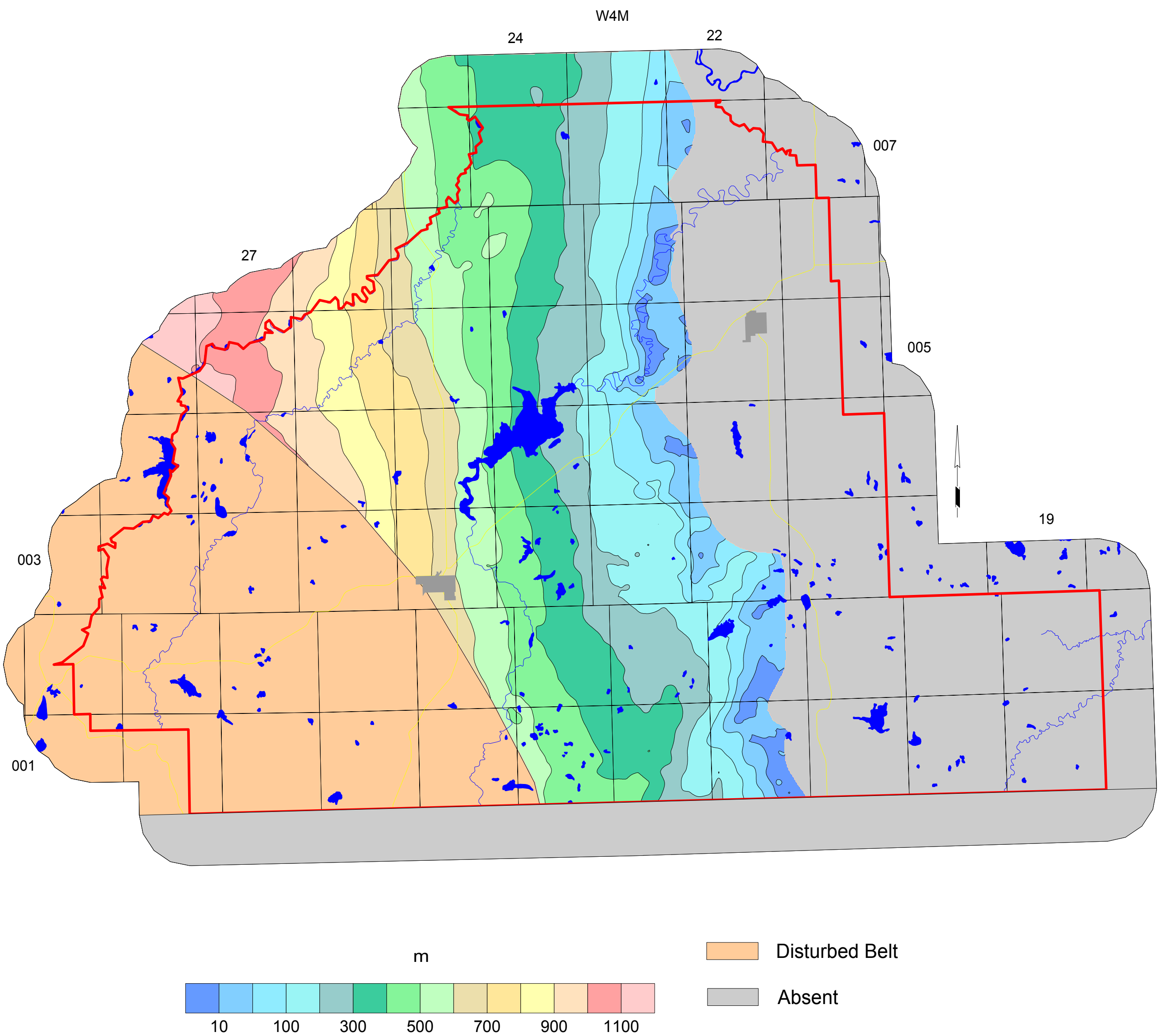
# Total Dissolved Solids in Groundwater from Middle Horseshoe Canyon Aquifer



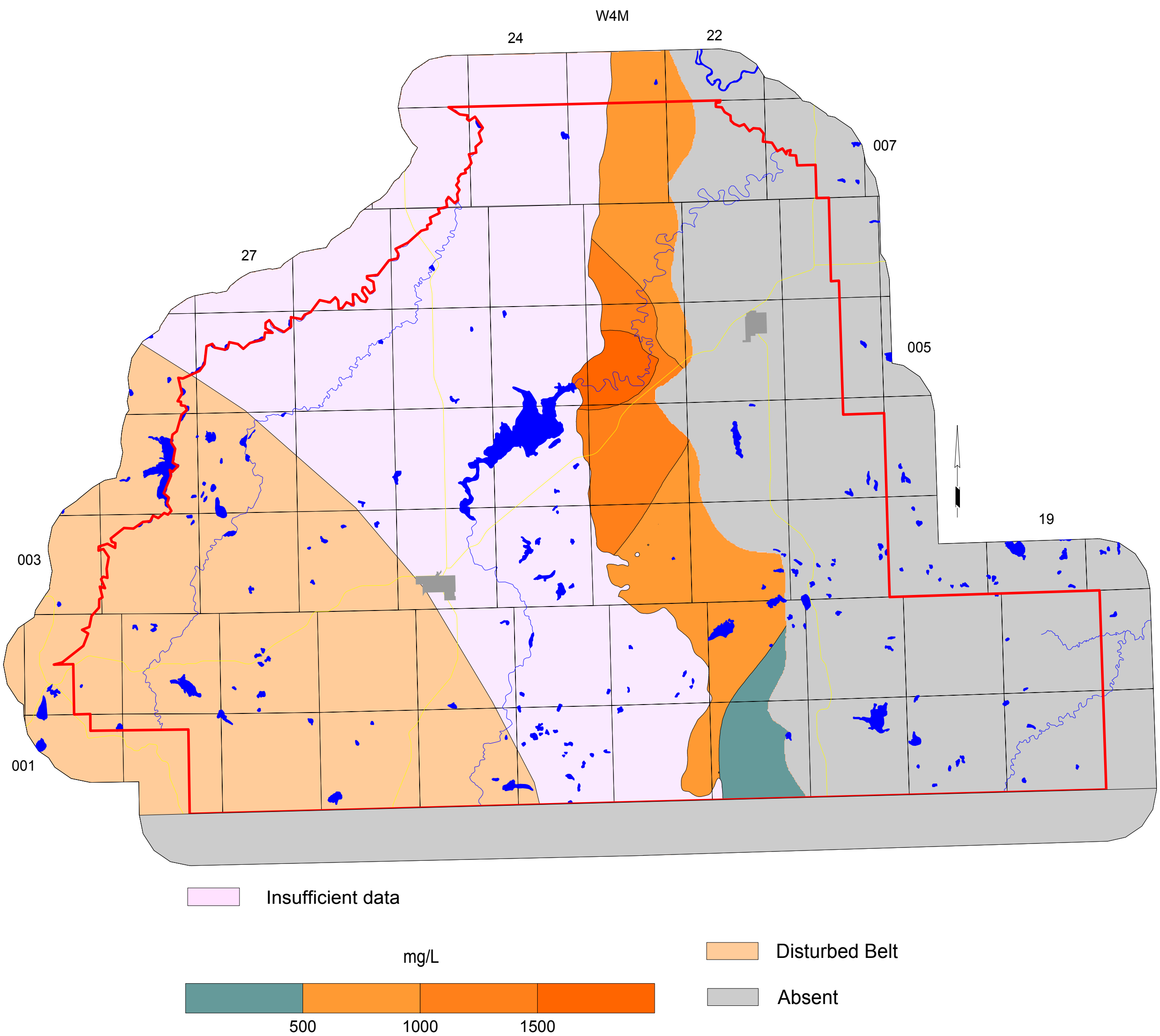
## Depth to Top of Lower Horseshoe Canyon Formation



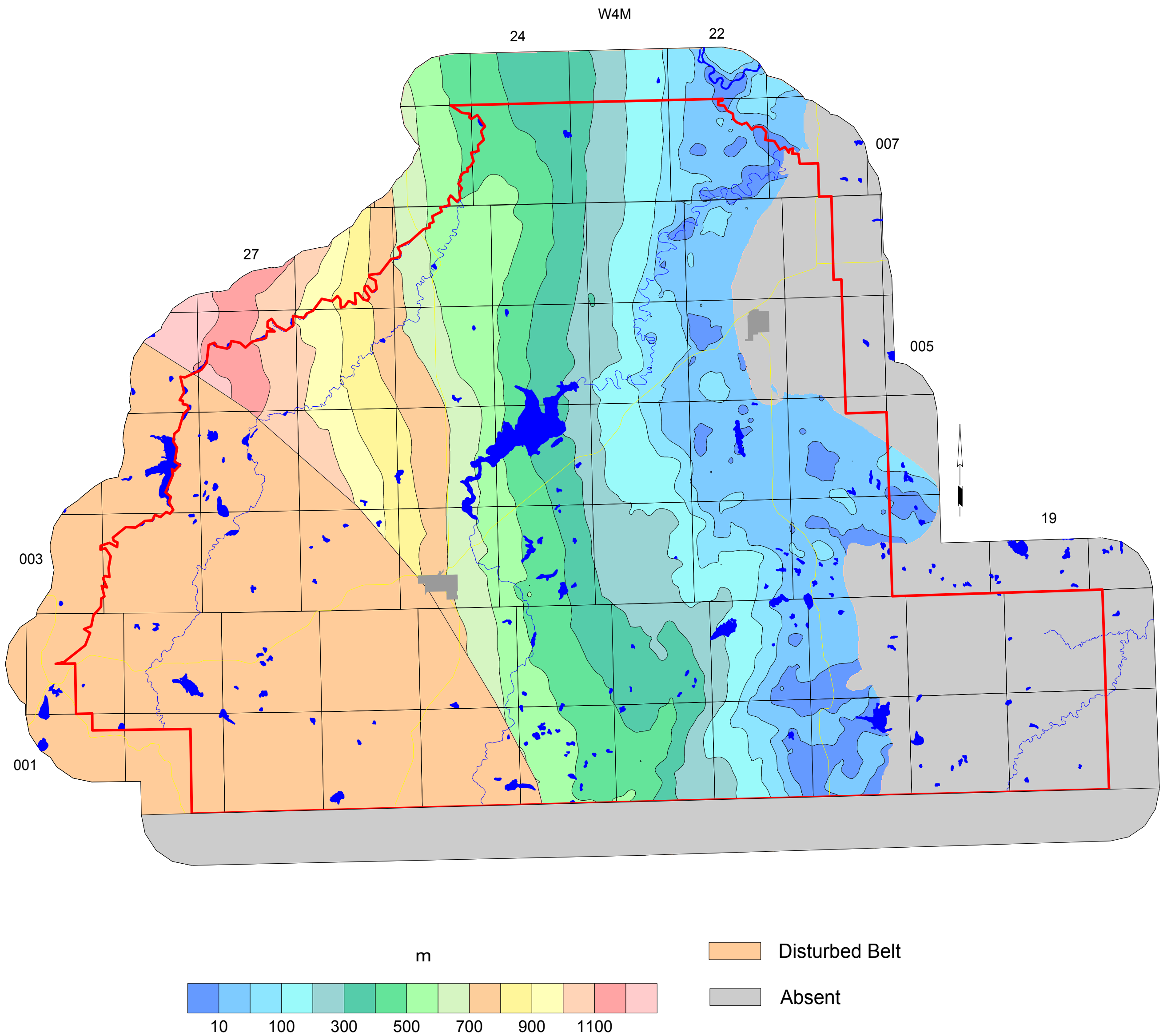
# Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer



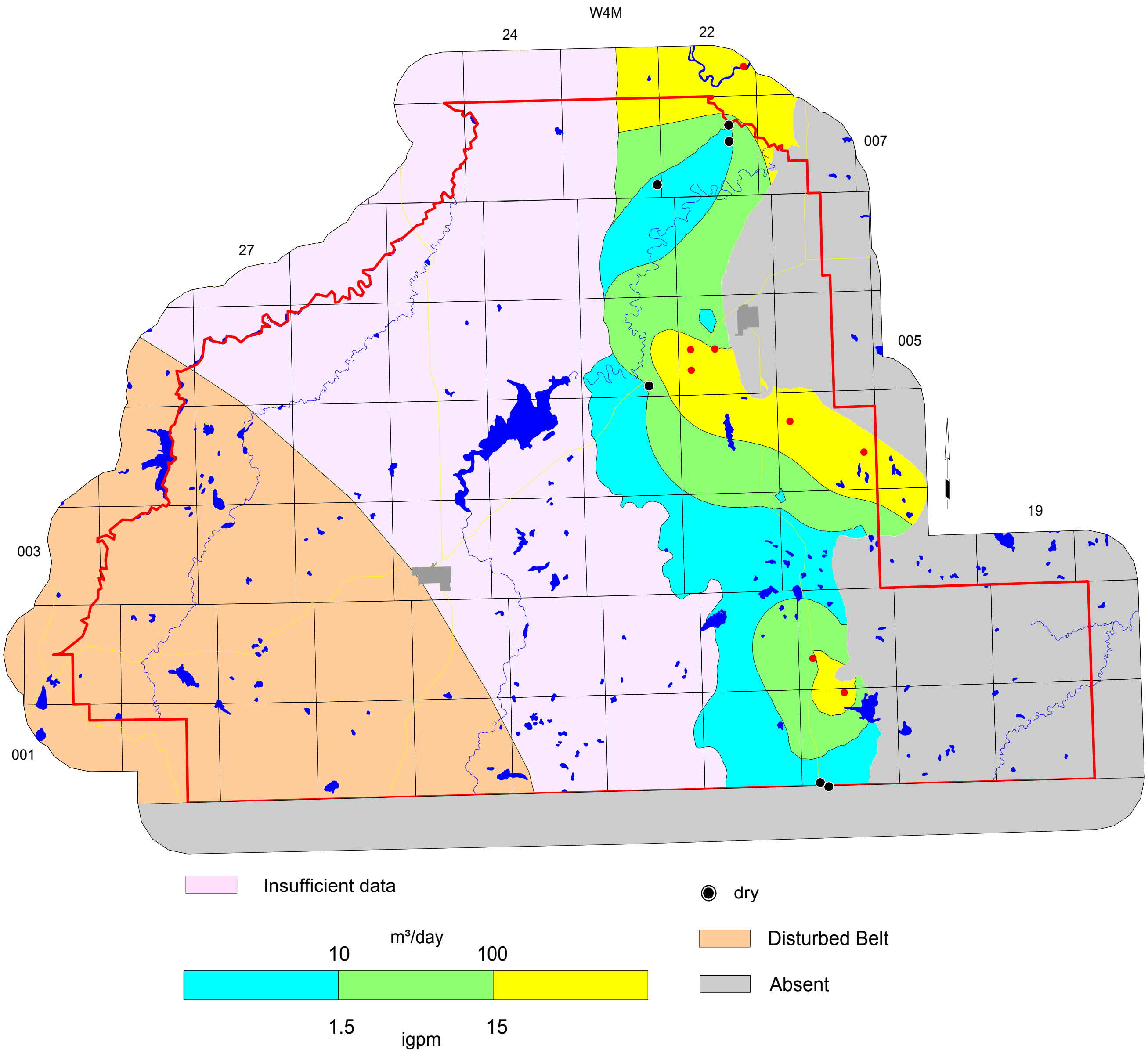
## Total Dissolved Solids in Groundwater from Lower Horseshoe Canyon Aquifer



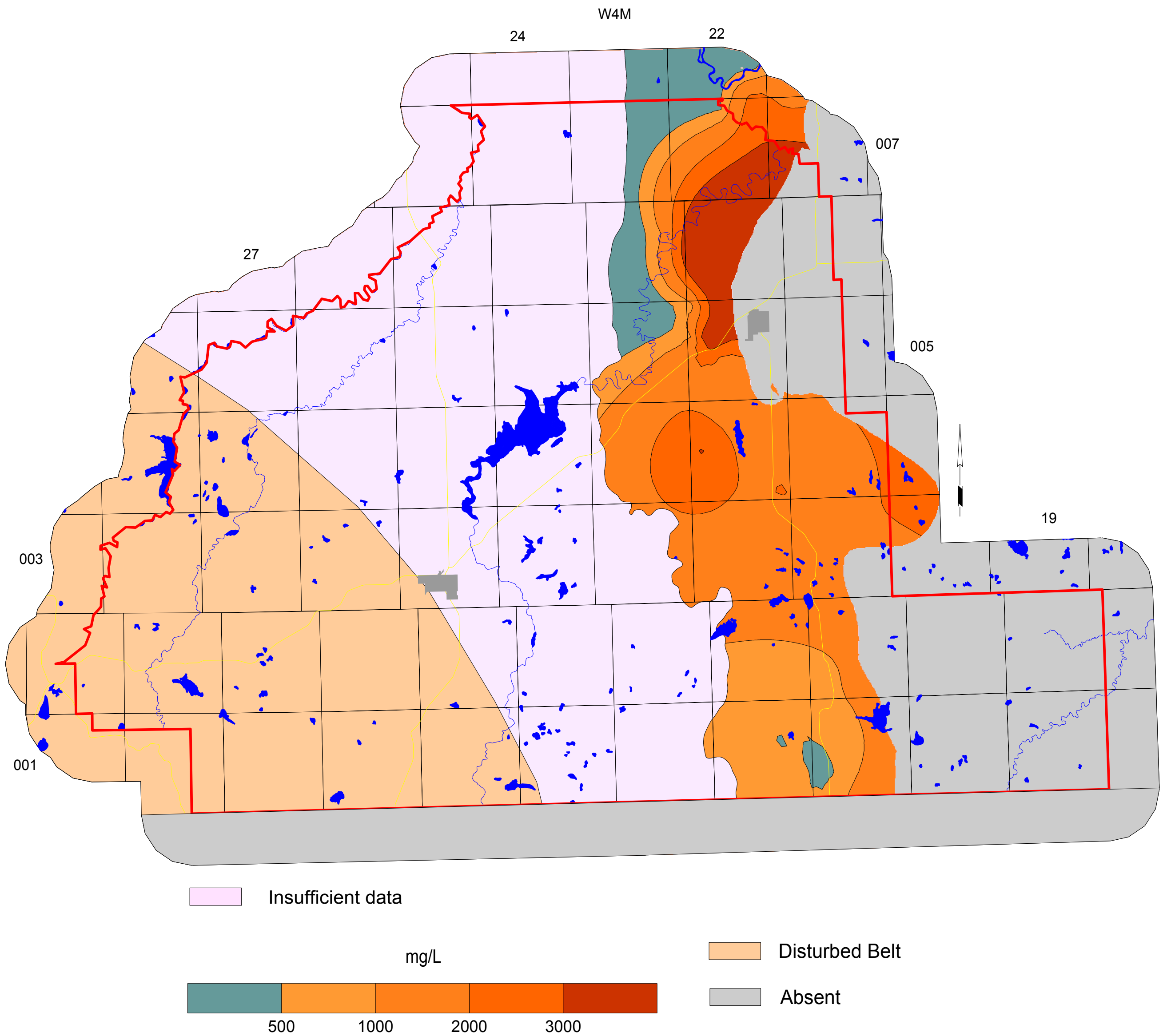
## Depth to Top of Bearpaw Formation



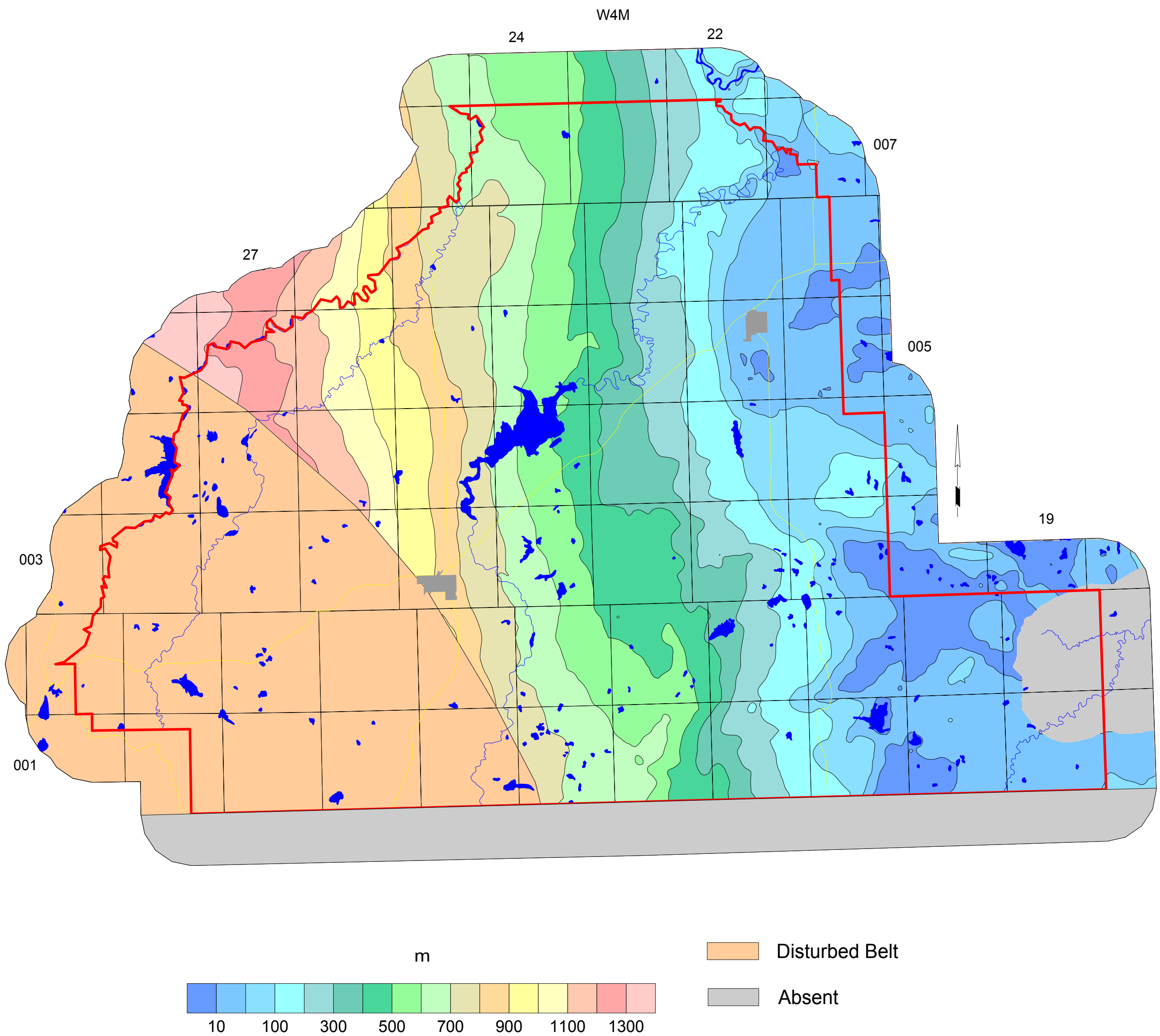
# Apparent Yield for Water Wells Completed through Bearpaw Aquifer



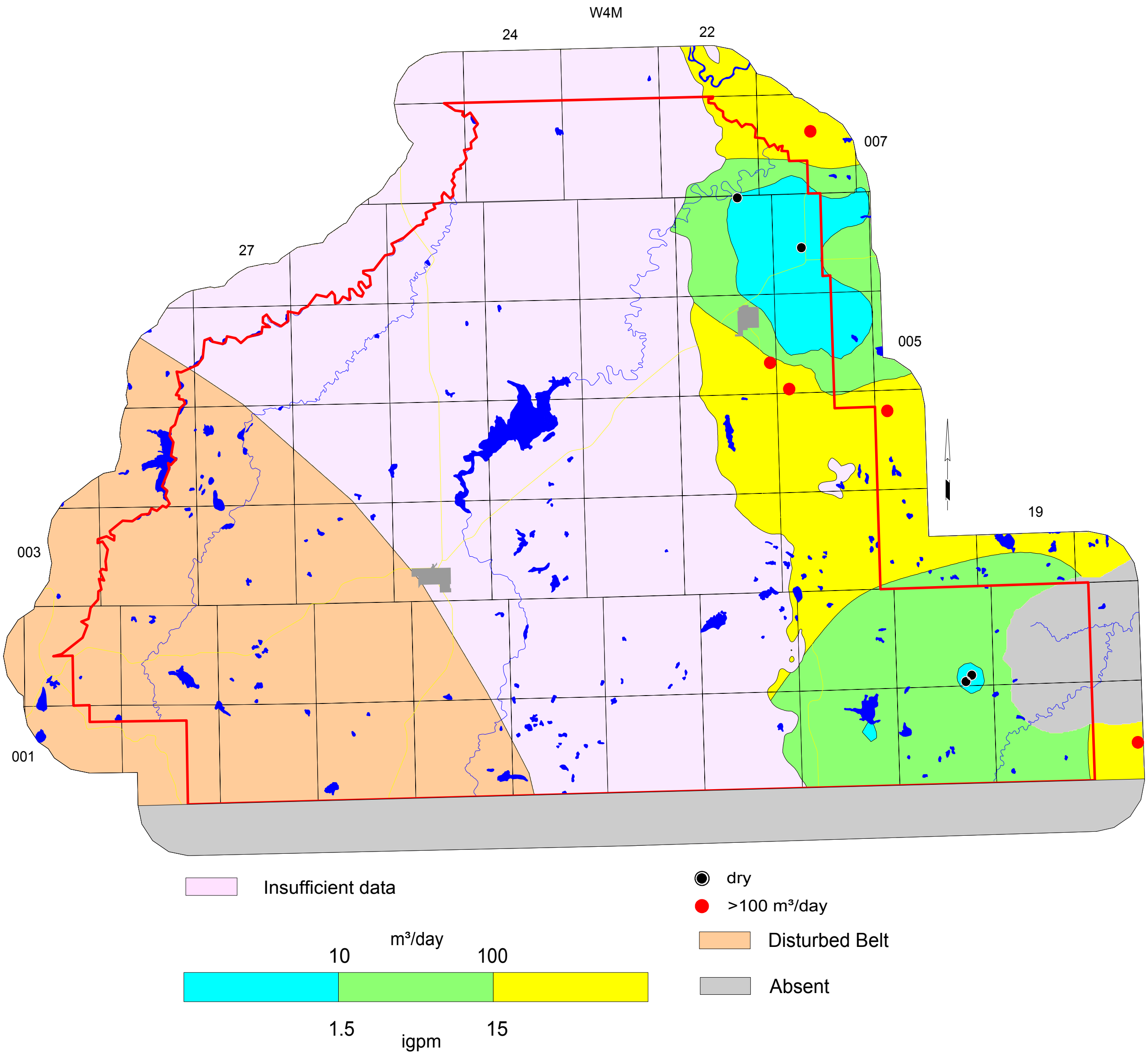
# Total Dissolved Solids in Groundwater from Bearpaw Aquifer



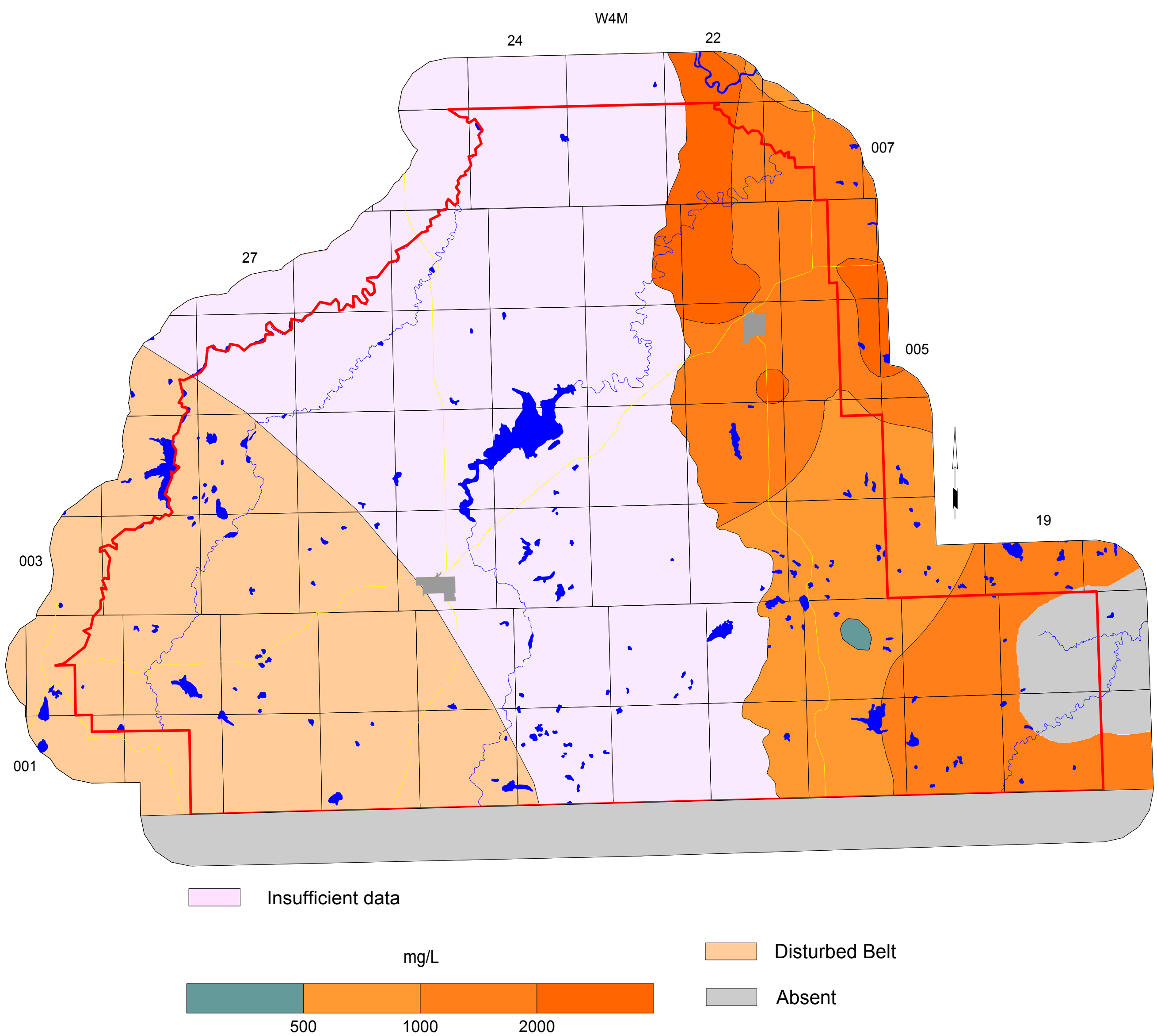
# Depth to Top of Oldman Formation



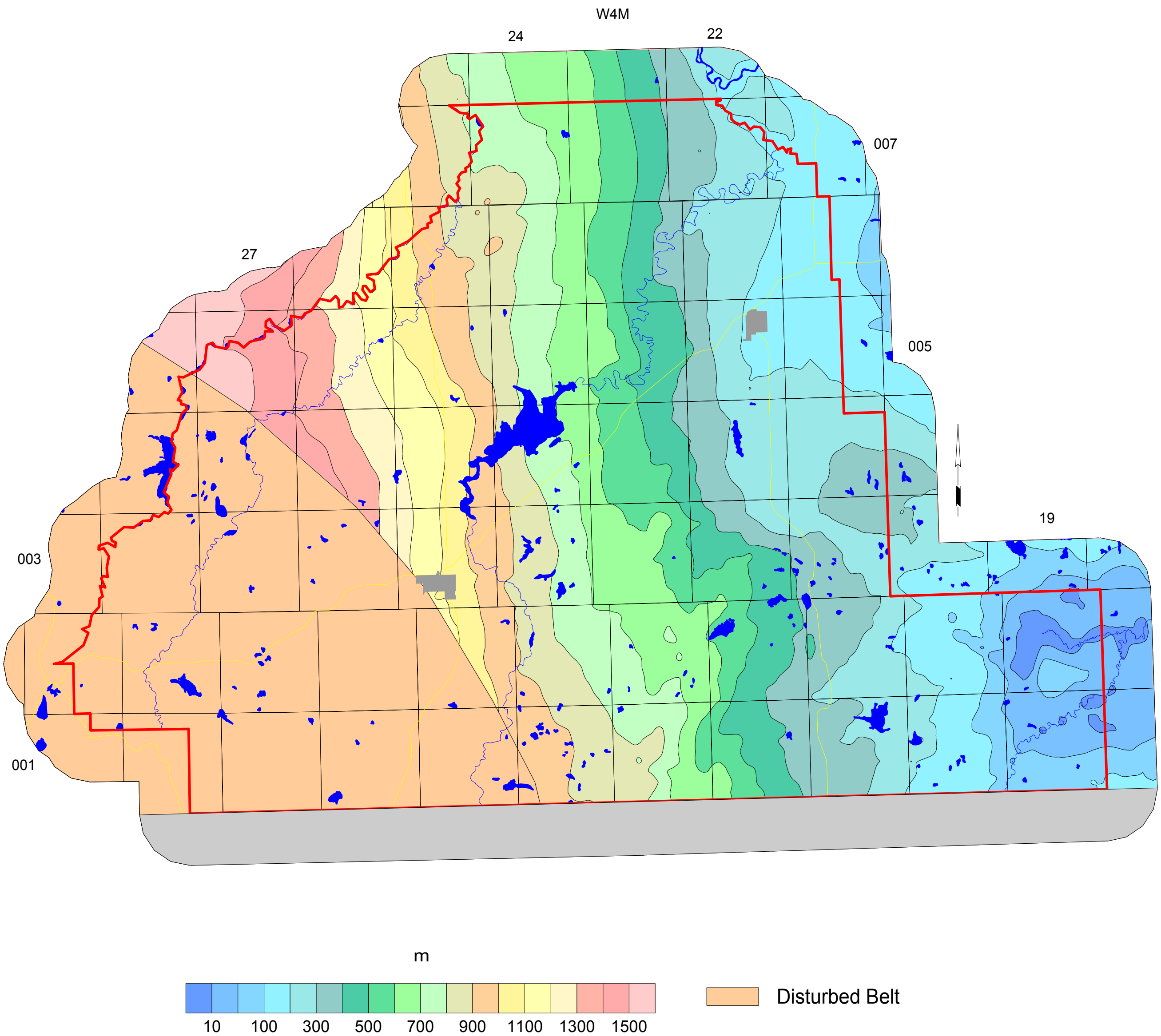
## Apparent Yield for Water Wells Completed through Oldman Aquifer



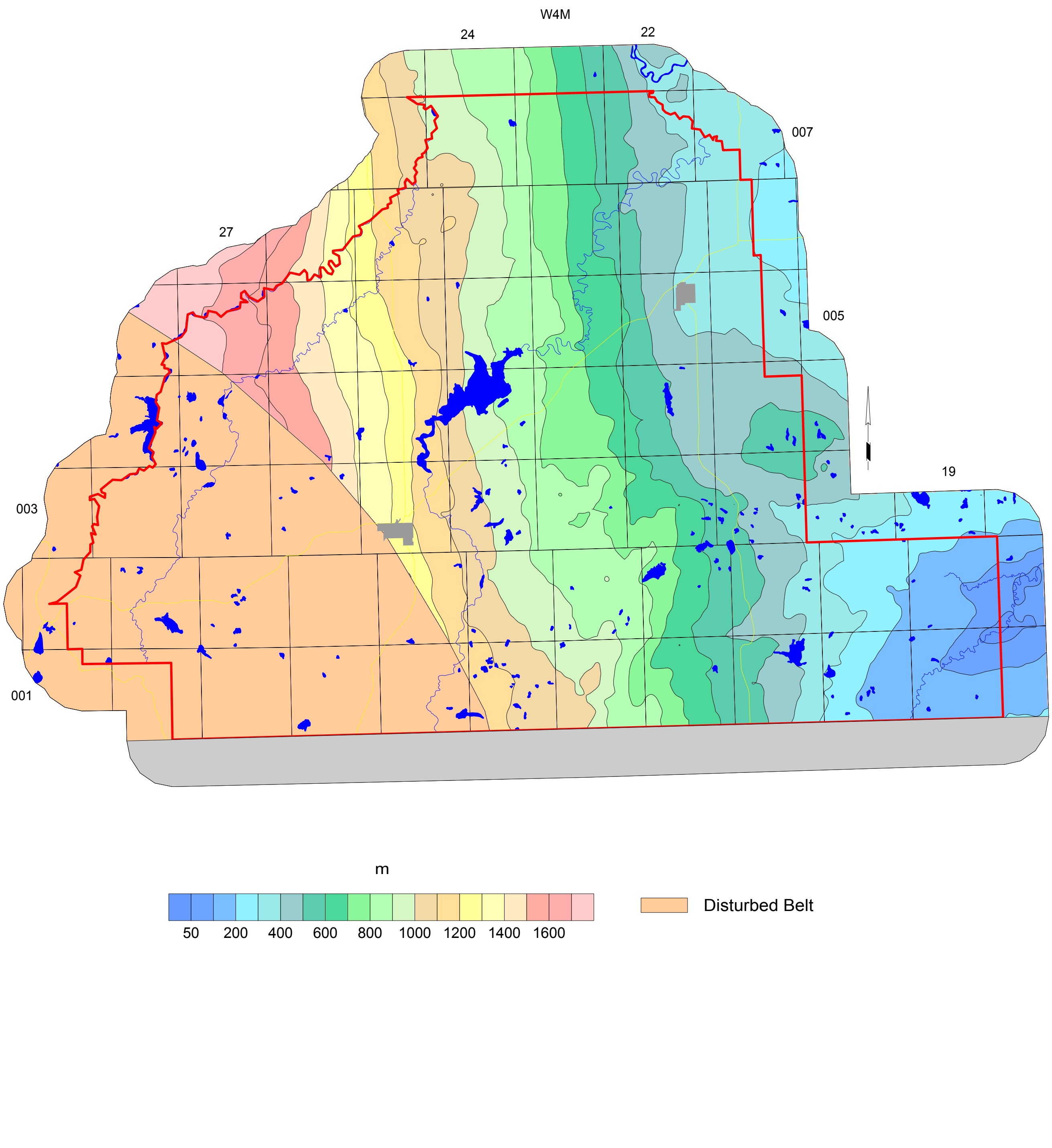
# Total Dissolved Solids in Groundwater from Oldman Aquifer



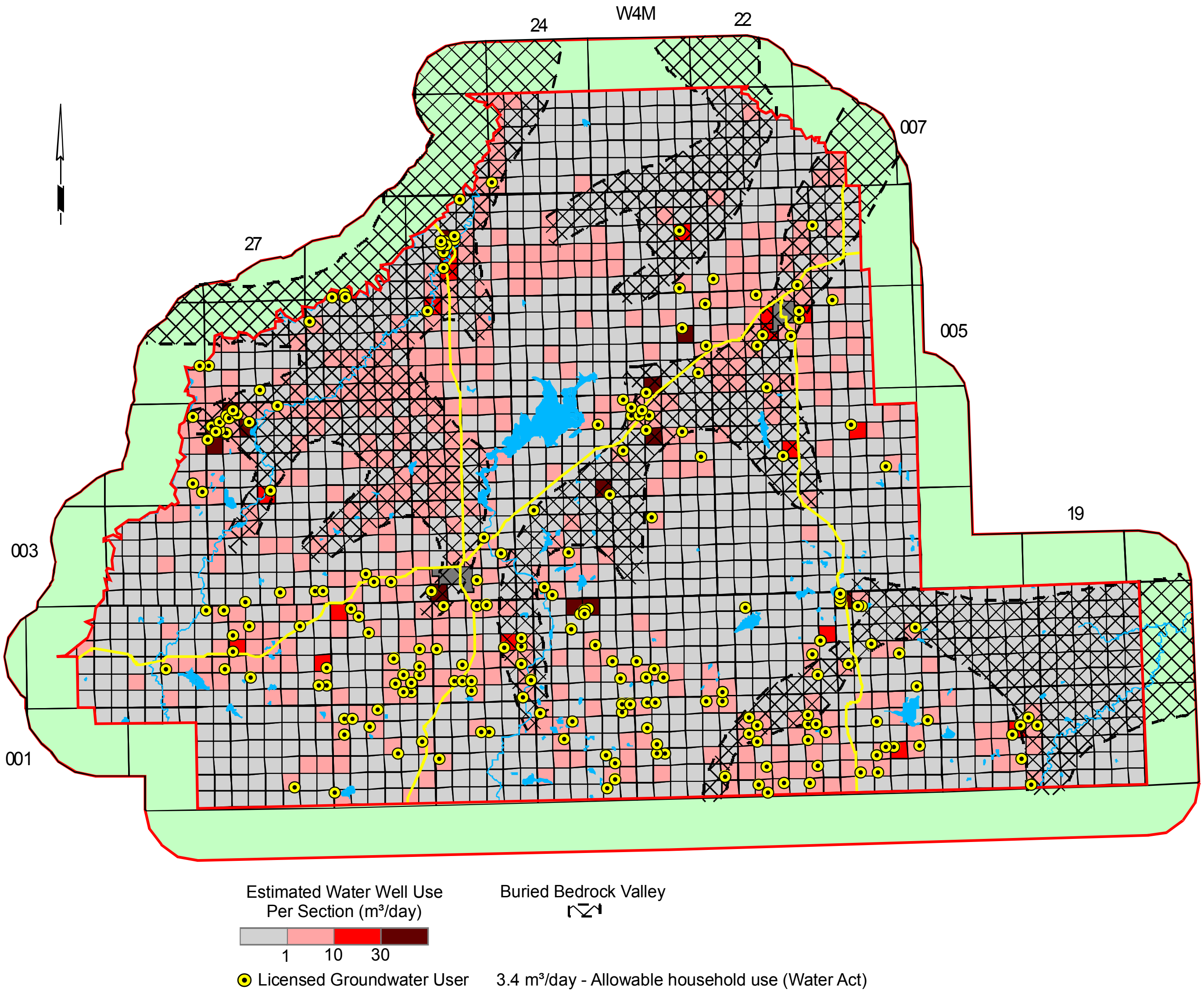
# Depth to Top of Foremost Formation



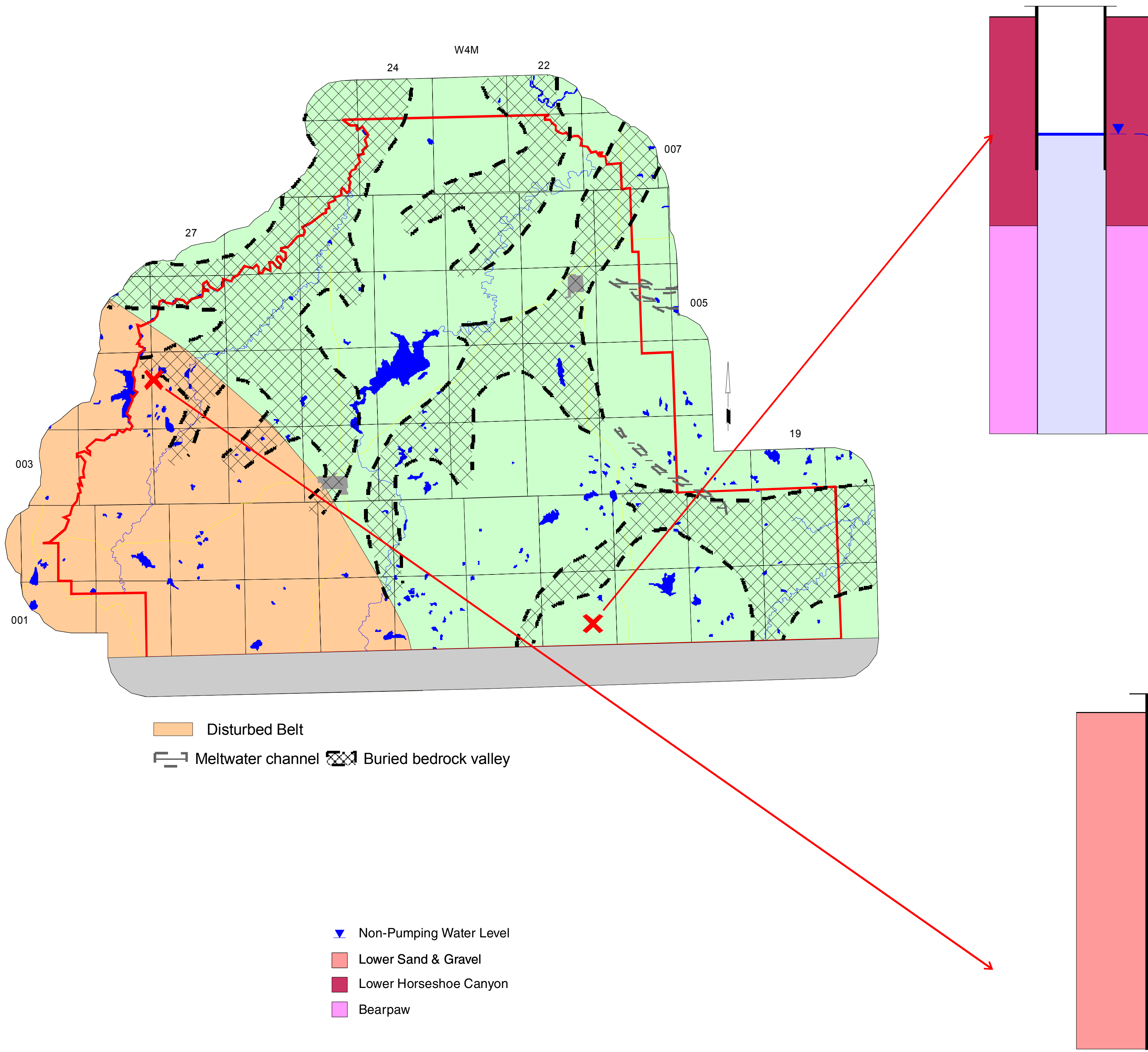
# Depth to Top of Lea Park Formation

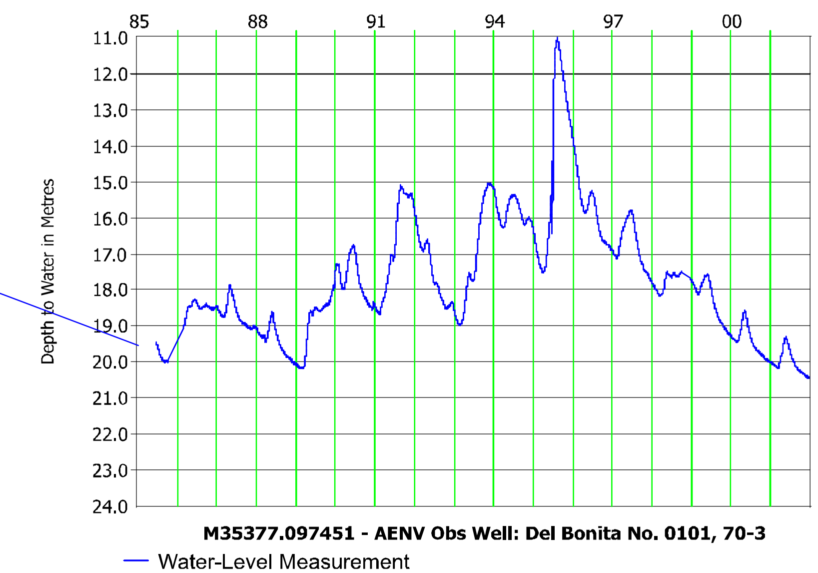


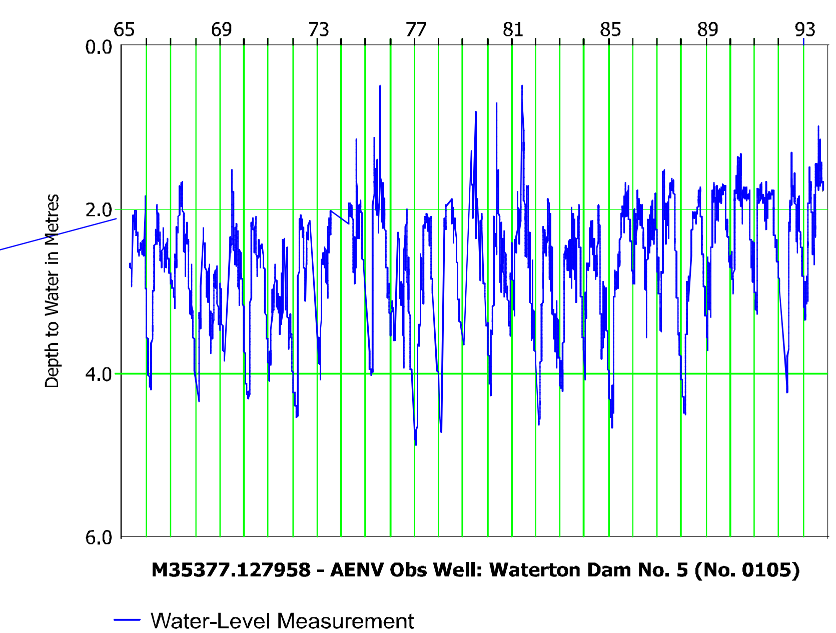
# Estimated Water Well Use Per Section



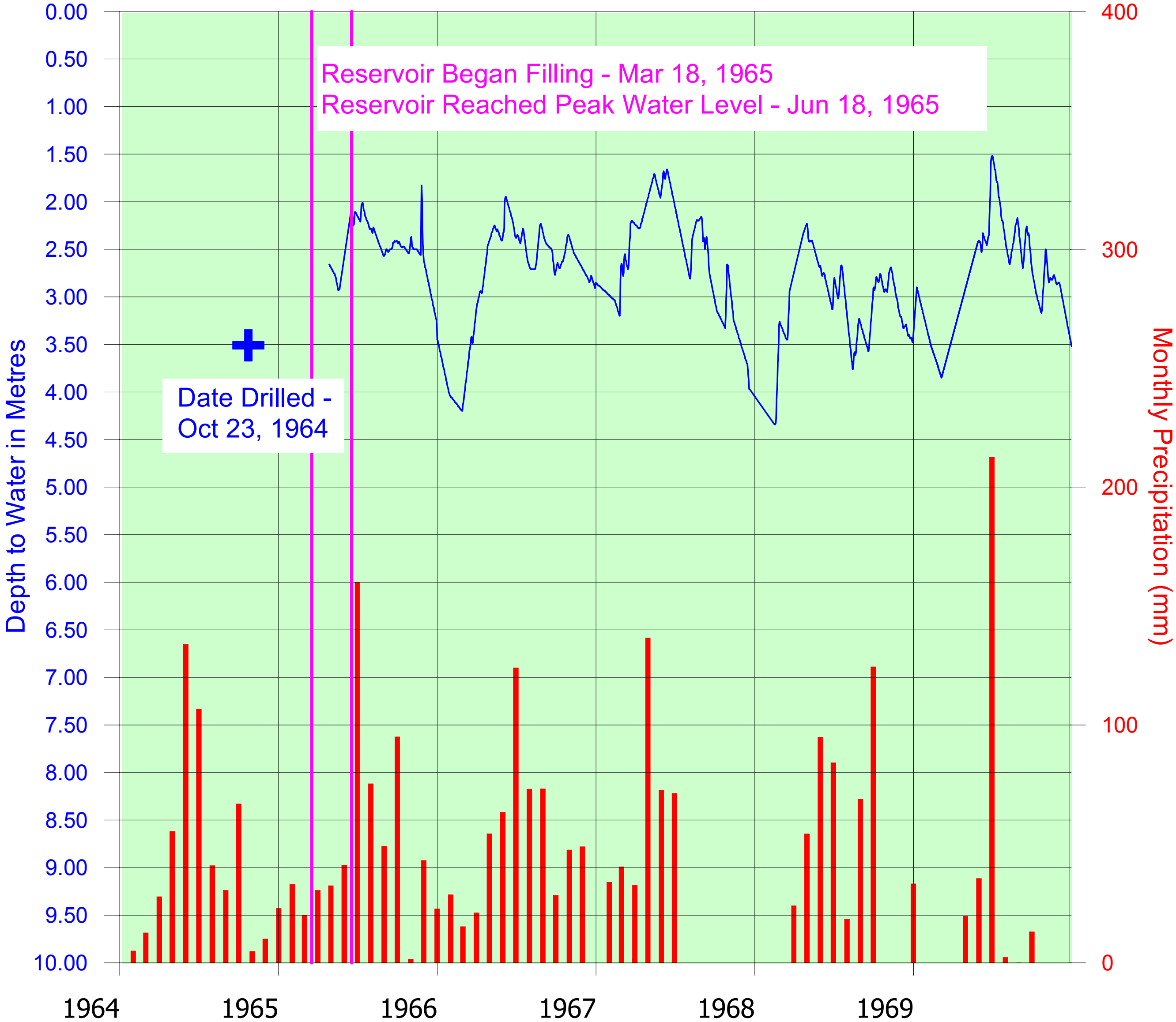
## Hydrographs



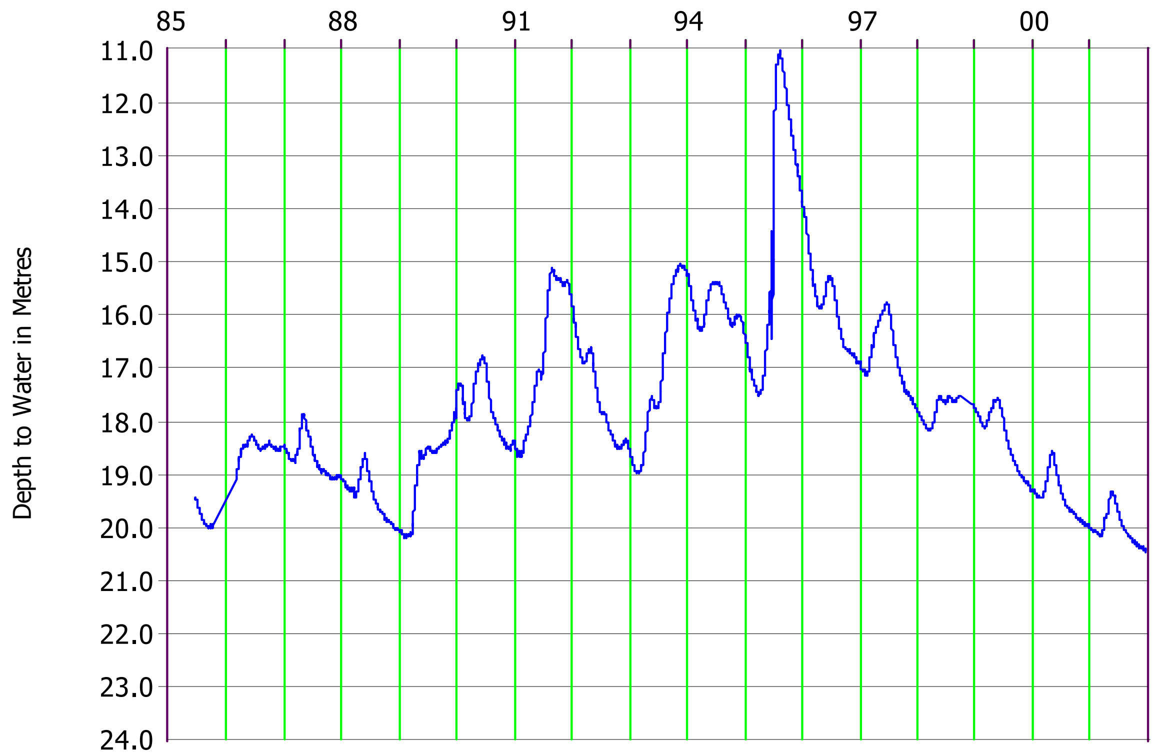



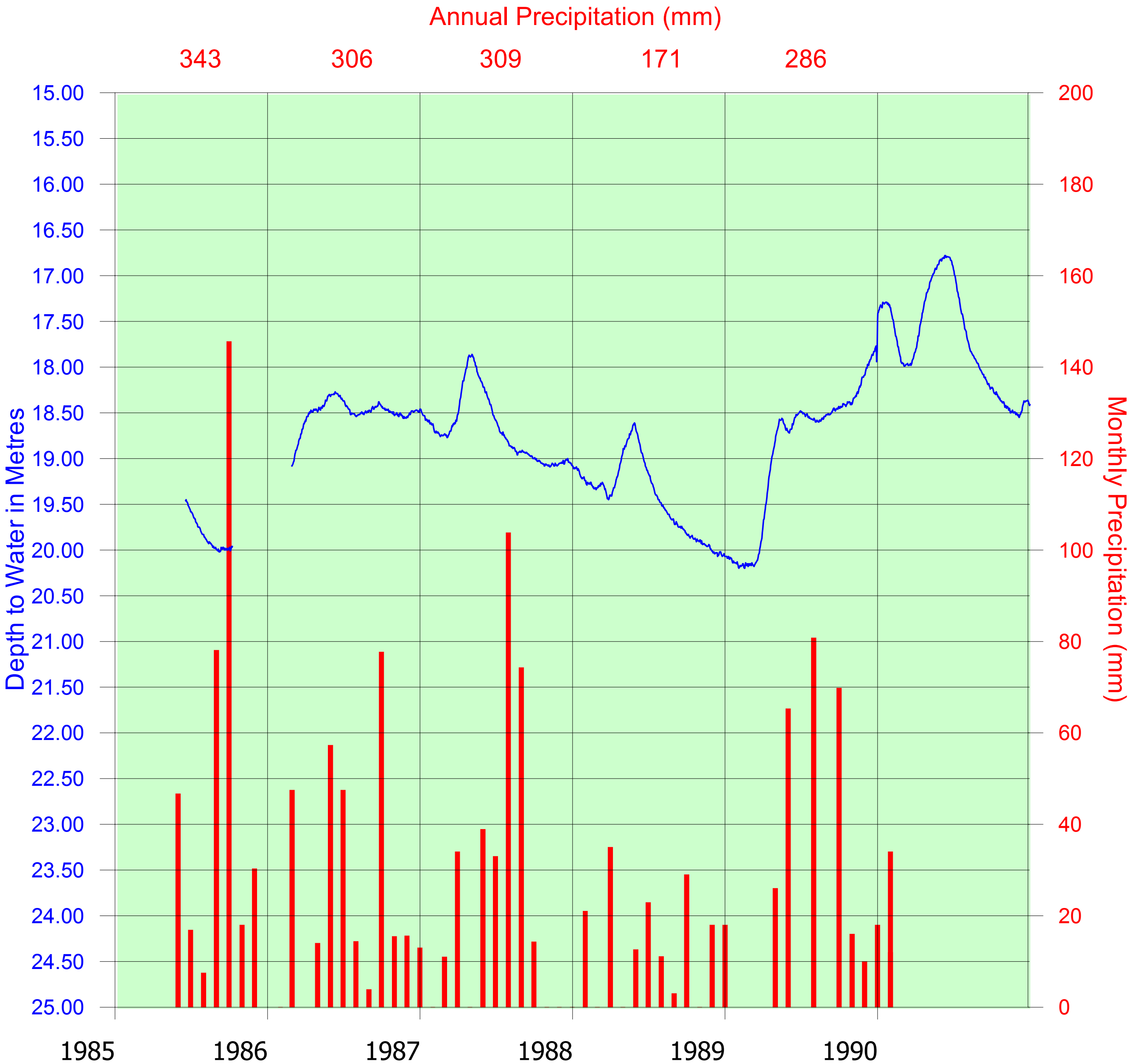
## Precipitation vs Water Levels in AENV Obs WW No. 105



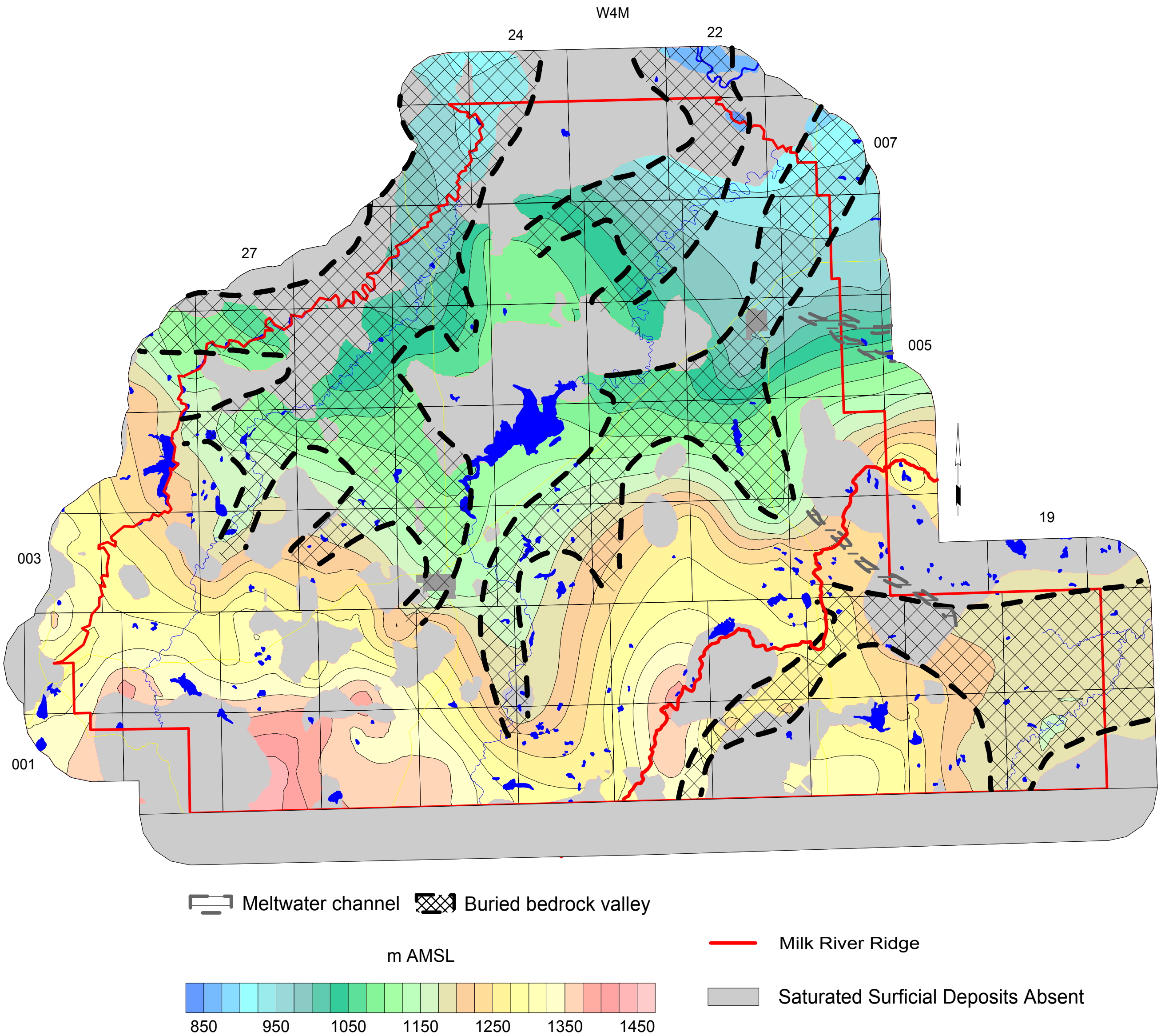
## Water-Level Measurements in AENV Obs WW No. 101



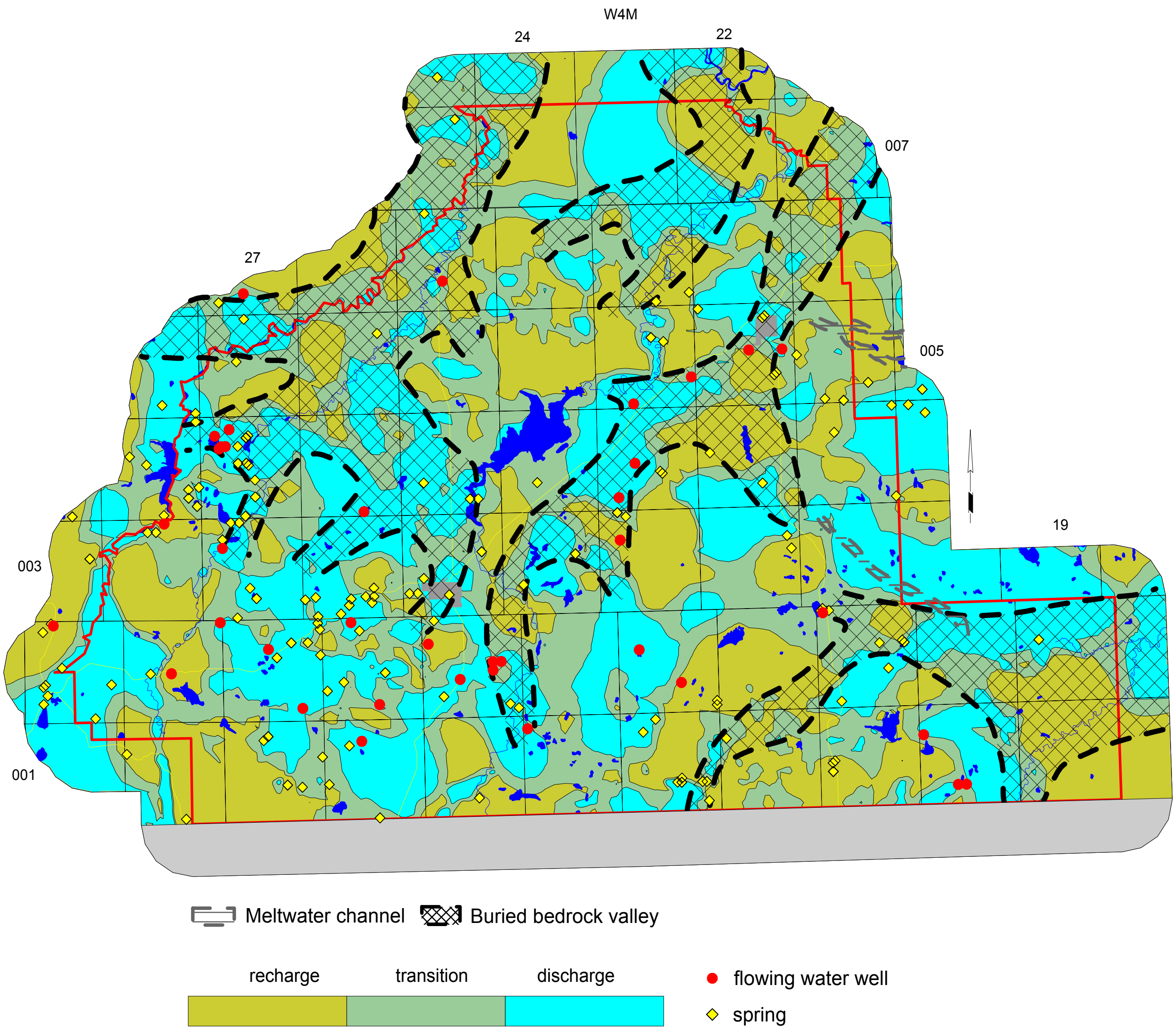
## Precipitation vs Water Levels in AENV Obs WW No. 101



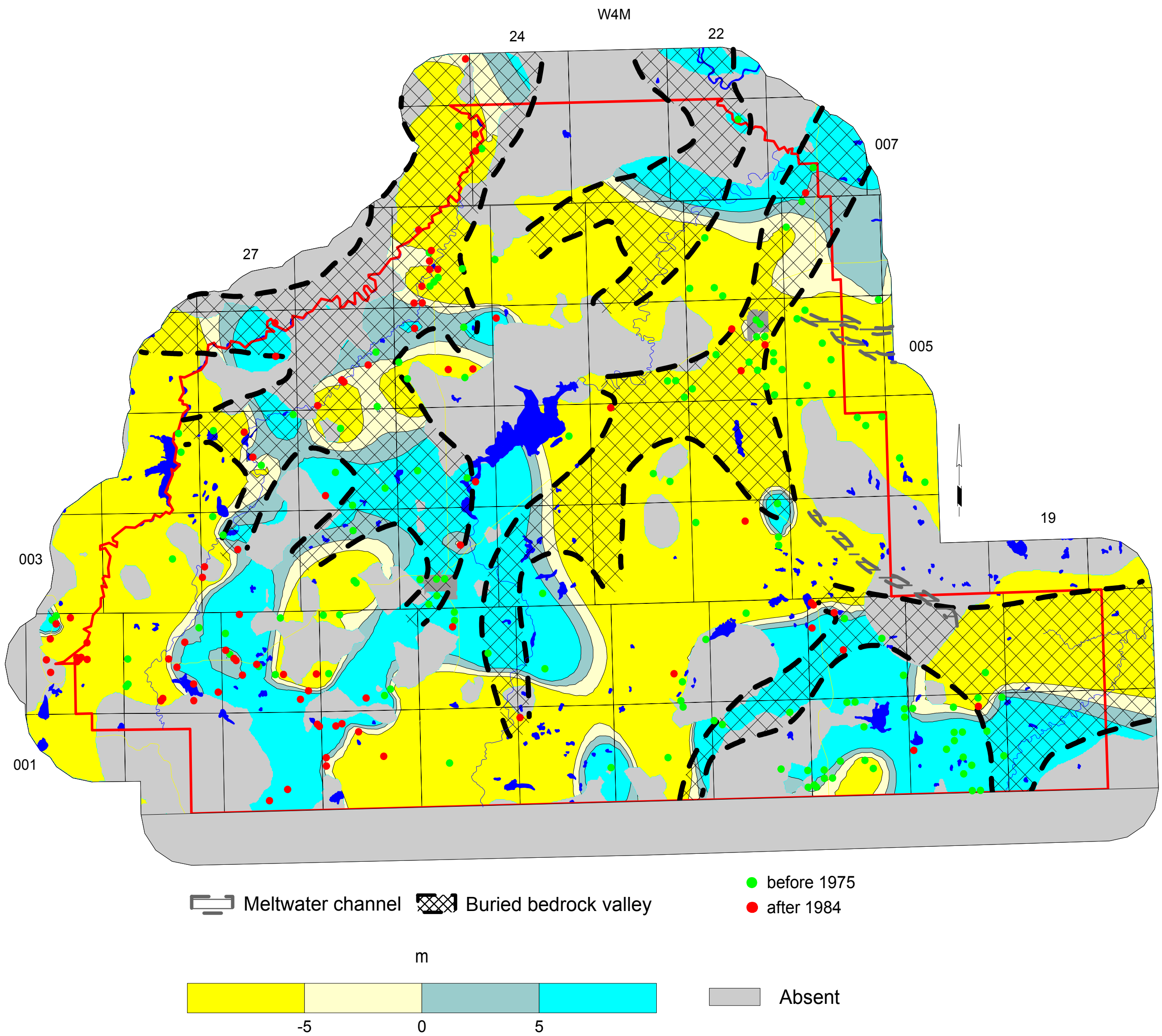
## Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep



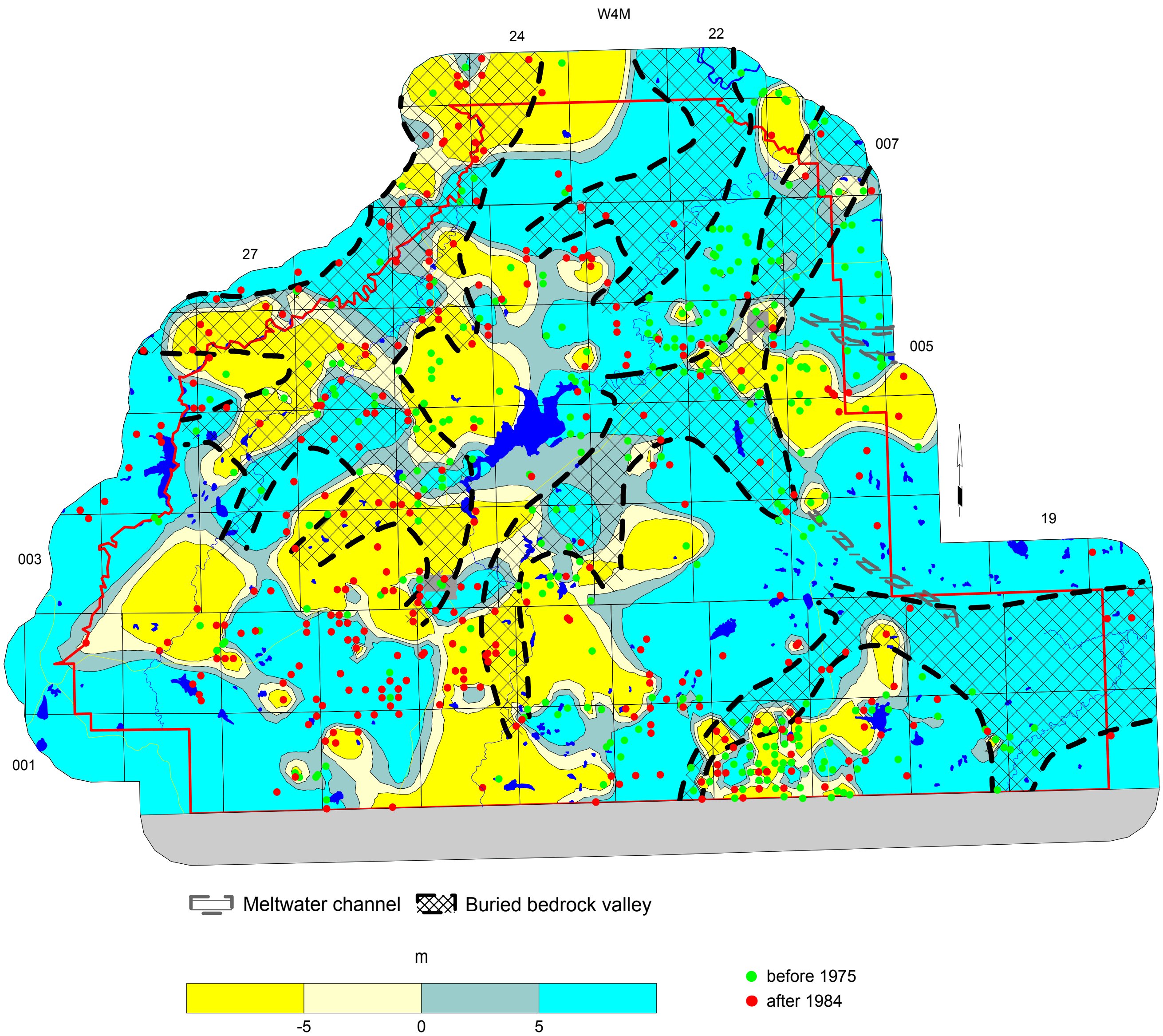
# Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)



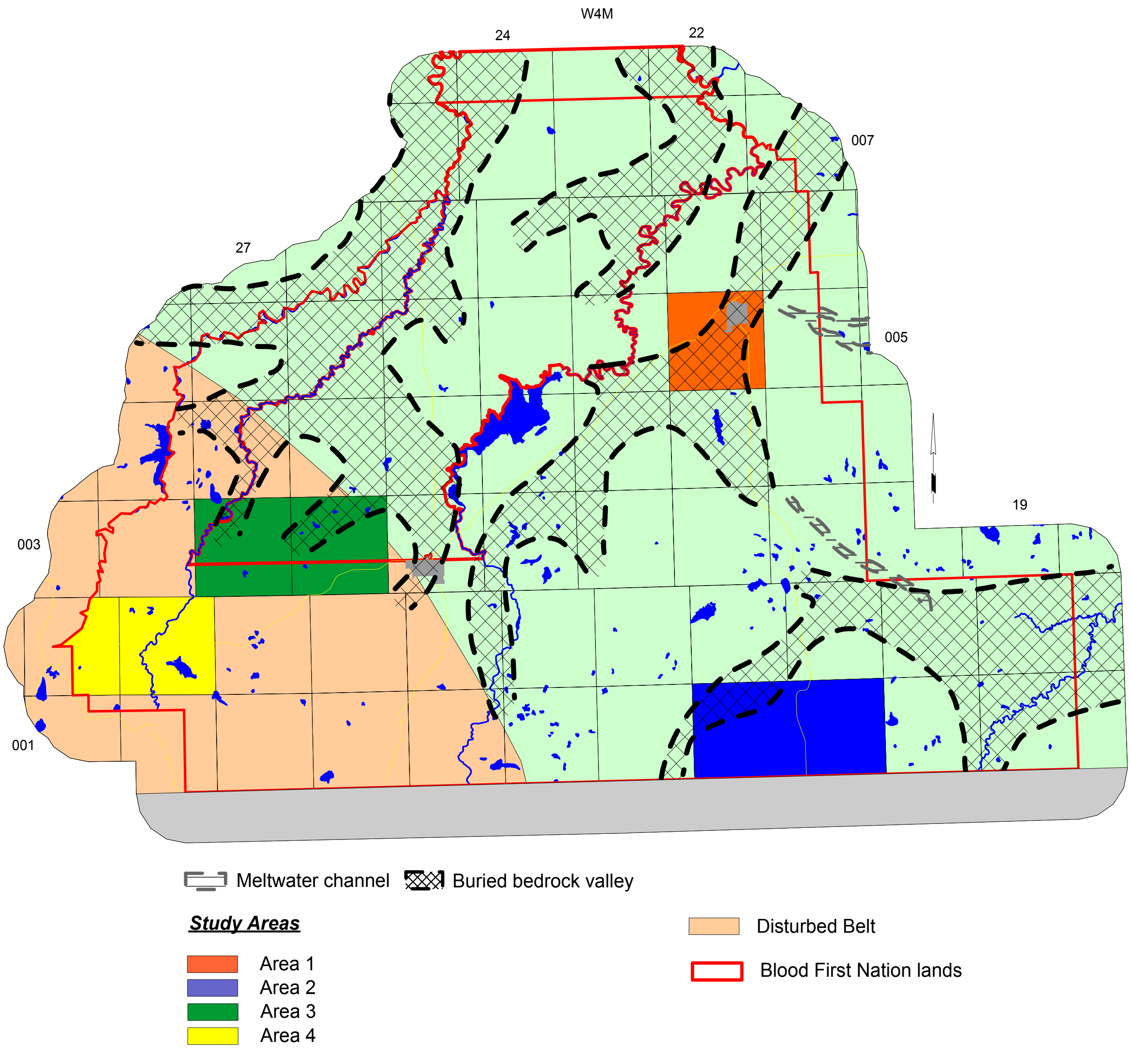
# Changes in Water Levels in Surficial Deposits



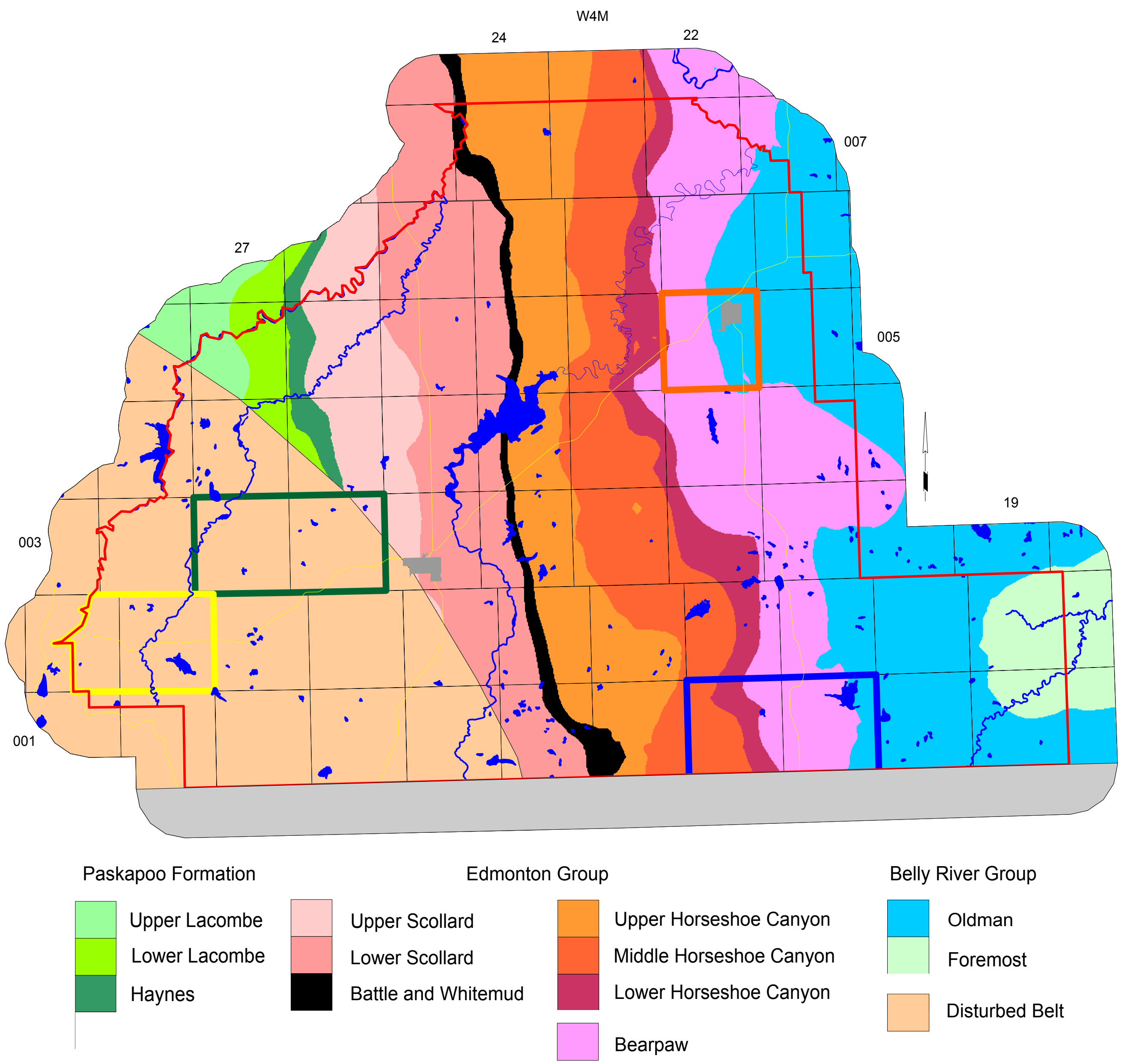
## Areas of Potential Groundwater Depletion - Upper Bedrock Aquifer(s)



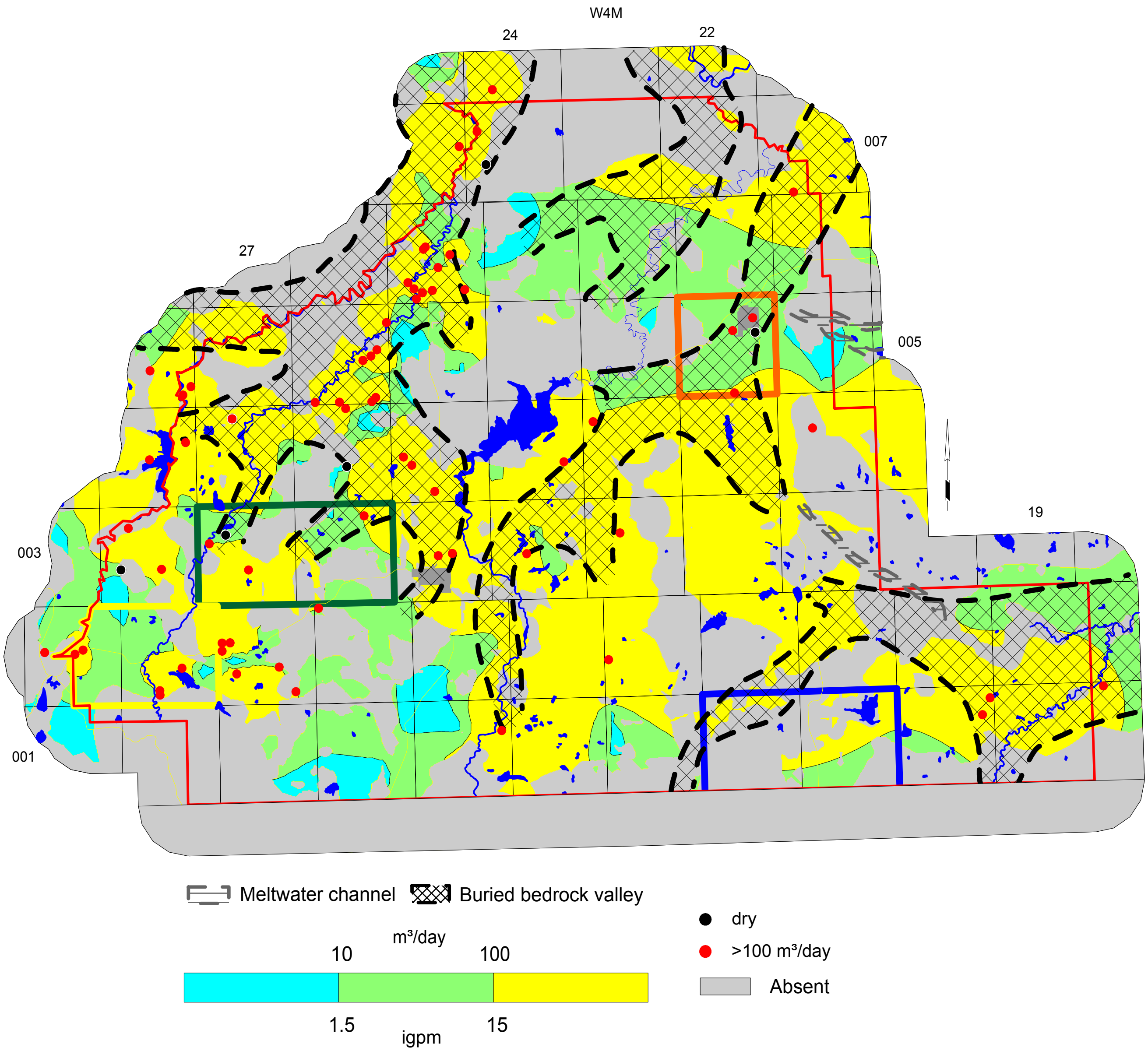
## Specific Study Areas



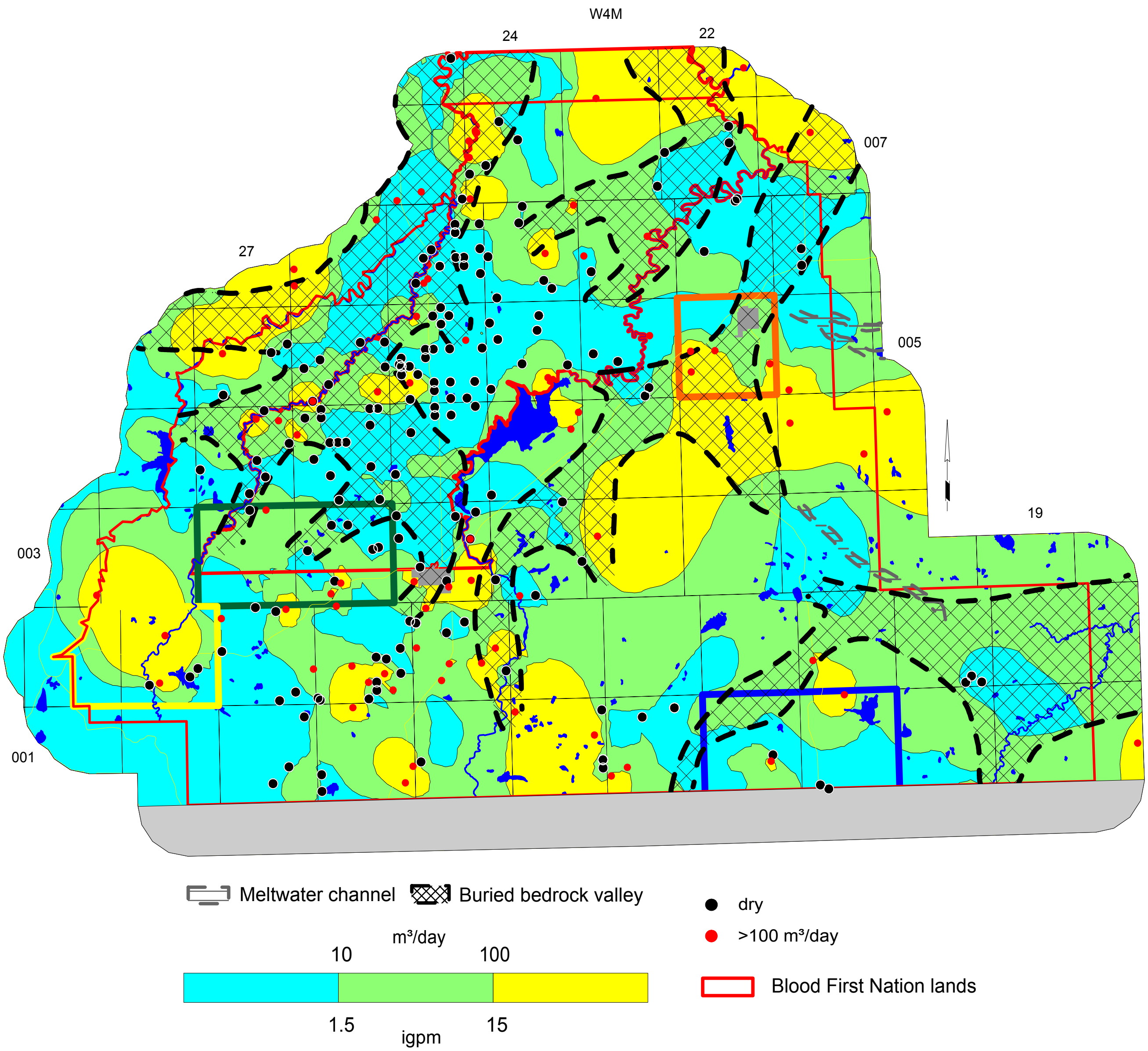
## Bedrock Geology of Specific Study Areas



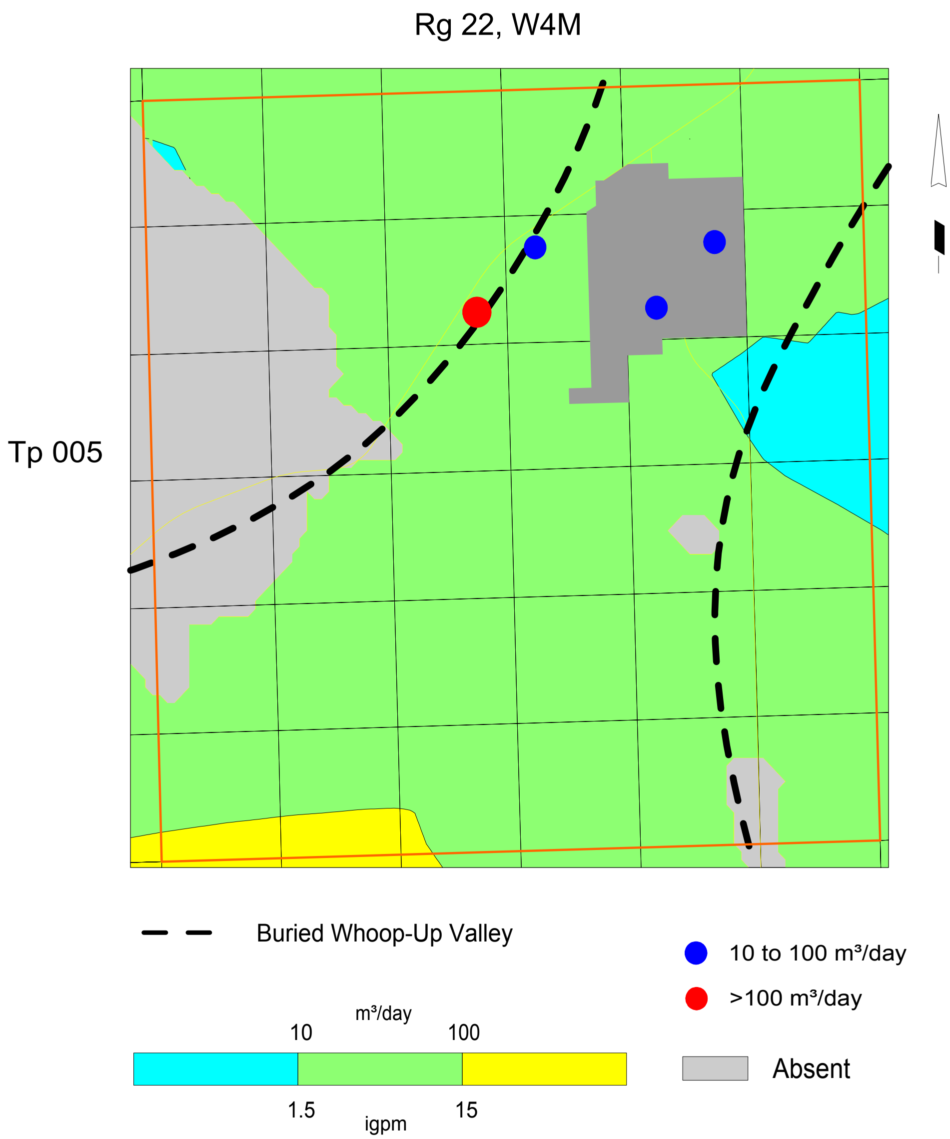
## Apparent Yield for Water Wells
## Completed in Sand and Gravel Aquifer(s) – Specific Study Areas



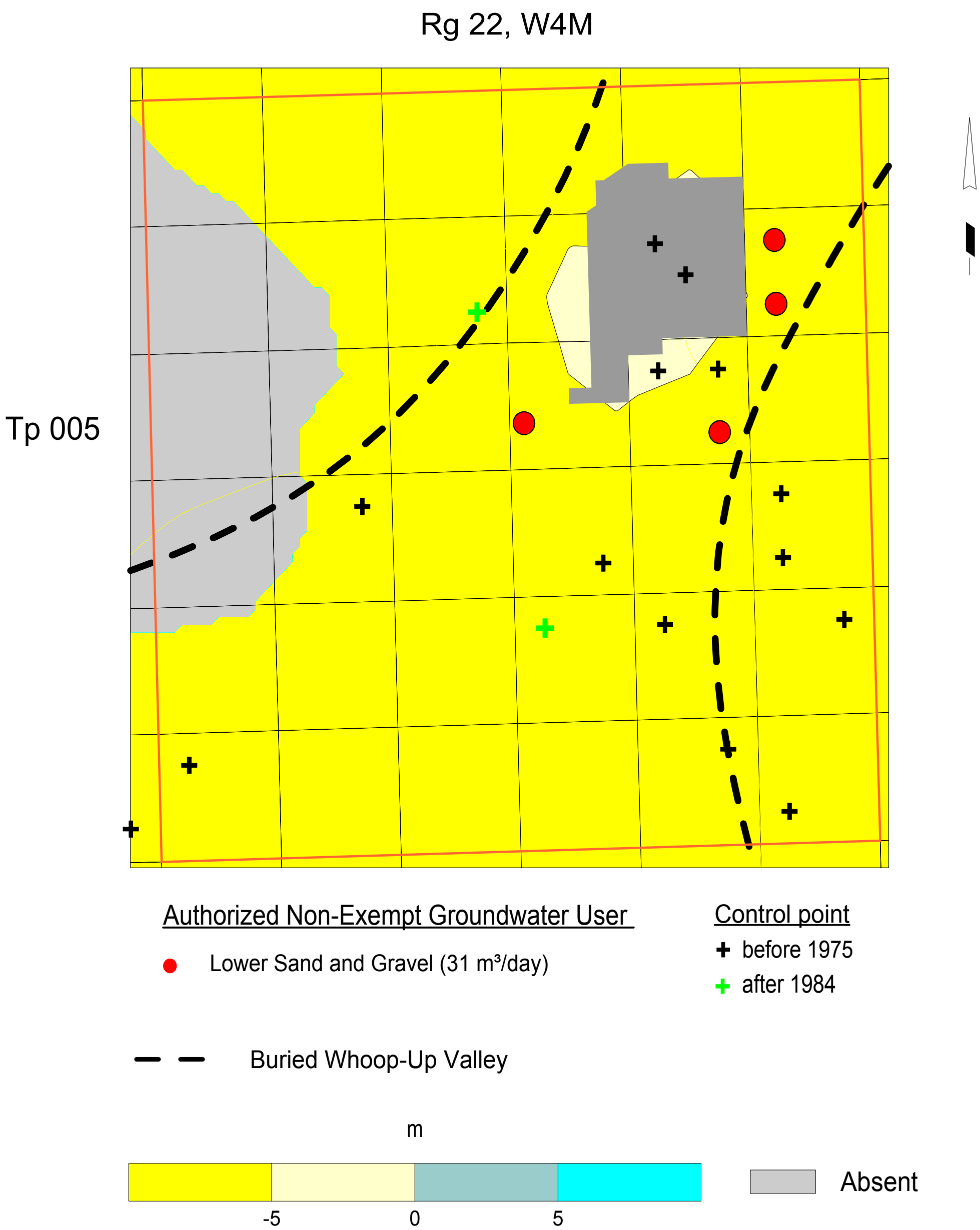
# Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s) – Specific Study Areas



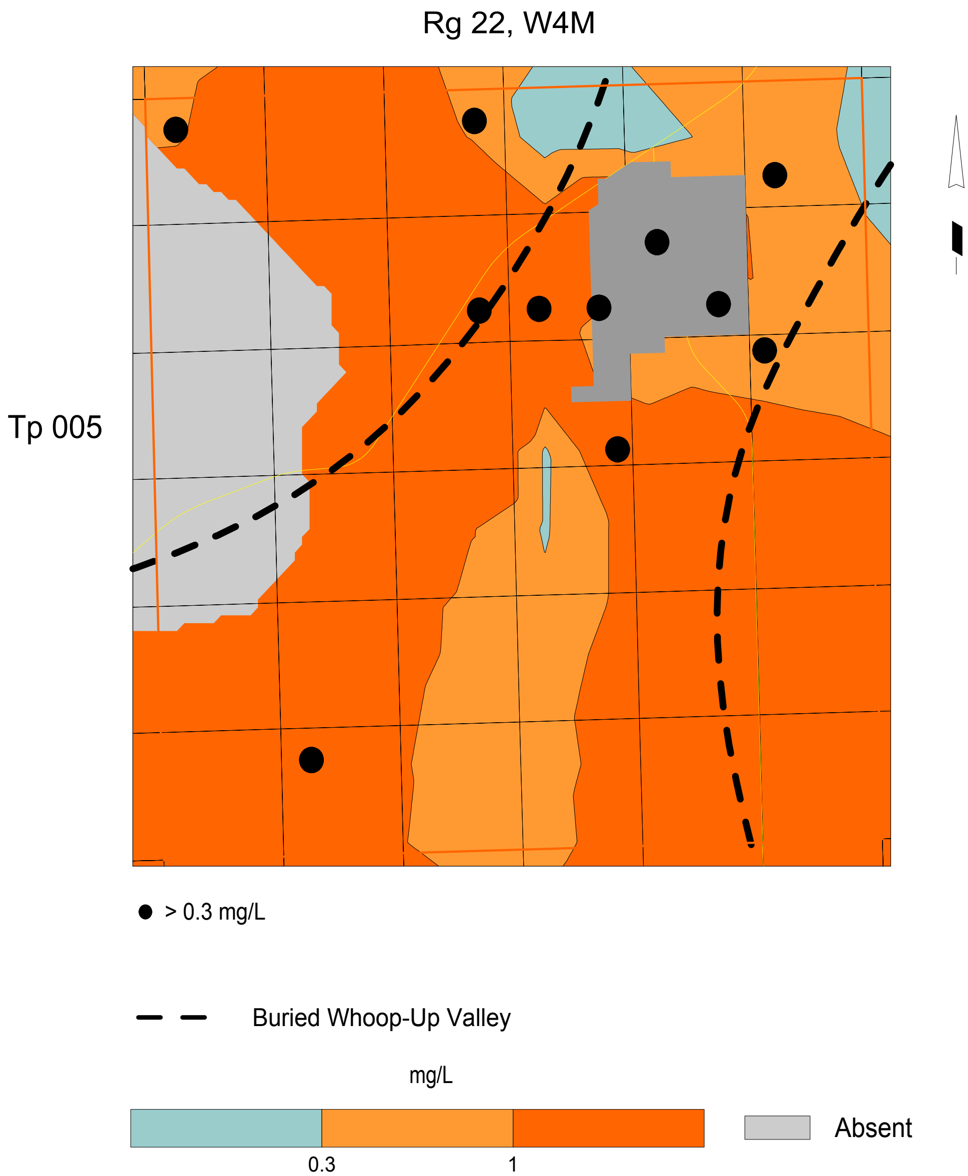
# Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer – Area 1



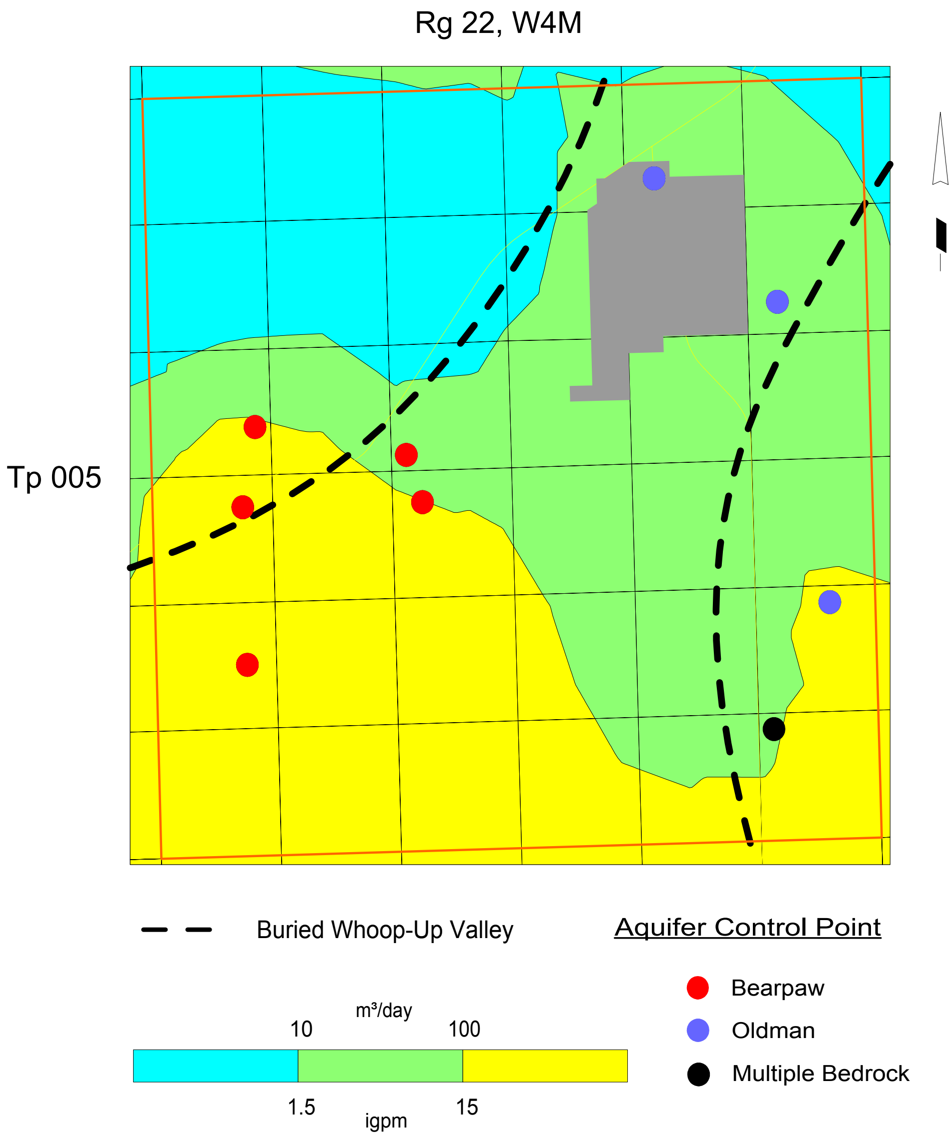
## Changes in Water Levels in Surficial Deposits – Area 1



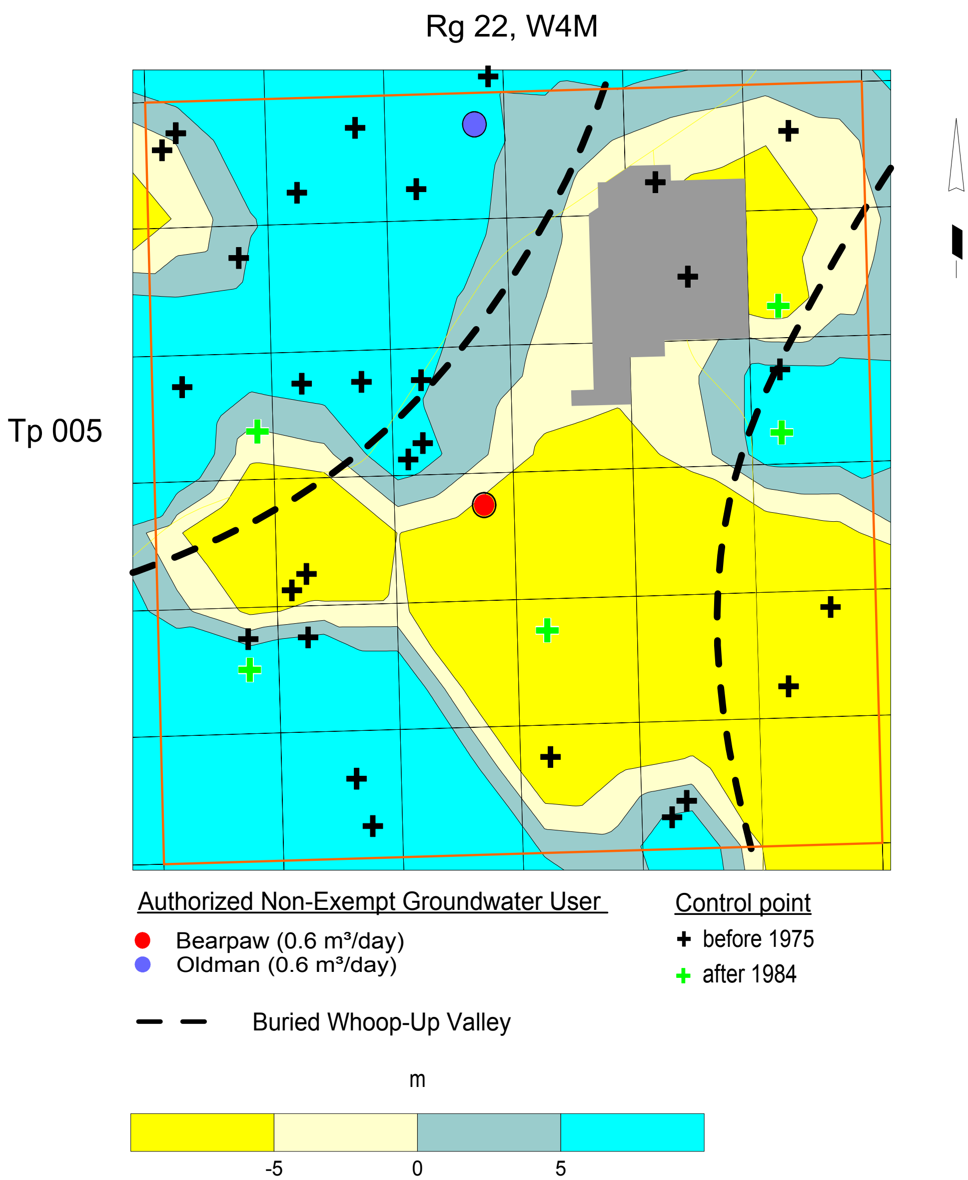
## Iron in Groundwater in Surficial Deposits – Area 1



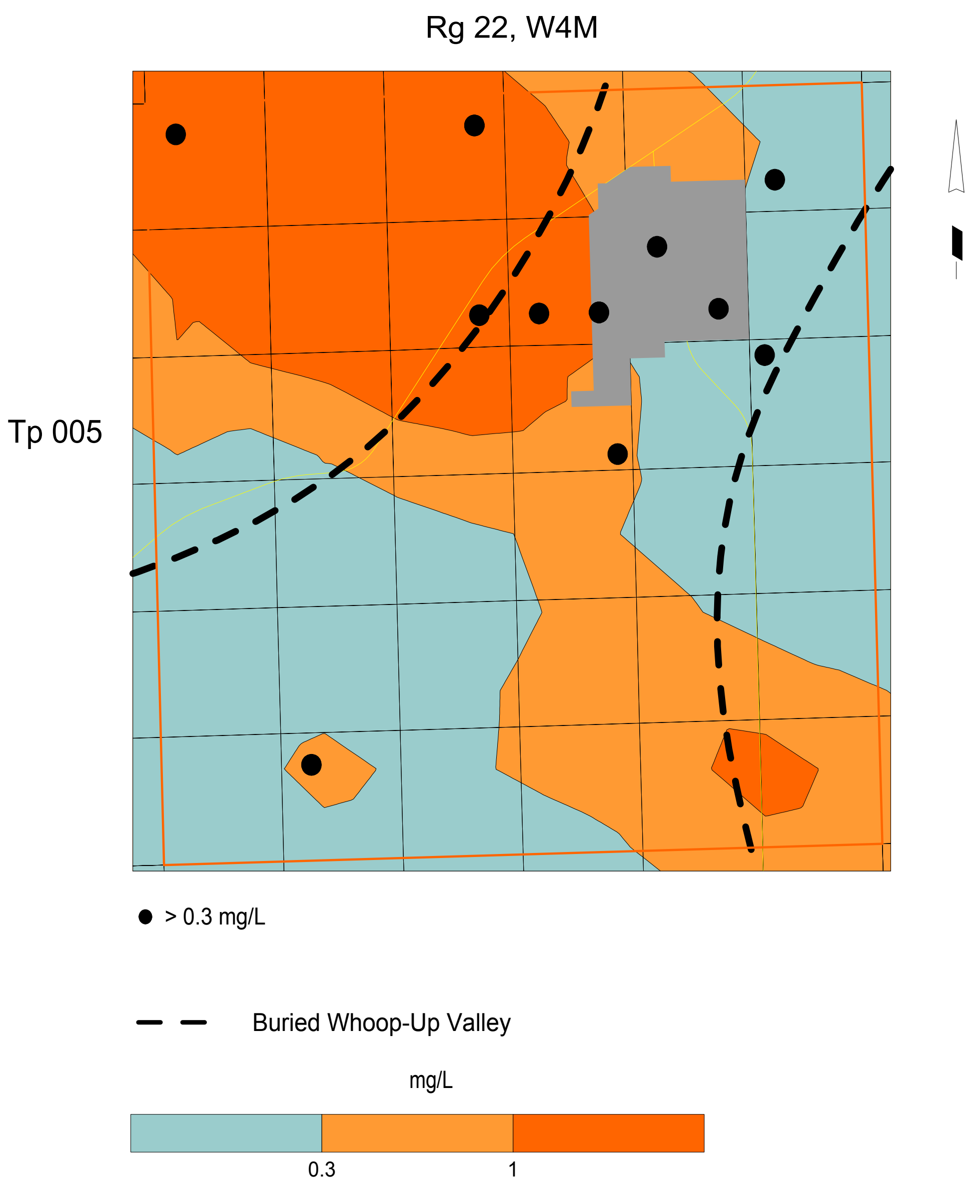
## Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s) – Area 1



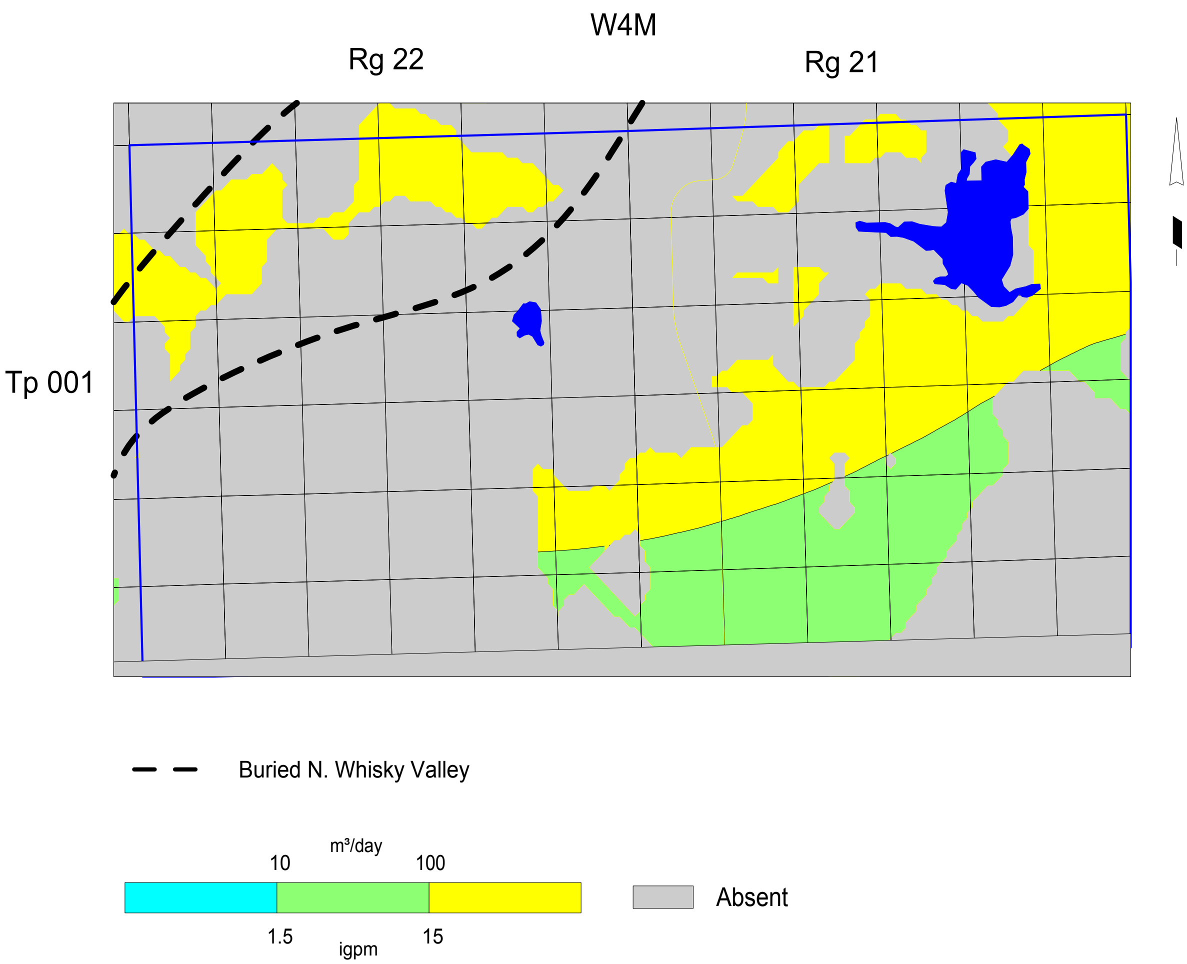
## *Areas of Potential Groundwater Depletion in Upper Bedrock Aquifer(s) – Area 1*



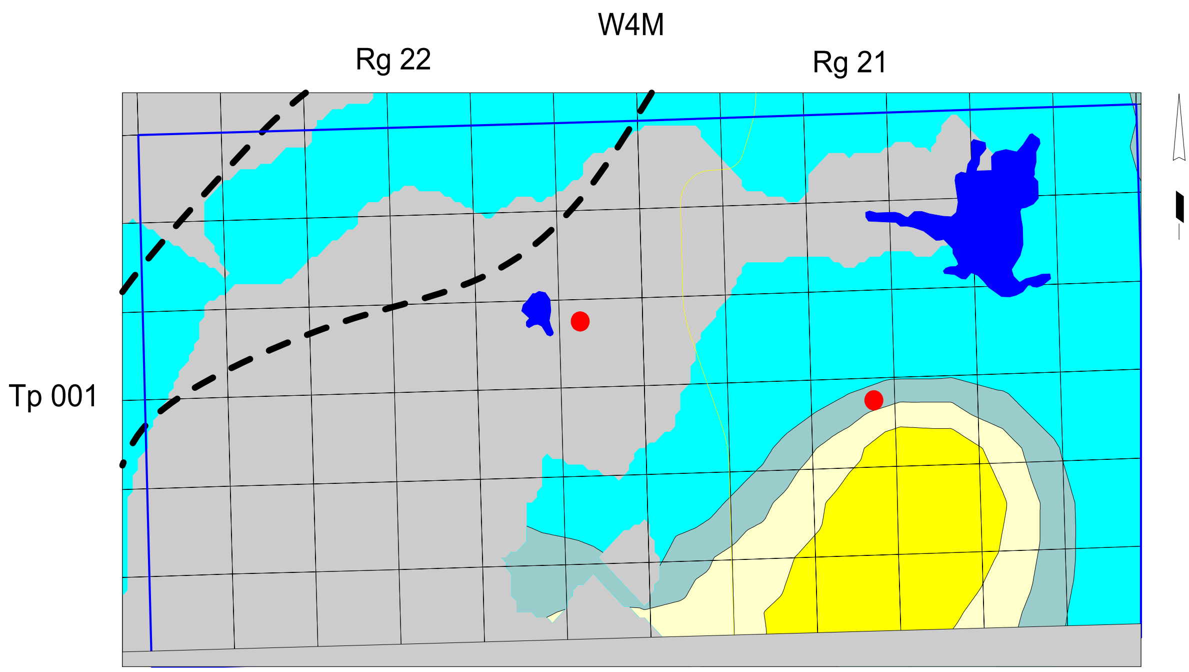
## Iron in Groundwater from Upper Bedrock Aquifer(s) – Area 1



# Apparent Yield for Water Wells
# Completed through Lower Sand and Gravel Aquifer – Area 2



## *Changes in Water Levels in Surficial Deposits – Area 2*




Authorized Non-Exempt Groundwater User

Lower Sand and Gravel (3.4 m³/day)

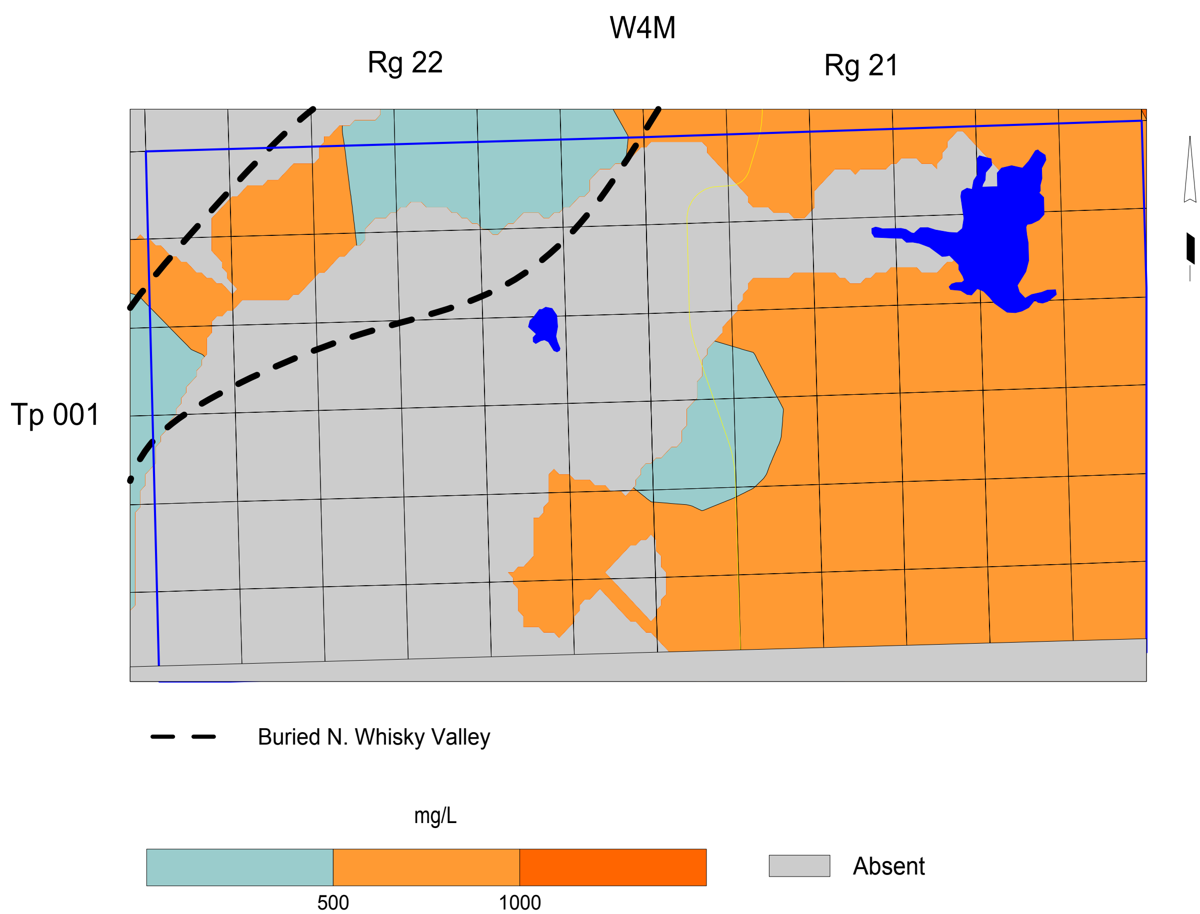
Buried N. Whisky Valley

m

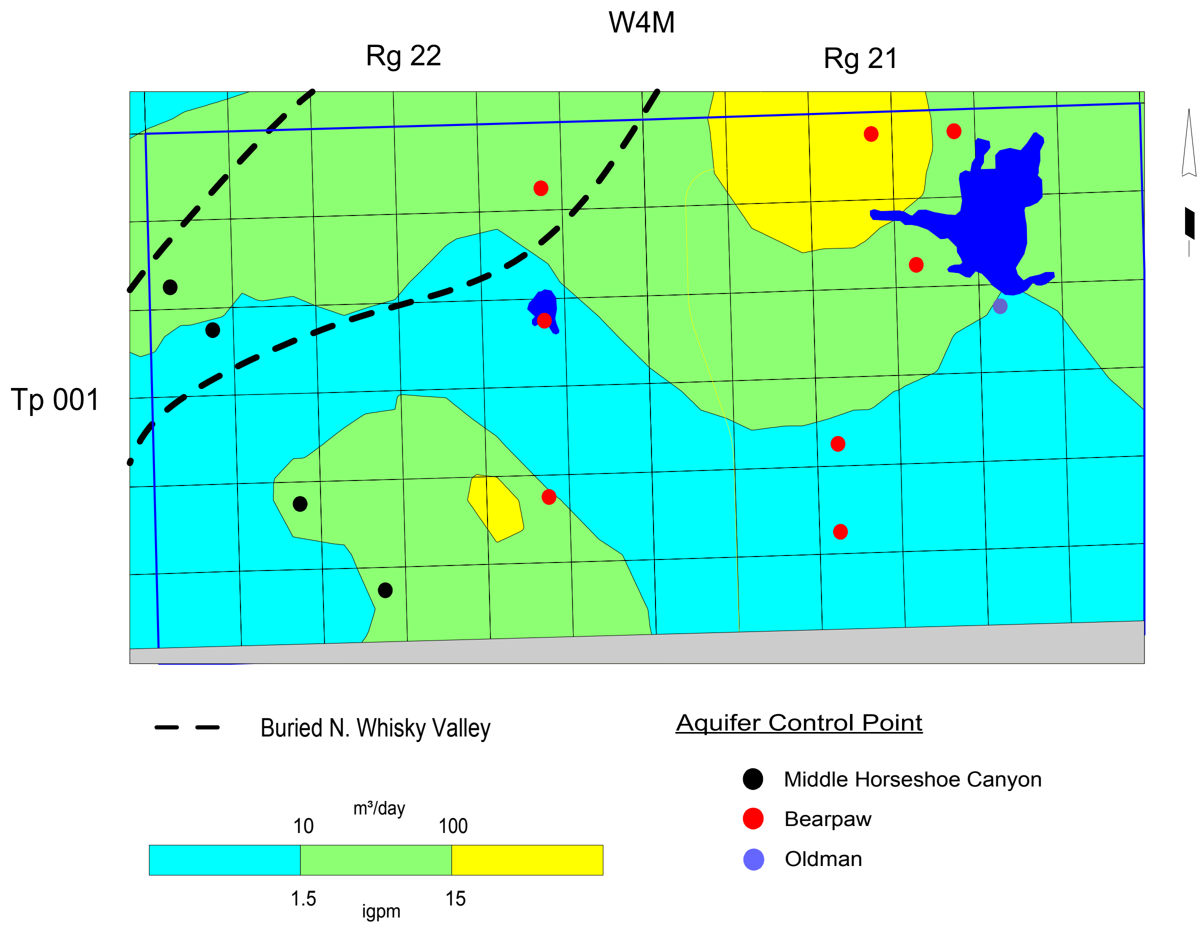
-5
0
5

Absent

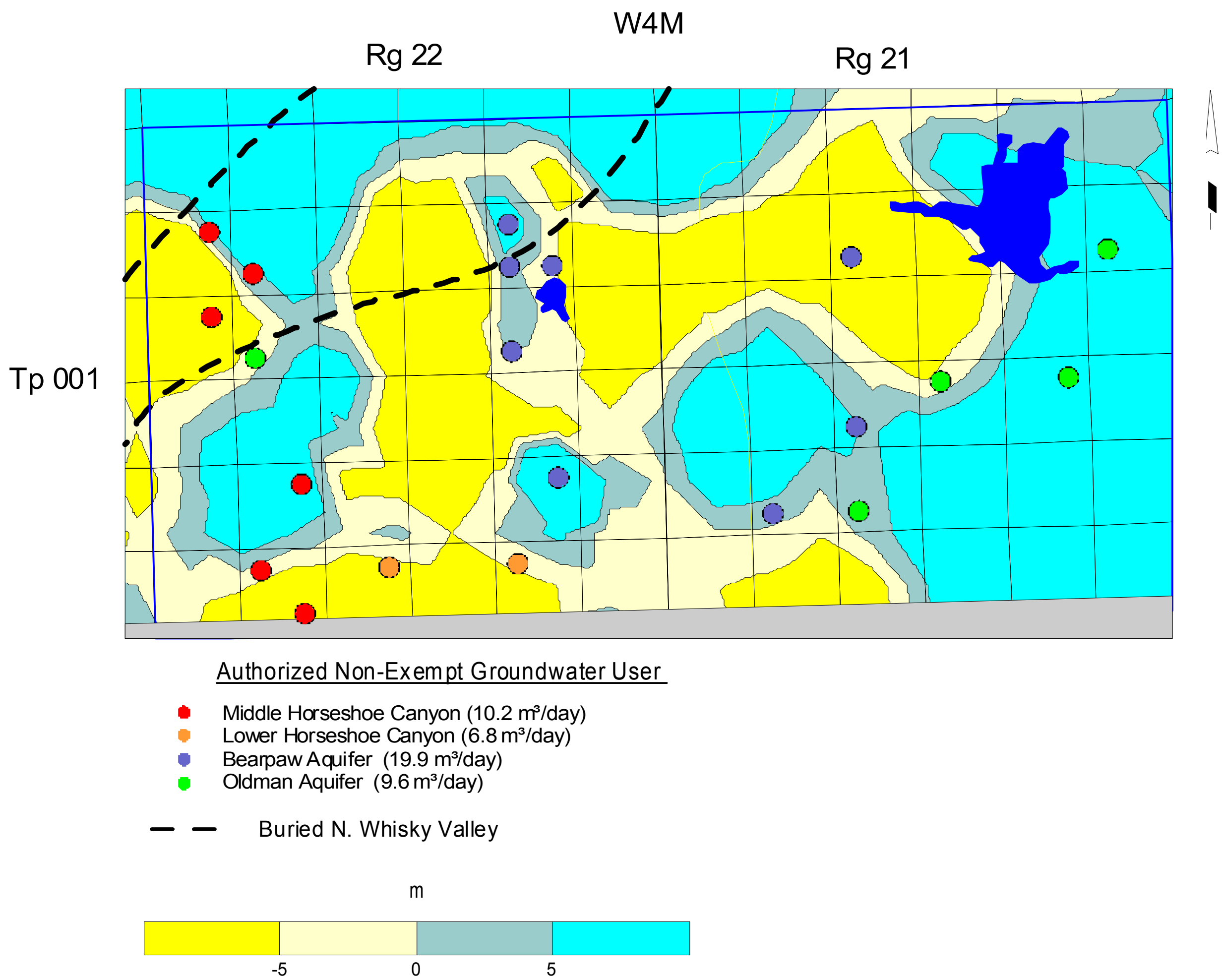
## Total Dissolved Solids in Groundwater from Surficial Deposits – Area 2



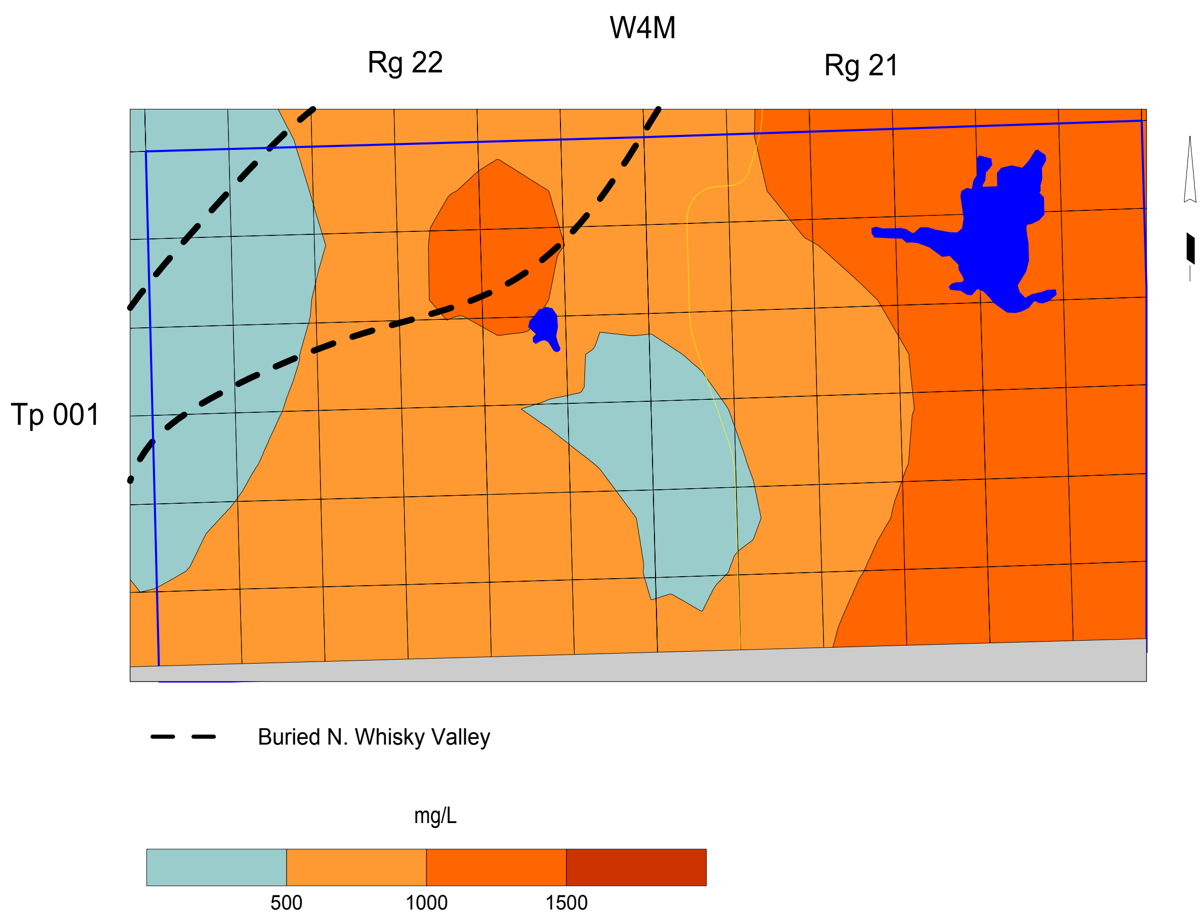
## Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s) – Area 2



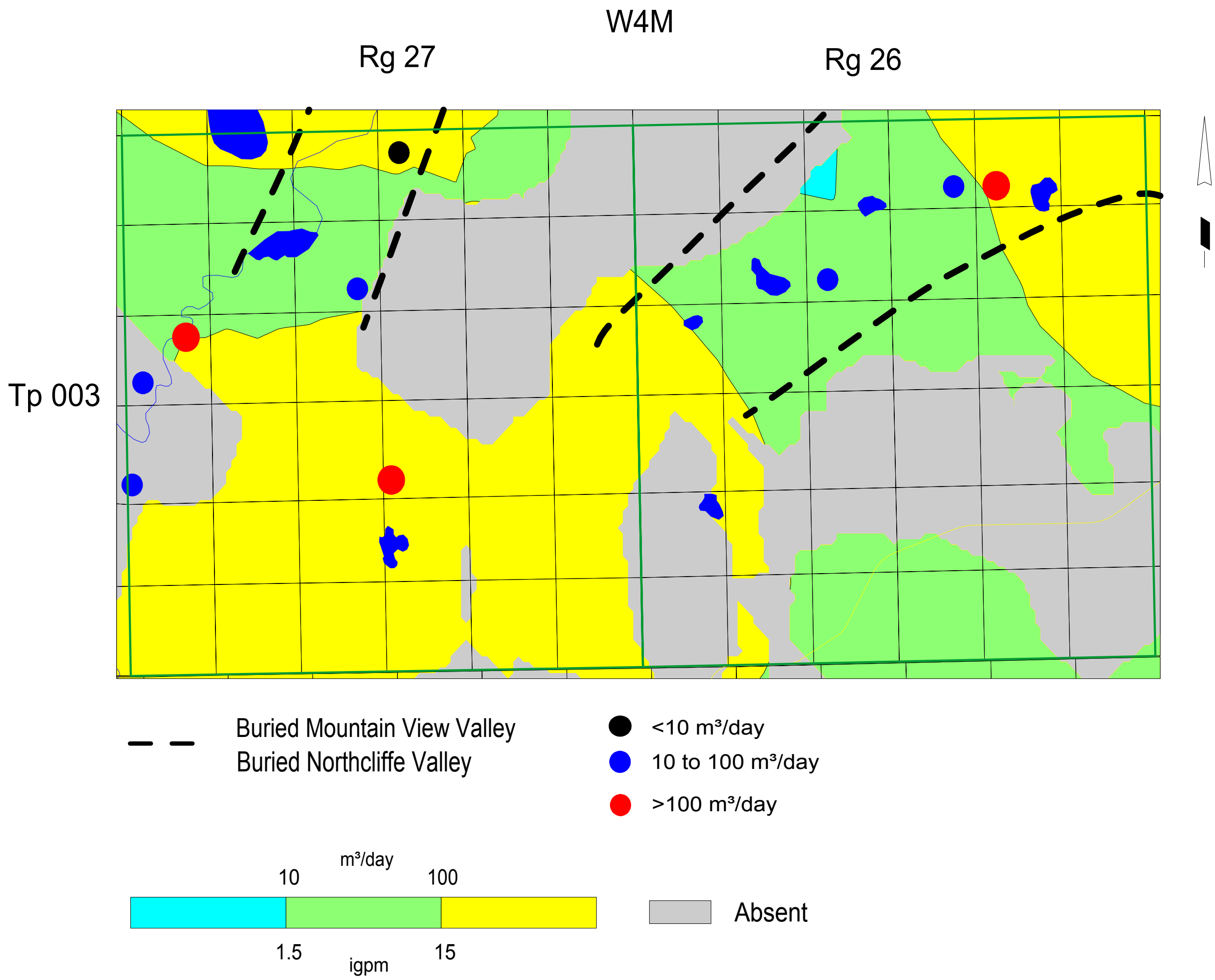
## Areas of Potential Groundwater Depletion in Upper Bedrock Aquifer(s) – Area 2



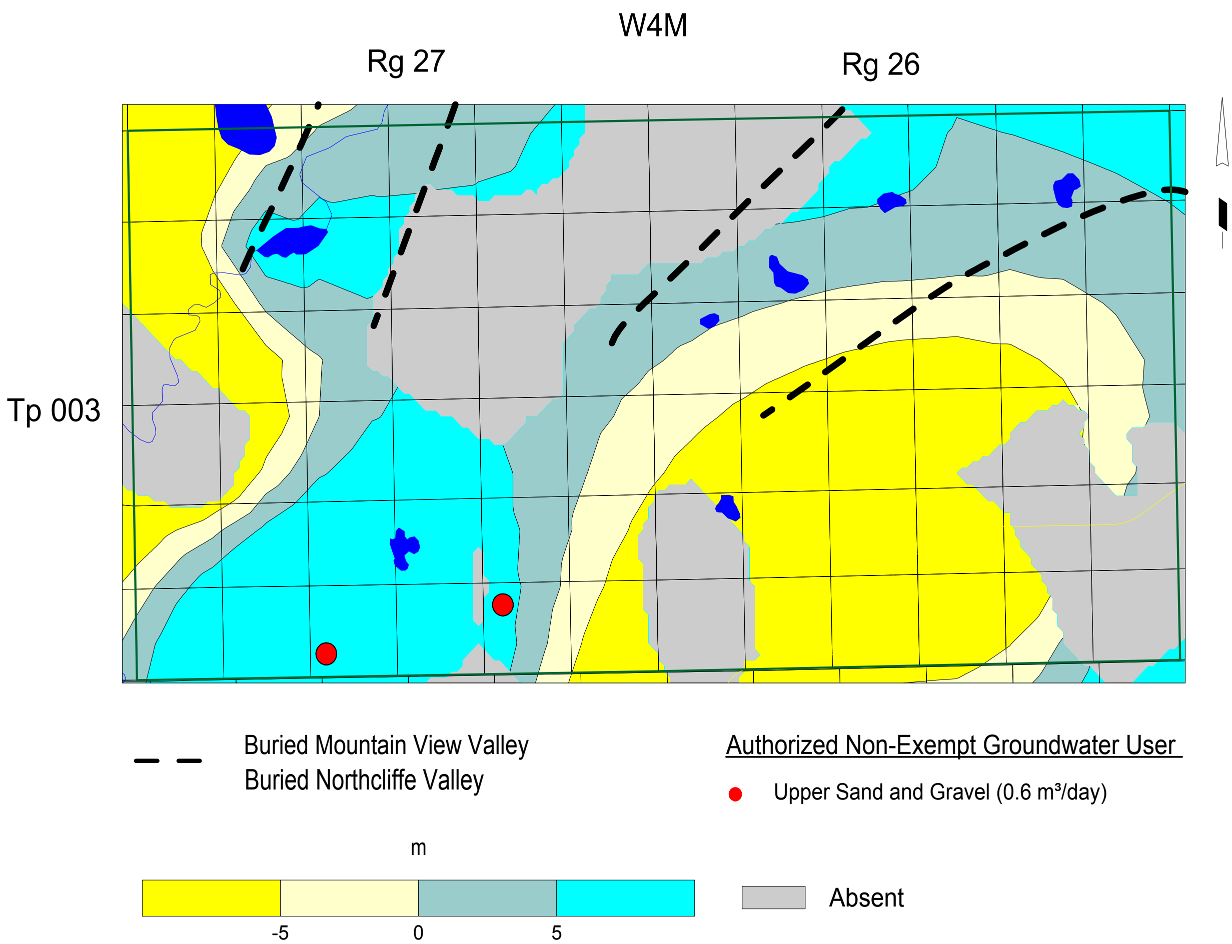
## Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s) – Area 2



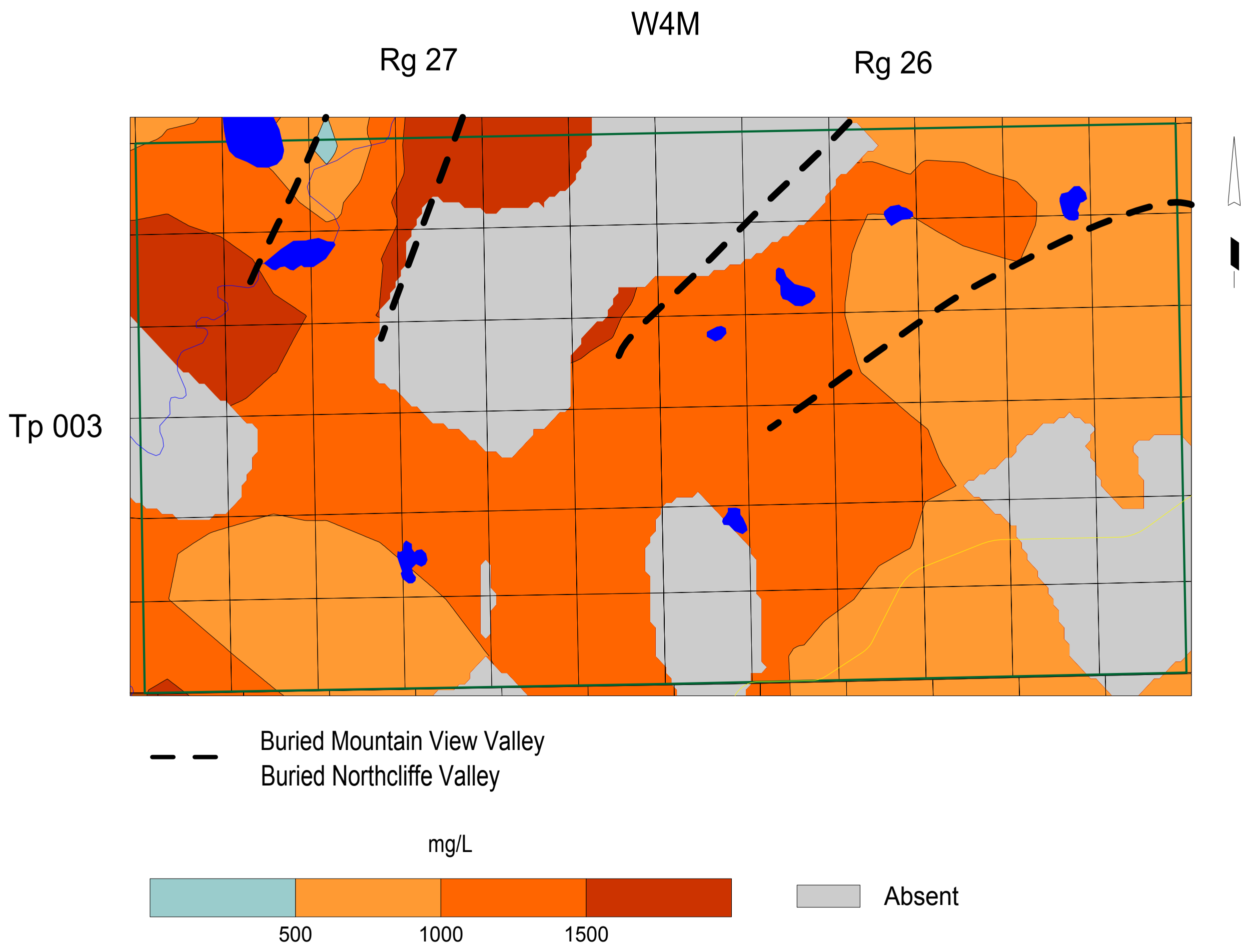
## Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s) – Area 3



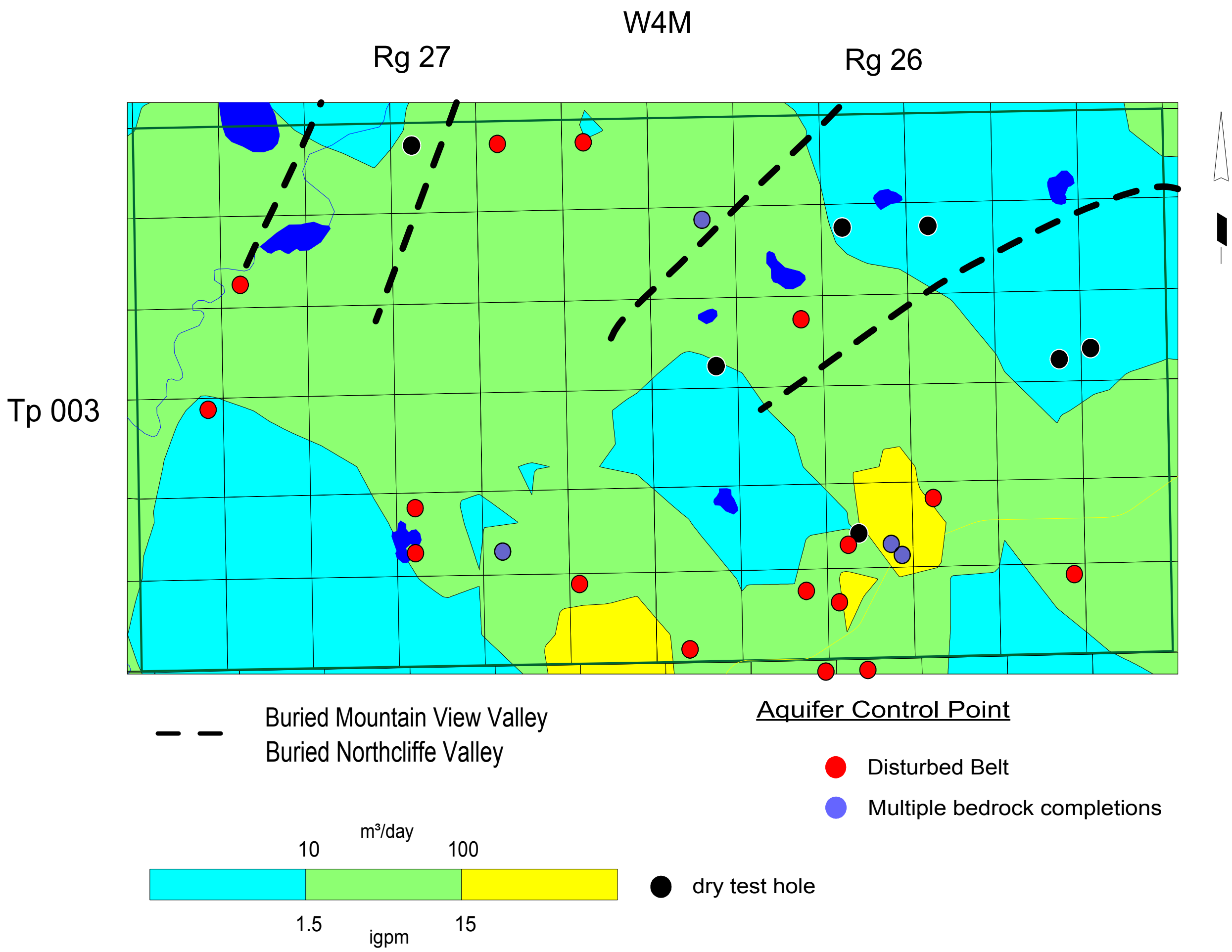
# Changes in Water Levels in Surficial Deposits – Area 3



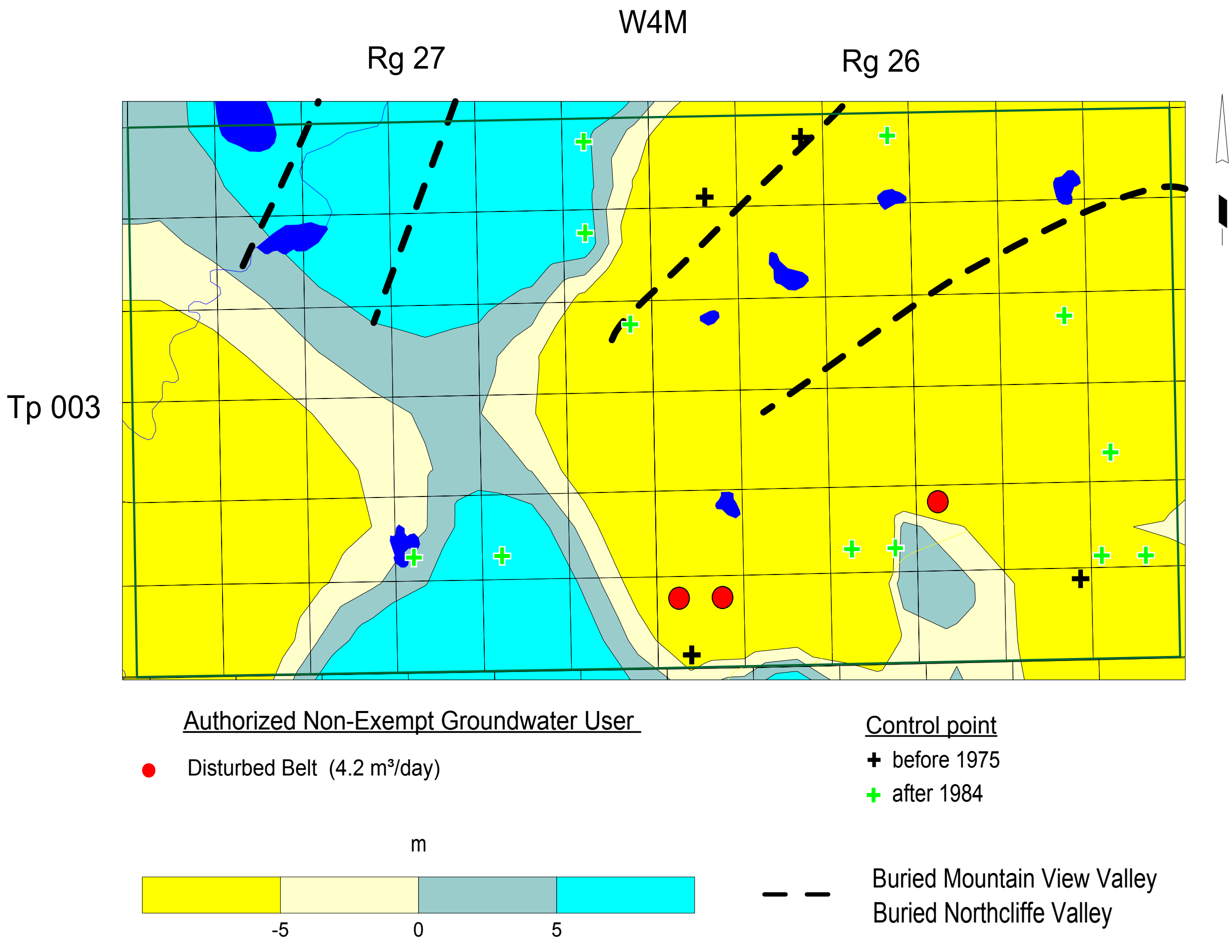
# Total Dissolved Solids in Groundwater from Surficial Deposits – Area 3



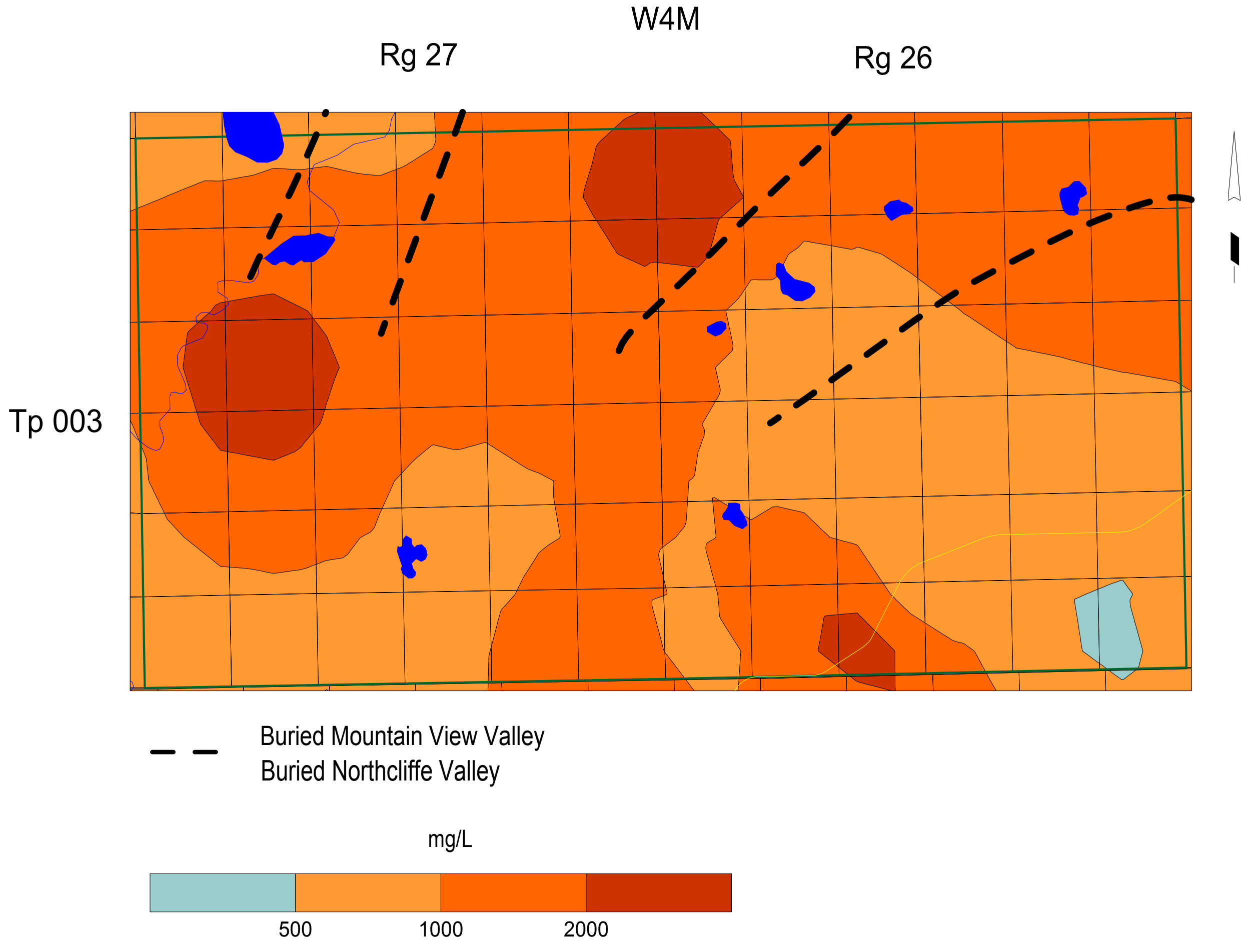
## Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s) – Area 3



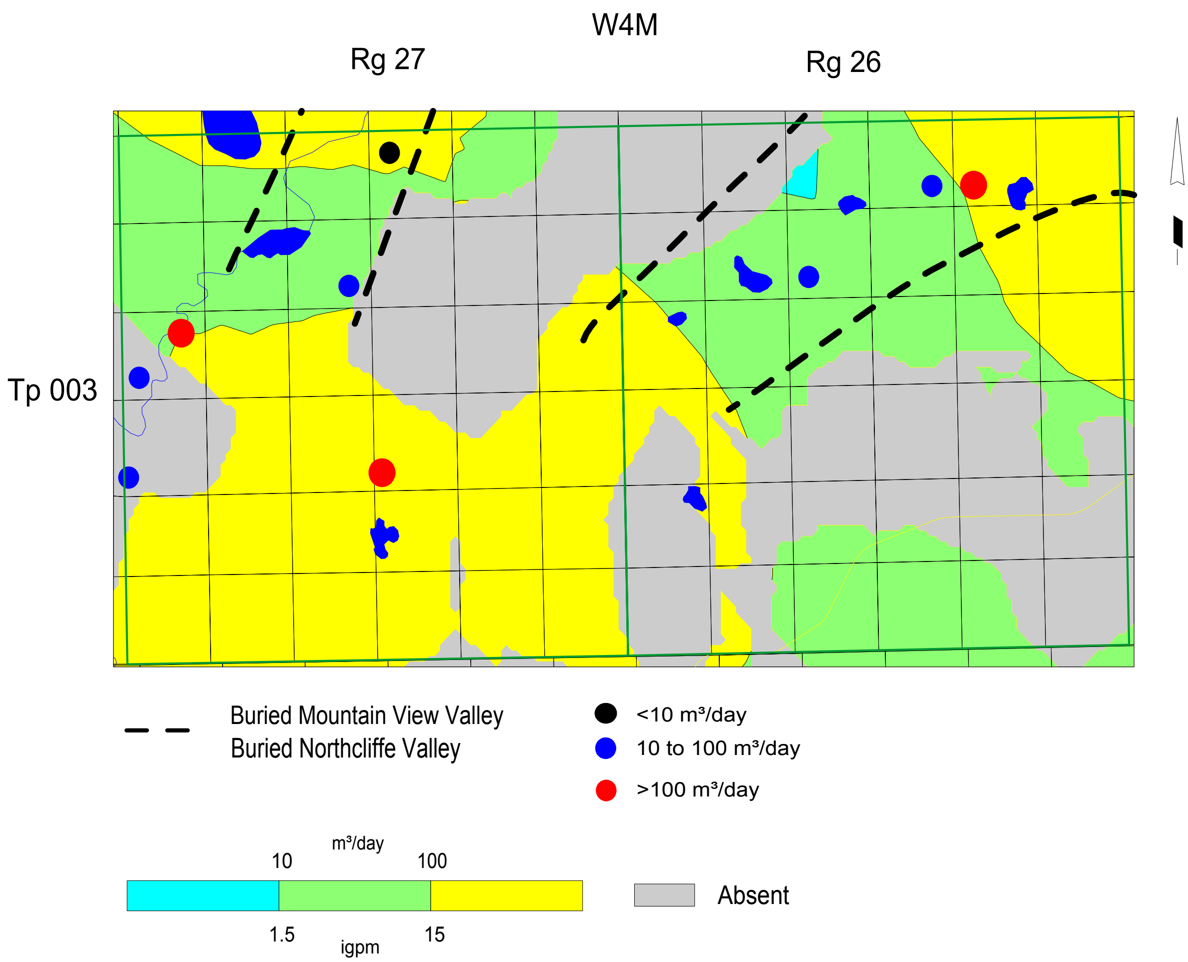
## Areas of Potential Groundwater Depletion in Upper Bedrock Aquifer(s) – Area 3



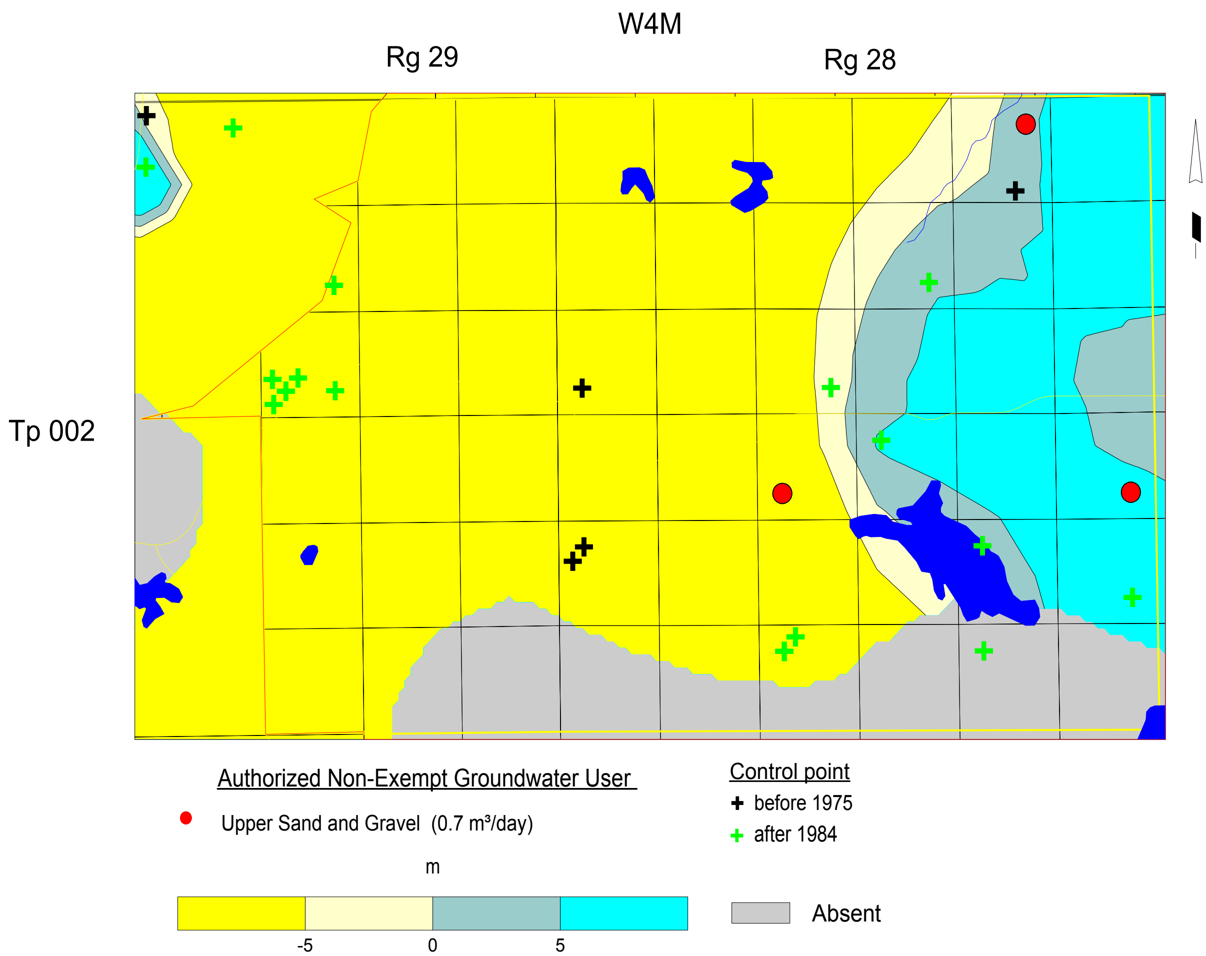
## Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s) – Area 3



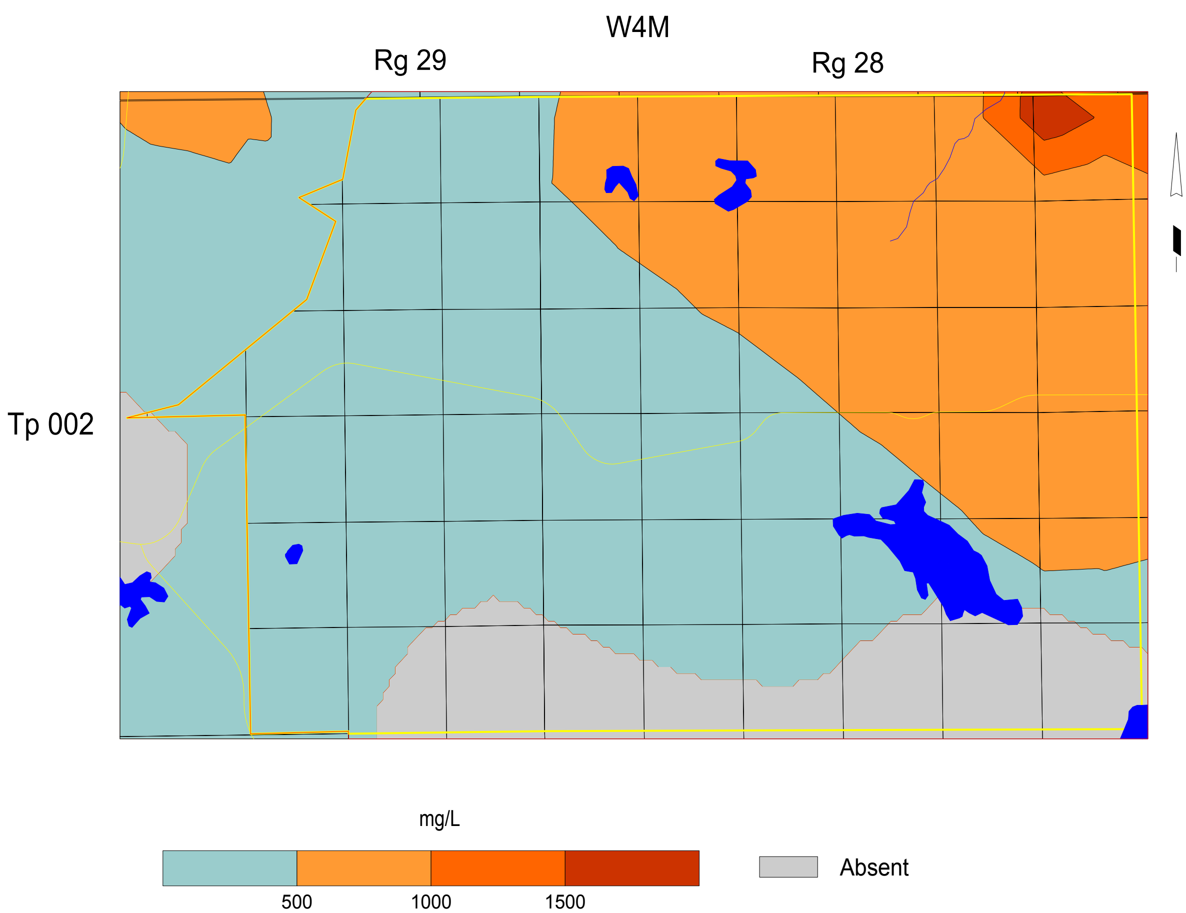
# Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s) – Area 4



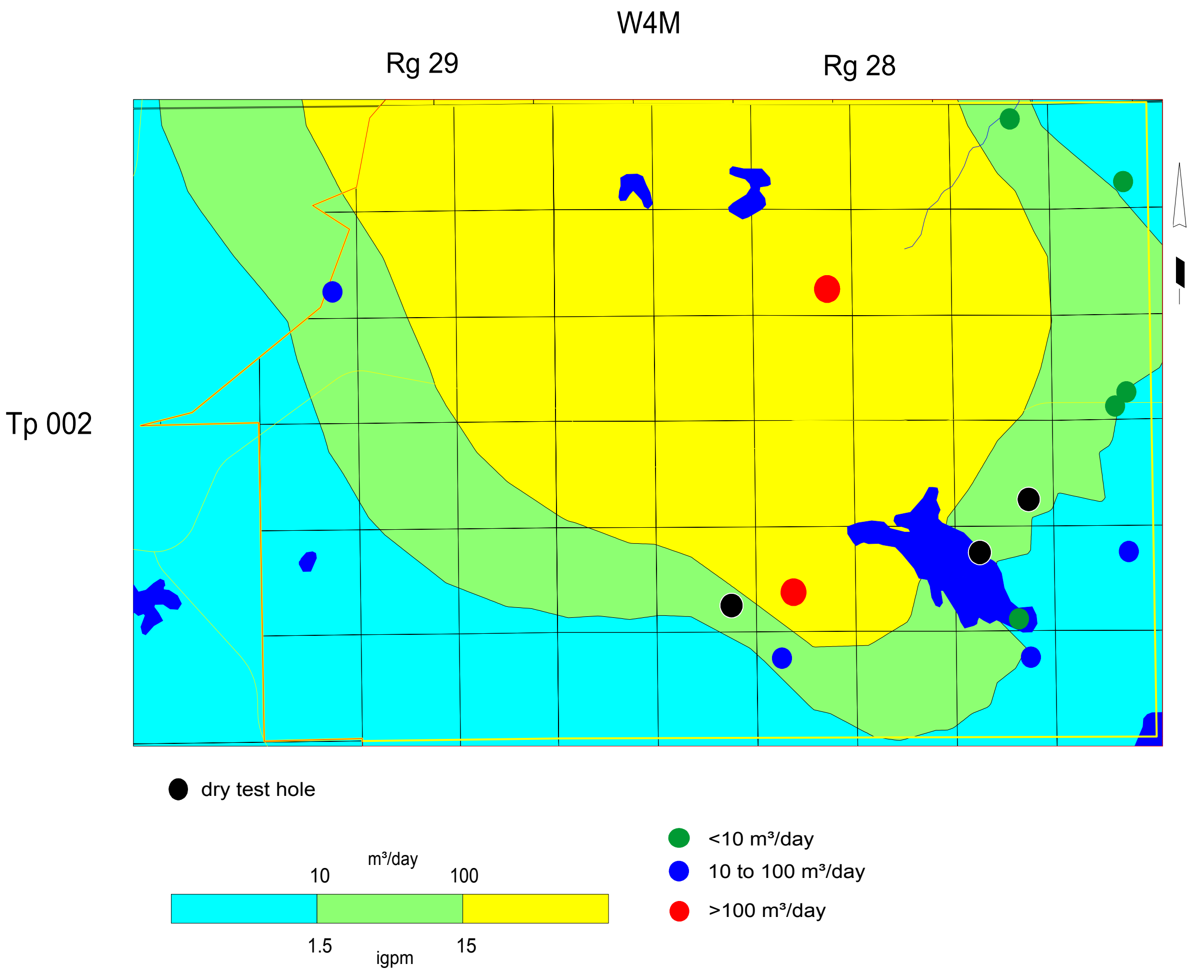
# Changes in Water Levels in Surficial Deposits – Area 4



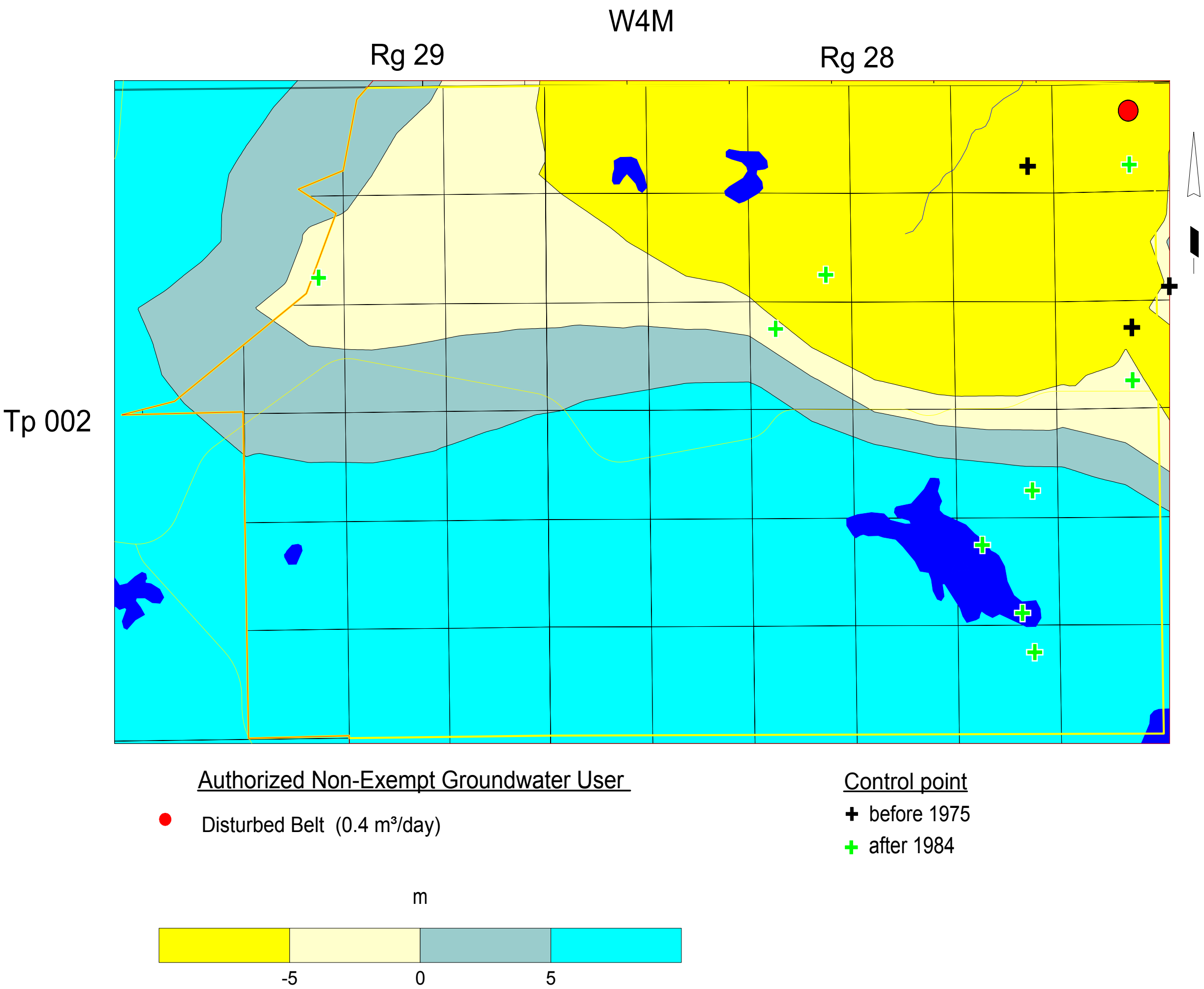
# Total Dissolved Solids in Groundwater from Surficial Deposits – Area 4



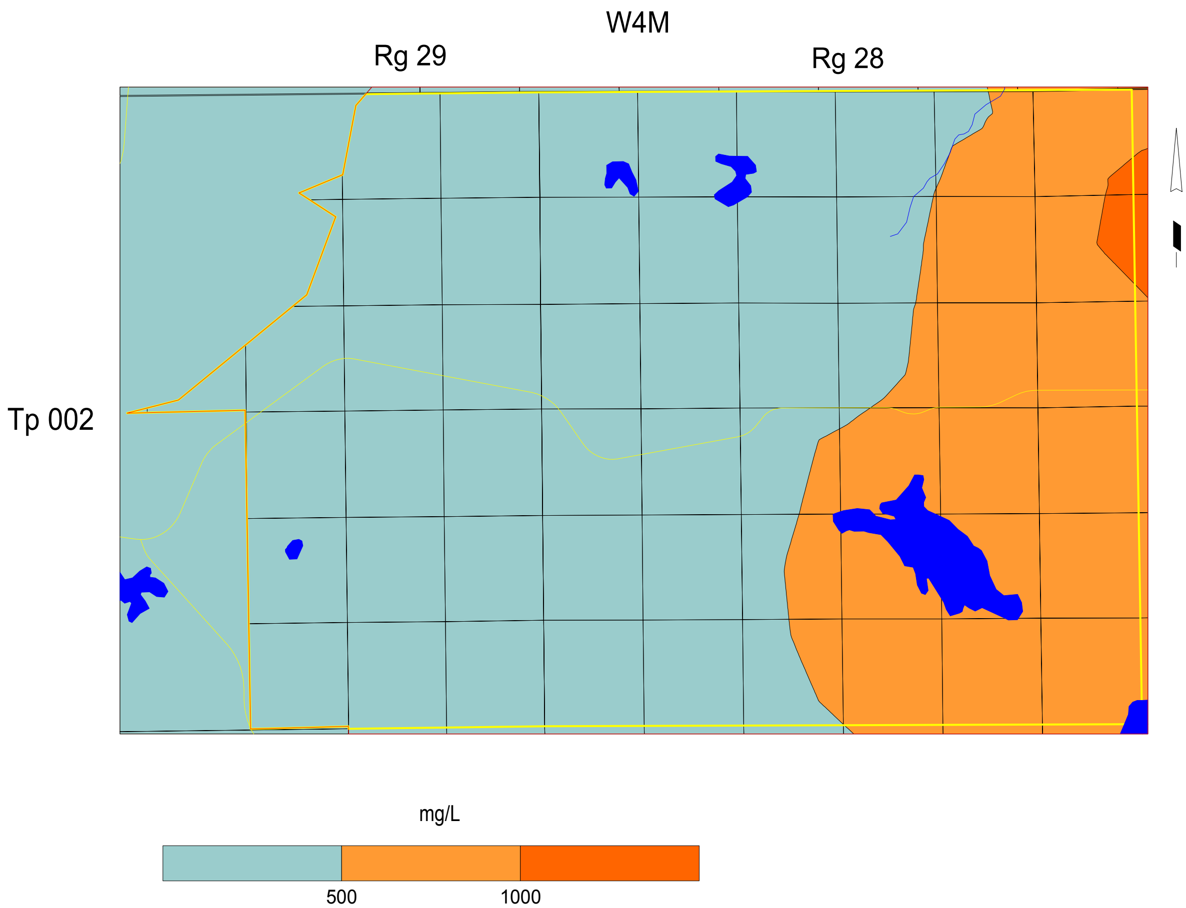
## Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s) – Area 4



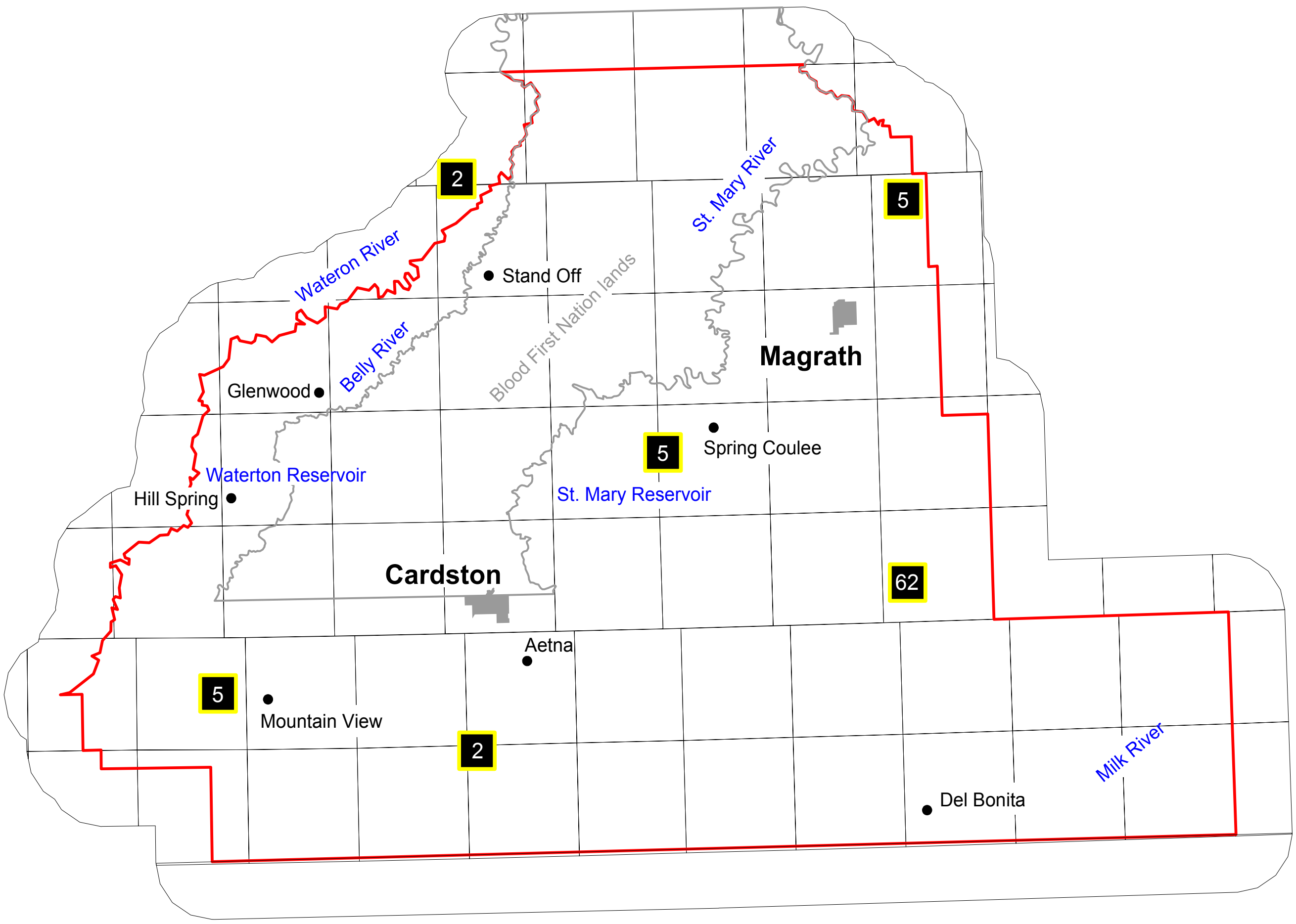
# Areas of Potential Groundwater Depletion in Upper Bedrock Aquifer(s) – Area 4



## Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s) – Area 4



# Cardston County – Overlay Map



# CARDSTON COUNTY

## Appendix B

### Maps and Figures on CD-ROM

## 1) General

Index Map/Surface Topography
River Sub-basins
Surface Casing Types used in Drilled Water Wells
Location of Water Wells and Springs
Location of Dry Water Test Holes
Depth of Existing Water Wells
Depth to Base of Groundwater Protection
Hydrogeological Map
Generalized Cross-Section (for terminology only)
Geologic Column
Cross-Section A - A'
Cross-Section B - B'
Cross-Section C - C'
Cross-Section D - D'
Cross-Section E - E'
Bedrock Topography
Bedrock Geology
E-Log Showing Base of Foremost Formation
Relative Permeability
Authorized Non-Exempt Groundwater Water Wells
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 Upper and Lower Surficial Deposits
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)
Changes in Water Levels in Surficial Deposits

### 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

Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)
Sulfate in Groundwater from Upper Bedrock Aquifer(s)
Chloride in Groundwater from Upper Bedrock Aquifer(s)
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Non-Pumping Water-Level Surface in Upper Bedrock Aquifer(s)
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### b) Disturbed Belt Formation

Non-Pumping Water-Level Surface - Disturbed Belt Aquifer
Apparent Yield for Water Wells Completed through Disturbed Belt Aquifer
Total Dissolved Solids in Groundwater from Disturbed Belt Aquifer
Sulfate in Groundwater from Disturbed Belt Aquifer
Chloride in Groundwater from Disturbed Belt Aquifer
Fluoride in Groundwater from Disturbed Aquifer
Piper Diagram - Disturbed Belt Aquifer

### c) Upper Lacombe Member

Depth to Top of Upper Lacombe Member
Structure-Contour Map - Upper Lacombe Member
Non-Pumping Water-Level Surface - Upper Lacombe Aquifer
Apparent Yield for Water Wells Completed through Upper Lacombe Aquifer
Total Dissolved Solids in Groundwater from Upper Lacombe Aquifer
Sulfate in Groundwater from Upper Lacombe Aquifer
Chloride in Groundwater from Upper Lacombe Aquifer
Fluoride in Groundwater from Upper Lacombe Aquifer
Piper Diagram - Upper Lacombe Aquifer

### d) Lower Lacombe Member

Depth to Top of Lower Lacombe Member
Structure-Contour Map - Lower Lacombe Member

### e) Haynes Member

Depth to Top of Haynes Member
Structure-Contour Map - Haynes Member
Piper Diagram - Haynes Aquifer

### c) Upper Scollard Formation

Depth to Top of Upper Scollard Formation
Structure-Contour Map - Upper Scollard Formation
Non-Pumping Water-Level Surface - Upper Scollard Aquifer
Apparent Yield for Water Wells Completed through Upper Scollard Aquifer
Total Dissolved Solids in Groundwater from Upper Scollard Aquifer
Sulfate in Groundwater from Upper Scollard Aquifer
Chloride in Groundwater from Upper Scollard Aquifer
Fluoride in Groundwater from Upper Scollard Aquifer
Piper Diagram - Upper Scollard Aquifer

### d) Lower Scollard Formation

Depth to Top of Lower Scollard Formation
Structure-Contour Map - Lower Scollard Formation
Non-Pumping Water-Level Surface - Lower Scollard Aquifer
Apparent Yield for Water Wells Completed through Lower Scollard Aquifer
Total Dissolved Solids in Groundwater from Lower Scollard Aquifer
Sulfate in Groundwater from Lower Scollard Aquifer
Chloride in Groundwater from Lower Scollard Aquifer
Fluoride in Groundwater from Lower Scollard Aquifer
Piper Diagram - Lower Scollard Aquifer

# CARDSTON 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**

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**ALBERTA REGULATION 205/98**

**Water Act**

**WATER (MINISTERIAL) REGULATION**

*Table of Contents*

# Chemical Analysis of Farm Water Supplies

**Adapted from Agdex 716 (D04) Published April 1991**

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

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

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

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

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

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

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

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

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

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

**Calcium**

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

**Magnesium**

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

**Iron**

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

**Sulphate (SO4)**

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

**Chloride**

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

**NO2 Nitrogen (Nitrite)**

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

The concentration in livestock water should not exceed 10 ppm.

**NO3 Nitrogen (Nitrate)**

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

**Fluoride**

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

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

**TDS Inorganic (Total Dissolved Solids)**

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

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

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

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

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

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

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

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

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

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

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

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

# Additional Information

VIDEOS

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

BOOKLET

Water Wells that Last (PFRA – Edmonton Office: 780-495-3307);
http://www.agric.gov.ab.ca/water/wells/index.html
Quality Farm Dugouts - http://www.agric.gov.ab.ca/esb/dugout.html

ALBERTA ENVIRONMENT

WATER - http://www3.gov.ab.ca/env/water.cfm

GROUNDWATER INFORMATION SYSTEM - http://www.telusgeomatics.com/tgpub/ag_water/

WATER WELL INSPECTORS
Jennifer McPherson (Edmonton: 780-427-6429)

WATER WELL LICENSING
Rob George (Edmonton: 780-427-6429)

GEOPHYSICAL INSPECTION SERVICE
Edmonton: 780-427-3932

COMPLAINT INVESTIGATIONS
Jerry Riddell (Edmonton: 780-422-4851)
Claude Eckert (Calgary: 403-297-6649)
Ian Franks (Lethbridge: 403-381-5998)

GENERAL LICENSING INQUIRIES
Lethbridge: 403-381-5392

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
Dean Lien (Edmonton: 780-427-2433)

PRAIRIE FARM REHABILITATION ADMINISTRATION (PFRA) BRANCH OF AGRICULTURE AND AGRI-FOOD CANADA (AAFC)

Vic Brown (Lethbridge: 403-327-4340) - brownv@agr.gc.ca
Terry Dash (Calgary: 403-292-5719) - dasht@agr.gc.ca

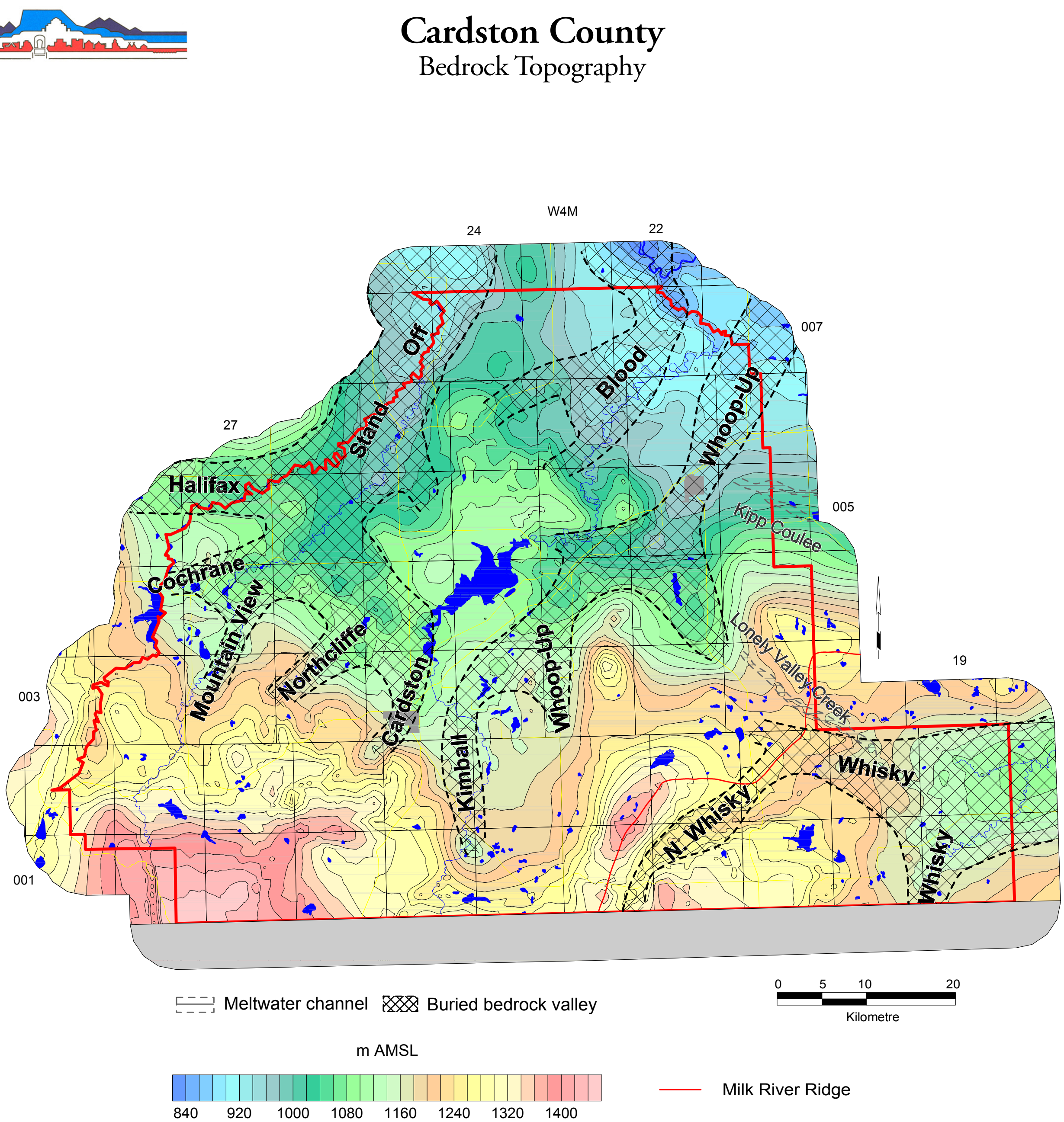
WILDROSE COUNTRY GROUND WATER MONITORING ASSOCIATION
Dave Andrews (Irricana: 403-935-4478)

LOCAL HEALTH DEPARTMENTS

# CARDSTON COUNTY
## Appendix D

## Maps and Figures Included as Large Plots

## *Bedrock Topography*

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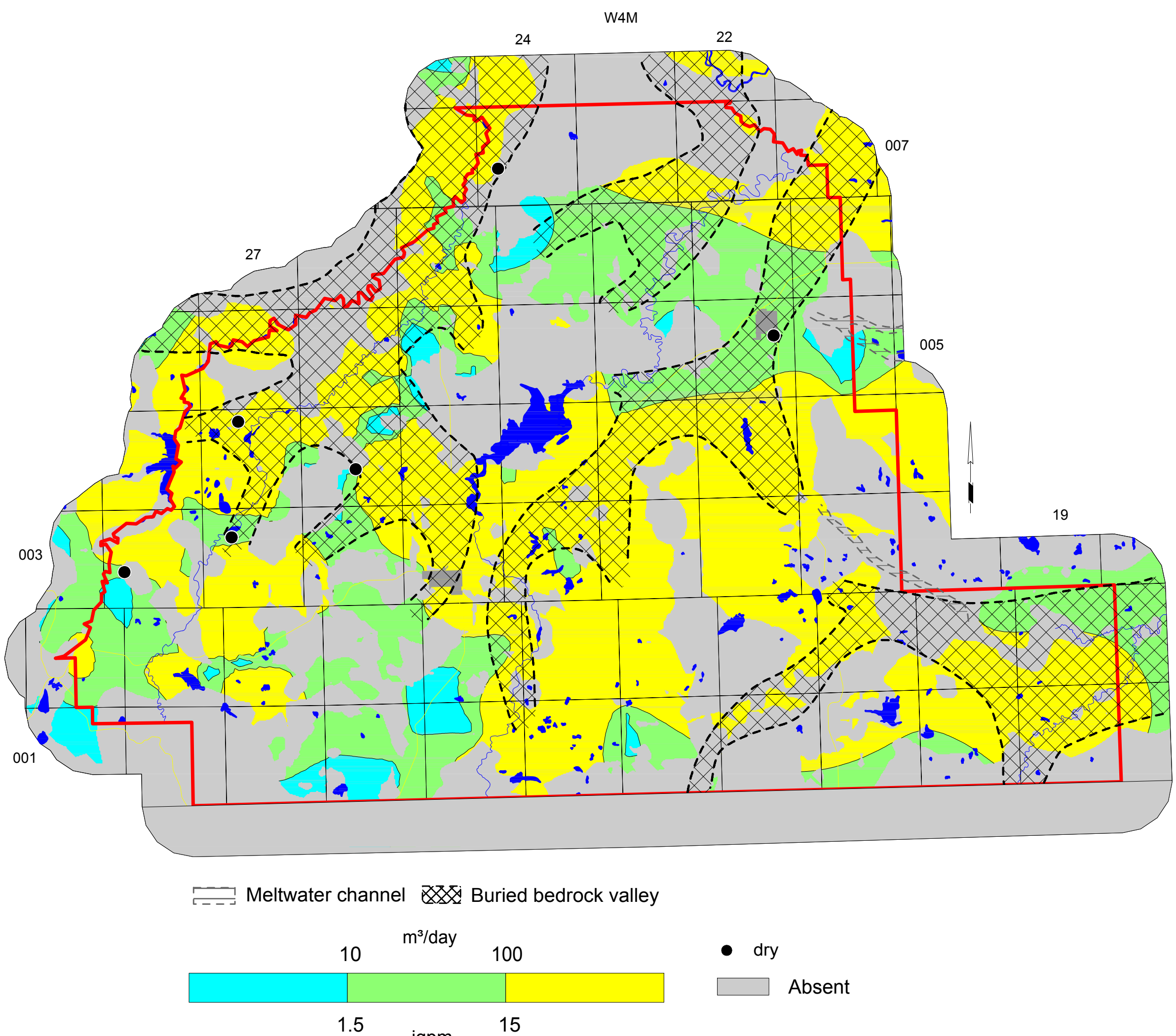
## *Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)*

# Cardston 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

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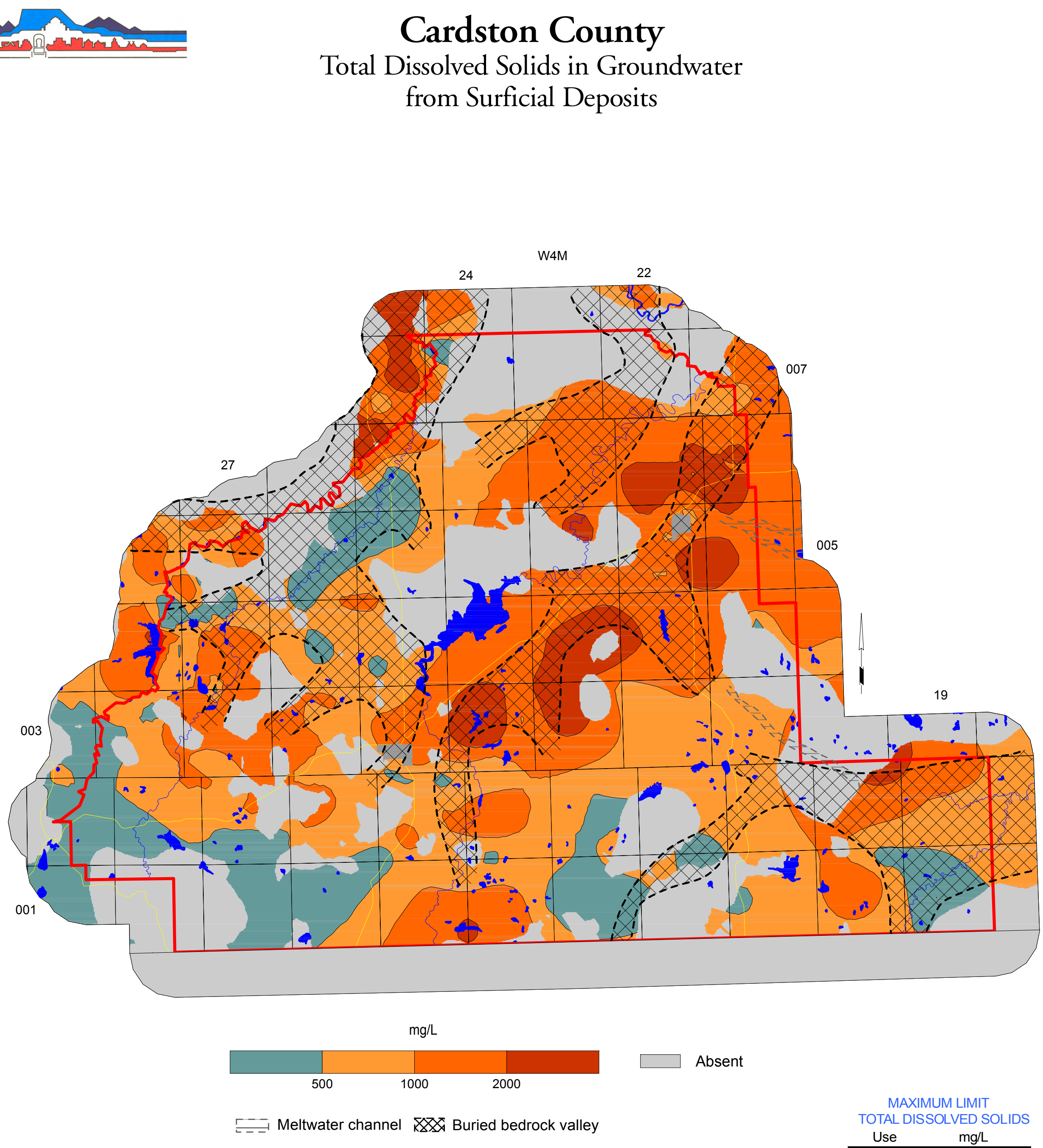
## *Total Dissolved Solids in Groundwater from Surficial Deposits*




MAXIMUM LIMIT
TOTAL DISSOLVED SOLIDS

| Use | mg/L |
|---|---|
| Residential | 500 |
| Livestock | 3,000 |
| Irrigation | 500 - 3,500 |
| Commercial | Depends on Purpose |
| Industrial | Depends on Purpose |

from: Canadian Water Quality Guidelines, 1992

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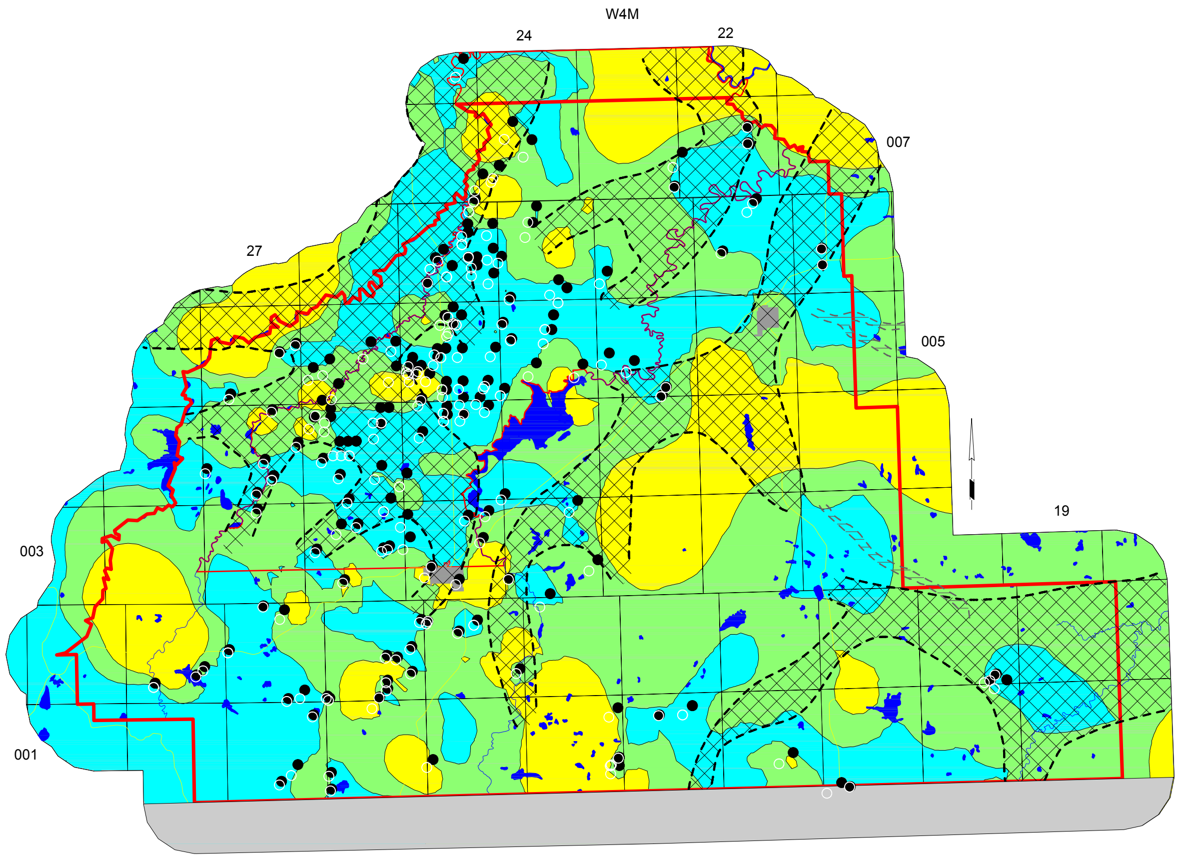
### *Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)*

# Cardston County

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




Meltwater channel  Buried bedrock valley

m³/day: 10, 100

igpm: 1.5, 15

dry test hole

Blood First Nation lands

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

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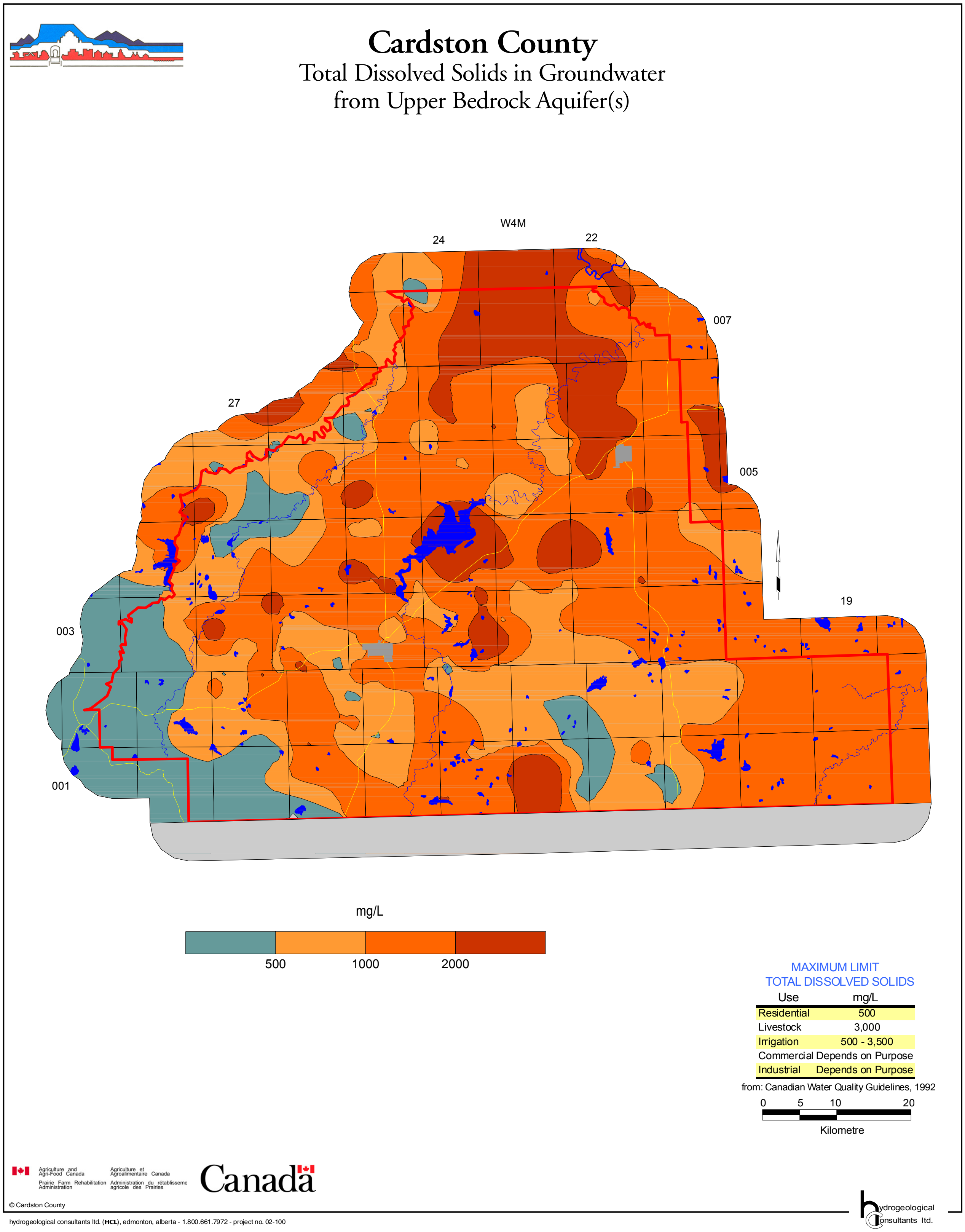
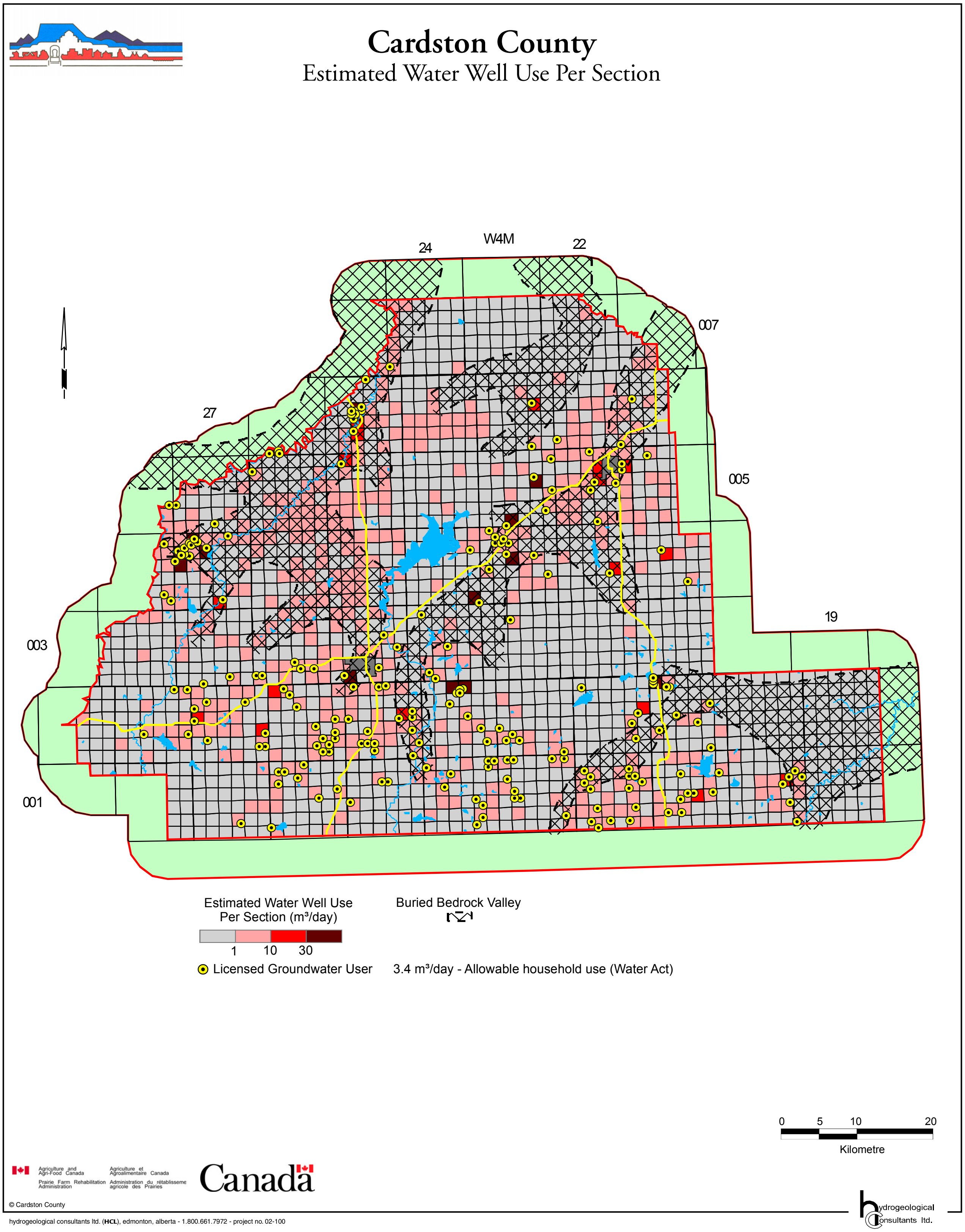
### *Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)*



## Estimated Water Well Use Per Section

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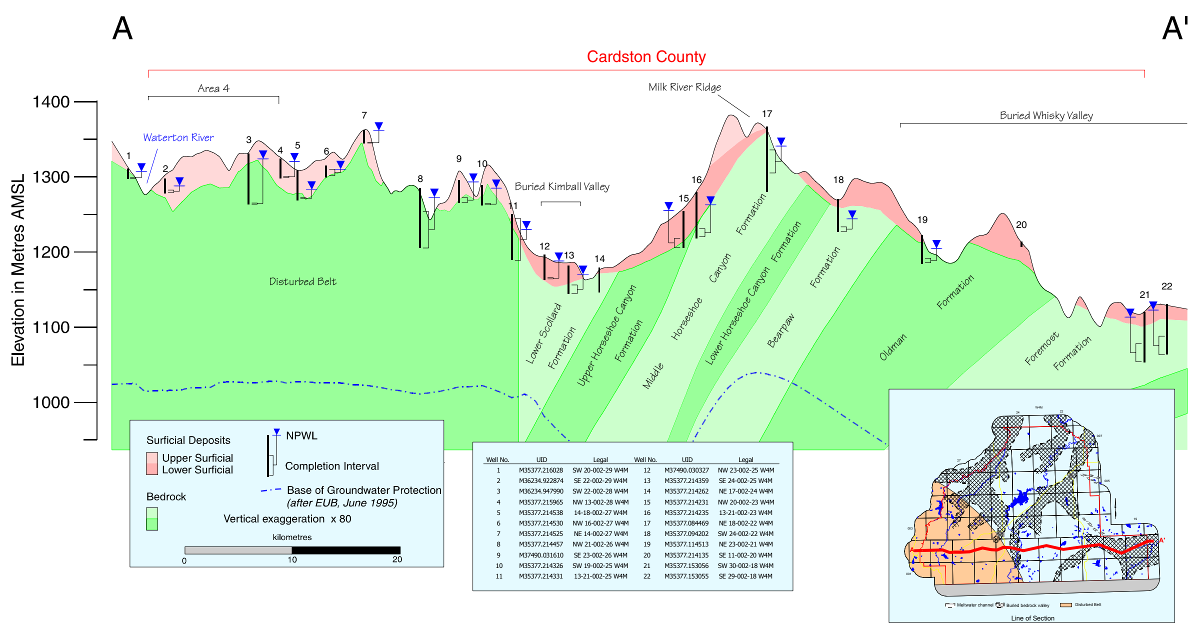
## *Cross-Section A - A'*

# Cardston County

## Cross-Section A - A'




| Well No. | UID | Legal | Well No. | UID | Legal |
|---|---|---|---|---|---|
| 1 | M35377.216028 | SW 20-002-29 W4M | 12 | M37490.030327 | NW 23-002-25 W4M |
| 2 | M36234.922874 | SE 22-002-29 W4M | 13 | M35377.214359 | SE 24-002-25 W4M |
| 3 | M36234.947990 | SW 22-002-28 W4M | 14 | M35377.214262 | NE 17-002-24 W4M |
| 4 | M35377.215965 | NW 13-002-28 W4M | 15 | M35377.214231 | NW 20-002-23 W4M |
| 5 | M35377.214538 | 14-18-002-27 W4M | 16 | M35377.214235 | 13-21-002-23 W4M |
| 6 | M35377.214530 | NW 16-002-27 W4M | 17 | M35377.084469 | NE 18-002-22 W4M |
| 7 | M35377.214525 | NE 14-002-27 W4M | 18 | M35377.094202 | SW 24-002-22 W4M |
| 8 | M35377.214457 | NW 21-002-26 W4M | 19 | M35377.114513 | NE 23-002-21 W4M |
| 9 | M37490.031610 | SE 23-002-26 W4M | 20 | M35377.214135 | SE 11-002-20 W4M |
| 10 | M35377.214326 | SW 19-002-25 W4M | 21 | M35377.153056 | SW 30-002-18 W4M |
| 11 | M35377.214331 | 13-21-002-25 W4M | 22 | M35377.153055 | SE 29-002-18 W4M |

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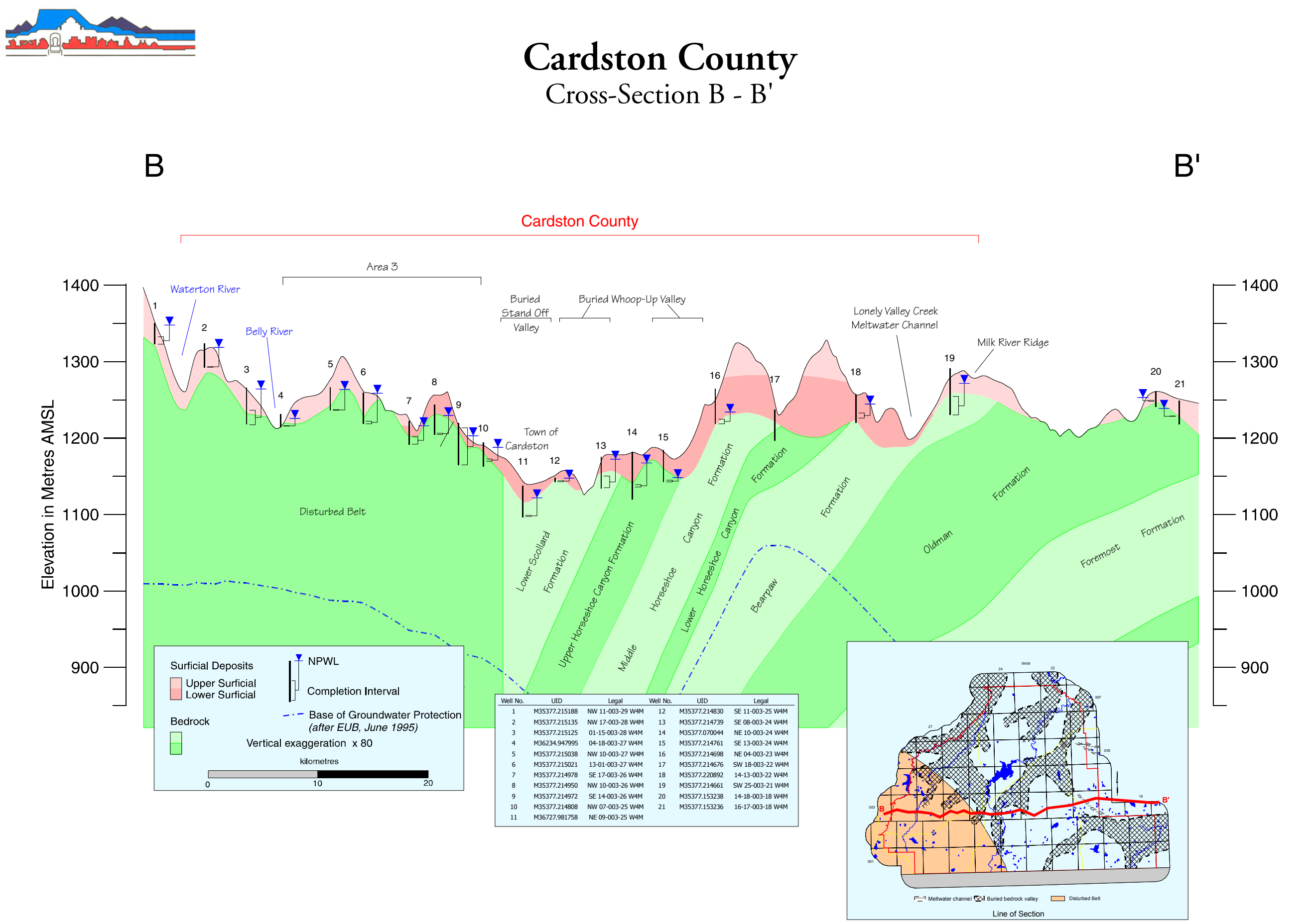
## *Cross-Section B - B'*




| Well No. | UID | Legal | Well No. | UID | Legal |
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| 1 | M35377.215188 | NW 11-003-29 W4M | 12 | M35377.214830 | SE 11-003-25 W4M |
| 2 | M35377.215135 | NW 17-003-28 W4M | 13 | M35377.214739 | SE 08-003-24 W4M |
| 3 | M35377.215125 | 01-15-003-28 W4M | 14 | M35377.070044 | NE 10-003-24 W4M |
| 4 | M36234.947995 | 04-18-003-27 W4M | 15 | M35377.214761 | SE 13-003-24 W4M |
| 5 | M35377.215038 | NW 10-003-27 W4M | 16 | M35377.214698 | NE 04-003-23 W4M |
| 6 | M35377.215021 | 13-01-003-27 W4M | 17 | M35377.214676 | SW 18-003-22 W4M |
| 7 | M35377.214978 | SE 17-003-26 W4M | 18 | M35377.220892 | 14-13-003-22 W4M |
| 8 | M35377.214950 | NW 10-003-26 W4M | 19 | M35377.214661 | SW 25-003-21 W4M |
| 9 | M35377.214972 | SE 14-003-26 W4M | 20 | M35377.153238 | 14-18-003-18 W4M |
| 10 | M35377.214808 | NW 07-003-25 W4M | 21 | M35377.153236 | 16-17-003-18 W4M |
| 11 | M36727.981758 | NE 09-003-25 W4M | | | |

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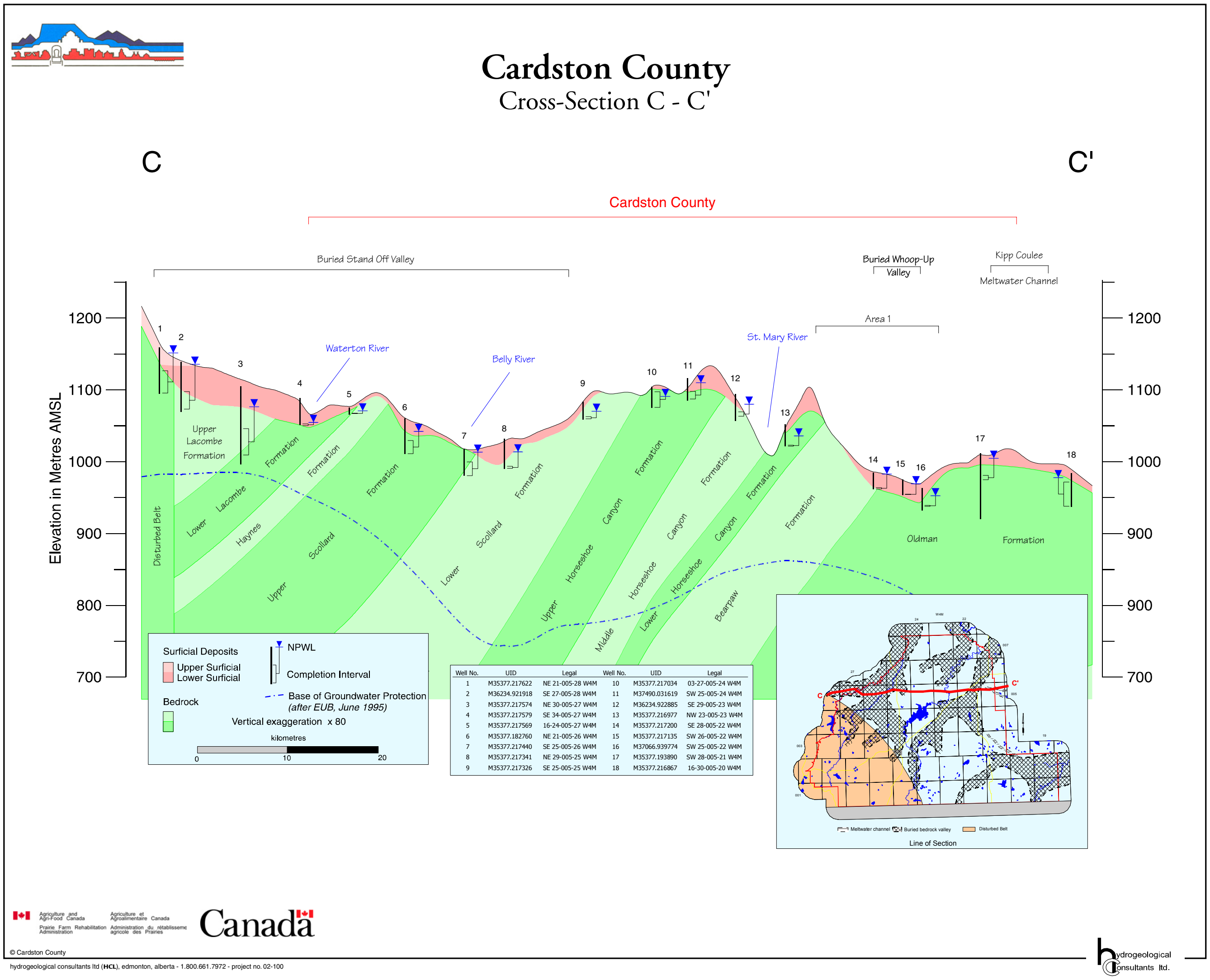
## *Cross-Section C - C'*




| Well No. | UID | Legal | Well No. | UID | Legal |
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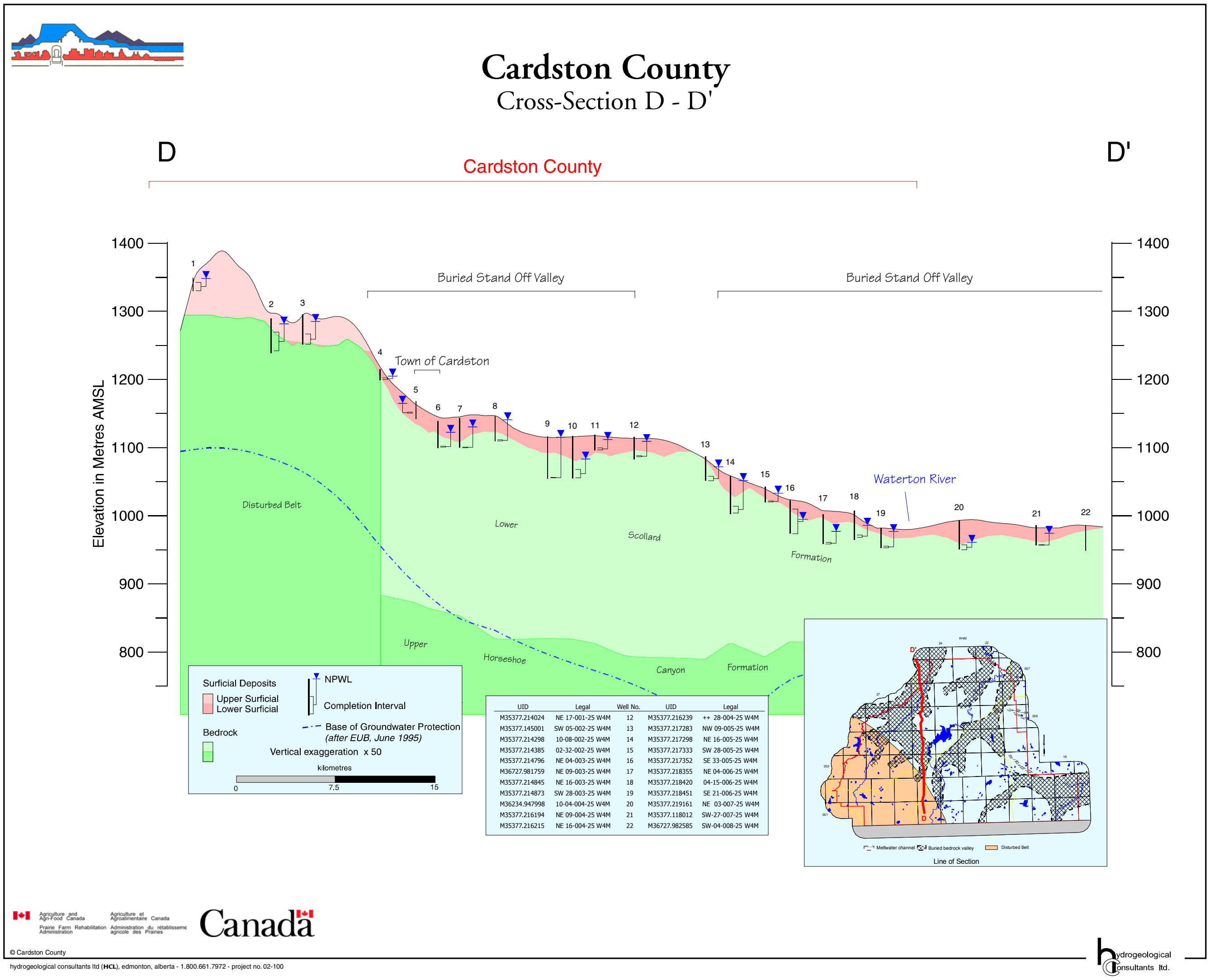
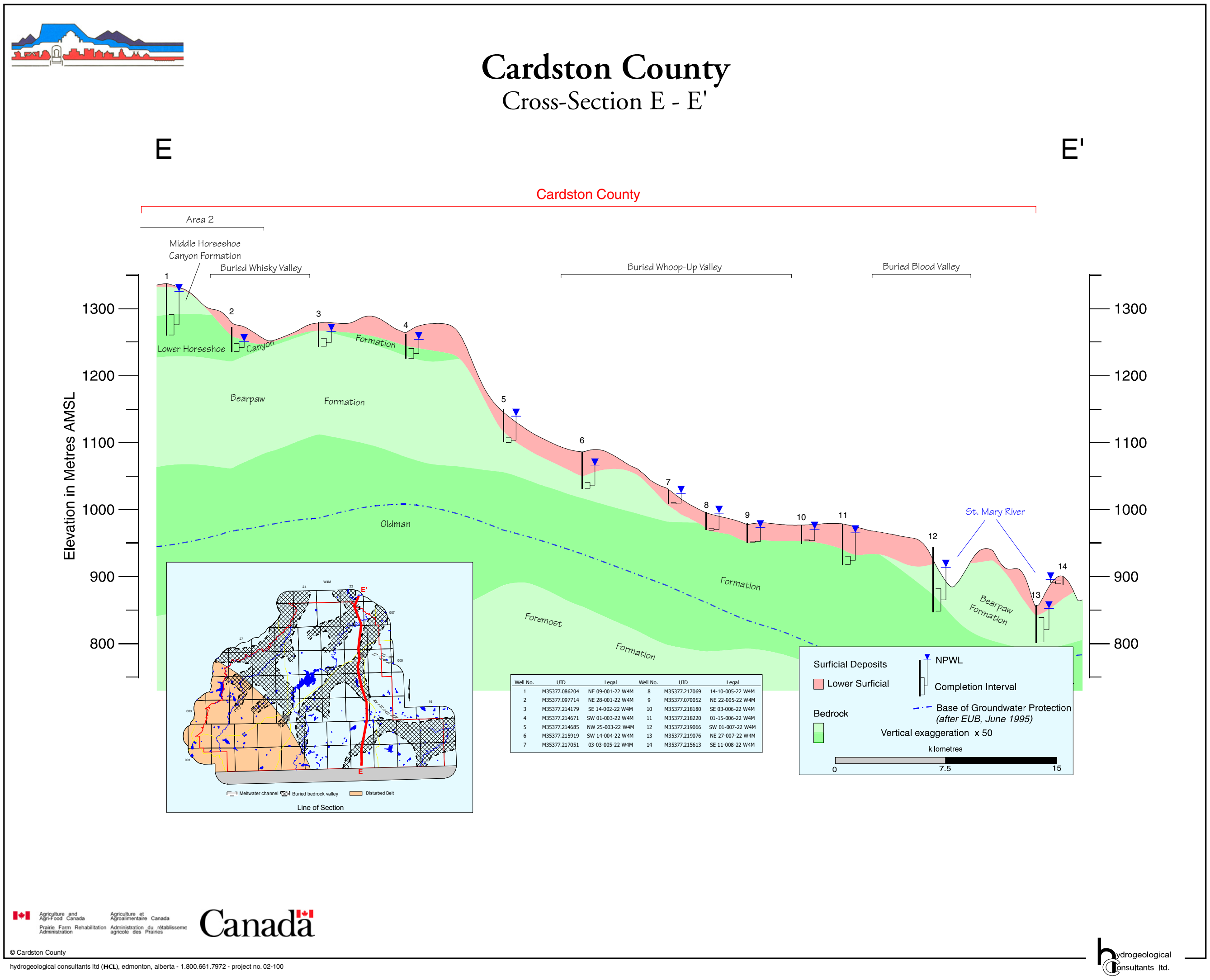
| 1 | M35377.217622 | NE 21-005-28 W4M | 10 | M35377.217034 | 03-27-005-24 W4M |
| 2 | M36234.921918 | SE 27-005-28 W4M | 11 | M37490.031619 | SW 25-005-24 W4M |
| 3 | M35377.217574 | NE 30-005-27 W4M | 12 | M36234.922885 | SE 29-005-23 W4M |
| 4 | M35377.217579 | SE 34-005-27 W4M | 13 | M35377.216977 | NW 23-005-23 W4M |
| 5 | M35377.217569 | 16-24-005-27 W4M | 14 | M35377.217200 | SE 28-005-22 W4M |
| 6 | M35377.182760 | NE 21-005-26 W4M | 15 | M35377.217135 | SW 26-005-22 W4M |
| 7 | M35377.217440 | SE 25-005-26 W4M | 16 | M37066.939774 | SW 25-005-22 W4M |
| 8 | M35377.217341 | NE 29-005-25 W4M | 17 | M35377.193890 | SW 28-005-21 W4M |
| 9 | M35377.217326 | SE 25-005-25 W4M | 18 | M35377.216867 | 16-30-005-20 W4M |

## *Cross-Section D - D'*




| UID | Legal | Well No. | UID | Legal |
|---|---|---|---|---|
| M35377.214024 | NE 17-001-25 W4M | 12 | M35377.216239 | ++ 28-004-25 W4M |
| M35377.145001 | SW 05-002-25 W4M | 13 | M35377.217283 | NW 09-005-25 W4M |
| M35377.214298 | 10-08-002-25 W4M | 14 | M35377.217298 | NE 16-005-25 W4M |
| M35377.214385 | 02-32-002-25 W4M | 15 | M35377.217333 | SW 28-005-25 W4M |
| M35377.214796 | NE 04-003-25 W4M | 16 | M35377.217352 | SE 33-005-25 W4M |
| M36727.981759 | NE 09-003-25 W4M | 17 | M35377.218355 | NE 04-006-25 W4M |
| M35377.214845 | NE 16-003-25 W4M | 18 | M35377.218420 | 04-15-006-25 W4M |
| M35377.214873 | SW 28-003-25 W4M | 19 | M35377.218451 | SE 21-006-25 W4M |
| M36234.947998 | 10-04-004-25 W4M | 20 | M35377.219161 | NE 03-007-25 W4M |
| M35377.216194 | NE 09-004-25 W4M | 21 | M35377.118012 | SW-27-007-25 W4M |
| M35377.216215 | NE 16-004-25 W4M | 22 | M36727.982585 | SW-04-008-25 W4M |

## *Cross-Section E - E'*




| Well No. | UID | Legal | Well No. | UID | Legal |
|---|---|---|---|---|---|
| 1 | M35377.086204 | NE 09-001-22 W4M | 8 | M35377.217069 | 14-10-005-22 W4M |
| 2 | M35377.097714 | NE 28-001-22 W4M | 9 | M35377.070052 | NE 22-005-22 W4M |
| 3 | M35377.214179 | SE 14-002-22 W4M | 10 | M35377.218180 | SE 03-006-22 W4M |
| 4 | M35377.214671 | SW 01-003-22 W4M | 11 | M35377.218220 | 01-15-006-22 W4M |
| 5 | M35377.214685 | NW 25-003-22 W4M | 12 | M35377.219066 | SW 01-007-22 W4M |
| 6 | M35377.215919 | SW 14-004-22 W4M | 13 | M35377.219076 | NE 27-007-22 W4M |
| 7 | M35377.217051 | 03-03-005-22 W4M | 14 | M35377.215613 | SE 11-008-22 W4M |

# CARDSTON COUNTY

## Appendix E

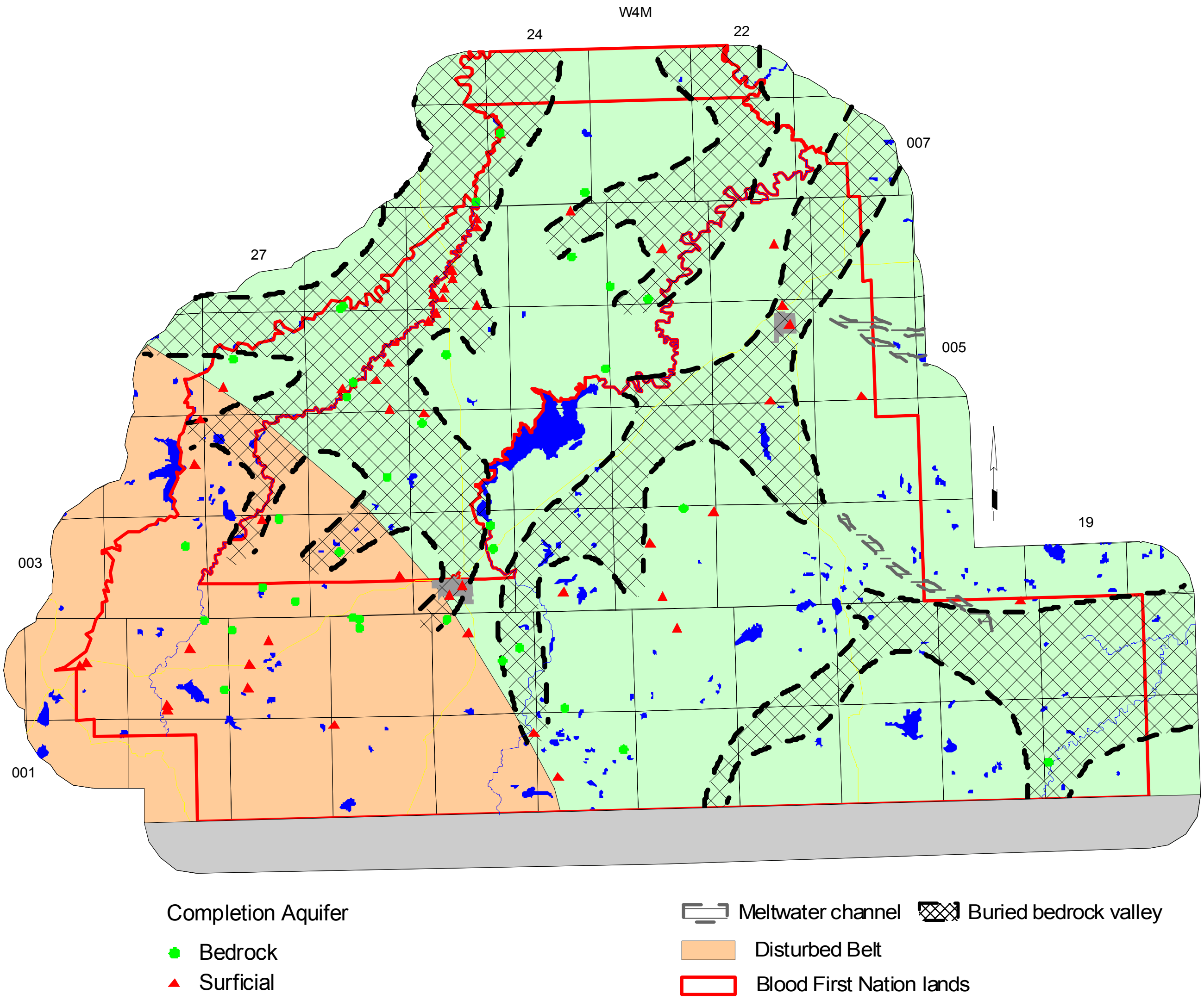
### Water Wells Recommended for Field Verification

### and

### County-Operated Water Wells

## Water Wells Recommended for Field Verification

*(details on following pages)*



**WATER WELLS RECOMMENDED FOR FIELD VERIFICATION**

| Owner | Location | Aquifer Name | Date Water Well Drilled | Completed Depth Metres | Completed Depth Feet | NPWL Metres | NPWL Feet | UID |
|---|---|---|---|---|---|---|---|---|
| Alberta Environment | NE 09-006-25 W4M | Lower Surficial | 03-Jan-80 | 21.64 | 71.0 | 2.38 | 7.8 | M35377.218394* |
| Alberta Environment | NE 09-006-25 W4M | Lower Surficial | 03-Jan-80 | 21.94 | 72.0 | 2.53 | 8.3 | M35377.218399* |
| Alberta Environment | NE 09-006-25 W4M | Lower Surficial | 05-Jan-80 | 21.94 | 72.0 | 1.98 | 6.5 | M35377.218396* |
| Alberta Environment | NE 09-006-25 W4M | Lower Surficial | 01-Apr-80 | 22.25 | 73.0 | 2.01 | 6.6 | M35377.218398* |
| Baker, Dennis | 14-04-002-28 W4M | Surficial | 06-Apr-85 | 14.63 | 48.0 | 3.05 | 10.0 | M35377.215954 |
| Balderson, F. | 08-22-006-22 W4M | Surficial | 26-Jun-79 | 48.77 | 160.0 | 24.38 | 80.0 | M35377.218232 |
| Blood Band Administration | 01-09-003-24 W4M | Surficial | 30-Jun-82 | 44.19 | 145.0 | 12.19 | 40.0 | M35377.214743* |
| Blood Band Administration | SE 30-007-24 W4M | Upper Horseshoe Canyon | 30-Aug-82 | 30.48 | 100.0 | 0.64 | 2.1 | M35377.219138* |
| Blood Band Housing Authority | NW 34-003-27 W4M | Lower Surficial | 27-Mar-81 | 5.18 | 17.0 | 1.07 | 3.5 | M35377.215095* |
| Blood Band Housing Authority | SE 13-005-24 W4M | Middle Horseshoe Canyon | 07-Jul-86 | 73.15 | 240.0 | 38.1 | 125.0 | M35377.217018* |
| Blood Band Housing Authority | SW 09-006-25 W4M | Surficial | 01-Jun-81 | 32.31 | 106.0 | 12.19 | 40.0 | M35377.218380* |
| Blood Tribe Admin | SE 30-007-24 W4M | Surficial | 18-Feb-81 | 27.43 | 90.0 | 0.3 | 1.0 | M35377.219135* |
| Blood, Dan | 04-07-006-23 W4M | Upper Horseshoe Canyon | 01-Mar-84 | 24.38 | 80.0 | 19.51 | 64.0 | M35377.218263* |
| Chief Moon, John | 14-04-005-26 W4M | Upper Scollard | 01-Sep-68 | 38.10 | 125.0 | 38.1 | 125.0 | M35377.217376* |
| Chiefmoon, Dan | 05-09-005-26 W4M | Lower Surficial | 23-Apr-84 | 6.10 | 20.0 | 3.05 | 10.0 | M35377.217390* |
| Codd, Ken | SE 20-005-27 W4M | Upper Lacombe | 03-Sep-82 | 49.68 | 163.0 | 22.86 | 75.0 | M35377.217565 |
| Crow Chief, Dan | NE 09-005-26 W4M | Upper Scollard | 16-Dec-84 | 14.32 | 47.0 | 0.61 | 2.0 | M35377.217395* |
| Crowchief, Duane | SW 32-005-25 W4M | Lower Surficial | 11-Feb-83 | 4.57 | 15.0 | 1.83 | 6.0 | M35377.217344* |
| Crowchief, Pat | SW 32-005-25 W4M | Lower Surficial | 11-Feb-83 | 4.57 | 15.0 | 1.83 | 6.0 | M35377.217345* |
| Dahl | 10-26-005-22 W4M | Surficial | 12-May-79 | 29.87 | 98.0 | 4.57 | 15.0 | M35377.217149 |
| Daychief, June | 15-05-006-25 W4M | Surficial | 01-Mar-84 | 33.53 | 110.0 | 19.81 | 65.0 | M35377.218363* |
| Deseret Ranches Ltd. | 15-28-002-23 W4M | Lower Surficial | 06-Jul-84 | 42.67 | 140.0 | 9.14 | 30.0 | M35377.214238 |
| Deseret Ranches Ltd. | NE 04-003-23 W4M | Lower Surficial | 10-Jul-84 | 45.72 | 150.0 | 30.48 | 100.0 | M35377.214698 |
| Deseret Ranches Ltd. | 16-35-002-20 W4M | Surficial | 04-Jul-83 | 19.81 | 65.0 | 5.03 | 16.5 | M35377.214137 |
| Eagle Tail Feathers, Garry | NE 20-003-26 W4M | Disturbed Belt | 17-Jan-82 | 13.41 | 44.0 | 7.01 | 23.0 | M35377.214983* |
| Eaglechild, Fannie | 12-04-006-25 W4M | Surficial | 01-Apr-84 | 22.55 | 74.0 | 9.14 | 30.0 | M35377.218352* |
| Fox, E. | 01-02-005-26 W4M | Lower Surficial | 16-Jun-69 | 6.10 | 20.0 | 3.05 | 10.0 | M35377.217369* |
| French Ranches Ltd. | SE 26-003-28 W4M | Disturbed Belt | 05-Oct-83 | 24.38 | 80.0 | 5.18 | 17.0 | M35377.215143 |
| Gladstone, Jim | SW 13-003-26 W4M | Surficial | 17-Sep-84 | 26.52 | 87.0 | 12.8 | 42.0 | M35377.214970* |
| Hartley, Ardelle | 12-08-005-27 W4M | Lower Surficial | 15-Oct-82 | 72.23 | 237.0 | 47.85 | 157.0 | M35377.217545 |
| Hengerer, Utrich | NE 36-004-28 W4M | Lower Surficial | 12-May-83 | 30.48 | 100.0 | 9.14 | 30.0 | M35377.216540 |
| Hern, Allan | SW 31-002-27 W4M | Disturbed Belt | 25-Nov-86 | 34.14 | 112.0 | 4.57 | 15.0 | M35377.091889 |
| Hillmer, Norman | NW 35-005-22 W4M | Surficial | 16-Sep-75 | 30.78 | 101.0 | 10.67 | 35.0 | M35377.217243 |
| Hutterville Colony Ltd. | SE 04-005-21 W4M | Surficial | 01-Jan-74 | 18.29 | 60.0 | 7.62 | 25.0 | M35377.216884 |
| Jacobs, Ross | 15-35-002-28 W4M | Disturbed Belt | 06-Oct-83 | 3.35 | 11.0 | 1.83 | 6.0 | M35377.216006 |
| Janisko, John | 13-01-003-27 W4M | Disturbed Belt | 18-May-84 | 41.45 | 136.0 | 1.52 | 5.0 | M35377.215021 |
| Jones, Glen | SE 27-002-28 W4M | Surficial | 19-Mar-85 | 7.62 | 25.0 | 3.66 | 12.0 | M35377.215999 |
| Kainai Industries Ltd. | SE 16-006-25 W4M | Surficial | 01-Dec-84 | 18.29 | 60.0 | 1.52 | 5.0 | M35377.218432 |
| Kainai Industries Ltd. | SW 35-006-25 W4M | Surficial | 01-Dec-84 | 54.86 | 180.0 | 17.07 | 56.0 | M35377.218496 |
| Leavitt, Eric | 14-32-002-26 W4M | Disturbed Belt | 07-May-82 | 21.33 | 70.0 | 8.23 | 27.0 | M35377.214501 |
| Leavitt, Ronald D. | NE 32-002-26 W4M | Disturbed Belt | 01-Jul-74 | 47.24 | 155.0 | -0.03 | -0.1 | M35377.214502 |
| Long, Roy | SE 05-002-24 W4M | Lower Scollard | 19-May-67 | 45.72 | 150.0 | 41.76 | 137.0 | M35377.214249 |
| Low Herd, Dale | 16-31-004-25 W4M | Surficial | 27-Apr-84 | 54.25 | 178.0 | 26.52 | 87.0 | M35377.216251* |
| Lybbert, Dan | NE 23-003-25 W4M | Lower Scollard | 11-Dec-81 | 13.11 | 43.0 | 2.74 | 9.0 | M35377.229365 |
| Malmberg, O. F. & Sons Ltd. | 13-21-003-23 W4M | Surficial | 09-Aug-84 | 59.43 | 195.0 | 17.37 | 57.0 | M35377.214712 |
| Many Bears, Jack | NW 26-006-25 W4M | Surficial | 14-Dec-68 | 53.64 | 176.0 | 39.32 | 129.0 | M35377.218483* |
| Many Chief, Ray | SE 31-004-25 W4M | Upper Scollard | 20-Dec-67 | 60.96 | 200.0 | 33.53 | 110.0 | M35377.216246* |
| Manybears, George | 04-02-006-25 W4M | Lower Surficial | 01-Apr-84 | 22.55 | 74.0 | 15.24 | 50.0 | M35377.218344* |
| Manyfingers, Ivan | NW 35-003-27 W4M | Disturbed Belt | 17-Jan-83 | 27.43 | 90.0 | 9.75 | 32.0 | M35377.215098* |
| May, Richard | 13-24-002-25 W4M | Lower Scollard | 25-Apr-83 | 33.53 | 110.0 | 18.29 | 60.0 | M35377.214361 |
| Meeks, Richard | 09-36-003-23 W4M | Surficial | 05-Jun-85 | 29.56 | 97.0 | 6.1 | 20.0 | M35377.214723 |
| Nelson, Dan | NE 12-002-28 W4M | Disturbed Belt | 30-Nov-84 | 29.87 | 98.0 | 5.18 | 17.0 | M35377.195850 |
| Nish, Lee | SW 17-001-24 W4M | Lower Surficial | 24-Jun-81 | 39.62 | 130.0 | 9.14 | 30.0 | M35377.113955 |

**WATER WELLS RECOMMENDED FOR FIELD VERIFICATION (continued)**

| Owner | Location | Aquifer Name | Date Water Well Drilled | Completed Depth Metres | Completed Depth Feet | NPWL Metres | NPWL Feet | UID |
|---|---|---|---|---|---|---|---|---|
| Nish, Tom | 16-25-001-25 W4M | Lower Surficial | 04-Jan-85 | 36.57 | 120.0 | 6.1 | 20.0 | M35377.214031 |
| Olsen, Ben | 07-22-002-29 W4M | Upper Surficial | 04-May-82 | 18.29 | 60.0 | 10.27 | 33.7 | M35377.216034 |
| Olsen, Kay | SE 32-002-26 W4M | Disturbed Belt | 27-Sep-86 | 35.36 | 116.0 | 1.83 | 6.0 | M35377.214492 |
| Pack, Dalin H. | NW 24-001-24 W4M | Upper Horseshoe Canyon | 01-May-81 | 42.67 | 140.0 | 24.45 | 80.2 | M35377.113735 |
| Parson, Bob | SW 22-002-29 W4M | Surficial | 25-Sep-86 | 42.97 | 141.0 | 12.5 | 41.0 | M35377.216037 |
| Pontarollo Bros Ltd. | 12-31-001-26 W4M | Surficial | 21-Aug-84 | 13.72 | 45.0 | 6.1 | 20.0 | M35377.214063 |
| Provincial Grazing | SW 18-001-19 W4M | Oldman | 12-Sep-77 | 51.81 | 170.0 | 37.79 | 124.0 | M35377.097076 |
| Quenelle, Brenda | NE 32-005-25 W4M | Lower Surficial | 01-Dec-84 | 18.29 | 60.0 | 9.75 | 32.0 | M35377.217349 |
| Quinton, Randy | 09-31-002-25 W4M | Disturbed Belt | 24-Apr-81 | 15.24 | 50.0 | 1.49 | 4.9 | M35377.214383 |
| Red Crow, Sam | SW 04-006-23 W4M | Middle Horseshoe Canyon | 27-Oct-82 | 31.39 | 103.0 | 7.01 | 23.0 | M35377.218262* |
| Rice, Fred | NW 10-003-27 W4M | Disturbed Belt | 14-May-84 | 30.48 | 100.0 | 3.05 | 10.0 | M35377.215038 |
| Riverside Colony Ltd. | SW 04-006-26 W4M | Upper Scollard | 01-Feb-67 | 12.19 | 40.0 | 1.22 | 4.0 | M35377.218497 |
| Riverside Colony Ltd. | 04-04-006-26 W4M | Upper Scollard | 31-May-83 | 17.68 | 58.0 | 7.62 | 25.0 | M35377.218499 |
| Shade, Bob | 02-14-004-26 W4M | Upper Scollard | 20-Apr-84 | 24.38 | 80.0 | 9.14 | 30.0 | M35377.216303* |
| Shaw, Mike | 04-23-002-25 W4M | Lower Scollard | 16-Jul-85 | 26.52 | 87.0 | 21.33 | 70.0 | M35377.214351 |
| Smith, Rick | 13-08-002-27 W4M | Upper Surficial | 05-Nov-81 | 12.19 | 40.0 | 6.71 | 22.0 | M35377.214514 |
| Smith, Wayne | 03-24-004-28 W4M | Surficial | 22-Jul-78 | 57.91 | 190.0 | 4.27 | 14.0 | M35377.216496 |
| Standing Alone, Allan | 10-01-007-24 W4M | Upper Horseshoe Canyon | 13-Feb-68 | 31.09 | 102.0 | 18.29 | 60.0 | M35377.219101* |
| Stanford, Dwight | 13-28-002-25 W4M | Lower Surficial | 10-May-85 | 15.85 | 52.0 | 6.71 | 22.0 | M35377.214369 |
| Stanford, Russel | 02-35-003-25 W4M | Lower Scollard | 23-May-85 | 5.79 | 19.0 | 1.22 | 4.0 | M35377.214889 |
| Still, Dale | 11-28-002-27 W4M | Upper Surficial | 31-Oct-81 | 15.85 | 52.0 | 12.19 | 40.0 | M35377.214582 |
| Striped Wolf, Cecil | 16-14-005-26 W4M | Surficial | 23-Apr-84 | 6.40 | 21.0 | 3.05 | 10.0 | M35377.217418* |
| Sweetgrass, Clifford | SW 22-006-23 W4M | Lower Surficial | 02-Jul-85 | 42.67 | 140.0 | 17.37 | 57.0 | M35377.218278* |
| Taylor, David | 03-03-005-22 W4M | Surficial | 19-May-73 | 21.33 | 70.0 | 5.49 | 18.0 | M35377.217051 |
| Tipi Ranches Ltd. | 13-35-003-23 W4M | Middle Horseshoe Canyon | 15-Aug-84 | 27.43 | 90.0 | 18.29 | 60.0 | M35377.214721 |
| Town of Cardston | 04-09-003-25 W4M | Surficial | 15-May-75 | 56.61 | 185.7 | 40.97 | 134.4 | M37405.667153 |
| Town of Cardston | 09-09-003-25 W4M | Surficial | 03-Jun-75 | 38.59 | 126.6 | 0 | 0.0 | M37406.542269 |
| Weasel Head, Charlie | 13-11-005-26 W4M | Surficial | 15-Feb-83 | 41.76 | 137.0 | 3.66 | 12.0 | M35377.217403* |
| Weasel Mocassin, Andrew | SW 01-007-25 W4M | Lower Scollard | 11-May-81 | 15.24 | 50.0 | 5.02 | 16.5 | M35377.219154* |
| Weaselhead | 16-15-006-24 W4M | Upper Horseshoe Canyon | 01-Aug-84 | 24.38 | 80.0 | 7.01 | 23.0 | M35377.218320* |
| Weaselhead, Frank | 09-34-006-24 W4M | Lower Scollard | 06-Oct-82 | 13.72 | 45.0 | 1.83 | 6.0 | M35377.218342* |
| Wells, Richard | SW 21-005-25 W4M | Lower Scollard | 01-Sep-67 | 30.48 | 100.0 | 5.49 | 18.0 | M35377.217318* |
| West, Darcy | 11-04-002-28 W4M | Surficial | 09-Jun-79 | 4.88 | 16.0 | 1.22 | 4.0 | M35377.215951 |
| West, Vernon | SW 20-002-27 W4M | Upper Surficial | 28-Apr-82 | 35.36 | 116.0 | 12.34 | 40.5 | M35377.214563 |
| Yule, Allen | SE 26-022-23 W4M | Surficial | 12-Sep-79 | 36.57 | 120.0 | 10.67 | 35.0 | M35377.221949 |

* Water wells located on the Blood First Nation lands

**CARDSTON COUNTY-OPERATED WATER WELL**

| Owner | Location | Aquifer Name | Date Water Well Drilled | Completed Depth Metres | Completed Depth Feet | NPWL Metres | NPWL Feet | UID |
|---|---|---|---|---|---|---|---|---|
| Cardston, Md Of | 04-33-004-23 W4M | Surficial | 29032 | 61.87 | 203.0 | #N/A | -- | M35377.216136 |