Regional Groundwater Assessment

Part of the South Saskatchewan River Basin
Parts of Tp 007 to 015, R 12 to 20, W4M

Prepared for M.D. of Taber

In conjunction with

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

Canada

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Our File No.: **07-322.03**

November 2007

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Acknowledgements

Hydrogeological Consultants Ltd. would like to thank the following people for their cooperation and helpful contributions on this project:

Mr. Vic Brown – AAFC-PFRA
Mr. Jon Hood – M.D. of Taber

For additional copies of the report/CD-ROM, please contact the following:

- 1-800-GEO-WELL
- The Groundwater Centre/Regional Groundwater Assessment

http://www.groundwatercentre.com/m_info_rgwa.asp

1 PROJECT OVERVIEW

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

How a municipality 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 can be used as a decision-support tool by the M.D. of Taber 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 the M.D. of Taber 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 the M.D. of Taber. The project study area includes the parts of the M.D. of Taber bounded by townships 007 to 015, ranges 12 to 20, W4M (herein referred to as the M.D.). The regional groundwater assessment provides information to assist in the management of the groundwater resource within the M.D. Groundwater resource management involves determining the suitability of various areas in the M.D. for particular activities. These activities can vary from the development of groundwater for country residential, agricultural or industrial purposes, to the siting of waste storage. **Proper management ensures protection and utilization of the groundwater resource for the maximum benefit of the people of the M.D.**

The regional groundwater assessment 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 aquifer(s) in the surficial deposits and in the upper bedrock.

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

[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 the M.D. of Taber, (b) the processes used for the present project, and (c) the groundwater characteristics in the M.D.

Additional technical details are available from files on the CD-ROM 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 are based on an analysis of hydrogeological data from those parts of townships 007 to 015, ranges 12 to 20, W4M, that make up the M.D., plus a buffer area of 5,000 metres. For convenience, some 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 M.D. 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 that are recommended for field-verification.

This report, and the accompanying support documents, has been prepared in SI Units (metric); for conversions, please refer to Conversion Table on page 54.

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3 See glossary

2 METHODOLOGY

2.1 Data Collection and Synthesis

The Alberta Environment (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) locations of some springs
4) locations for some water wells determined during water well surveys
5) chemical analyses for some groundwaters[4]
6) locations of some flowing shot holes
7) locations 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 M.D. 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 NAD83 datum. This means that a record for the NW ¼ of section 15, township 007, range 13, W4M would have a horizontal coordinate with an Easting of 238,766 metres and a Northing of 5,493,475 metres, the centre of the quarter section. If the water well has been repositioned by AAFC-PFRA using orthorectified aerial photographs, 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 M.D., more than one water well is completed at one legal location. Digitally processing this information is difficult. To obtain a better understanding of the completed depths of water wells, a digital surface was prepared representing the minimum depth for water wells and a second digital surface was prepared for the maximum depth. Both of these surfaces are used in the groundwater query on the CD-ROM. When the maximum and minimum water well depths are similar, there is only one aquifer that is being used at a given location.

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

Where possible, determinations are made from individual records 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[5].

[4] Since 1986, Alberta Health and Wellness has restricted access to chemical analysis data, and hence the database includes only limited amounts of chemical data after 1986.
[5] See glossary

Also, where sufficient information is available, values for apparent transmissivity[6] and apparent yield[7] are calculated, based on the aquifer test summary data supplied on the water well drilling reports. Where valid detailed aquifer test results exist, the interpreted data provide values for aquifer transmissivity and effective transmissivity. Since the last regional hydrogeological maps covering the M.D. were published in 1974 (Tokarsky; and Ozoray and Lytviak), 1976 (Borneuf), and 1977 (Stevenson and Borneuf) using data collected in 1970 and 1971, nearly 800 values for apparent transmissivity and nearly 700 values for apparent yield have been added to the groundwater database. With the addition of the apparent yield values, including a 0.1-cubic metres per day (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 M.D. (Figure 1 and page A-13). 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 Geological Survey (AGS) hydrogeological maps (Ozoray and Lytviak, 1974, and Borneuf, 1976). In general, the AGS maps show higher estimated long-term yields. The differences between the two map renderings may be a result of fewer apparent yield values, not applying a 0.1-m³/day value for “dry” water wells, and the gridding method employed by the AGS.

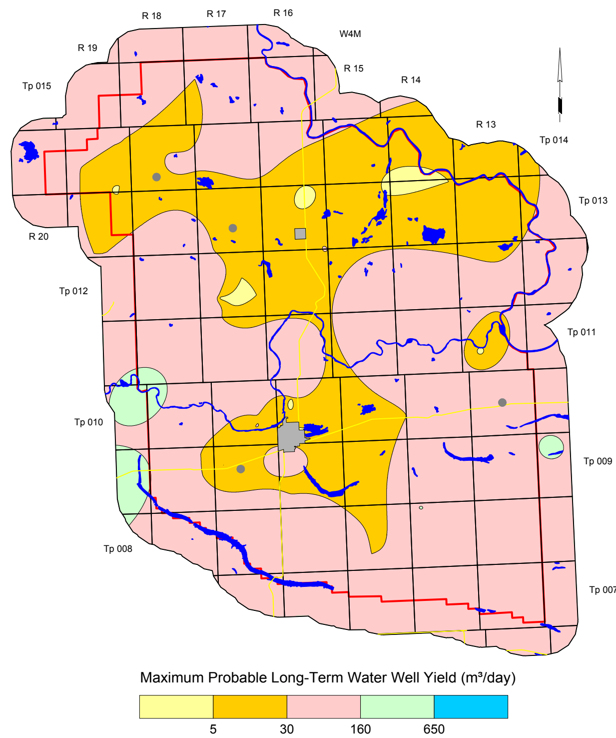

Figure 1. Hydrogeological Map

The EUB well database includes records for wells drilled for 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.

6 For definitions of Transmissivity, see glossary
7 For definitions of Yield, see glossary

2.2 Spatial Distribution of Geologic Units

Determination of the spatial distribution of the geologic units 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 geologic units 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[8] 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.

2.3 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 geologic unit, the parameters from the water well records are assigned to the individual geologic units. The parameters include non-pumping (static) water level (NPWL), apparent transmissivity, and apparent water well yield. The parameters are provided and calculated from data included on the water well drilling reports. 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 declined, the NPWL may now be lower and, accordingly, the potential apparent yield would be reduced. The total dissolved solids (TDS), sulfate, chloride, Nitrate + Nitrite (as N), fluoride and total hardness concentrations from the chemical analyses of the groundwaters are also assigned to applicable geologic units. Nitrate + Nitrite (as N) concentrations can often be attributed to physical conditions at or near the water well, and may not indicate general aquifer conditions.

Constituent	Recommended Maximum Concentration SGCDWQ (mg/L)	Colour Blends Used on Maps to Indicate Areas that are Below SGCDWQ	Colour Blends Used on Maps to Indicate Areas that Exceed SGCDWQ
Total Dissolved Solids	500		
Nitrate + Nitrite (as N)	10		
Sulfate	500		
Chloride	250		
Fluoride	1.5		

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives (AOs) except for Fluoride and Nitrate + Nitrite (as N), which are for Maximum Acceptable Concentrations (MACs)
SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality Federal-Provincial-Territorial Committee on Drinking Water, March 2006

Blue hues have been chosen to represent map areas where the chemical parameters are below the Summary of Guidelines for Canadian Drinking Water Quality (SGCDWQ) and orange hues have been chosen to represent map areas where the chemical parameters are above the SGCDWQ.

[8] See glossary

After 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 007 to 015, ranges 12 to 20, 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.

On some maps, values are posted as a way of showing anomalies to the underlying grid or as a means of emphasizing either the lack of sufficient data or areas where there is concentrated hydrogeological data control.

2.4 Maps and Cross-Sections

After 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.

After the appropriate grids are available, the maps are prepared by contouring the grids. For the Upper Bedrock Aquifer(s) where areas of sufficient data are not available from the groundwater database, prepared maps have been masked with a solid faded pink colour to indicate these areas. These masks have been added to the hydrogeological maps for the Milk River Formation. 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.

Water well records to be used on cross-sections are chosen from the groundwater database, and where possible have the following criteria: geo-referenced lithology; completion interval; and NPWL. Data from these water well control points are then placed in the AutoCAD drawing with an appropriate vertical exaggeration. Tops from individual geologic units are then transferred to the cross-section from the digitally prepared surfaces.

After the technical details of a cross-section have been finalized, the drawing file is moved to the software package CorelDraw! for simplification and presentation in a hard-copy form. Nine cross-sections are presented in Appendix A of this report and as poster-size drawings forwarded with this report; two (D-D’ and I-I’) 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.

2.5 Software

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

- Acrobat 7.0
- AquaChem 4.0
- ArcView 3.2
- AutoCAD 2004
- CorelDraw! 12.0
- Grapher 3
- Microsoft Office 2003
- Surfer 8

3 INTRODUCTION

3.1 Setting

The M.D. of Taber is situated in southern Alberta, within the Eastern Alberta Plains physiographic region. The M.D. is within the South Saskatchewan River, Bow River, Oldman River and Seven Persons Creek sub-basins of the South Saskatchewan River basin (see page A-4); the Bow River forms the northeastern boundary. The other M.D. boundaries mainly follow township or section lines, which include parts of the area bounded by townships 007 to 015, ranges 15 to 20, W4M.

Regionally, the topographic surface varies between 700 and 950 metres above mean sea level (AMSL). The highest elevations occur mainly in the southern part of the M.D., and the lowest elevations occur mainly in association with the Oldman River and the Bow River, as shown on Figure 2 and page A-5.

The area is well drained by the Oldman River and the Bow River.

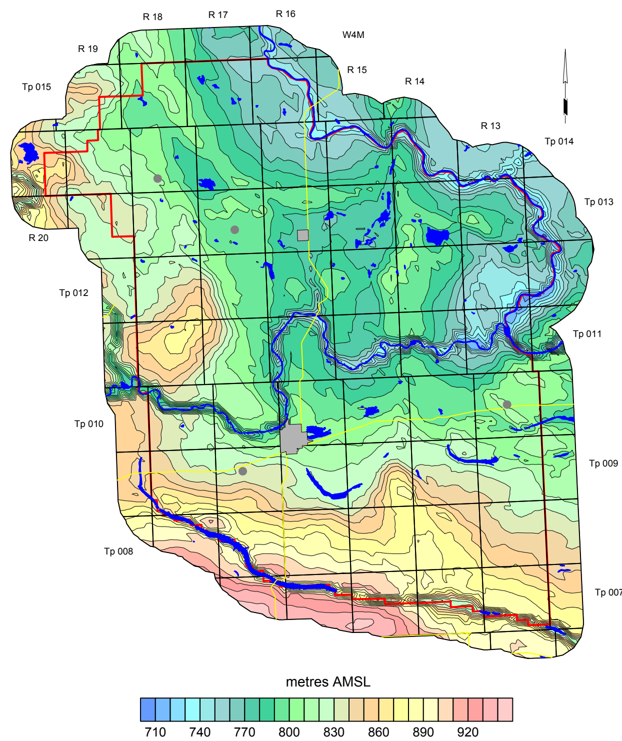

Figure 2. Surface Topography

3.2 Climate

The M.D. of Taber lies within the semiarid Bsk climate. This classification is based on potential evapotranspiration [9] 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 M.D. is located in the Mixed Grassland region.

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

The mean annual precipitation averaged from two meteorological stations within the M.D. measured 376 millimetres (mm), based on data from 1971 to 2000. The annual temperature averaged 5.6° C, with the mean monthly temperature reaching a high of 18.7° C in July, and dropping to a low of -8.7° C in January. The calculated annual potential evapotranspiration is 562 millimetres.

[9] See glossary

4 BACKGROUND INFORMATION

4.1 Number, Type and Depth of Water Wells

There are currently 1,508 records in the groundwater database for the M.D., of which 985 are water wells. Of the 985 water wells, there is a proposed use for 801 water wells, as shown in the adjacent table. Of the 801 water wells, there are records for domestic (257), domestic/stock (278) or stock (199) purposes. The remaining 67 water wells were completed for industrial (30), observation (8), irrigation (8), municipal (7), and other numerous categories (14); 184 water well designations are classified as "unknown". Of the 607 water wells having a completion date, 375 (62%) of the water wells were completed before 1955, of which 318 were determined during federal water well surveys from 1904 to 1937. Of the remaining 232 (38%) water wells having a completion date and proposed use, 141 (23%) were completed between 1970 and 1989.

Date Completed	Domestic	Domestic/Stock	Stock	Municipal	Industrial	Observation	Monitoring	Irrigation	Investigation	Other	Standby	Total
No Date	135	22	19	2	10	2	0	2	0	2	0	194
pre-1955	34	199	132	3	2	0	0	1	0	1	3	375
1955	6	5	4	0	0	0	0	1	0	0	0	16
1960	2	6	2	0	1	1	0	0	0	0	0	12
1965	5	6	6	0	2	0	0	0	0	0	0	19
1970	13	8	4	1	2	0	0	0	0	0	0	28
1975	5	6	5	0	1	0	0	0	0	1	0	18
1980	25	8	13	0	4	0	0	2	3	0	0	55
1985	9	16	7	0	1	5	0	2	0	0	0	40
1990	5	1	3	1	4	0	3	0	0	0	0	17
1995	11	1	2	0	3	0	0	0	0	0	0	17
2000	7	0	2	0	0	0	0	0	0	1	0	10
Total	257	278	199	7	30	8	3	8	3	5	3	801

Table 1. Proposed Use for Water Wells

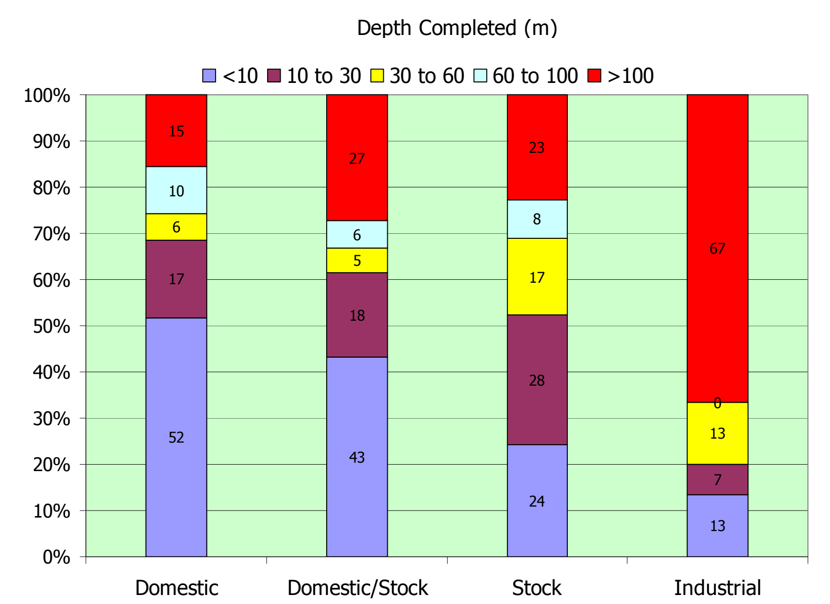

Figure 3. Proposed Use vs Completed Depth

In the M.D., the majority of the water wells were completed for domestic, domestic/stock, stock, and industrial purposes, as shown above in Table 1.

The highest percentages of domestic (52%) and domestic/stock (43%) water wells are completed at depths of less than ten metres below ground surface; there was no dominant completion interval for stock water wells. The highest percentage of industrial water wells (67%) are completed at depths of more than 100 metres below ground surface, as shown in Figure 3.

Details for lithology[10] are available for 640 records.

[10] See glossary

4.2 Number of Water Wells in Surficial and Bedrock Aquifers

There are 100 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 100 water wells with completion interval and lithologic information, 54 are completed in surficial aquifers.

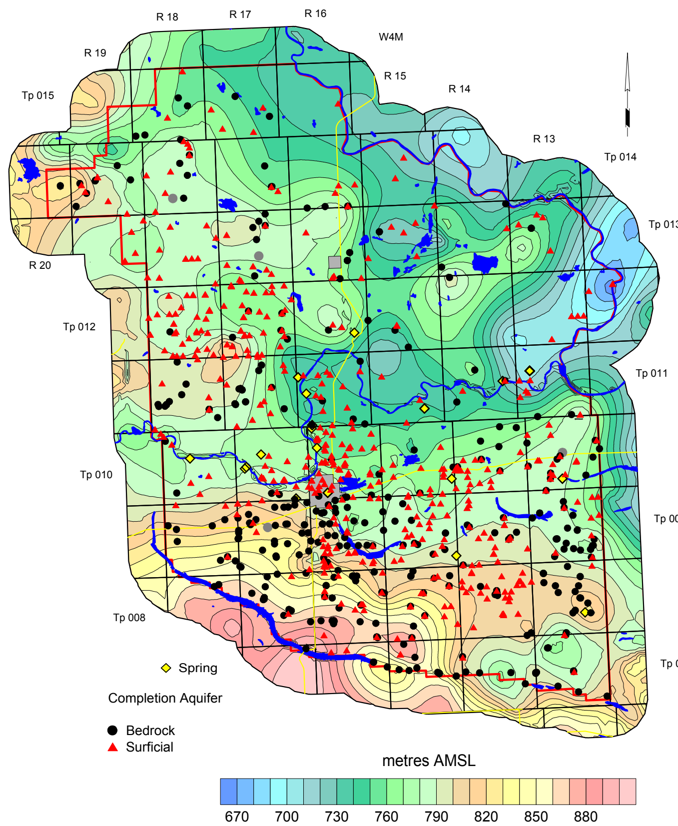

Figure 4. Locations of Water Wells and Springs Relative to Bedrock Topography

From the present hydrogeological analysis, 526 water wells are completed in aquifers in the surficial deposits. This number of water wells (526) is nearly ten times the number (54) 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. From Figure 4 (also page A-8), it can be seen that water wells completed in surficial deposits are largely absent in areas of higher bedrock elevations.

The data for 46 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**. However, at least a reported completion depth is available for 379 water wells completed below the bedrock surface. Water wells completed in bedrock aquifer are largely absent in areas of lower bedrock elevations, as shown on Figure 4.

Within the M.D. of Taber, there are currently records for 36 springs in the groundwater database, including 14 springs that were documented by Borneuf (1983). The springs are located mainly near the Oldman River. There are eight springs having at least one TDS value, with 17 springs having a TDS of more than 500 milligrams per litre (mg/L). There are seven springs in the groundwater database with flow rates; the flow rates range from 1.5 litres per minute (lpm) to 4,612 lpm.

4.3 Casing Diameter and Type

Data for casing diameters are available for 570 water wells, with 305 (54%) indicated as having a diameter of less than 275 mm and 265 (46%) having a diameter of more than 275 mm. The casing diameters of greater than 275 mm are mainly bored, hand dug, or dug by backhoe water wells and those with a surface-casing diameter of less than 275 mm are mainly drilled water wells. The entire water well database for the M.D. suggests that 343 water wells in the M.D. were bored, hand dug or dug by backhoe and 386 are drilled water wells.

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 M.D., casing-diameter information is available for 311 of the 526 water wells completed in the surficial deposits, of which 253 surficial water wells have a casing diameter of greater than 275 mm and are assumed to be bored, hand dug or dug by backhoe water wells. Within the M.D., casing-diameter information is available for 230 of the 379 water wells completed below the top of bedrock, of which 219 have a surface-casing diameter of less than 275 mm and have been mainly completed with either a perforated liner or as open hole. Water wells completed in bedrock aquifers usually do not require water well screens, although some of the sandstones may be friable[11] and water well screens are a necessity. In the M.D., six bedrock water wells are completed with a water well screen.

Where the casing material is known, steel surface casing materials have been used in 65% of the drilled water wells over the last 50 years. For the remaining drilled water wells with known surface casing material, 18% were completed with galvanized steel casing, 11% were completed with plastic casing, and the remaining six percent were completed with culvert, wood, or concrete. Plastic casing was first used in July 1980, and is currently being used in 40% of the water wells drilled in the M.D.

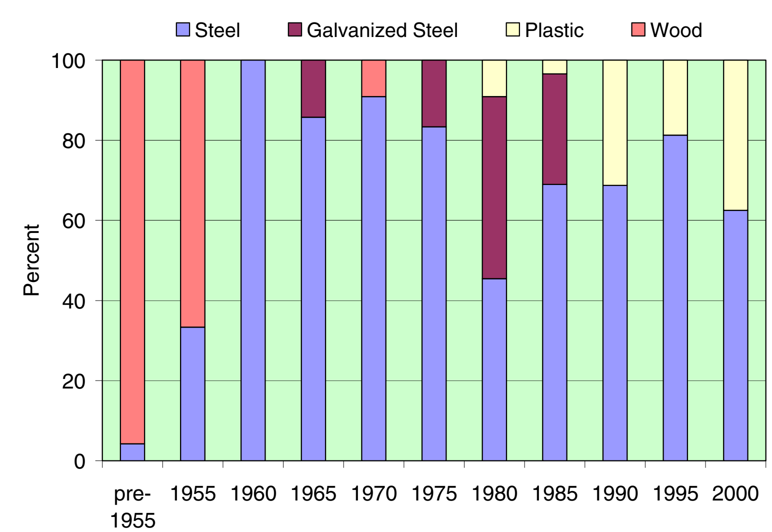

Figure 5. Surface Casing Types Used in Drilled Water Wells

4.4 Dry Water Test Holes

In the M.D., there are 1,508 records in the groundwater database. Of these 1,508 records, 36 (2%) are indicated as being "dry" or "abandoned" with "insufficient water"[12]. Of the 36 "dry" water test holes, 15 are completed in surficial deposits and 20 are completed in bedrock; the aquifer for the remaining one "dry" water test hole is unknown.

[11] See glossary
[12] "dry" can be due to a variety of reasons: skill of driller, type of drilling rig/method used, the geology encountered

4.5 Requirements for Licensing

With some exemptions, a diversion of groundwater starting after 01 Jan 1999 must have a licence. Exemptions include (1) the diversion for household use of up to 3.4 cubic metres per day (1,250 m³/year [750 imperial gallons per day[13]]), (2) the diversion of groundwaters with total dissolved solids in excess of 4,000 mg/L, (3) the diversion from a manually pumped water well, or (4) a diversion of groundwater that was eligible for registration as "Traditional Agriculture Use" but was not registered can continue to be used for Traditional Agriculture Use but without the protection of the *Water Act*.

In the last update from the AENV groundwater database, 78 groundwater licences and/or registrations were shown to be within the M.D., with the most recent groundwater user being licensed in April 2006. Of the 78 licensed and registered groundwater users, 68 (87%) are registrations of Traditional Agriculture Use under the *Water Act*. These 68 registered users will continue to divert groundwater for stock watering and/or crop spraying. Typically, the groundwater diversion for crop spraying averages less than one m³/day so most registered groundwater diversion is for stock watering. Of the remaining ten groundwater users, eight are for agricultural purposes (mainly stock watering), one is for municipal purposes (mainly urban), and the remaining one is for industrial purposes. Of the 68 registrations, 38 (56%) could be linked to the AENV groundwater database. Of the ten licensed groundwater diversions in the M.D., seven (70%) could be linked to the AENV groundwater database. The maximum amount of groundwater that can be diverted each year from the water wells associated with these licences and/or registrations is 1,177 m³/day, although actual use could be less. Of the 1,177 m³/day, 190 m³/day (16.2%) is registered for Traditional Agriculture Use, 652 m³/day (55.4%) is licensed for agricultural purposes, 297 m³/day (25.3%) is licensed for industrial purposes, and 37 m³/day (3.2%) is licensed for commercial purposes, as shown below in Table 2. A figure showing the locations of the groundwater users with either a licence or a registration is in Appendix A (page A-9) and on the CD-ROM. Table 2 also shows a breakdown of the 78 groundwater licences and/or registrations by the aquifer in which the water well is completed. Fifty-four percent of the total quantity of licensed and registered groundwater use is from the surficial aquifers. The water wells associated with the 78 licensed and registered use where a specific aquifer cannot be determined is because insufficient completion information is available.

Aquifer **	No. of Licences and/or Registrations	Registrations (m³/day)	Licensed Groundwater Users* (m³/day)				
			Agricultural	Industrial	Commericial	Groundwater Diversion (m³/day)	Percentage
Upper Sand and Gravel	35	57	571	0	0	628	53.4
Lower Sand and Gravel	3	7	0	0	0	7	0.6
Mulitple Bedrock Completion	6	11	24	0	0	35	3.0
Bearpaw	1	2	0	0	0	2	0.2
Oldman	1	0	0	0	0	0.1	0.0
Foremost	4	35	0	0	0	35	3.0
Lea Park	0	0	0	0	0	0	0.0
Milk River	19	59	57	0	0	116	9.9
Viking	1	0	0	297	0	297	25.3
Unknown	8	18	0	0	37	55	4.7
Total[(1)]	78	190	652	297	37	1,177	100.0
Percentage		16.2	55.4	25.3	3.2	100	

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

Table 2. Licensed and/or Registered Groundwater Diversions

[13] see conversion table on page 54

Based on the 2006 Agriculture Census (Statistics Canada), the calculated water requirement for 475,605 livestock for the M.D. is in the order of 10,394 m³/day. This number includes intensive livestock use but not domestic animals and is based on an estimate of water use per livestock type. Of the 10,394 m³/day calculated livestock use, AENV has authorized a groundwater diversion of 842 m³/day (agricultural and registration) (8%) and licensed a surface-water diversion (stock and registration) based on consumptive use of 1,565 m³/day (15%) for a total diversion of 2,407 m³/day. Agriculture purpose includes water diverted and used for stockwatering and feedlot use. This assumes the majority of the groundwater and surface water authorized for diversion for Traditional Agriculture Use is for watering livestock. Using this assumption, 23% of the estimated total water requirements of 10,394 m³/day is accounted for.

Livestock Type	Number	Estimated Water Requirement (m³/day)
Total hens and chickens	205,499	42
Turkeys	0	0
Other poultry	2,475	1
Total cattle and calves	151,043	8,240
Total pigs	110,760	2,014
Total sheep and lambs	3,459	31
Horses and ponies	1,089	50
Goats	642	6
Mink	0	0
Fox	0	0
Bison	140	6
Deer and elk	0	0
Llamas and alpacas	498	5
Totals	475,605	10,394

Table 3. Estimated Water Requirement for Livestock in the M.D. of Taber

The remaining 7,987 m³/day (77%) of the calculated water requirement for livestock use would have to be from other, including unlicensed, sources. The discrepancy may be partially accounted for in several ways. Based on some monitoring and reporting situations, the estimated water requirements for livestock, used by AENV, tend to be somewhat high. Some livestock water requirements would be made up from free-standing water following precipitation events, thus reducing the expected quantity needed. Also, it should be noted that 'household use', as defined in the *Water Act*, can provide sufficient water for about 75 head of cattle, with no need for a licence. It is possible that some such use may have been registered as Traditional Agriculture Use and would therefore be included in the registration quantity. Also, diversions of groundwater and surface water that were eligible for registration as Traditional Agriculture Use can continue to be used for traditional agricultural purposes without the need for authorization.

4.6 Base of Groundwater Protection

In general, AENV defines the Base of Groundwater Protection (BGP) 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 BGP can be determined. These values are gridded using the Kriging method to prepare a depth to the BGP 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 a TDS concentration that exceeds 4,000 mg/L, the groundwater use does not require licensing by AENV. The depth to the BGP is mainly less than 140 metres below ground surface in the northeastern parts of the M.D. but can be more than 340 metres below ground surface in the southwestern parts of the M.D., as shown on Figure 6 on the following page, on the cross-sections presented with this report, in Appendix A, and on the CD-ROM.

There are 893 water wells with completed depth data, of which 66 appear to be completed below the BGP. Chemistry details are available for 295 of the 893 water wells; 63 of the 295 water wells have TDS concentrations that are greater than 4,000 mg/L, as shown on the adjacent figure. Of the 29 water wells that are completed below the BGP, 12 have TDS concentrations of less than 4,000 mg/L, and 17 have TDS concentrations that are greater than or equal to 4,000 mg/L, as shown in the table below.

No. of Water Wells Completed	TDS	
	< 4,000 mg/L	> 4,000 mg/L
above BGP	220	46
below BGP	12	17
Total Number	232	63

Table 4. Number of Water Well with a Completed Depth and a TDS Value

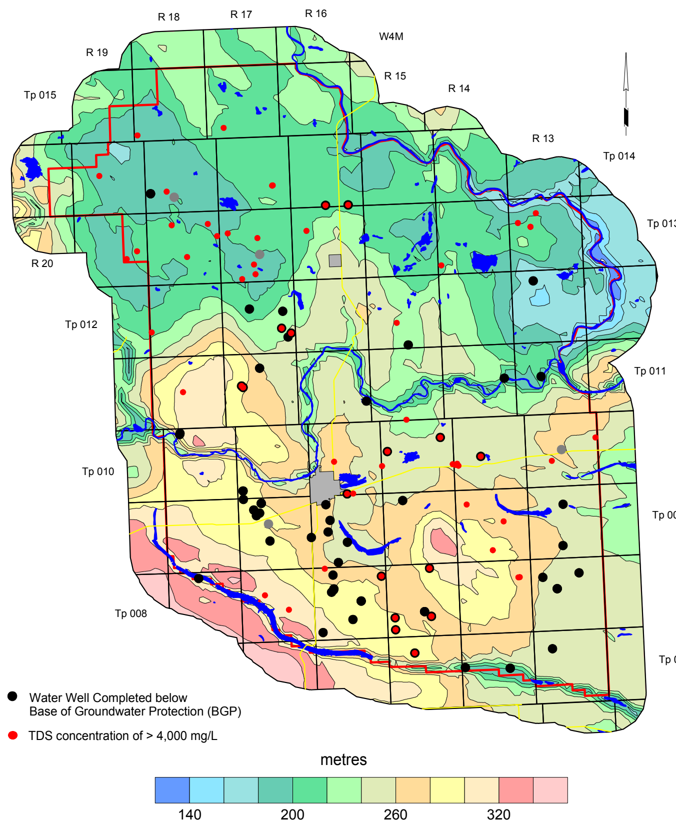

Figure 6. Depth to Base of Groundwater Protection (after EUB, 1995 and Tokarsky, 1986)

In the northern part of the M.D., the BGP trends from the west below the top of the Oldman Formation to the east below the portion of the Milk River Formation that has been developed for water supplies. In the southern part of the M.D., the BGP is mainly below the portion of the Milk River Formation that has been developed for water supplies (see pages A-14 to A-22).

Proper management of the groundwater resource requires water-level data. These data are often collected from observation water wells. At the present time, there are three AENV-operated observation water wells within the M.D. (see page A-54 for the observation water well locations). Of the three observation water wells, only one is currently being monitored (see section 7.1 of this report). 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 M.D. is too few to provide a reliable groundwater budget (see section 7.0 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 the M.D. of Flagstaff.

The County of Grande Prairie was involved in a Regional Groundwater Assessment in 2002 and, from the study, it was identified that there is a shortage of information related to changes in the water levels in the various aquifers in the region. In an attempt to supplement the existing data, a groundwater monitoring program has been set up to measure the water levels in 50 selected water wells each month over the next five years; and in three water wells, water levels are being measured six times a day with a dedicated data logger. Also, groundwater samples are to be collected from the 50 monitored water wells in the County of Grande Prairie to determine if changes in the groundwater quality are taking place.

5 TERMS

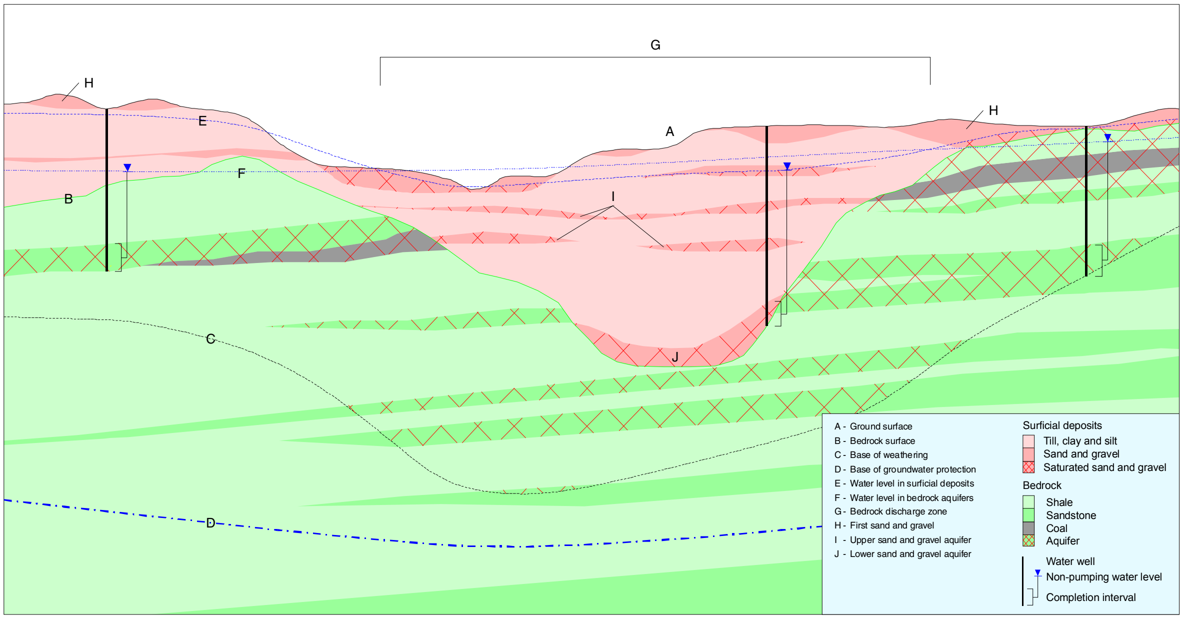

Figure 7. Generalized Cross-Section (for terminology only)

(for larger version, see page A-11)

		Group and Formation				Member		Zone	
Lithology	Lithologic Description	Average Thickness (m)	Group	Designation (thickness)	Designation	Average Thickness (m)	Designation	Average Thickness (m)	Designation
	sand, gravel, till, clay, silt	<140			Surficial Deposits	<140	Upper	<30	First Sand and Gravel
						<50	Lower		
	shale, sandstone, siltstone	60-120			Bearpaw Formation				
	sandstone, siltstone, shale, coal	<300	Belly River Group	40-130	Oldman Formation		Dinosaur Member	<25	Lethbridge Coal Zone
							Upper Siltstone Member		
							Comrey Member		
	sandstone, shale			<200	Foremost Formation	<70	Birch Lake Member		Taber Coal Zone
						<60	Ribstone Creek Member		
						<70	Victoria Member		McKay Coal Zone
						0-30	Brosseau Member		
	shale, siltstone	100-150			Lea Park Formation (Pakowki)				
	sandstone, siltstone, shale, coal	120-150			Milk River Formation	<50	Sandstone Unit		
	shale, siltstone	200-1000	Colorado Group		Colorado Shales				
	sandstone, mudstone, shale	50			Viking Formation				

Figure 8. Geologic Column

(for larger version, see page A-12)

6 AQUIFERS

6.1 Background

An aquifer is a permeable geologic unit[14] that is saturated. In this context, "geologic unit" refers to subsurface materials, such as sand, gravel, sandstone and coal. Aquifers occur in one of two general geological settings in the M.D. The first geological setting includes the sediments that overlie the bedrock surface. In this report, these sediments are referred to as the surficial deposits. The second geological setting includes aquifers in the upper bedrock. If the NPWL is above the top of the geologic 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 geologic unit, this type of aquifer is a water-table aquifer. 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.

6.2 Surficial Deposits – Geological Characteristics

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. For the present study, the surficial deposits have been assigned to two different groupings in the M.D.: (a) Lower Surficial, and (b) Upper Surficial. The Lower Surficial deposits include pre-glacial fluvial[15] deposits. The Upper Surficial deposits include the traditional glacial sediments of till[16] and ice-contact deposits. Pre-glacial materials are expected to be present in association with linear bedrock lows.

While the surficial deposits are treated as one hydrogeologic unit[17], they consist of three hydraulic units[18]. The first unit is the preglacial sand and gravel deposits of the Lower Surficial deposits that directly overlie the bedrock surface, 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 that occurs close to ground surface. For a graphical depiction of the above description, please refer to Figure 7, page 14 and to page A-11. 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.

The base of the surficial deposits is the bedrock surface, represented by the bedrock topography as shown on the following page on Figure 9 and on page A-23. Regionally, the bedrock surface varies between 660 and 910 metres AMSL. The lowest elevations occur in the buried bedrock valleys.

Over the majority of the M.D., the surficial deposits are less than 50 metres thick (see CD-ROM). The exceptions are mainly in association with areas where buried bedrock valleys are present, where the deposits can have a thickness ranging from 50 to 100 metres.

14 See glossary
15 See glossary
16 See glossary
17 See glossary
18 See glossary

6.2.1 Buried Valleys

The main buried bedrock valleys in the M.D. that have west-east features have been designated as the Lethbridge Buried Valley and the Tee Pee Buried Valley.

The Vauxhall Buried Valley is a tributary to the Tee Pee Buried Valley. Both the Tee Pee Buried Valley and the Skiff Buried Valley join the Lethbridge Buried Valley, east of the M.D. of Taber study area.

The Tee Pee Buried Valley is the main easterly-trending buried bedrock valley in the northern part of the M.D., and is partially coincidental with the Bow River at the M.D.'s northern border. The Valley ranges from approximately three to nine kilometres wide within the study area, with local bedrock relief being less than 30 metres. Sand and gravel deposits can be expected in association with the bedrock low, but the thickness of the sand and gravel deposits is expected to be mainly less than 10 metres (see page A-24).

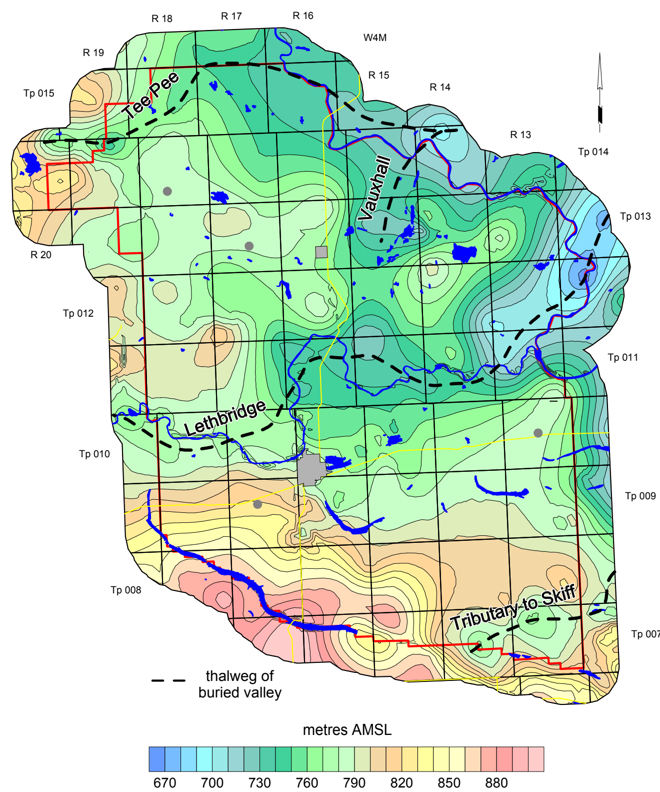

Figure 9. Bedrock Surface Topography

The Lethbridge Buried Valley is the main easterly-trending buried bedrock valley in the M.D., and is partially coincidental with the Oldman River. The Valley is four to 12 kilometres wide, with local bedrock relief being up to 60 metres. Sand and gravel deposits can be expected in association with the bedrock low, but the thickness of the sand and gravel deposits is expected to be between five and 20 metres.

The Vauxhall Buried Valley trends northeasterly in the northern part of the M.D. The southern extent of the Valley is not clearly defined based on the available bedrock elevations, and has been approximated on Figure 9 based on Geiger's interpretation (Geiger, 1968). The Valley is less than nine kilometres wide, with local bedrock relief being in the order of 30 metres. Sand and gravel deposits can be expected in association with the Vauxhall Buried Valley, with the sand and gravel deposits expected to be mainly between ten and 20 metres thick.

The tributary to the Skiff Buried Valley trends mainly easterly in the southeastern part of the M.D. The Valley ranges mainly from two to six kilometres wide, with local bedrock relief being in the order of 20 metres. Sand and gravel deposits can be expected in association with the tributary to the Skiff Buried Valley, with the sand and gravel deposits expected to be mainly between five and 15 metres thick.

Lower surficial deposits occur over the M.D., but mainly in buried bedrock valleys. The total thickness of the lower surficial deposits is mainly less than five metres, but can be more than 15 metres in the Lethbridge Buried Valley (see CD-ROM). The lowest part of the lower surficial deposits includes pre-glacial sand and gravel deposits. These deposits would generally overlie the bedrock surface in the Vauxhall Buried Valley and the Lethbridge Buried Valley, as shown below on Cross-Section D-D' and page A-17. The lowest sand and gravel deposits are of fluvial origin, are usually less than five metres thick and may be discontinuous (see CD-ROM).

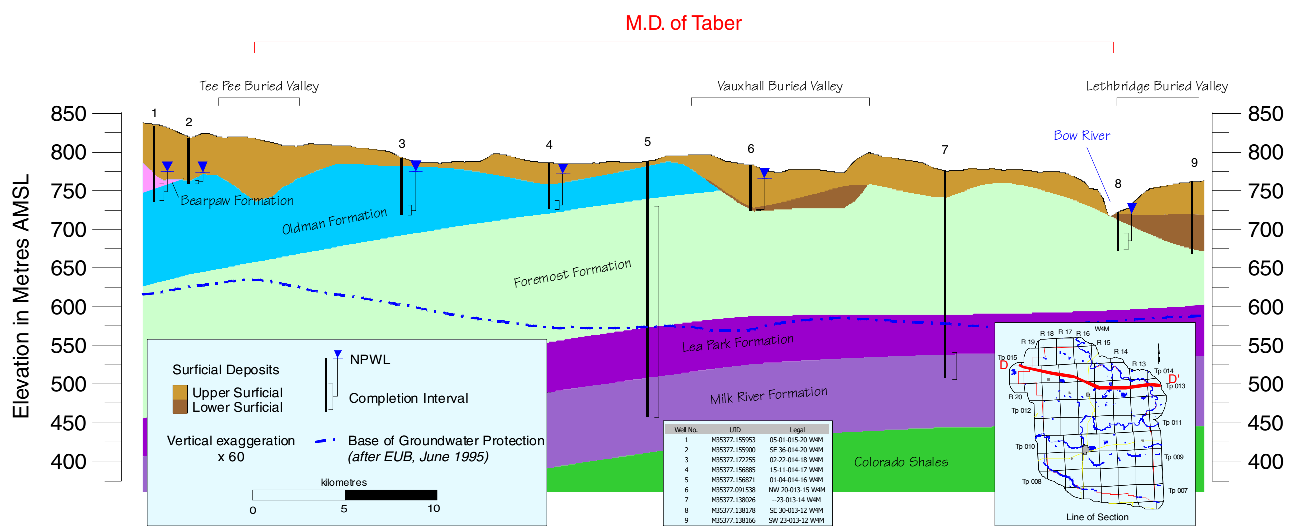

Figure 10. Cross-Section D - D'

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 throughout most of the M.D. (see CD-ROM). The upper sand and gravel deposits are mainly less than five metres thick (see CD-ROM).

Sand and gravel deposits can occur throughout the surficial deposits. The total thickness of sand and gravel deposits is generally less than five metres but can be more than five metres in association with buried bedrock valleys (see page A-24 and on CD-ROM).

The combined thickness of all sand and gravel deposits has been determined as a function of the total thickness of the surficial deposits. Where sand and gravel deposits are present, the sand and gravel deposits are less than 25% of the total thickness of the surficial deposits, as shown on the adjacent figure. The areas where sand and gravel deposits constitute more than 25% of the total thickness of the surficial deposits are in association with buried bedrock valleys, as shown on the adjacent figure.

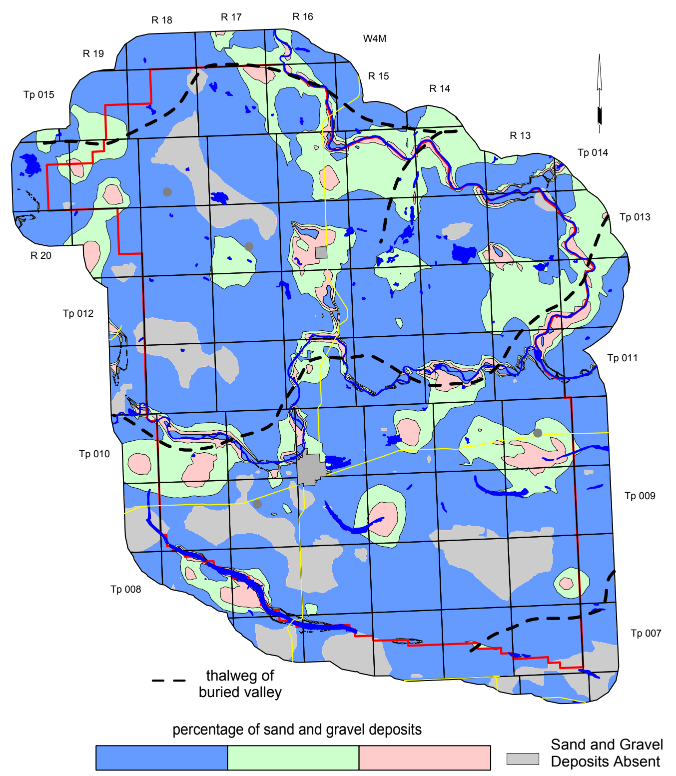

Figure 11. Percentage of Sand and Gravel in Surficial Deposits

6.2.2 Sand and Gravel Aquifer(s)

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 15% of the M.D., saturated sand and gravel deposits are not present; these areas are designated as grey on the adjacent map. In the M.D., the thickness of the Sand and Gravel Aquifer(s) is generally less than five metres, but can be more than five metres in areas of, or near buried bedrock valleys, as shown in Figure 12, in Appendix A and on the CD-ROM.

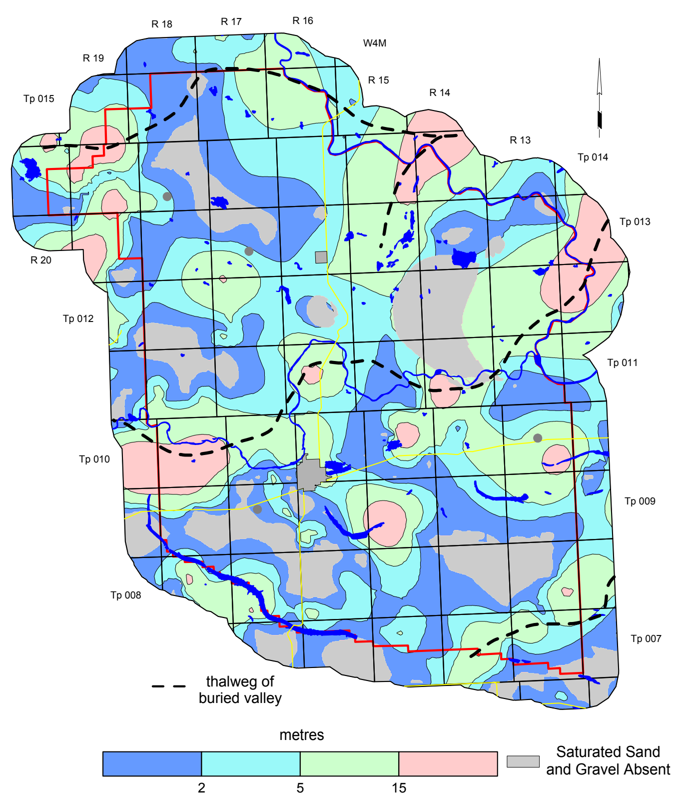

Figure 12. Thickness of Sand and Gravel Aquifer(s)

Of the 985 water wells in the database, 526 were defined as being completed in surficial aquifers (see page 9). Of the 526 water wells, 507 are completed in aquifers in the Upper Surficial deposits, and 19 are completed in aquifers in the Lower Surficial deposits. Water wells completed in the Lower Surficial deposits are mainly in proximity of buried bedrock valleys, and water wells completed in the Upper Surficial deposits are frequently in buried bedrock valleys but are also located at higher bedrock elevations, as shown on Figure 13.

In the M.D., there are 30 records for surficial water wells with apparent yield data, which is six percent of the 526 surficial water wells. Ten (33.3%) of the 30 water wells completed in the Sand and Gravel Aquifer(s) have apparent yields that are less than ten m³/day, 13 (43.3%) have apparent yield values that range from 10 to 50 m³/day, and seven (23.3%) have apparent yield values that are greater than 50 m³/day. In addition to the 30 records for surficial water wells with apparent yield data, there are 15 records that indicate that the water test hole is “dry”. In order to depict a more accurate yield map, an apparent yield of 0.1 m³/day was assigned to each of the 15 “dry” water test holes prior to gridding.

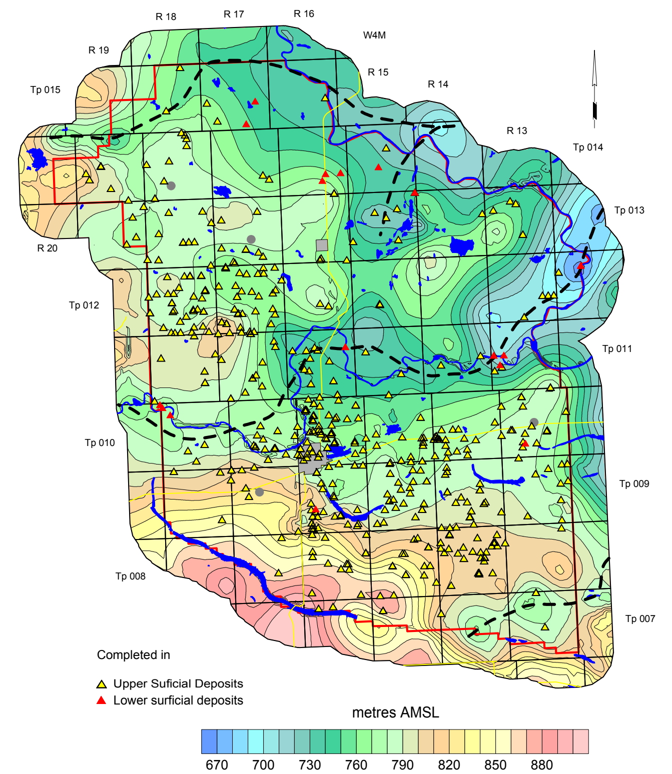

Figure 13. Location of Surficial Water Wells Relative to Bedrock Topography

Aquifer	No. of Water Wells with Values for Apparent Yield (*)	Number of Water Wells with Apparent Yields <10 m³/day	10 to 50 m³/day	>50 m³/day
Upper Surficial	28	9	12	7
Lower Surficial	2	1	1	0
Totals	30	10	13	7

* - does not include dry test holes

Table 5. Apparent Yields of Sand and Gravel Aquifer(s)

Figure 14 on the following page shows expected yields for water wells completed in the Sand and Gravel Aquifer(s).

The adjacent map shows expected yields for water wells completed in the Sand and Gravel Aquifer(s).

Based on the aquifers that have been developed by existing water wells, these data show that water wells with yields of more than 50 m³/day (7.5 igpm) from the Sand and Gravel Aquifer(s) may be possible in the southwestern part of the M.D., where the Sand and Gravel Aquifer(s) are present.

There are a significant number of dry water test holes that have been drilled or bored throughout the M.D. Of the 15 “dry” water test holes, all were drilled or bored to less than 30 metres below ground surface.

Apparent yields for water wells completed in the Sand and Gravel Aquifer(s) vary significantly over the M.D. both with location and with depth. As Figure 15 shows, most apparent yields are less than 50 m³/day, and the majority of the water wells completed in the Sand and Gravel Aquifer(s) are less than 25 metres deep.

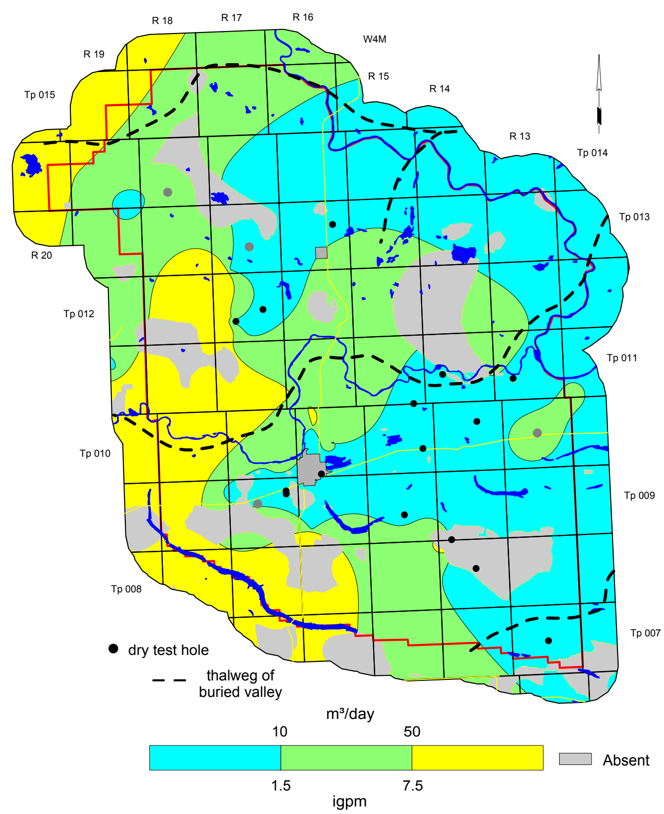

Figure 14. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)

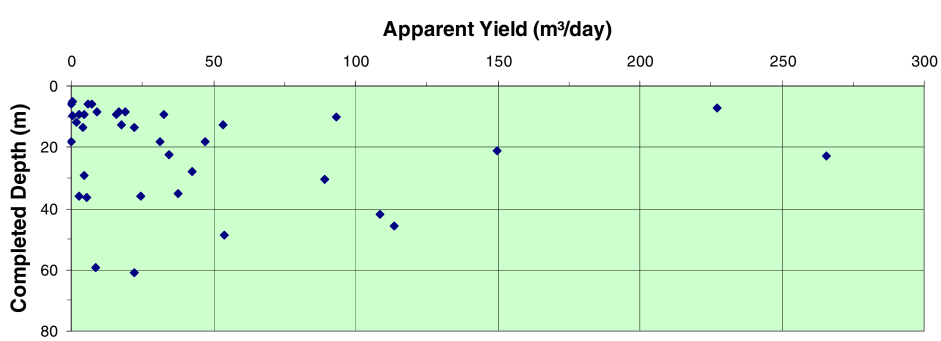

Figure 15. Sand and Gravel Water Well Yields vs Completed Depth

6.2.2.1 Chemical Quality of Groundwater from Surficial Deposits

The chemical analysis results of groundwaters from the surficial deposits have not been differentiated based on aquifers in the Upper or Lower Surficial deposits. The main reason for not separating the chemical analysis results into the different aquifers is the lack of data that can be attributed to the Lower Sand and Gravel Aquifer. This is in part related to the number of control points from the Aquifer, which is in part related to the limited areal extent of the Lower Surficial deposits. The other justification for not separating the analyses was that there appeared to be no major chemical difference between the groundwaters from the Upper and Lower Sand and Gravel Aquifer(s).

Groundwaters from an aquifer in the surficial deposits can be expected to be chemically hard, with a total hardness of at least a few hundred mg/L (see CD-ROM), and a dissolved iron concentration such that the groundwater must be treated before being used for domestic needs. Seventy percent of the groundwaters from the surficial deposits are reported to have dissolved iron concentrations of less than the aesthetic objective (AO) of 0.3 mg/L. However, many iron analyses results are questionable due to varying sampling and analytical methodologies.

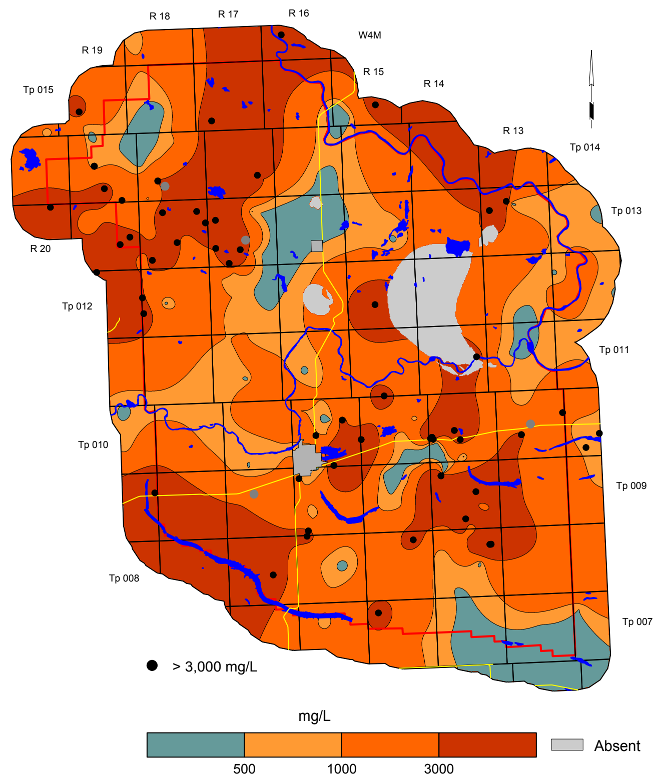

Figure 16. Total Dissolved Solids in Groundwater from Surficial Deposits

The Piper tri-linear diagram[19] for the surficial deposits (see page A-34) shows that the groundwaters from the surficial deposits are mainly a calcium-magnesium-bicarbonate or a calcium-magnesium sulfate type.

The bicarbonate-type groundwaters appear to occur closer to areas of recharge and along sand and gravel-filled buried valleys than to the sulfate-type waters, with some exceptions. Sulfate-type groundwaters are common in areas of groundwater discharge, areas of low permeability, and areas of slow groundwater movement (Tokarsky, 1974), as shown on page A-35, and on the CD-ROM.

More than 60% of the groundwaters from the surficial deposits have a TDS concentration of more than 1,000 mg/L. 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; in more than 75% of the samples analyzed for surficial deposits in the M.D., the chloride ion concentration is less than 50 mg/L (see CD-ROM). In the M.D., the Nitrate + Nitrite (as N) concentrations in the groundwaters from the surficial deposits exceed the maximum acceptable concentrations (MAC) of ten mg/L in nine of the 77 groundwater samples analyzed (up to about 1986). A plot of Nitrate + Nitrite (as N) in surficial aquifers is on the accompanying CD-ROM.

[19] See glossary

The minimum, maximum and median [20] concentrations of TDS, sodium, sulfate, chloride and Nitrate + Nitrite (as N) in the groundwaters from water wells completed in the surficial deposits in the M.D. have been compared to the Summary of Guidelines for Canadian Drinking Water Quality (SGCDWQ) in the adjacent table. The range of concentrations shown in Table 5 is from values in the groundwater database; however, the extreme minimum and maximum concentrations generally represent less than 0.2% of the total number of analyses and should have little effect on the median values. These extreme values are not used in the preparation of the figures.

Constituent	No. of Analyses	Range for M.D. in mg/L Minimum	Maximum	Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	198	208	11,662	**1,541**	500
Sodium	119	2	570	122	200
Sulfate	201	17	6,970	**696**	500
Chloride	197	0	368	21	250
Nitrate + Nitrite (as N)	77	0	36	0.3	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-Territorial Committee on Drinking Water, March 2006

Table 6. Concentrations of Constituents in Groundwaters from Surficial Deposits

Of the five constituents that have been compared to the SGCDWQ, median concentrations of TDS and sulfate exceed the guidelines.

[20] See glossary

6.2.3 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 85% of the M.D.

6.2.3.1 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 M.D., the thickness of the Upper Sand and Gravel Aquifer is mainly less than five metres but can be more than five metres in the buried bedrock valleys.

6.2.3.2 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.

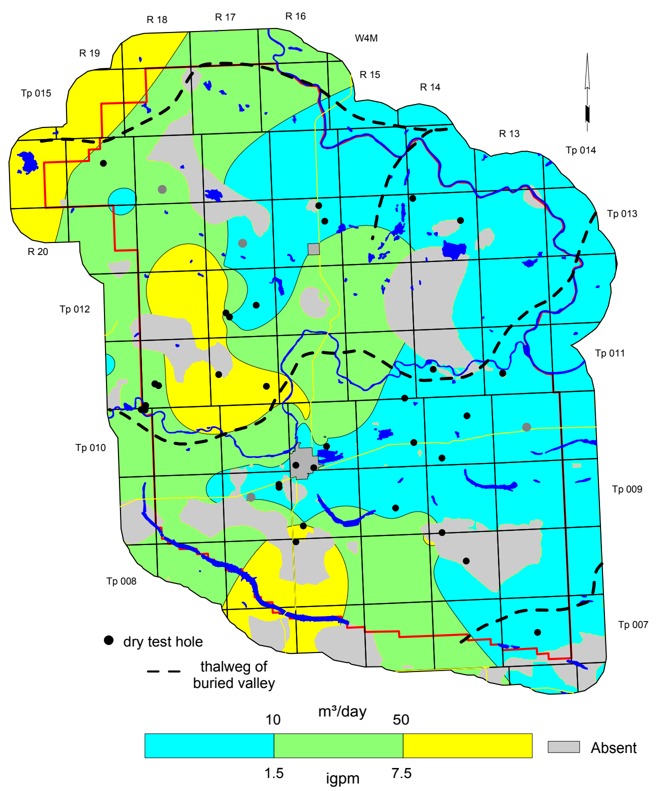

Figure 17. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

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.

Figure 17 indicates that in 55% of the M.D., water wells completed through the Upper Sand and Gravel Aquifer are expected to have apparent yields that are less than 10 m³/day. In the M.D., there are 15 "dry" water test holes completed in the Upper Sand and Gravel Aquifer.

In the M.D., there are 35 licensed and registered water wells that are completed through the Upper Sand and Gravel Aquifer, for a total authorized diversion of 628 m³/day (Table 2, page 11), with a median authorized amount of 1.2 m³/day. The highest authorized groundwater use is for a water supply well completed to a depth of 4.2 metres below ground level (BGL) in the Upper Sand and Gravel Aquifer that is licensed to divert 274 m³/day for stock purposes in 04-27-010-16 W4M. Thirteen of the 35 licences and registrations for water wells completed through the Upper Sand and Gravel Aquifer could be linked to a water well in the AENV groundwater database.

6.2.4 Lower Sand and Gravel Aquifer

The Lower Sand and Gravel Aquifer, the oldest of the surficial deposits, is a saturated sand and gravel deposit that occurs at or near the base of the surficial deposits in the deeper part of the buried bedrock valleys. The thickness of the Lower Sand and Gravel Aquifer is generally less than five metres but can be more than five metres mainly in association with Lethbridge Buried Valley (see page A-24 and on CD-ROM).

6.2.4.1 Depth to Top

The depth to the top of the Lower Sand and Gravel Aquifer ranges from ground surface to more than 50 metres BGL (see CD-ROM).

6.2.4.2 Apparent Yield

The four apparent yield values for individual water wells completed through the Lower Sand and Gravel Aquifer range from less than ten to greater than 100 m³/day. The two apparent yield values that are greater than 100 m³/day are for water wells in areas of the Lethbridge Buried Valley, as shown on Figure 18.

In the M.D., there are no "dry" water test holes completed in the Lower Sand and Gravel Aquifer.

In the M.D., there are three registrations for water wells that are completed through the Lower Sand and Gravel Aquifer, for a total authorized diversion of 6.7 m³/day (Table 2, page 11).

The three registrations for water wells completed through the Lower Sand and Gravel Aquifer could be linked to a water well in the AENV groundwater database.

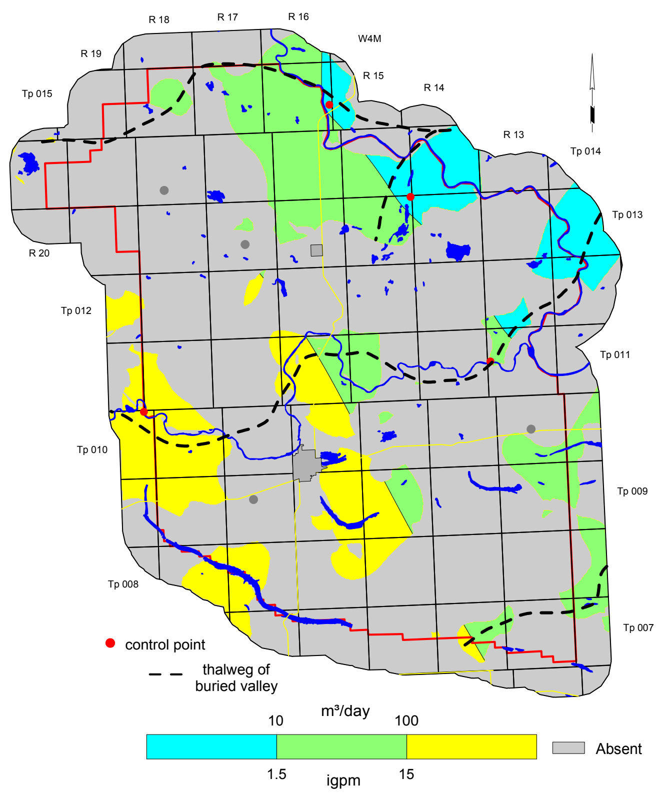

Figure 18. Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer

6.3 Bedrock

6.3.1 Geological Characteristics

The upper bedrock in the M.D. study area includes the Bearpaw Formation and the Belly River Group. The Belly River Group includes the Oldman and Foremost formations. Some of this bedrock contains saturated rocks that are permeable enough to transmit groundwater for a specific need.

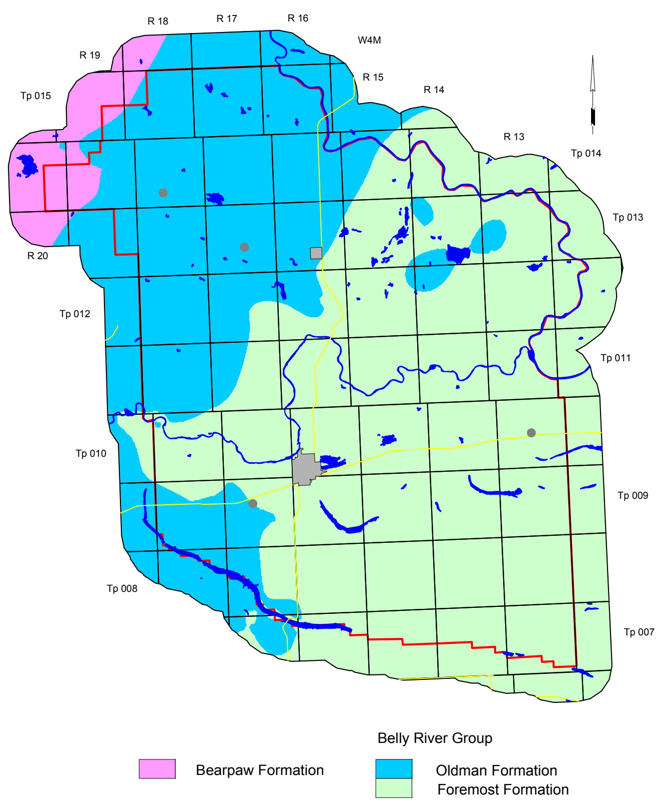

Figure 19. Bedrock Geology

The adjacent bedrock geology map and cross-section on the following page, showing the subcrop of different geologic units, has been prepared in part from the interpretation of geophysical logs related to oil and gas activity. A generalized geologic column is illustrated in Figure 8, in Appendix A and on the CD-ROM.

The Bearpaw Formation is in the order of 70 metres thick and is the upper bedrock in the extreme northwestern part of the study area. The Bearpaw Formation includes transgressive, shallow marine (shoreface) and open marine facies [21] deposits. 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). In the study area, the Bearpaw Formation is composed mainly of shale and as such is a regional aquitard[22], and as such, there are insufficient or no hydrogeological data within the study area to prepare meaningful maps. The only maps association with the Bearpaw Formation to be included on the CD-ROM will be structure-contour maps.

The Oldman Formation is present in the western parts of the M.D. and has a maximum thickness of 125 metres. The Oldman Formation is composed of continental deposits, sandstone, siltstone, shale and coal. The Oldman Formation is the upper part of the Belly River Group.

The Foremost Formation is the upper bedrock in most of the M.D. The Foremost Formation, composed of sandstone and shale units, is in the order of 175 metres thick and is between the overlying Oldman Formation and the underlying Lea Park (Pakowki) Formation. The Foremost Formation includes both sandstone and shale units. Coal zones occur within the Foremost Formation along with 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 (Pakowki) Formation. The top of the Lea Park (Pakowki) Formation represents a geologic time

[21] See glossary
[22] See glossary

border between the marine environment of the Lea Park (Pakowki) Formation and the mostly continental environment of the Foremost Formation. The top of the Lea Park (Pakowki) Formation is the bottom of the higher resistivity layer that occurs within a few metres below a regionally identifiable bentonite marker, as shown on page A-33. This marker occurs approximately 100 metres above the Milk River Shoulder. The Lea Park (Pakowki) Formation is mostly composed of shale, with only minor amounts of bentonitic siltstone present in some areas. Regionally, the Lea Park (Pakowki) Formation is an aquitard. Because the Lea Park (Pakowki) Formation is an aquitard, there will be no direct review in this report. Structure-contour maps associated with the Lea Park (Pakowki) Formation are included in Appendix A and on the CD-ROM.

The Milk River Formation underlies the entire M.D. and has an average thickness of approximately 100 metres. In southern Alberta, the Milk River Formation is composed mostly of thick-bedded sandstone with shale and is the main source of groundwater in the southeastern part of the M.D., in the County of Forty Mile, and is also an important supply of natural gas. The portion of the Milk River Formation that has been developed for water supplies mainly occurs in the upper part of the Formation above the Base of Groundwater Protection, as shown on the cross-sections in this report, and on pages A-14 to A-22.

The Colorado Shales, present under the entire M.D., are mainly shale units between the Milk River Formation and the Mannville Group. The Viking Formation, a 50-metre-thick sandstone unit that sometimes can be distinguished near the base of the Colorado Group, is composed of well-washed and variable shaly, fine- to coarse-grained sandstone, with subordinate conglomerate and pebbly sandstone. In the southern part of the province, the Viking Formation is developed as a source of groundwater. In the M.D. of Taber, a water source well completed from 850 to 1,105 metres below ground surface in the Viking Formation in 08-29-014-18 W4M is authorized to divert 297 m³/day for industrial purposes. From Dec 1989 to Dec 1999, the water source well produced 277,533 cubic metres.

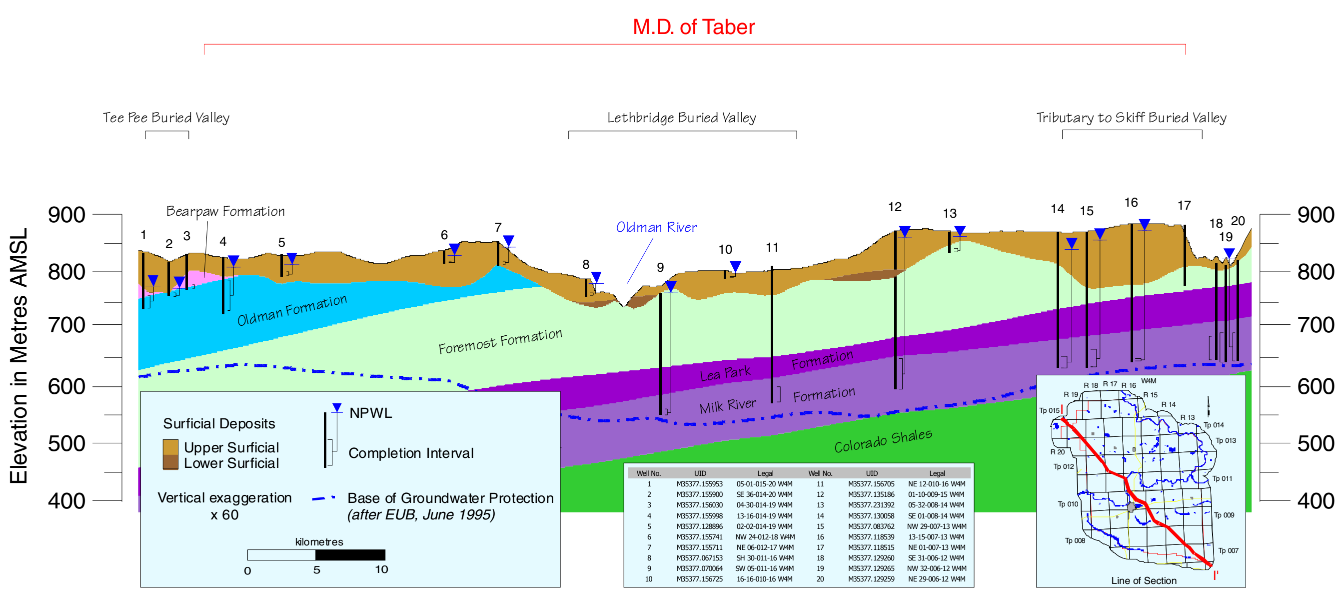

Figure 20. Cross-Section I - I'

6.3.2 Upper Bedrock Completion Aquifer(s)

Of the 985 water wells in the database, 379 were defined as being completed below the top of bedrock (see page 9). 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 completion interval was the bottom 20% of the total completed depth of a water well. With this assumption, it has been possible to designate the specific bedrock aquifer of completion to 352 bedrock water wells. The remaining 27 of the total 379 upper bedrock water wells are identified as being completed in more than one bedrock aquifer, as shown in Table 6. The bedrock water wells are mainly completed in the Milk River Aquifer. Hydrogeological data associated with the water wells completed in saline aquifers were not used in the preparation of figures.

Geologic Unit	No. of Bedrock Water Wells
Bearpaw	2
Oldman	45
Foremost	111
Lea Park (Pakowki)	0
Milk River	156
Saline	38
Multiple Bedrock Completions	27
Total	379

Table 7. Completion Aquifer for Upper Bedrock Water Wells

There are 26 records for bedrock water wells in the M.D. that have apparent yield values, which is eight percent of the 341 non-saline bedrock water wells.

Sixty-five percent of the water wells completed in the Upper Bedrock Aquifer(s) have apparent yield values of less than 50 m³/day, with a median apparent yield of 35 m³/day. Many of the areas with yields of more than 50 m³/day are completed in the Milk River Aquifer, and in association with the buried bedrock valleys. These higher yield areas may identify areas of increased permeability resulting from the weathering process.

In addition to the 26 records for bedrock water wells in the M.D. with apparent yield values, there are 20 records that indicate that the water well/water test hole 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 20 “dry” water test holes prior to gridding.

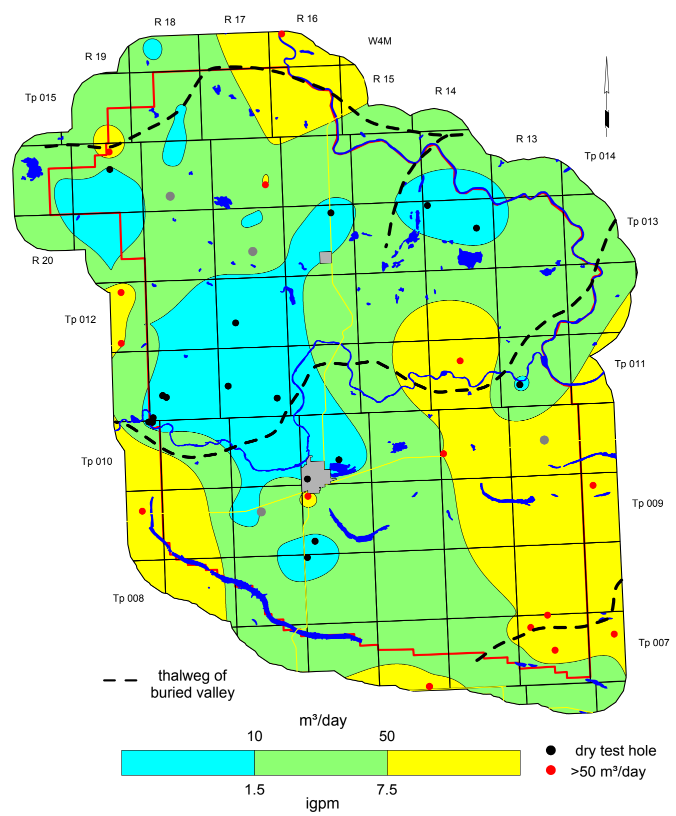

Figure 21. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

Of the 26 water wells completed in bedrock aquifers with apparent yield values, nine (35%) have apparent yields that are less than ten m³/day, eight (30%) have apparent yield values that range from 10 to 50 m³/day, and nine (35%) have apparent yield values that are greater than 50 m³/day, as shown in Table 7.

Aquifer	No. of Water Wells with Values for Apparent Yield (*)	Number of Water Wells with Apparent Yields <10 m³/day	10 to 50 m³/day	>50 m³/day
Bearpaw	1	1	0	0
Oldman	10	6	2	2
Foremost	10	2	4	4
Milk River	5	0	2	3
Totals	26	9	8	9

* - does not include dry test holes

Table 8. Apparent Yields of Bedrock Aquifers

Apparent yields for water wells completed in the Upper Bedrock Aquifer(s) vary significantly over the M.D. both with location and with depth. As Figure 22 shows, most apparent yields are less than 25 m³/day and the majority of the water wells are less than 75 metres deep. Most of the water wells with apparent yields of greater than 50 m³/day are less than 60 metres deep.

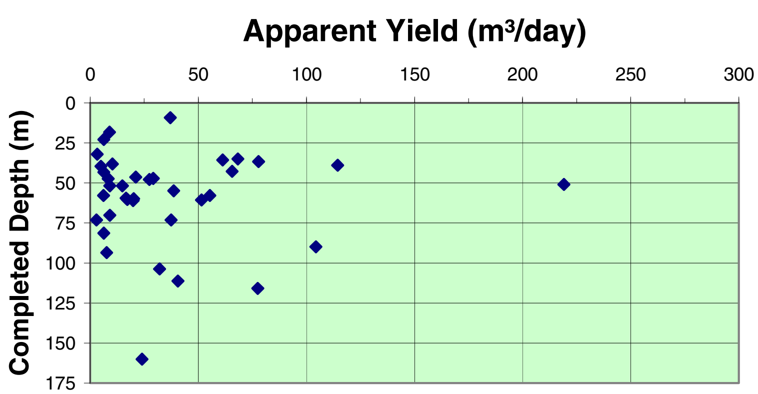

Figure 22. Bedrock Water Well Yields vs Completed Depth

6.3.3 Chemical Quality of Groundwater

The Piper tri-linear diagram for Upper Bedrock Aquifer(s) (page A-34) shows that groundwaters from bedrock aquifers are mainly sodium-bicarbonate or sodium-sulfate-type waters; the majority of these groundwaters have a sodium ion concentration that exceeds 500 mg/L. Because the sodium concentration can be elevated, the groundwater can pose a risk to people on low-sodium diets.

In the M.D., approximately 16% 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 21% of the groundwater samples from the entire M.D. are between 0.5 and 1.5 mg/L and approximately 63% exceed the MAC for fluoride of 1.5 mg/L, with fluoride concentrations of greater than five mg/L occurring in the southeastern part of the M.D. (see CD-ROM).

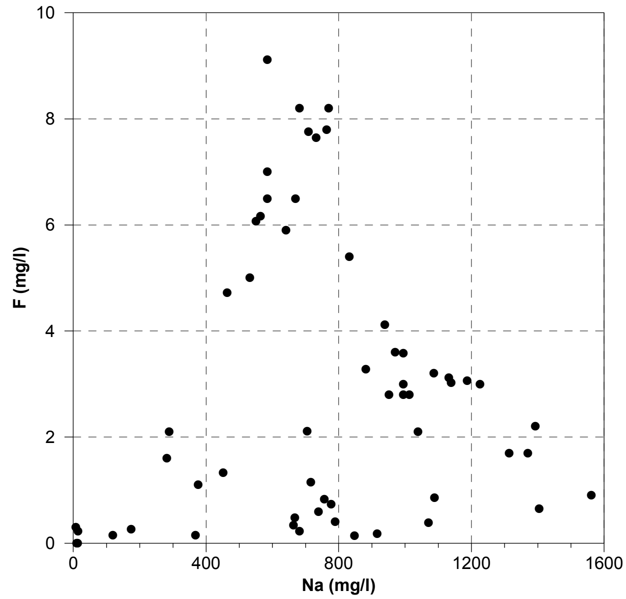

Figure 23. Fluoride vs Sodium Concentrations in Groundwater in Upper Bedrock Aquifer(s)

The fluoride concentrations in the groundwaters appear to be a function of the sodium concentration. Below a sodium concentration of 200 mg/L, there is generally very little fluoride in the groundwater. When the sodium concentration reaches 400 mg/L, the maximum fluoride concentration can increase dramatically. As the sodium concentration increases, the maximum solubility of fluoride decreases and once the sodium concentration reaches 900 mg/L, the maximum solubility of fluoride is mainly above the MAC of 1.5 mg/L, as shown above in Figure 23 and on page A-39.

The TDS concentrations in the groundwaters from the Upper Bedrock Aquifer(s) range from less than 500 mg/L to 5,000 mg/L, with most of the groundwaters with higher TDS concentrations occurring in the northern part of the M.D. (see page A-38). In the M.D., 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 M.D., 51% of the chloride concentrations in the groundwaters from the Upper Bedrock Aquifer(s) are greater than 250 mg/L. In the M.D., there were two groundwater samples that had Nitrate + Nitrite (as N) concentrations that were greater than the SGCDWQ for the Upper Bedrock Aquifer(s). Approximately 90% of the total hardness values in the groundwaters from the Upper Bedrock Aquifer(s) are less than 200 mg/L.

Constituent	No. of Analyses	Range for M.D. in mg/L Minimum	Maximum	Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	124	167	8,542	2,522	500
Sodium	761	0	2,810	363	200
Sulfate	114	0	3,898	23	500
Chloride	119	2	1,630	267	250
Fluoride	96	0	9.11	2.0	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. Concentrations of Constituents in Groundwaters from Upper Bedrock Aquifer(s)

The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and fluoride in the groundwaters from water wells completed in the upper bedrock in the M.D. have been compared to the SGCDWQ in Table 8. Of the five constituents compared to the SGCDWQ, median concentrations of TDS, sodium, chloride, and fluoride exceed the guidelines.

6.3.4 Oldman Aquifer

The Oldman Aquifer comprises the permeable parts of the Oldman Formation, as defined for the present program. The Oldman Formation subcrops under the surficial deposits in the western parts of the M.D. The thickness of the Oldman Formation varies from less than two metres at the eastern edge of the subcrop to 120 metres in the northwestern part of the M.D. The regional groundwater flow direction in the Oldman Aquifer is downgradient, northwest toward the Oldman River and northeast toward the Bow River (see CD-ROM).

6.3.4.1 Depth to Top

The depth to the top of the Oldman Formation is variable, ranging from less than 20 metres at the eastern edge of the subcrop to 90 metres in the extreme northwestern part of the M.D., and is a reflection of the thickness of the surficial deposits.

6.3.4.2 Apparent Yield

The apparent yields for individual water wells completed through the Oldman Aquifer range mainly from 10 to 50 m³/day, and have a median apparent yield value of 20 m³/day. The higher yielding areas appear to be mainly just outside the western M.D. border, as shown below on Figure 24.

There are six "dry" water test holes that are completed in the Oldman Aquifer.

There is one registered groundwater water well that is completed through the Oldman Aquifer, for a total groundwater diversion of 0.1 m³/day. This water well is in NE 34-013-17 W4M, and was linked to a water well in the AENV groundwater database.

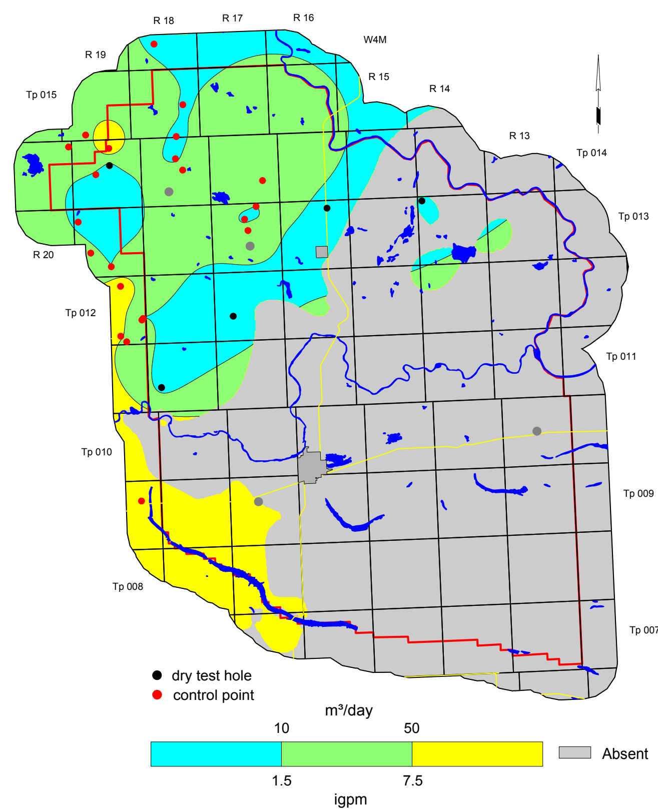

Figure 24. Apparent Yield for Water Wells Completed through Oldman Aquifer

6.3.4.3 Quality

The groundwaters from the Oldman Aquifer are mainly a sodium-sulfate-type (see Piper diagram on CD-ROM), with groundwater samples having TDS concentrations ranging from less than 500 to 5,000 mg/L (page A-42). Nearly 90% of the TDS concentrations in groundwater from the Oldman Aquifer are greater than 1,000 mg/L. The higher TDS values are expected at the eastern edge of the Aquifer. Two-thirds of the sulfate concentrations in groundwaters from the Oldman Aquifer are greater than the SGCWQ of 500 mg/L. The sulfate concentrations of greater than 1,500 mg/L are expected mainly at the eastern edge of the Aquifer. Eighty percent of the chloride concentrations from the Olldman Aquifer are less than 50 mg/L, and 30% of the groundwater samples have fluoride concentrations that are greater than 1.5 mg/L.

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, and sulfate from water wells completed in the Oldman Aquifer are greater than the median concentrations from water wells completed in all Upper Bedrock Aquifer(s).

Constituent	No. of Analyses	Range for M.D. in mg/L Minimum	Maximum	Median	All Bedrock Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	17	332	8,542	2724	2,522	500
Sodium	10	118.0	2,070	836	363	200
Sulfate	15	195	3,898	952	23	500
Chloride	16	6	324	85	267	250
Fluoride	13	0	2	0.8	2.0	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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Federal-Provincial Subcommittee on Drinking Water, March 2006

Table 10. Apparent Concentrations of Constituents in Groundwaters from Oldman Aquifer

6.3.5 Foremost Aquifer

The Foremost Aquifer comprises the permeable parts of the Foremost Formation that underlie the Oldman Formation. The Foremost Formation is present under all of the M.D. Structure contours have been prepared for the top of the Foremost Formation. The structure contours show that the Foremost Formation ranges in elevation from 640 to 900 metres AMSL and has a maximum thickness of 170 metres. The regional groundwater flow direction in the Foremost Aquifer is downgradient, north toward the Oldman River and northeast toward the Bow River (see CD-ROM).

6.3.5.1 Depth to Top

The depth to the top of the Foremost Formation ranges from less than ten metres near the Oldman and Bow rivers to 225 metres in the extreme northwestern part of the M.D. (page A-43).

6.3.5.2 Apparent Yield

The apparent yields for individual water wells completed through the Foremost Aquifer are mainly in the range of 10 to 50 m³/day as shown on Figure 25, and have a median apparent yield value of 30 m³day. There are little or no data for the Aquifer in the southeastern parts of the M.D. In these areas, the Milk River Formation is the primary groundwater supply.

There are 13 “dry” water test holes that are completed in the Foremost Aquifer.

There are four licensed and/or registered groundwater users that have water wells completed through the Foremost Aquifer, for a total authorized groundwater diversion of 35 m³/day, with a median authorized amount of 7.8 m³/day. The highest authorized groundwater use is for a water supply well completed to a depth of 91.4 metres BGL in the Foremost Aquifer that is registered to divert 17.1 m³/day in NW 15-009-14 W4M.

Two of the four registrations could be linked to water wells in the AENV groundwater database.

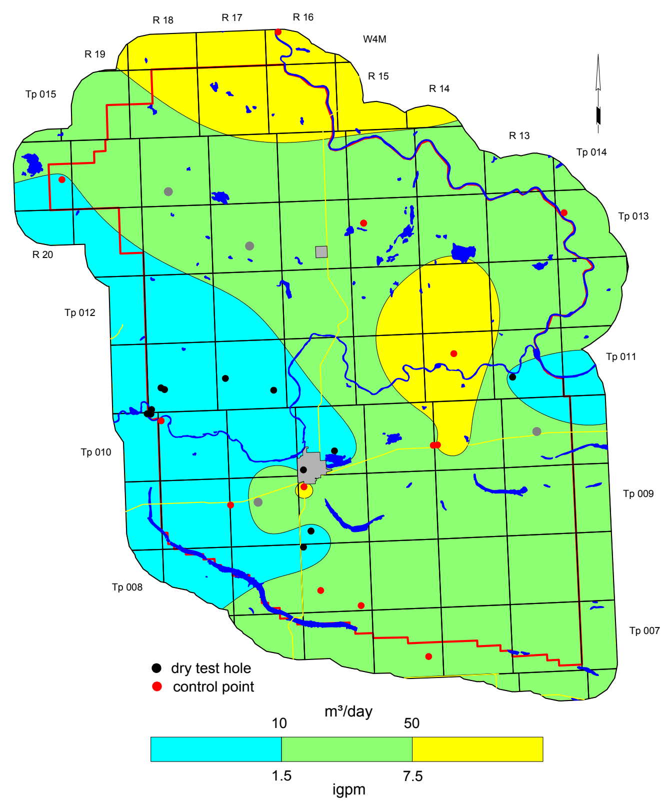

Figure 25. Apparent Yield for Water Wells Completed through Foremost Aquifer

6.3.5.3 Quality

The groundwaters from the Foremost Aquifer have no dominant cation but are either a sulfate-type or bicarbonate-type (see Piper diagram on CD-ROM), with groundwater samples having TDS concentrations that mainly range from 1,000 mg/L to 5,000 mg/L (page A-45). Seventy-seven percent of the TDS concentrations in groundwater from the Foremost Aquifer are greater than 1,000 mg/L. The sulfate concentrations are mainly greater than 150 mg/L, with 40% of the groundwater samples having sulfate concentrations of more than 500 mg/L. Seventy percent of the chloride concentrations from the Foremost Aquifer are less than 100 mg/L, and 76% of the groundwater samples have fluoride concentrations that are less than 1.5 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 sodium and sulfate from water wells completed in the Foremost Aquifer are greater than the median concentrations from water wells completed in all Upper Bedrock Aquifer(s).

Constituent	No. of Analyses	Range for M.D. in mg/L Minimum	Maximum	Median	All Bedrock Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	26	167	6,302	2199	2,522	500
Sodium	19	7.0	2,185	577	363	200
Sulfate	23	2	3,070	480	23	500
Chloride	25	2	652	51	267	250
Fluoride	21	0	5	0.3	2.0	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 Foremost Aquifer

6.3.6 Milk River Aquifer

The Milk River Aquifer comprises the permeable parts of the Milk River Formation that underlie the Foremost Formation. The Milk River Formation is present under all of the M.D. Structure contours have been prepared for the top of the Milk River Formation. The structure contours show that the Milk River Formation ranges in elevation from 400 to 730 metres AMSL and has a maximum thickness of 110 metres. The regional groundwater flow direction in the Milk River Aquifer is downgradient, north toward the Oldman River and the Bow River (see CD-ROM).

6.3.6.1 Depth to Top

The depth to the top of the Milk River Formation ranges from 100 metres below ground surface at the eastern extent to 450 metres BGL in the extreme northwestern part of the M.D. (page A-47).

6.3.6.2 Apparent Yield

The apparent yields for individual water wells completed through the Milk River Aquifer are mainly greater than 30 m³/day, and have a median apparent yield value of 55 m³/day. However, in areas where groundwater levels have fallen (see section 7.4.2), the potential apparent yield would be reduced.

As of March 2004, 98 water wells were reclaimed under the Milk River Aquifer Reclamation and Conservation (MRARC) program funded by AAFC-PFRA, AENV, and the County of Forty Mile. There are 23 of these reclaimed water wells shown on the adjacent map.

There is one “dry” water test hole that is completed in the Milk River Aquifer.

There are 19 licensed and/or registered groundwater users that have water wells completed through the Milk River Aquifer, for a total authorized groundwater diversion of 116 m³/day, with a median authorized amount of 3.0 m³/day. The highest allocation is for a water supply well completed in the depth interval from 192 to 241 metres below ground surface in the Milk River Aquifer, that is licensed to divert 23.6 m³/day for agricultural (stock) purposes in 01-11-010-13 W4M.

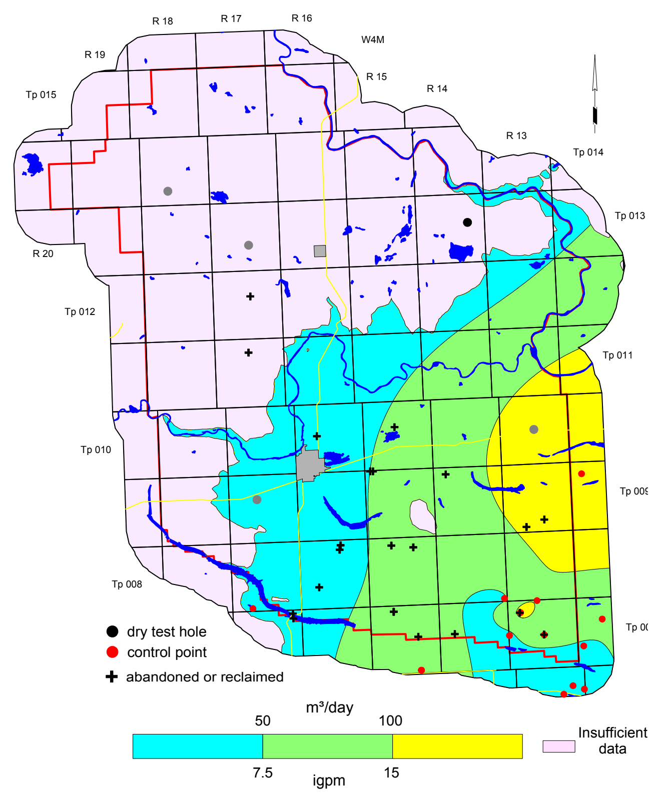

Figure 26. Apparent Yield for Water Wells Completed through Milk River Aquifer

Eighteen of the 19 licences and/or registrations could be linked to water wells in the AENV groundwater database.

6.3.6.3 Quality

The groundwaters from the Milk River Aquifer are mainly a sodium-bicarbonate-type or sodium-bicarbonate-chloride-type water (see CD-ROM).

Meyboom (1960) distinguished four chemical types of groundwaters from the Milk River Aquifer (Types A, B, C and D). Meyboom demonstrated that the degree of mineralization in groundwaters from the Milk River Aquifer increased to the north, east and west from the Sweet Grass Hills. Type A groundwaters are characterized by a moderate degree of mineralization, sodium-bicarbonate type-waters with TDS concentrations of less than 1,000 mg/L. In Type B groundwaters, the degree of mineralization has decreased and the sulfate concentrations have increased. Type D groundwaters are characterized by a high degree of mineralization, are sodium-chloride-type waters and believed by Meyboom to be unaltered connate[23] water. Type C groundwaters are transitional between Type A and Type D with alkalinity between 1,000 and 1,200 mg/L.

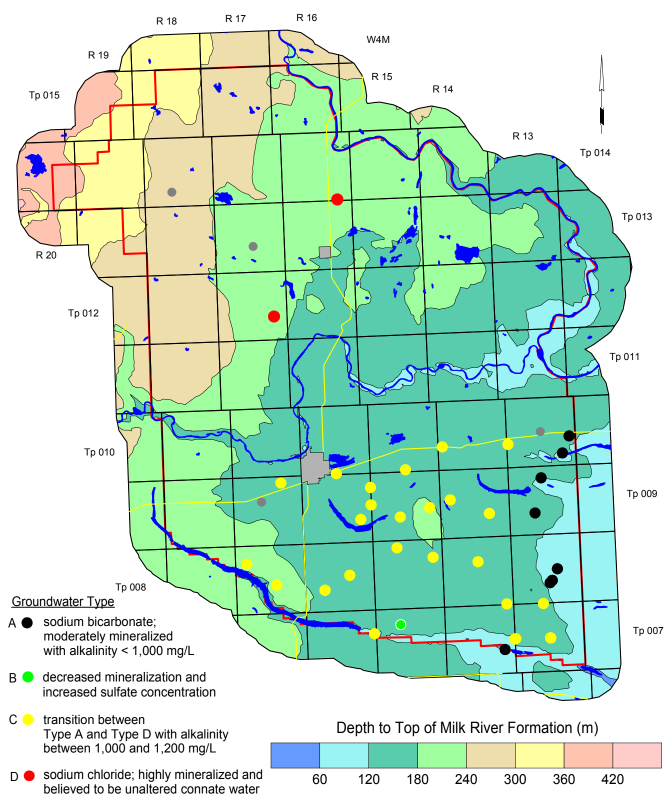

Figure 27. Types of Groundwaters from Milk River Aquifer (modified after Meyboom, 1960)

The four types of groundwaters from the Milk River Aquifer shown on Figure 25 were determined using Meyboom's criteria of varying concentrations of alkalinity, sulfate and chloride from chemical analyses of groundwater from water wells completed in the Milk River Aquifer and have been compared to the depth to the top of the Milk River Formation. Although there are anomalies, there appears to be a consistent relationship between groundwater type and depth to top of Formation.

Type A groundwaters from the Milk River Aquifer are mainly where the depth to top of the Formation is between 60 and 120 metres below ground surface. In the M.D., there is only one groundwater sample that meets the criteria of a Type B groundwater from the Milk River Aquifer. The water well is completed in the same depth interval as Type C groundwaters, and is located near the tributary to the Buried Skiff Valley. Type C groundwaters from the Milk River Aquifer are mainly where the top of the Milk River Formation is between 120 and 180 metres below ground surface. Type D groundwaters from the Aquifer are where the depth to top of the Formation is between 180 and 240 metres below ground surface.

The TDS concentrations in the groundwaters from the Milk River Aquifer range mainly from 1,000 to 3,000 mg/L (see page A-49). Ninety-five percent of the sulfate concentrations in groundwaters from the Milk River Aquifer are less than 100 mg/L. More than 90% of the chloride concentrations from the Milk River Aquifer are greater than 100 mg/L, and 87% of the fluoride concentrations from the Milk River Aquifer are greater than 1.5 mg/L.

[23] Chemical composition of groundwater at time of rock formation and, therefore, not altered by meteoric water.

The fluoride concentrations in the groundwaters from the Milk River Aquifer range from less than 0.5 mg/L to more than 5 mg/L in the western part of the M.D. (see CD-ROM). The median fluoride concentrations in groundwaters from the Milk River Aquifer have been compared to the median fluoride concentrations in groundwaters from the Oldman and Foremost aquifers. The bar chart shows that the highest median fluoride concentration in the Milk River Aquifer of 3.1 mg/L is more than two milligrams per litre higher than the groundwaters in the Oldman Aquifer.

Of the five constituents that have been compared to the SGCDWQ, the median values of TDS, sodium, chloride and flouride exceed the guidelines. The median concentrations of TDS, sodium, chloride and flouride from water wells completed in the Milk River Aquifer are greater than the median concentrations from water wells completed in all Upper Bedrock Aquifer(s).

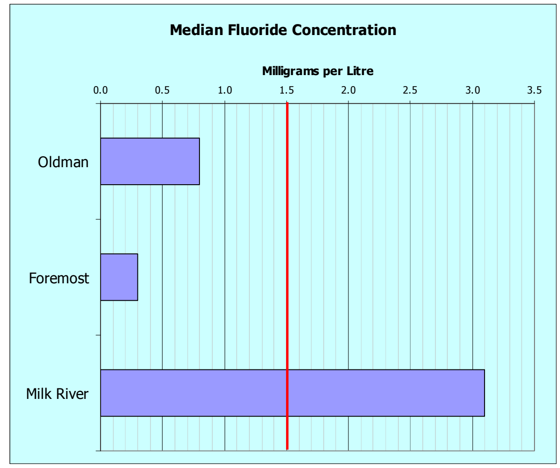

Figure 28. Median Fluoride Concentrations

Constituent	No. of Analyses	Range for M.D. in mg/L Minimum	Maximum	Median	All Bedrock Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	64	1182	6,847	2566	2,522	500
Sodium	38	463.0	3,425	888	363	200
Sulfate	60	0	385	5	23	500
Chloride	61	14	1630	523	267	250
Fluoride	47	0	9	3.1	2.0	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 Milk River Aquifer

7 GROUNDWATER BUDGET

7.1 Hydrographs

In the M.D., there are three observation water wells (Obs WWs) that are part of the AENV Groundwater Observation Well Network (GOWN) where water levels are being or have been measured and recorded as a function of time: (1) Enchant 2520E (GOWN 278) in 02-02-014-19 W4M; (2) Hays 2523E (GOWN 279) in 16-36-013-15 W4M; and (3) Hays 2524E (GOWN 280) in 16-36-013-15 W4M (see page A-54).

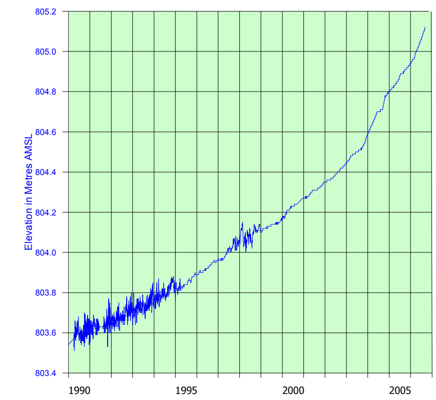

Figure 29. Hydrograph – AENV Obs WW No. 278

AENV Obs WW No. 278 is located southeast of the Little Bow Lake Reservoir and is completed from 32.9 to 36.0 metres below ground surface in the Upper Sand and Gravel Aquifer. The water level in AENV Obs WW No. 278 has been measured since April 1990. Since 1990, the water level in AENV Obs WW No. 278 has had a net rise of 1.55 metres over the entire monitoring period. As per a conversation in August 2007 with Jeff Gutsell, a hydrogeologist at the AENV Lethbridge office, the water-level rise is a result of leakage from the nearby irrigation canal. A screen capture (Google Earth), shown in Figure 30, and on page A-55 shows the proximity of the Obs WW to the irrigation canal.

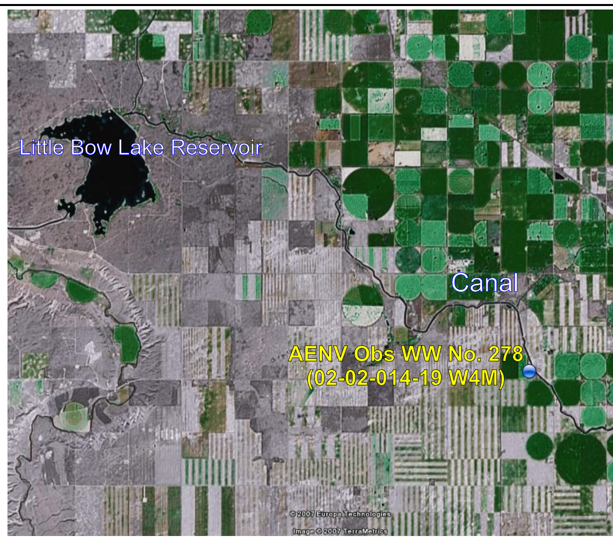

Figure 30. Location of AENV Obs WW No. 278 in Relation to an Irrigation Canal

AENV Obs WW No. 280 is completed from 7.3 to 9.1 metres below ground surface in the Upper Sand and Gravel Aquifer. The water level in AENV Obs WW No. 280 was measured from Jan 1990 to Aug 1997. The hydrograph shows that there are annual fluctuations ranging from 0.25 metres in 1990 to 0.8 metres in 1992. The hydrograph shows at least two peaks per year for the entire monitoring interval. The first peak in a given year would be associated with recharge when the frost leaves the ground in late spring/early summer and the second peak coincides with the end of the growing season after most vegetation has been killed by frost and before the ground is frozen.

The water-level fluctuations in ANEV Obs WW No. 279 (see page A-57) and in AENV Obs WW No. 280 shown in Figure 31 have been compared to the monthly precipitation measured at the Taber weather station. In most years, there appears to be a close relationship between the monthly precipitation and the water level.

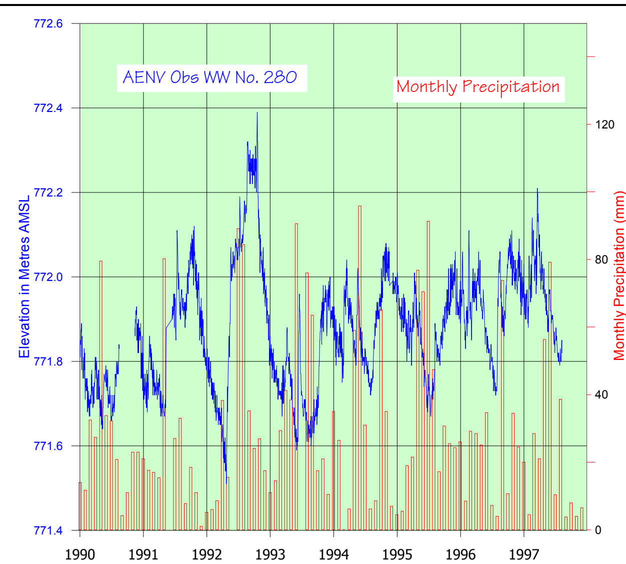

Figure 31. Comparison of Water Levels in AENV Obs WW No. 280 to Precipitation

7.2 Estimated Groundwater Use in the M.D. of Taber

An estimate of the quantity of groundwater removed from each geologic unit in the M.D. of Taber must include both the groundwater diversions with licences and/or registrations and the groundwater diversions without licences and/or registrations. As stated previously on page 12 of this report, the daily water requirement for livestock for the M.D. based on the 2006 census is 10,394 cubic metres. AENV has licensed the use of 2,408 m³/day for livestock, which includes both surface water (based on consumptive use) and groundwater in the M.D. of Taber. To obtain an estimate of the quantity of groundwater being diverted from the individual geologic units, it has been assumed that the remaining 7,986 m³/day of water required for livestock watering is obtained from other approved sources of surface water. Under the *Water Act*, Section 51(6), "a licensee of water for irrigation purposes is entitled to divert, as part of the acquired water,

(a) up to a maximum of 1,250 cubic metres of water per year for household purposes,

and

(b) up to a maximum of 6,250 cubic metres of water per year for the purposes of raising animals", or….

As a result, an additional 1,027 m³/day could be diverted for stock watering use based on the 60 licensed users in the M.D. authorized to divert surface water for irrigation purposes. In addition to the 1,027 m³/day, an amendment to a Licence for the Taber Irrigation District (TID) allows the TID to deliver water for purposes other than irrigation, including stock watering, for up 27,047 m³/day.

Ranchers do not need to license the water source for free-ranging cattle that have access to surface water, as long as the water is not pumped to a dugout or cattle waterer. It is also suspected that there are many unlicensed dugouts used for stock.

Because of the limitations of the data, it has, therefore, been assumed that all livestock use has been accounted for.

In the M.D., there are a total of 477 water wells being used for domestic/stock (278) or stock (199) purposes. It has been assumed that these 477 water wells are active; however, many are very old and may not be in use or may have been abandoned.

Groundwater for household use requires 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 535 domestic or domestic/stock water wells in the M.D. of Taber serving a population of 6,012, the domestic use per water well is 2.6 m³/day. Because it does not appear that there is any stock use without a licence and/or registration, 2.6 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.

	Domestic and Domestic/Stock Diversions					*Licensed and/or Registered Groundwater Diversions*	*Total Groundwater Diversions*
Aquifer Designation	Number of Domestic	Daily Use (2.6 m³/day)	Number of Domestic and Stock	Daily Use (2.6 m³/day)	Totals m³/day	Totals (m³/day)	Totals (m³/day)
Upper Sand and Gravel	149	387	164	426	814	628	1442
Lower Sand and Gravel	7	18	3	8	26	7	33
Mulitple Bedrock Completion	3	8	18	47	55	35	90
Bearpaw	0	0	1	3	3	2	5
Oldman	17	44	9	23	68	0	68
Foremost	22	57	20	52	109	35	145
Lea Park	0	0	0	0	0	0	0
Milk River	31	81	53	138	218	116	335
Saline	0	0	2	5	5	297	303
Unknown	28	73	8	21	94	55	149
Totals (1)	257	668	278	723	1391	1,177	2,568

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

Table 13. Total Domestic and Stock Groundwater Diversions by Aquifer

Based on using 2.6 m³/day for all available domestic or domestic/stock water wells, and the protected amount for licensed and/or registered water wells, an estimate of the groundwater use from each geologic unit was prepared, as shown in Table 12. The data provided in Table 12 indicate that 56% of the 2,568 m³/day is from the Upper Sand and Gravel Aquifer.

By assigning 2.6 m³/day for all available domestic or domestic/stock water wells, and using the total maximum authorized diversion associated with any licensed and/or registered water well, a map has been prepared that shows the estimated groundwater use in terms of volume per section per day for the M.D. (not including springs).

There are 1,766 sections in the M.D. In 78% (1,386) of the sections in the M.D., there is no domestic, stock or licensed and/or registered groundwater user. The groundwater use for the remaining 380 sections varies from 0.1 m³/day to 297 m³/day, with an average use per section of 6.9 m³/day. The estimated water well use per section can be more than ten m³/day in 27 of the 380 sections. Twenty-nine of the total of 78 licensed and/or registered groundwater users are in areas where the groundwater use is between five and ten m³/day; and twenty-two licensed and/or registered groundwater users are in areas where the groundwater use is greater than ten m³/day.

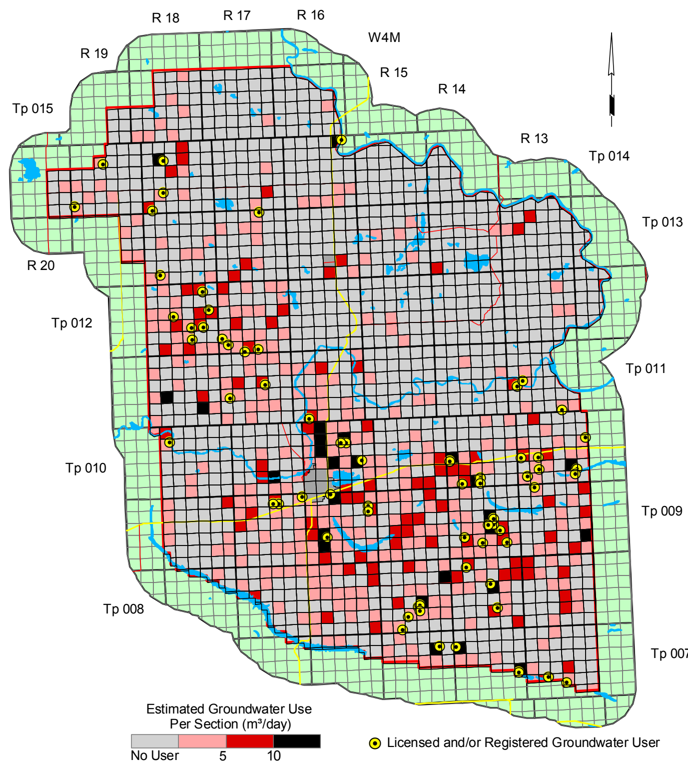

Figure 32. Estimated Water Well Use Per Section

In summary, the estimated total groundwater use within the M.D. is 2,568 m³/day, with the breakdown as shown in Table 13. Of the 2,568 m³/day, 1,475 m³/day (57%) is being diverted from surficial aquifers, and 944 m³/day (37%) is being diverted from bedrock aquifers. The remaining 149 m³/day (6%) is being withdrawn from unknown aquifer units. Approximately 46% of the total estimated groundwater use is from licensed and/or registered water wells.

Groundwater Use within the M.D. of Taber (m³/day)		%
Domestic/Stock (including agriculture and/or registrations)	2,233	*87*
Municipal (licensed)	0	*0*
Commercial/industrial (licensed)	335	*13*
Total	2,568	*100*

Table 14. Total Groundwater Diversions

7.3 Groundwater Flow

A direct measurement of groundwater recharge or discharge is not possible from the data that are available for the M.D. One indirect method of measuring recharge is to determine the quantity of groundwater flowing laterally through each individual aquifer. This method assumes that there is sufficient recharge to the aquifer to maintain

Aquifer/Area	Trans (m^2/day)	Gradient (m/m)	Width (km)	Flow (m^3/day)	Aquifer Flow (m^3/day)	Licensed and/or Registered Diversion (m^3/day)
Upper Surficial					7,472	628
Lethbridge Valley*						
North	14	0.00625	30	2,625		
North - Taber	14	0.00208	10	292		
East - Lamond	14	0.00313	10	438		
South - Vauxhaul	14	0.0025	25	875		
East - Oldman	14	0.00278	8	311		
Tee Pee						
east	14	0.00313	25	1,094		
north	14	0.00313	30	1,313		
Chin Lakes						
northeast	14	0.00375	10	525		
Lower Surficial					15,579	7
Lethbridge Valley*						
East	300	0.00033	10	1,000		
Vauxhall						
North	300	0.002	20	12,500		
Tributary to Skiff						
East	300	0.001	3	1,298		
Tee Pee						
East	300	0.001	5	781		
Oldman Formation					838	0.1
Enchant Highlands						
Northeast	2	0.003	30	150		
North	2	0.004	20	167		
Southwest	2	0.001	15	38		
Lamond Highlands						
Southeast	2	0.009	10	188		
South	2	0.004	10	83		
Chin Lakes Highland						
Northwest	2	0.003	10	63		
Northeast	2	0.004	20	150		
Foremost Formation					1,813	35
Enchant Highlands						
Northeast	4	0.002	40	333		
Southeast	4	0.003	25	313		
Southwest	4	0.004	10	167		
Chin Lakes Highland						
Northeast	4	0.003	60	750		
Northwest	4	0.006	10	250		
Milk River Formation					350	116
Northeast	1	0.003	20	50		
Northwest	1	0.005	60	300		

* This assumes the gravel aquifer is continuous from west to east and has saturated thickness of at least two metres.

Table 15. Groundwater Budget

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 M.D.

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

Table 15 indicates that there is more groundwater flowing through the aquifers than has been authorized to be diverted from the individual aquifers. 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 for future investigations.

7.3.1 Quantity of Groundwater

An estimate of the volume of groundwater stored in the surficial deposits is 0.7 to 3.9 cubic kilometres. This volume is based on an areal extent of 2,600 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 non-pumping 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 and for calculations of recharge/discharge areas. 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 the main flow direction toward the Oldman and Bow River valleys.

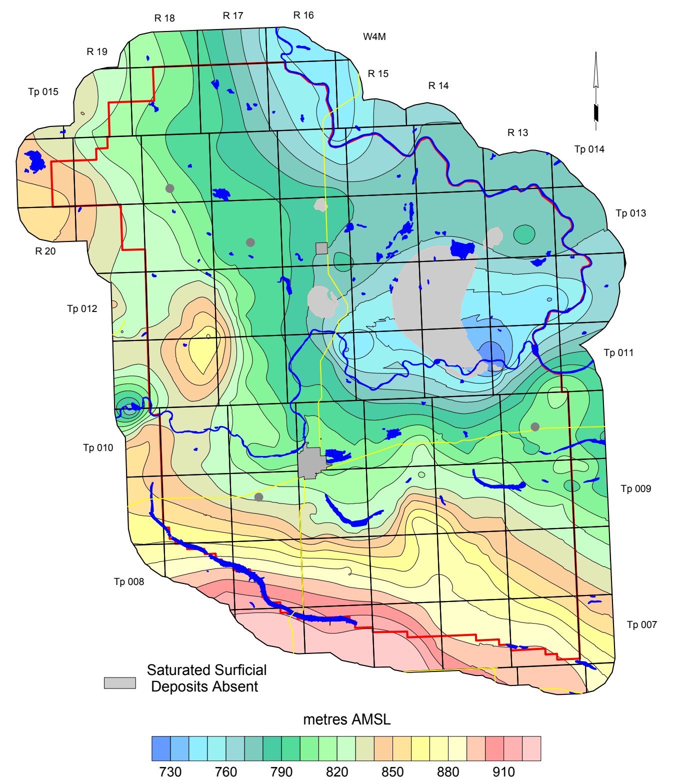

Figure 33. Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep

7.3.2 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.

7.3.2.1 Bedrock Aquifers

In the absence of sufficient water-level data in the surficial deposits and in the upper bedrock aquifer(s), 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 five 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 five metres below and ten metres above the bedrock surface, the area is classified as a transition, that is, no recharge and no discharge.

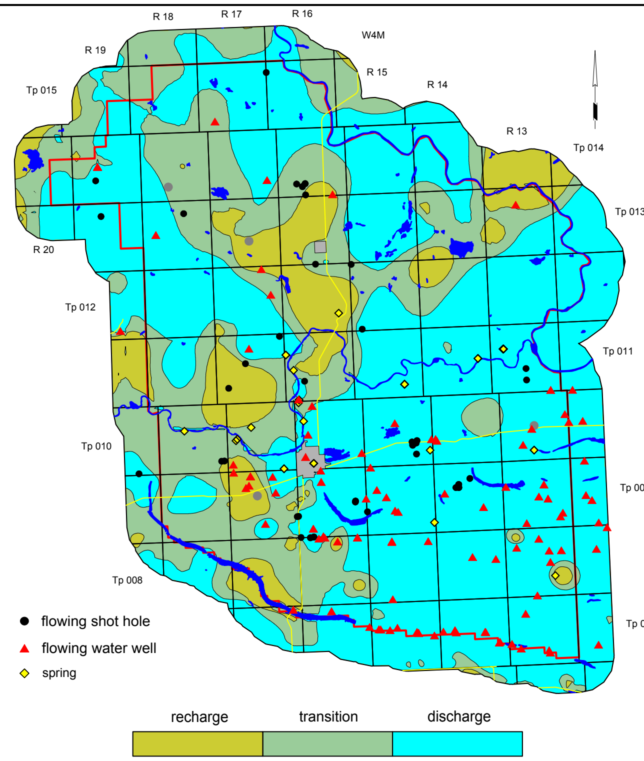

Figure 34. Bedrock Recharge/Discharge Areas

Figure 34 shows that, in nearly 15% of the M.D., there is a downward hydraulic gradient from the bedrock surface toward the upper bedrock aquifer(s) (i. e. recharge).

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

With nearly 15% of the M.D. land area being one of recharge to the bedrock, and the average precipitation being 376 mm per year, 0.4% of the annual precipitation is sufficient to provide the total calculated quantity of groundwater flowing through the upper bedrock aquifer(s).

7.4 Areas of Groundwater Decline

In order to determine the areas of possible water-level decline in the Sand and Gravel Aquifer(s) and in the Upper Bedrock Aquifer(s), the following approach was used. The available non-pumping water-level elevation for each water well was first sorted by location, and then by date of water-level measurement. The dates of measurements in the Sand and Gravel Aquifer(s) and in the Upper Bedrock Aquifer(s) (see CD-ROM) were required to differ by at least one year, and in most cases differed by 15 years. The method of calculating changes in water levels is at best an estimate. Additional data would be needed to verify water-level change.

7.4.1 Sand and Gravel Aquifer(s)

Of the 455 surficial water wells with a non-pumping water level and date in the M.D. and buffer area, there are 41 with sufficient control to prepared the adjacent map.

Where the earliest water level is at a higher elevation than the latest water level, there is the possibility that some groundwater decline has occurred. 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 rise or a decline in NPWL of more than five metres may reflect the nature of gridding a limited number of control points.

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.

Figure 35 indicates that in 45% of the M.D. where surficial deposits are present, it is possible that the non-pumping water level has declined.

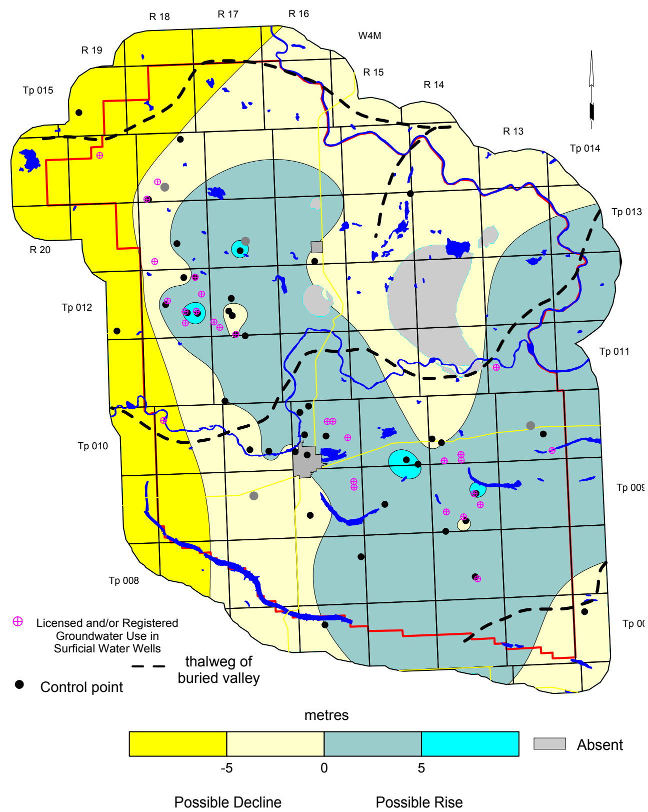

Figure 35. Changes in Water Levels in Surficial Deposits

7.4.2 Milk River Aquifer

The Milk River Aquifer is the main source of groundwater for domestic and stock purposes in the M.D.

The database indicates that there have been at least 246 water test holes in the M.D. drilled into the Milk River Aquifer since 1910, of which 156 appear not to be in use. The water-level decline in the Milk River Aquifer has been a subject of research since 1910, with Meyboom (1960) being the main source of reference and comparison.

Of the 128 water wells completed in the Milk River Aquifer with a non-pumping water level and date in the M.D. and buffer area, there are 16 with sufficient control to prepared the adjacent map. Of the 16 water wells, there are more than 30 years between water-level measurements for 12 water wells. The adjacent map indicates that in 38% of the M.D. having sufficient data, it is possible that the non-pumping water level has declined. Of the 19 licensed and/or registered groundwater users completed in the Milk River Aquifer, 12 occur in areas where a water-level decline may have occurred.

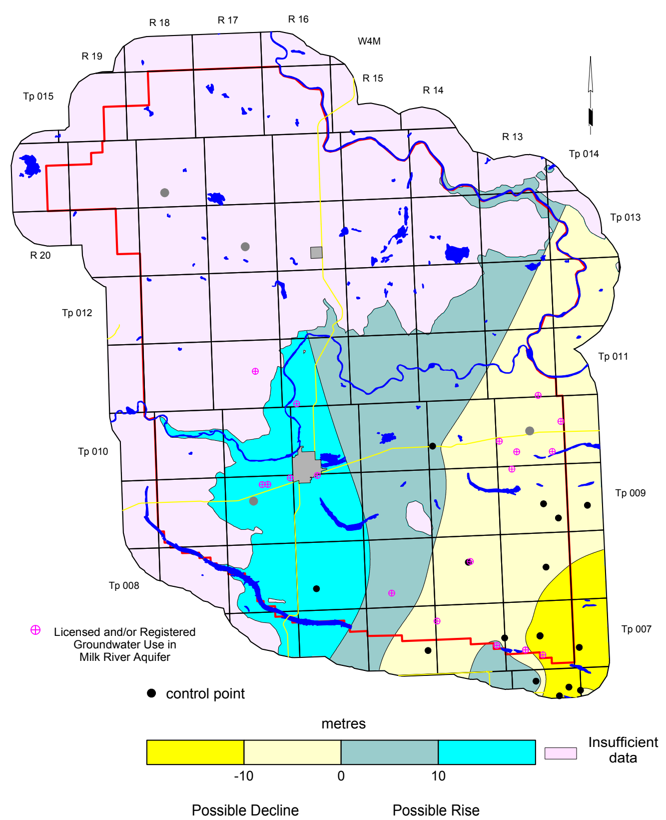

Figure 36. Areas of Potential Groundwater Decline – Milk River Aquifer

Where the earliest water level is at a higher elevation than the latest water level, there is the possibility that some groundwater decline has occurred. Most of the areas in which the map suggests that there has been a rise in NPWL may reflect the nature of gridding a limited number of control points.

In areas where a water-level decline is projected, 65% of the areas have no estimated water well use; 23% of the use is less than five m³/day; 9% of the use is between five and ten m³/day; and the remaining 3% of the declines occurred where the estimated groundwater use per section is greater than 10 m³/day, as shown below in Table 15.

Estimated Water Well Use Per Section (m³/day)	*% of Area with a Decline*
<10	*8*
10 to 50	*24*
>50	*3*
no use	*65*

Table 16. Water-Level Decline in Milk River Aquifer

The areas of groundwater decline in the Milk River Aquifer 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, or due to uncontrolled, unused, flowing water wells, or because the water wells are not on file with AENV.

8 RECOMMENDATIONS

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

1) the quality of the data
2) the coordinate system used for the horizontal control
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. From 1999 to 2002, the status of 74 water wells in the M.D. was field-checked by AAFC-PFRA personnel (see Appendix E). This water well inventory program was one of several steps initiated by the Milk River Aquifer Groundwater Management Advisory Committee to protect the Milk River Aquifer (AAFC-PFRA, Oct 2003). Of the 74 field-checked water wells, 35 water wells were in use and 39 were inactive. A water level was measured in 11 water wells, of which two water-level measurements were from inactive water wells. The groundwater database indicates that of the 11 field-checked water wells where a water level was measured, there is only one water well record (see Appendix E) with an available completion interval top and completion interval bottom, an NPWL and a calculated apparent transmissivity and apparent yield value. This water well was last used in 1993, and was reclaimed by PFRA in June, 2000.

In order to better quantify the groundwater resources, it is recommended that some additional water wells be field verified. Appendix E includes a list of 15 water wells where field verification is recommended. Seven of the water wells in the list are water wells indicated as having a complete water well drilling report and the results of at least a partial chemical analysis; the list also includes eight water wells for which the M.D. has responsibility.

As part of the field verification of these 15 water wells, there is a need to obtain meaningful horizontal coordinates for each water well and the verification of certain parameters such as water level, specific capacity, completed depth, and the collection of a groundwater sample for at least a routine chemical analysis.

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 seven water wells listed in Appendix E for which water well drilling reports are available, the eight M.D.-operated water wells listed in Appendix E, plus the nine water wells recommended for further testing listed in Appendix E 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 83 or some other system that will allow conversion to 10TM NAD 83 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.

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 24 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 58% successful in this study (see CD-ROM); forty-two percent of the 78 licensed and/or registered 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 unlicensed and not registered 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 County of Rocky View and in the M.D. of Flagstaff, 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. M.D. personnel and/or local residents could measure the water levels in the water wells regularly.

The County of Grande Prairie recognizes that economic growth must be balanced with environmental objectives to ensure the preservation and enhancement of its prosperity, and the quality of life for its residents and, has therefore, taken special interest in ensuring long-term water supplies by proposing further groundwater investigation within the area to try to quantify the availability of groundwater through further studies.

In 2006, the County of Grande Prairie committed to and requested funding for a five-year program to sample and monitor 50 water wells. Funding for the first two years from the existing Canada-Alberta Water Supply Expansion Program (CAWSEP) was requested to initiate and cover costs to the maximum allowable for a project of this nature. For years three, four, and five, the County of Grande Prairie will then work together with any future programming that may be available to continue this project.

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 M.D. taking an active role in the activities associated with the construction of lease sites for the drilling of hydrocarbon wells and conducting of seismic programs.

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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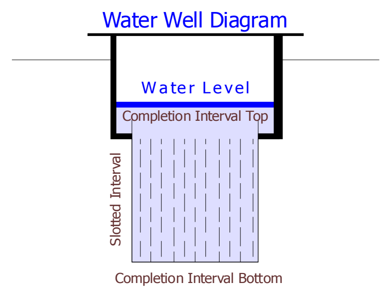
10 GLOSSARY

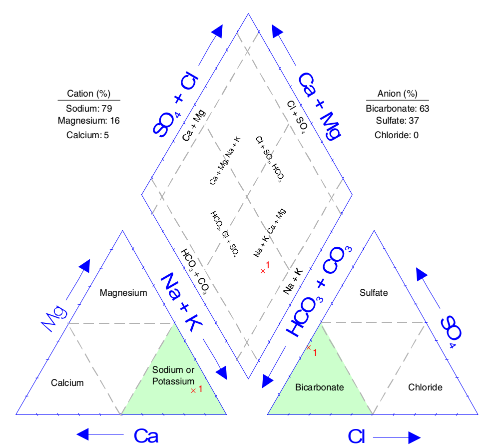
AAFC-PFRA	Prairie Farm Rehabilitation Administration Branch of Agriculture and Agri-Food Canada
AENV	Alberta Environment
AMSL	above mean sea level
Anion	negatively charged ion
Aquifer	a formation, group of formations, or part of a formation that contains saturated permeable rocks capable of transmitting 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
BGP	Base of Groundwater Protection
Borehole	includes all “work types” except springs
Bsk	a climate classification that is characterized by its moisture deficiency, where mean annual potential evapotranspiration exceeds the mean annual precipitation (Thornthwaite and Mather, 1957).
Cation	positively charged ion
Completion Interval	see diagram



Completion Interval

DEM	Digital Elevation Model
DST	drill stem test
EUB	Alberta Energy and Utilities Board
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)
Friable	poorly cemented
Geologic Unit	a distinguishable rock unit based on rock type and/or rock age
Hydraulic Conductivity	the rate of flow of water through a unit cross-section under a unit hydraulic gradient; units are length/time
Hydraulic Unit	a rock type where changes in hydraulic head at one location directly impact hydraulic-head conditions at all locations measurable in less than a year

Hydrogeologic Unit	a hydrogeologic setting comprised of one or more saturated rock types where groundwater characteristics are closely related
Kriging	a geo-statistical method for gridding irregularly-spaced data (Cressie, 1990)
Lithology	description of rock material
Lsd	Legal Subdivision
m^2/day	metres squared per day
m^3	cubic metres
m^3/day	cubic metres per day
mg/L	milligrams per litre
Median	the value at the centre of an ordered range of numbers
NPWL	non-pumping water level
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
SGCDWQ	Summary of Guidelines for Canadian Drinking Water Quality
Surficial Deposits	includes all sediments above the bedrock
Thalweg	the lowest elevation of a linear bedrock low
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, discharge rate and time of discharge

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 and 70% of available drawdown

Long-Term Yield: the method used for determining the theoretical long-term yield in the Alberta Environment Groundwater Evaluation Guidelines, and based on effective transmissivity

11 CONVERSIONS

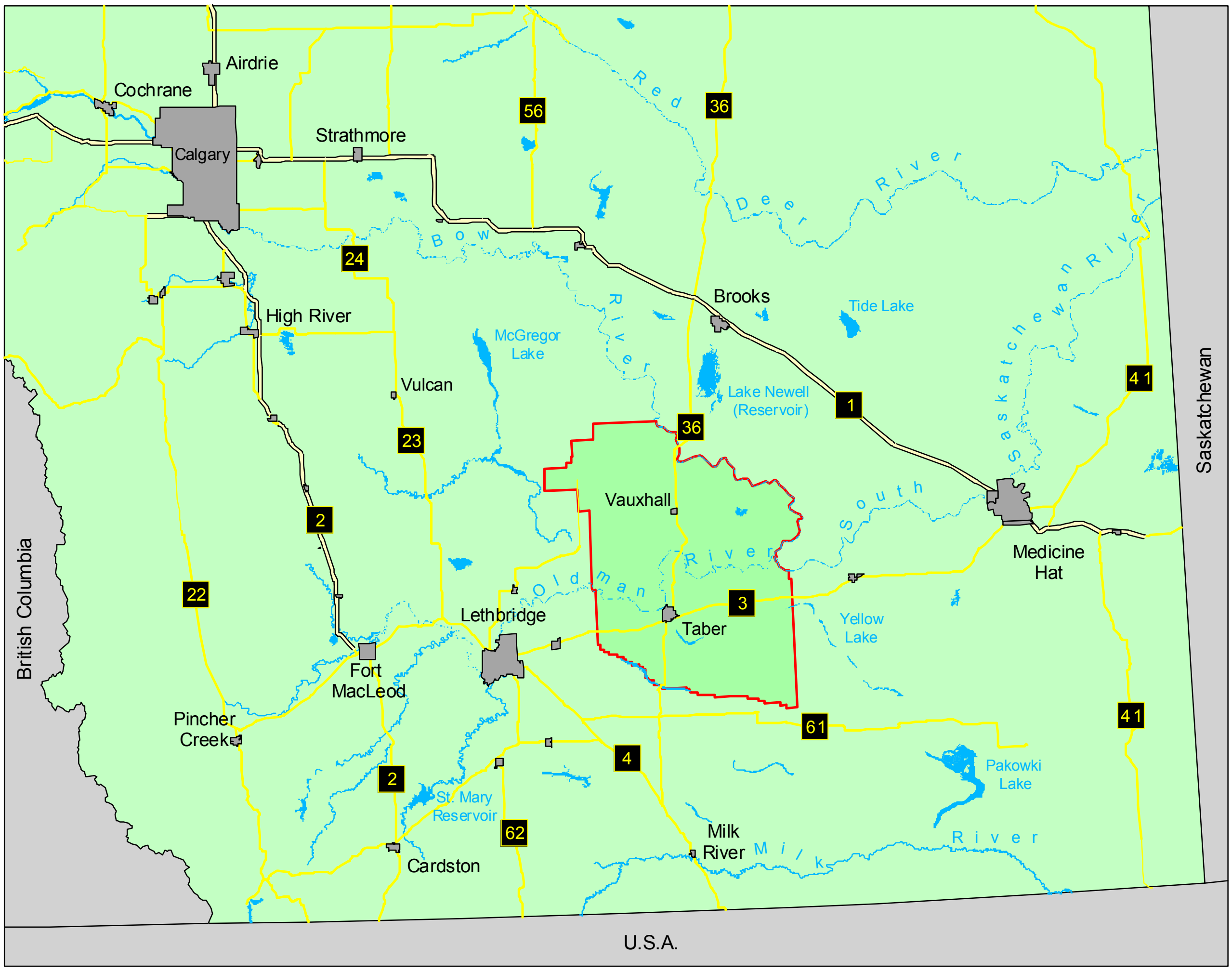
Multiply	by	To Obtain
Length/Area		
feet (ft)	0.3 048	metres
metres (m)	3.2 810	feet
hectares (ha)	2.4 711	acres
centimetre (cm)	0.0 328	feet
centimetre	0.3 937	inches
acres (ac)	0.4 047	hectares
inches (in)	25.4 000	millimetres
miles (mi)	1.6 093	kilometres
kilometre (km)	0.6 214	miles (statute)
square feet (ft^2)	0.0 929	square metres (m^2)
square metres (m^2)	10.7 639	square feet (ft^2)
square metres (m^2)	0.0 000	square kilometres (km^2)
Concentration		
grains/gallon (UK)	14.2 700	parts per million (ppm)
ppm	0.9 989	mg/L
mg/L	1.0 011	ppm
Volume (capacity)		
acre feet	1233.4 818	cubic metres
cubic feet	0.0 283	cubic metres
cubic metres	35.3 147	cubic feet
cubic metres	219.9 692	gallons (UK)
cubic metres	264.1 721	gallons (US liquid)
cubic metres	1000.0 000	litres
gallons (UK)	0.0 045	cubic metres
imperial gallons	4.5 460	litres
Rate		
litres per minute (lpm)	0.2 200	UK gallons per minute (igpm)
litres per minute	1.4 400	cubic metres/day (m^3/day)
igpm	6.5 463	cubic metres/day (m^3/day)
cubic metres/day	0.1 528	igpm

M.D. OF TABER

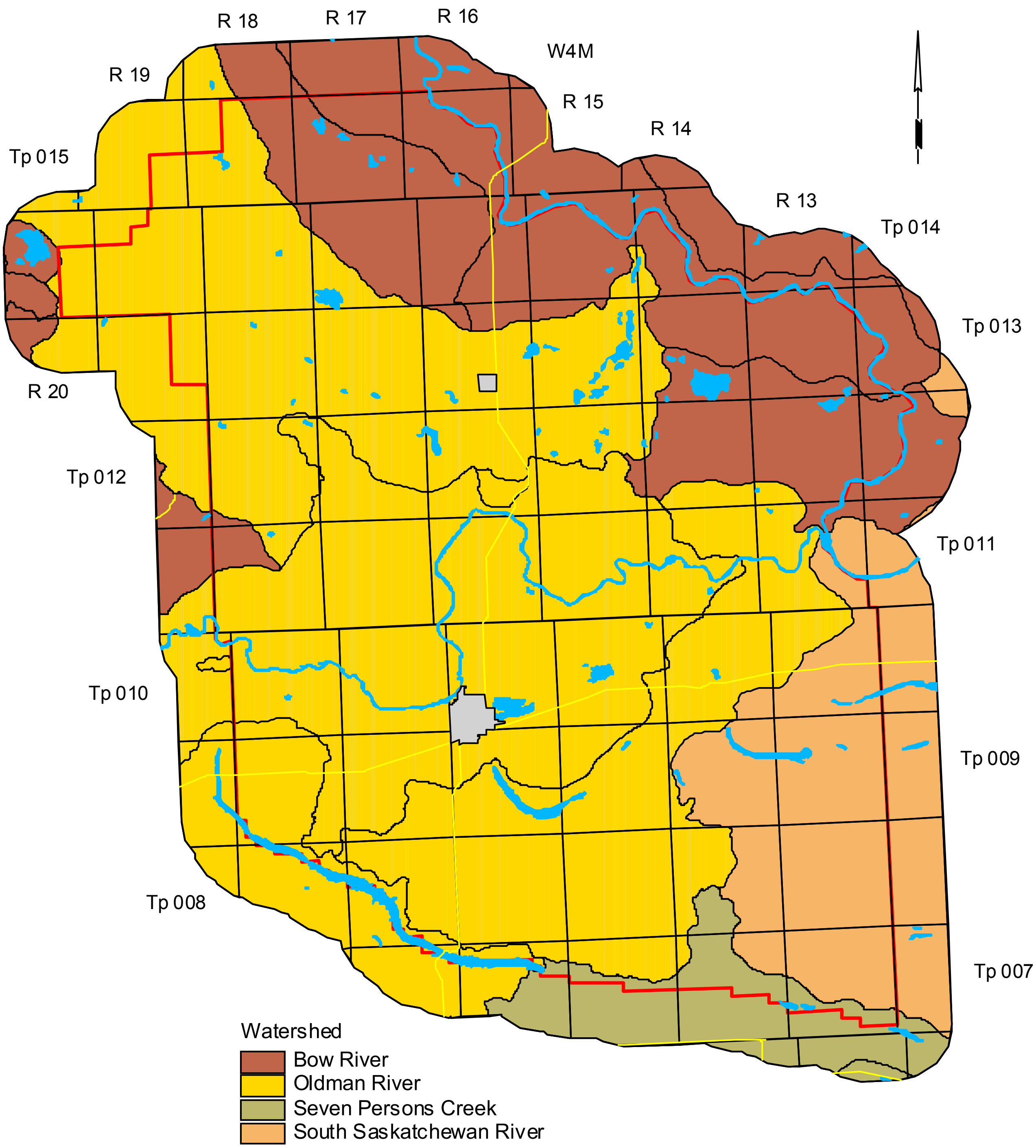
Appendix A

Hydrogeological Maps and Figures

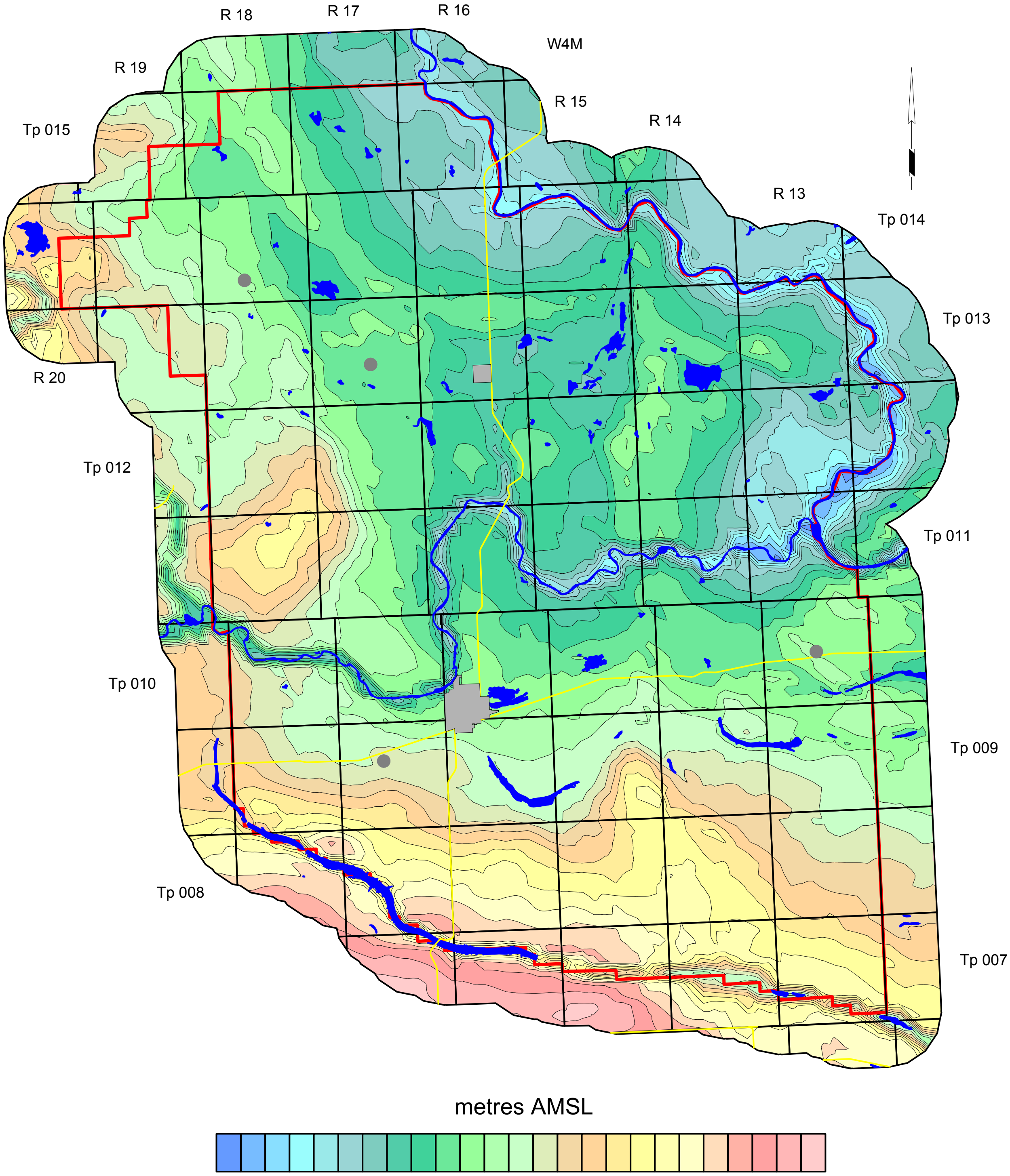
Index Map


Airdrie
Cochrane
Calgary
Strathmore
56
36
Red
Deer
River
Bow
24
High River
McGregor Lake
Brooks
Tide Lake
Lake Newell (Reservoir)
Vulcan
23
River
1
36
41
Saskatchewan
Saskatchewan River
Vauxhall
South
2
22
British Columbia
Oldman
River
3
Taber
Lethbridge
Medicine Hat
Yellow Lake
Fort MacLeod
Pincher Creek
61
41
4
2
St. Mary Reservoir
Pakowki Lake
62
Milk River
Milk
River
Cardston
U.S.A.

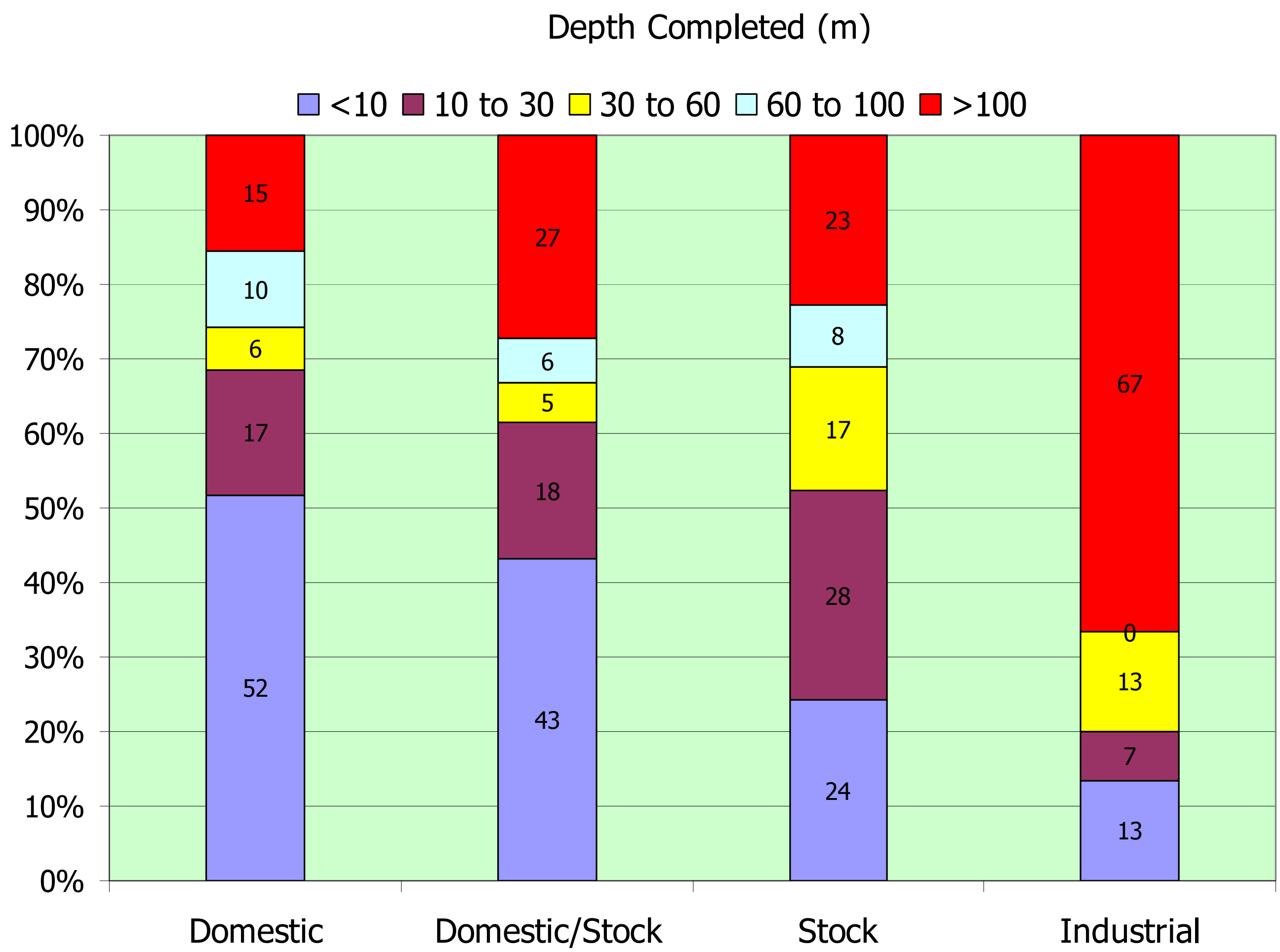
River Sub-Basins

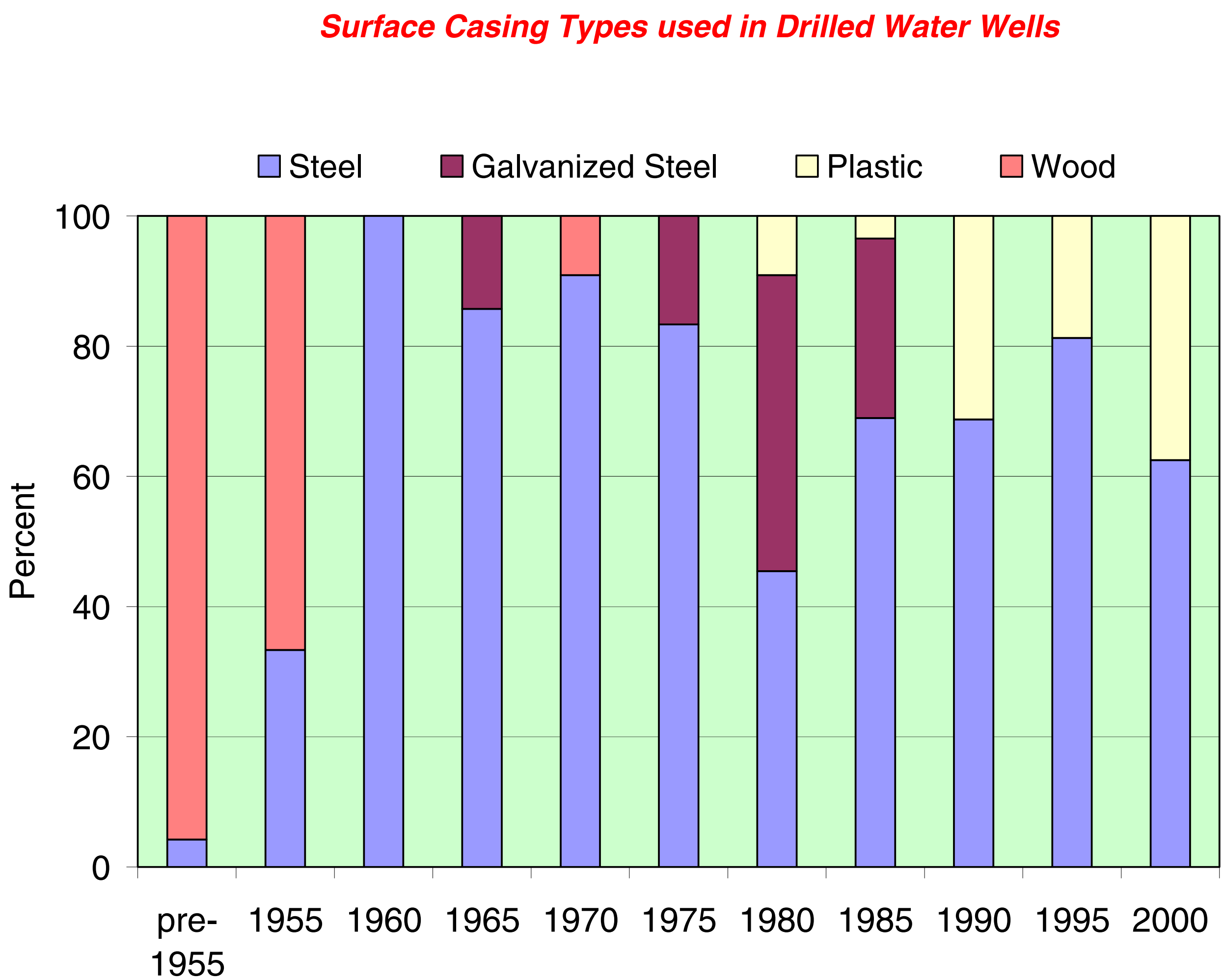


Surface Topography

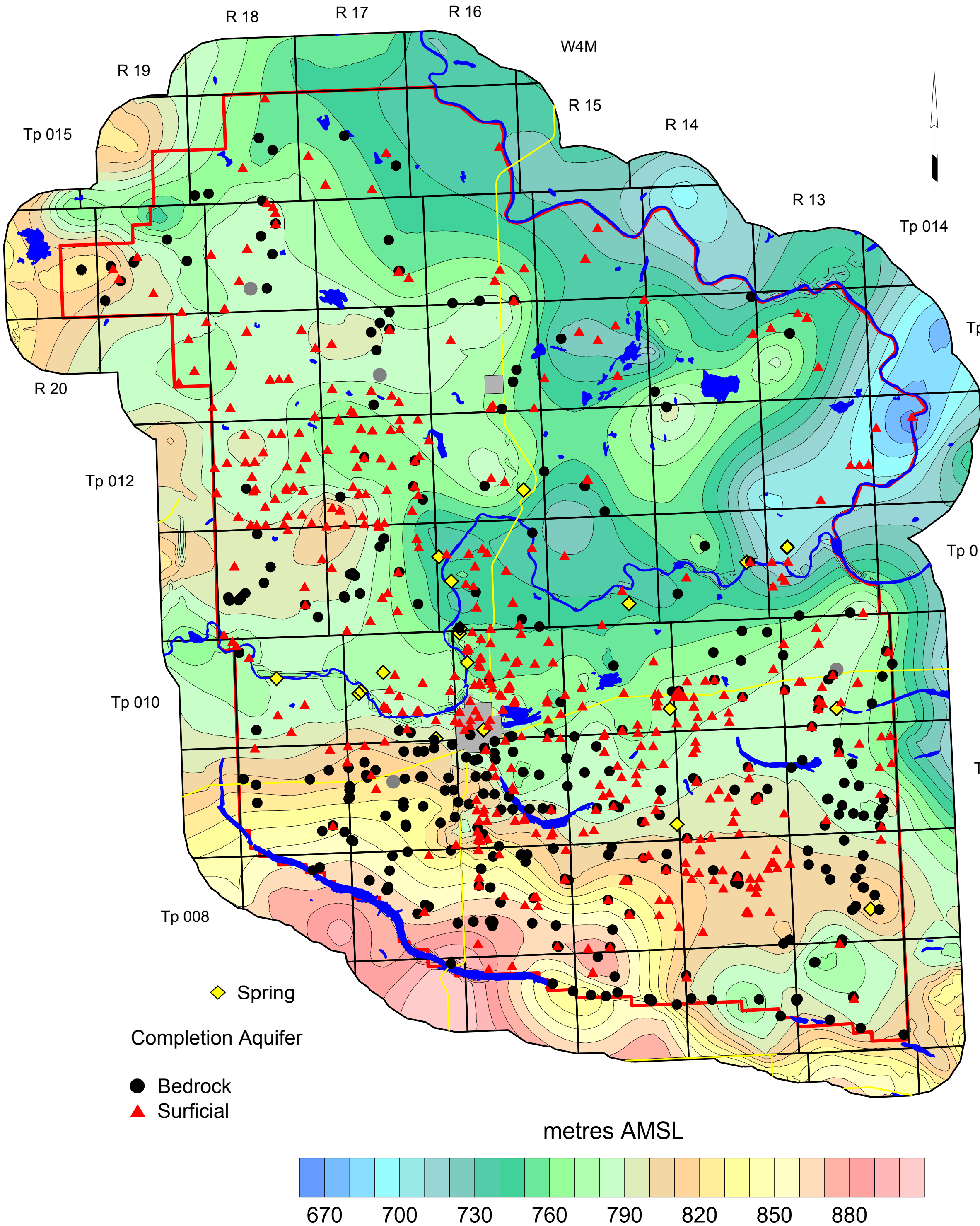


Proposed Use vs Completed Depth

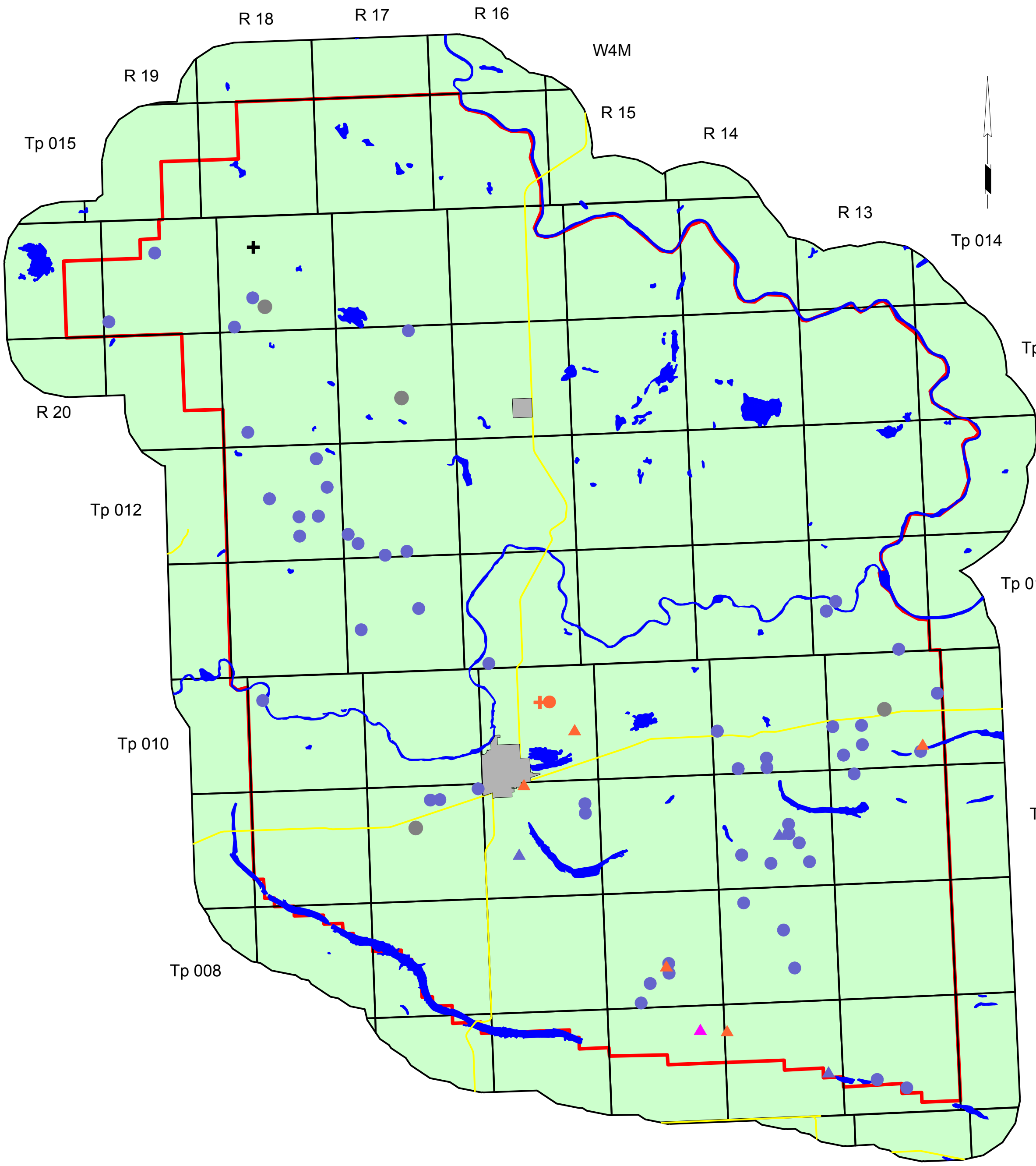



Surface Casing Types used in Drilled Water Wells
Steel
Galvanized Steel
Plastic
Wood
Percent
0
20
40
60
80
100
pre-1955
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000

Location of Water Wells and Springs Relative to Bedrock Topography



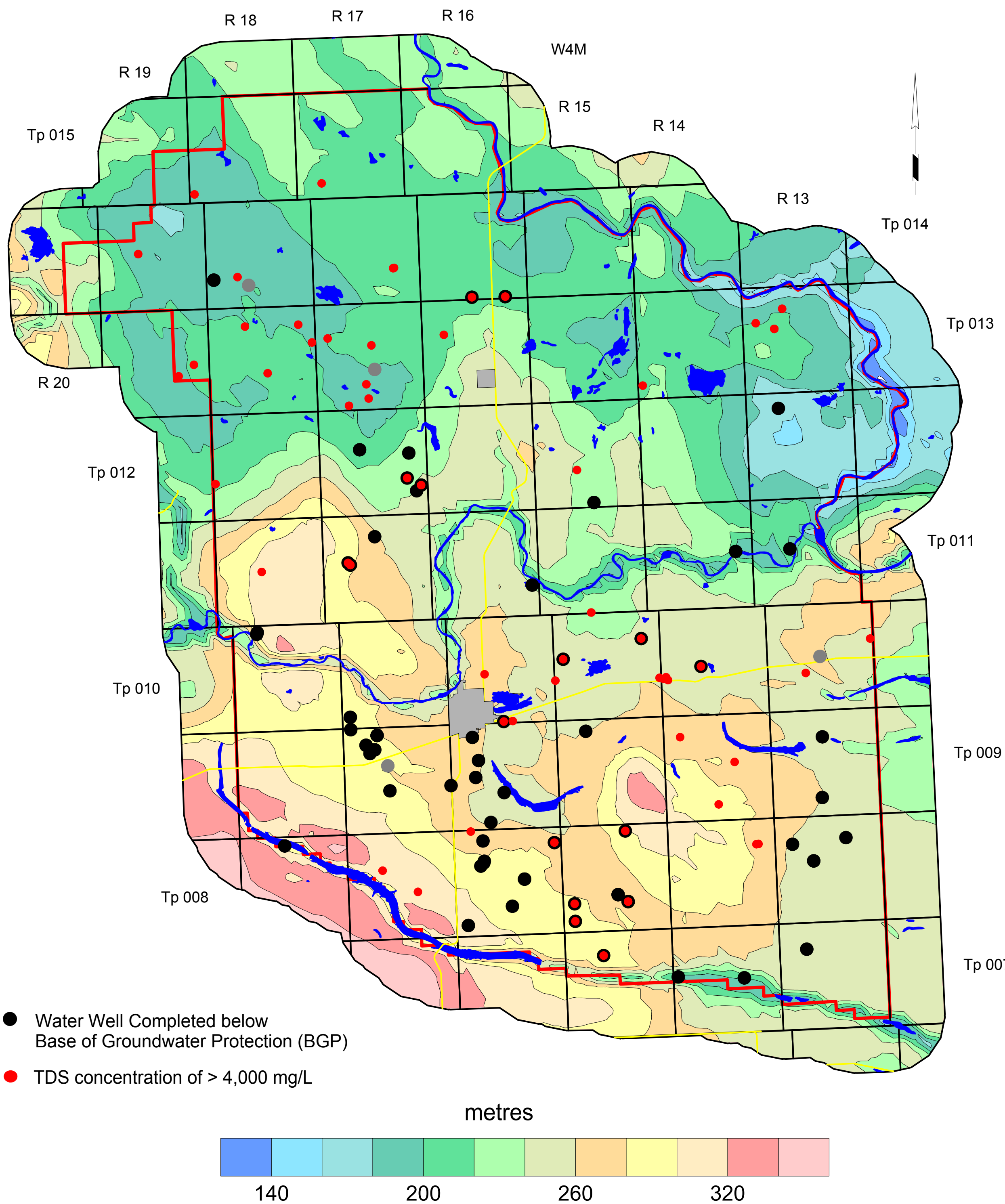
Licensed and Registered Groundwater Water Wells



m³/day	registration	agricultural	industrial	commercial
< 10	● (65)	● (1)	● (0)	● (0)
10 to 50	▲ (3)	▲ (5)	▲ (0)	▲ (1)
> 50	+ (0)	+ (2)	+ (1)	+ (0)

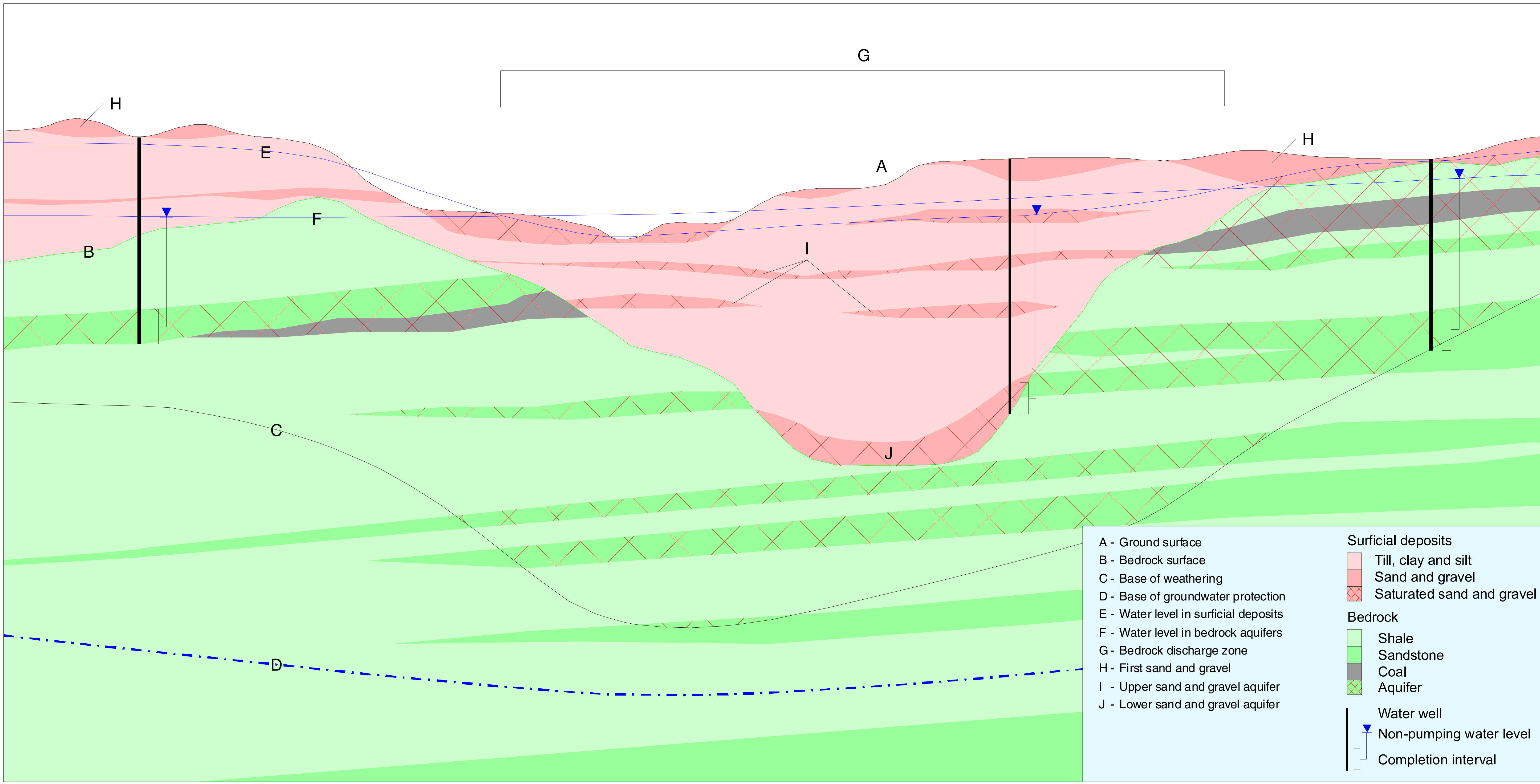
Depth to Base of Groundwater Protection

(modified after EUB, 1995)



Generalized Cross-Section

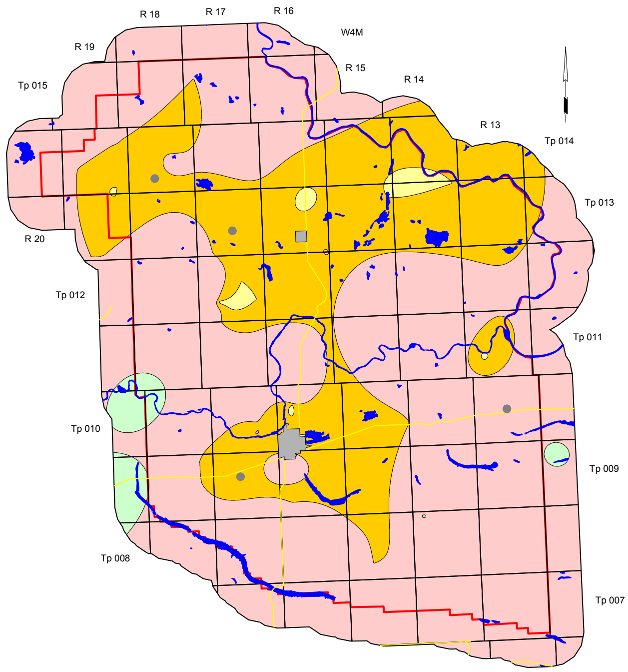
(for terminology only)



Geologic Column

Lithology	Lithologic Description	Group and Formation: Average Thickness (m)	Group	Formation Thickness (m)	Group and Formation: Designation	Member: Average Thickness (m)	Member: Designation	Zone: Average Thickness (m)	Zone: Designation
	sand, gravel, till, clay, silt	<140			Surficial Deposits	<140	Upper	<30	First Sand and Gravel
						<50	Lower		
	shale, sandstone, siltstone	60-120			Bearpaw Formation				
	sandstone, siltstone, shale, coal	<300	Belly River Group	40-130	Oldman Formation		Dinosaur Member	<25	Lethbridge Coal Zone
							Upper Siltstone Member		
							Comrey Member		
	sandstone, shale			<200	Foremost Formation	<70	Birch Lake Member		Taber Coal Zone
						<60	Ribstone Creek Member		
						<70	Victoria Member		McKay Coal Zone
						0-30	Brosseau Member		
	shale, siltstone	100-150			Lea Park Formation (Pakowki)				
	sandstone, siltstone, shale, coal	120-150			Milk River Formation	<50	Sandstone Unit		
	shale, siltstone	200-1000	Colorado Group		Colorado Shales				
	sandstone, mudstone, shale	50			Viking Formation				

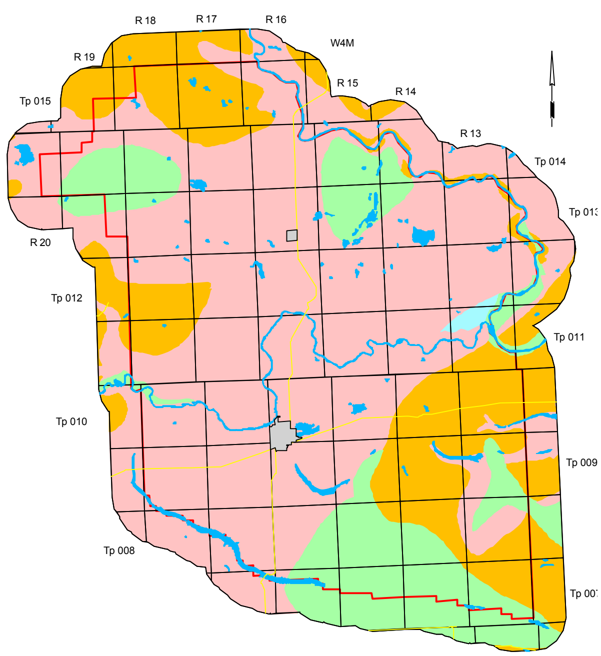
Hydrogeological Maps



Maximum Probable Long-Term Water Well Yield (m³/day)

5 30 160 650

2007 Hydrogeological Consultants Ltd. (HCL)

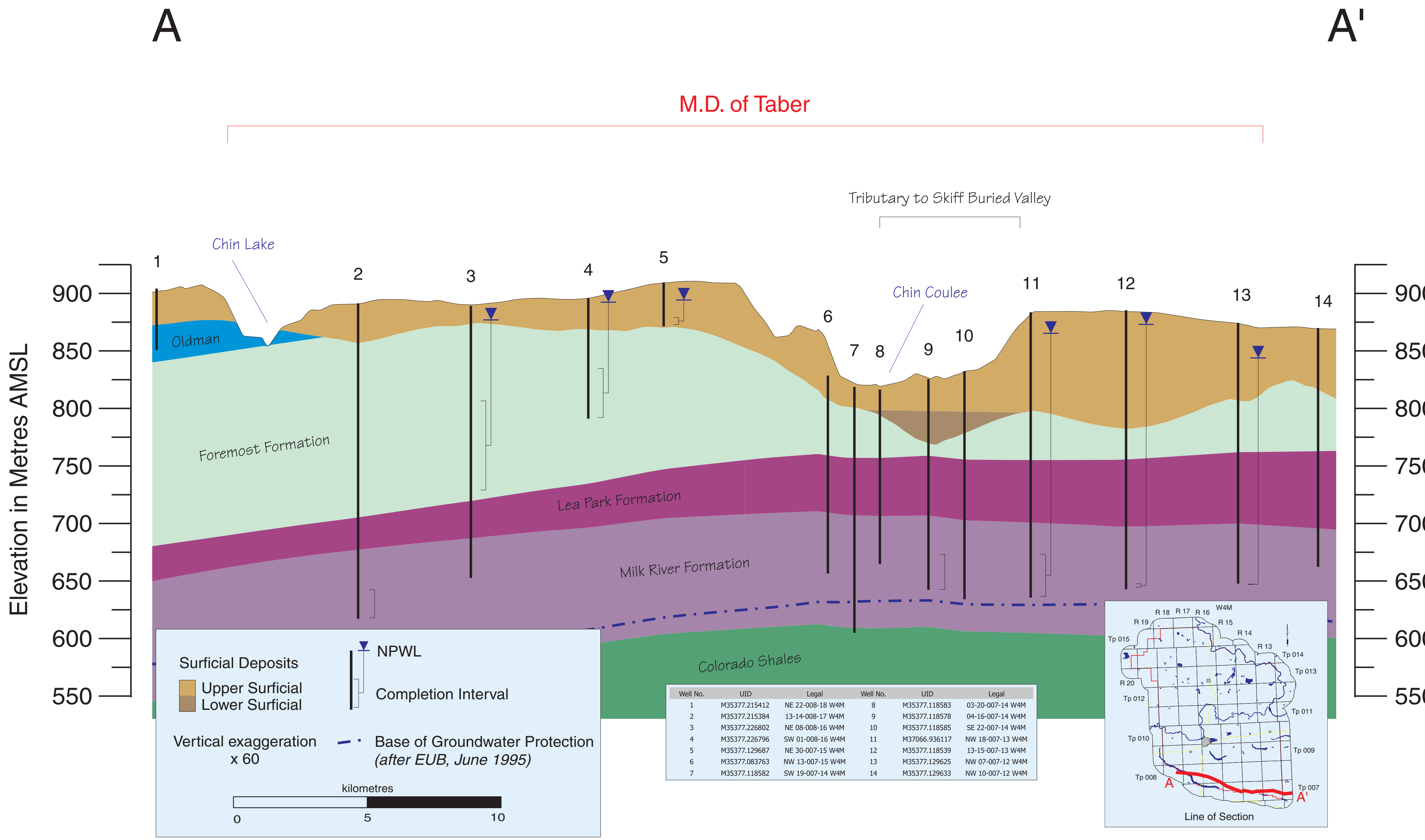


Maximum Probable Long-Term Water Well Yield (m³/day)

5 - 30 | 30 - 160 | 160 - 650 | 650 - 3300

[*after Tokarsky, 1974, Ozoray and Lytiak, 1974; Borneuf, 1976, Stevenson and Borneuf, 1977*]

Cross-Section A - A'



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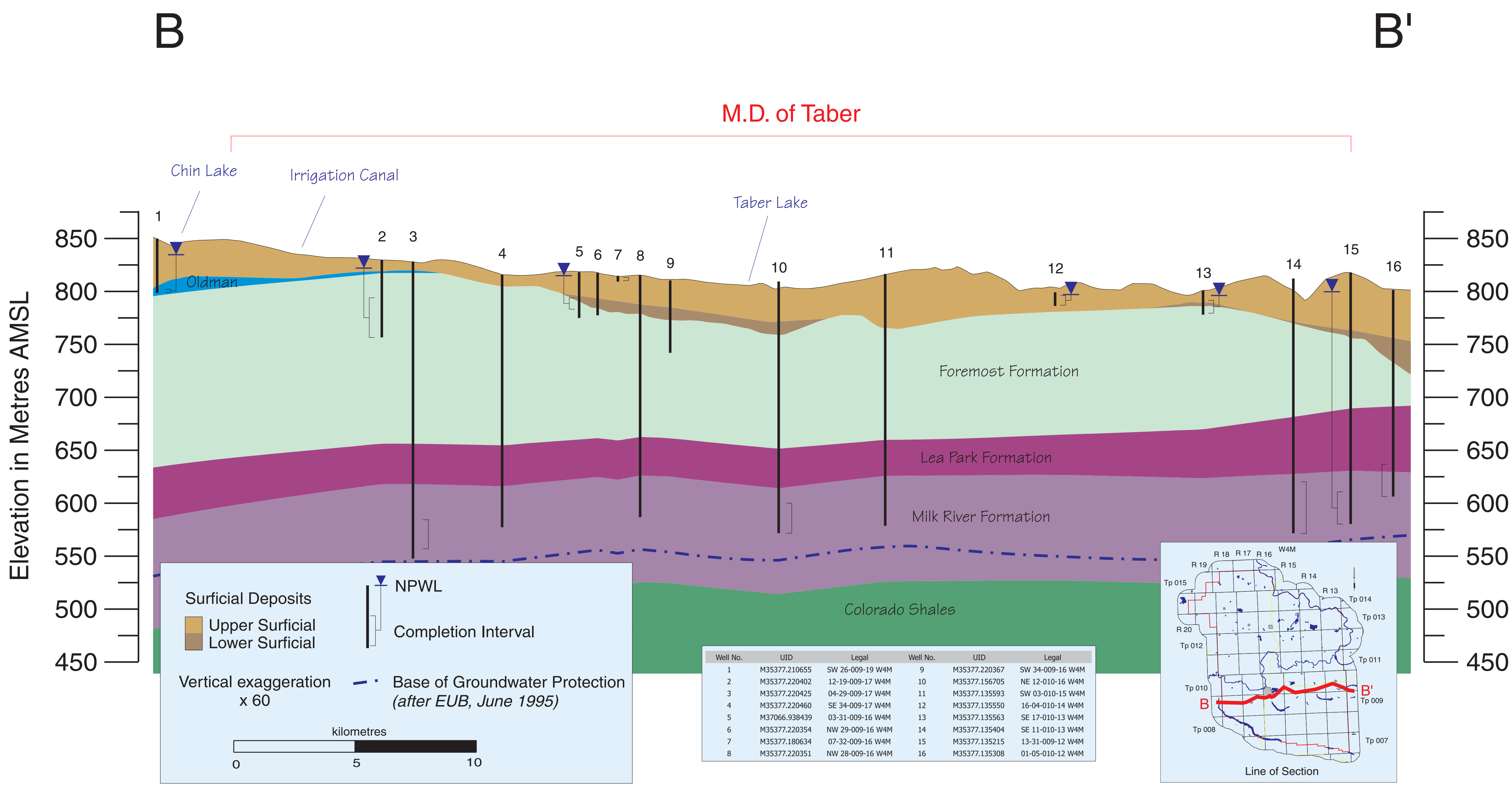
3	M35377.226802	NE 08-008-16 W4M	10	M35377.118585	SE 22-007-14 W4M
4	M35377.226796	SW 01-008-16 W4M	11	M37066.936117	NW 18-007-13 W4M
5	M35377.129687	NE 30-007-15 W4M	12	M35377.118539	13-15-007-13 W4M
6	M35377.083763	NW 13-007-15 W4M	13	M35377.129625	NW 07-007-12 W4M
7	M35377.118582	SW 19-007-14 W4M	14	M35377.129633	NW 10-007-12 W4M

Cross-Section B - B'



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3	M35377.220425	04-29-009-17 W4M	11	M35377.135593	SW 03-010-15 W4M
4	M35377.220460	SE 34-009-17 W4M	12	M35377.135550	16-04-010-14 W4M
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6	M35377.220354	NW 29-009-16 W4M	14	M35377.135404	SE 11-010-13 W4M
7	M35377.180634	07-32-009-16 W4M	15	M35377.135215	13-31-009-12 W4M
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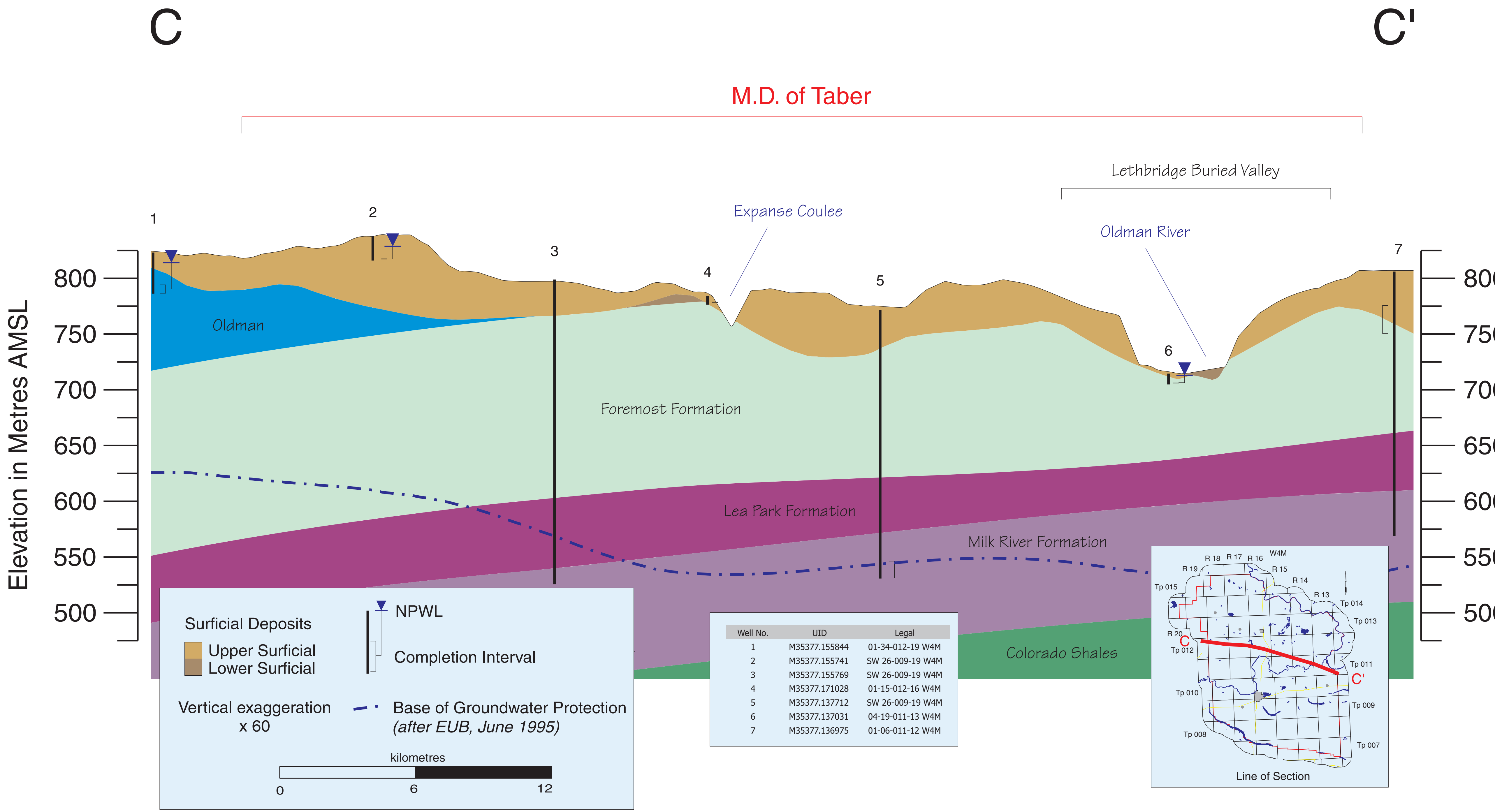
Cross-Section C - C'



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4	M35377.171028	01-15-012-16 W4M
5	M35377.137712	SW 26-009-19 W4M
6	M35377.137031	04-19-011-13 W4M
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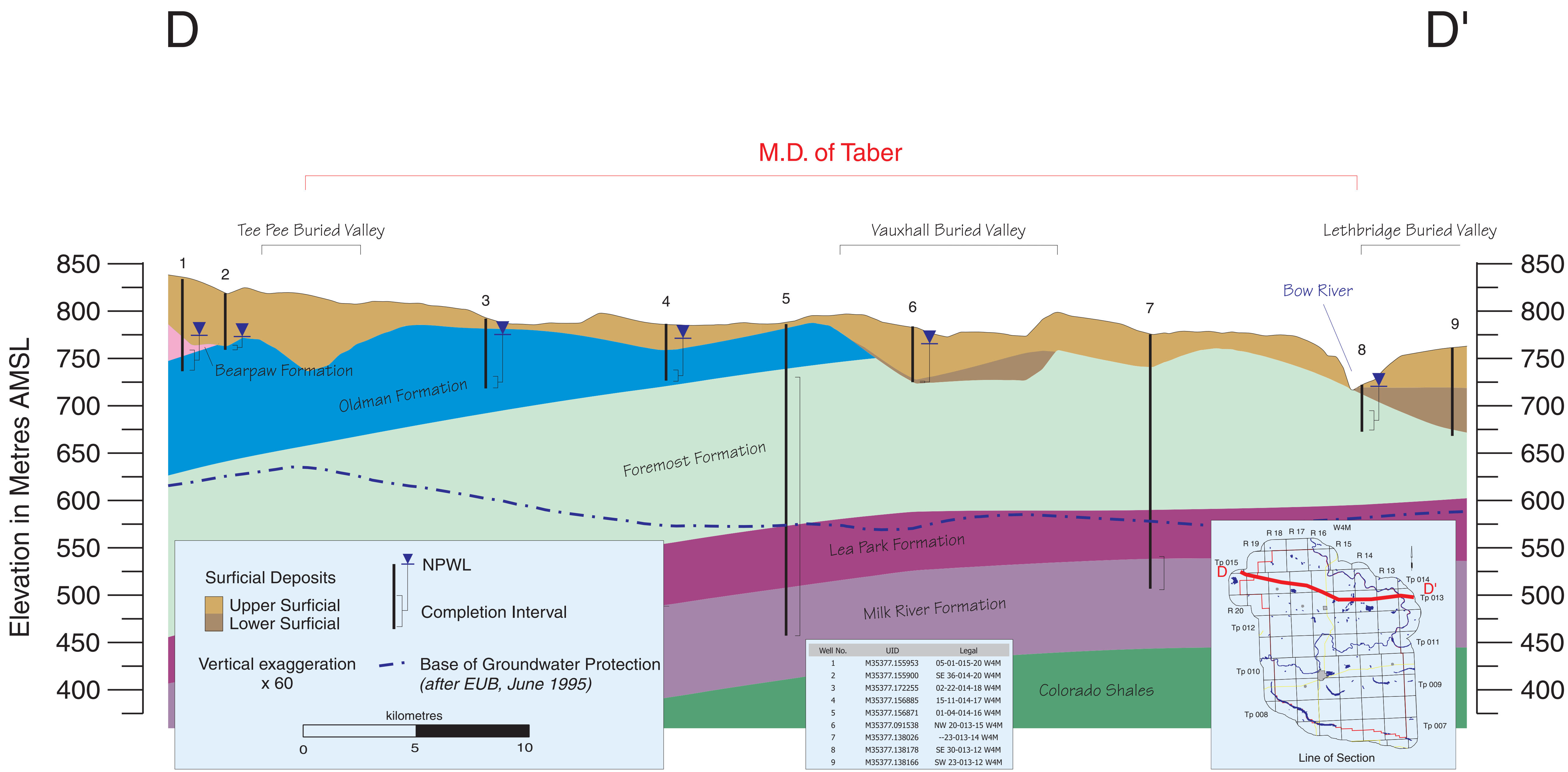
Cross-Section D - D'



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5	M35377.156871	01-04-014-16 W4M
6	M35377.091538	NW 20-013-15 W4M
7	M35377.138026	--23-013-14 W4M
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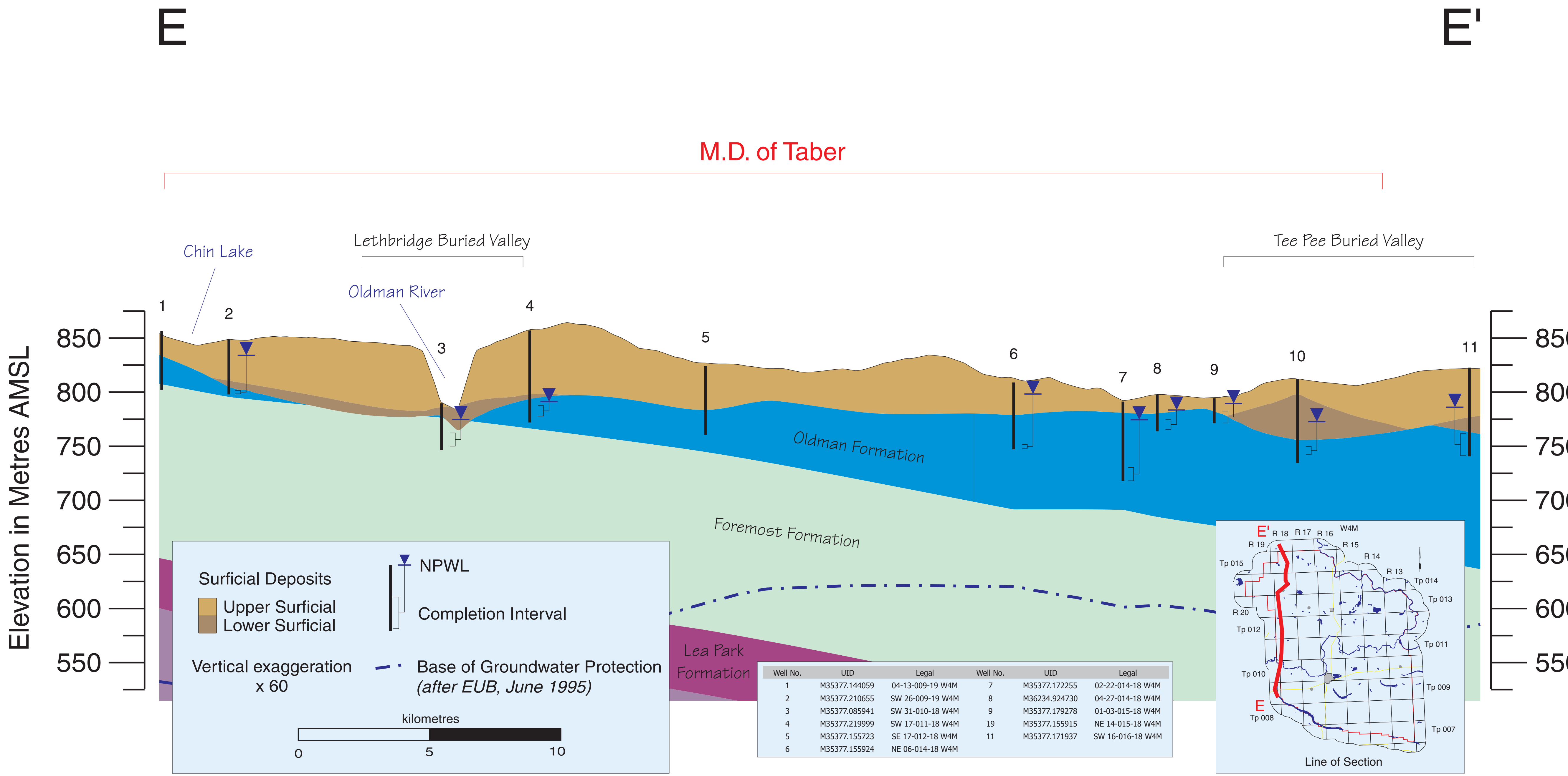
Cross-Section E - E'



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3	M35377.085941	SW 31-010-18 W4M	9	M35377.179278	01-03-015-18 W4M
4	M35377.219999	SW 17-011-18 W4M	19	M35377.155915	NE 14-015-18 W4M
5	M35377.155723	SE 17-012-18 W4M	11	M35377.171937	SW 16-016-18 W4M
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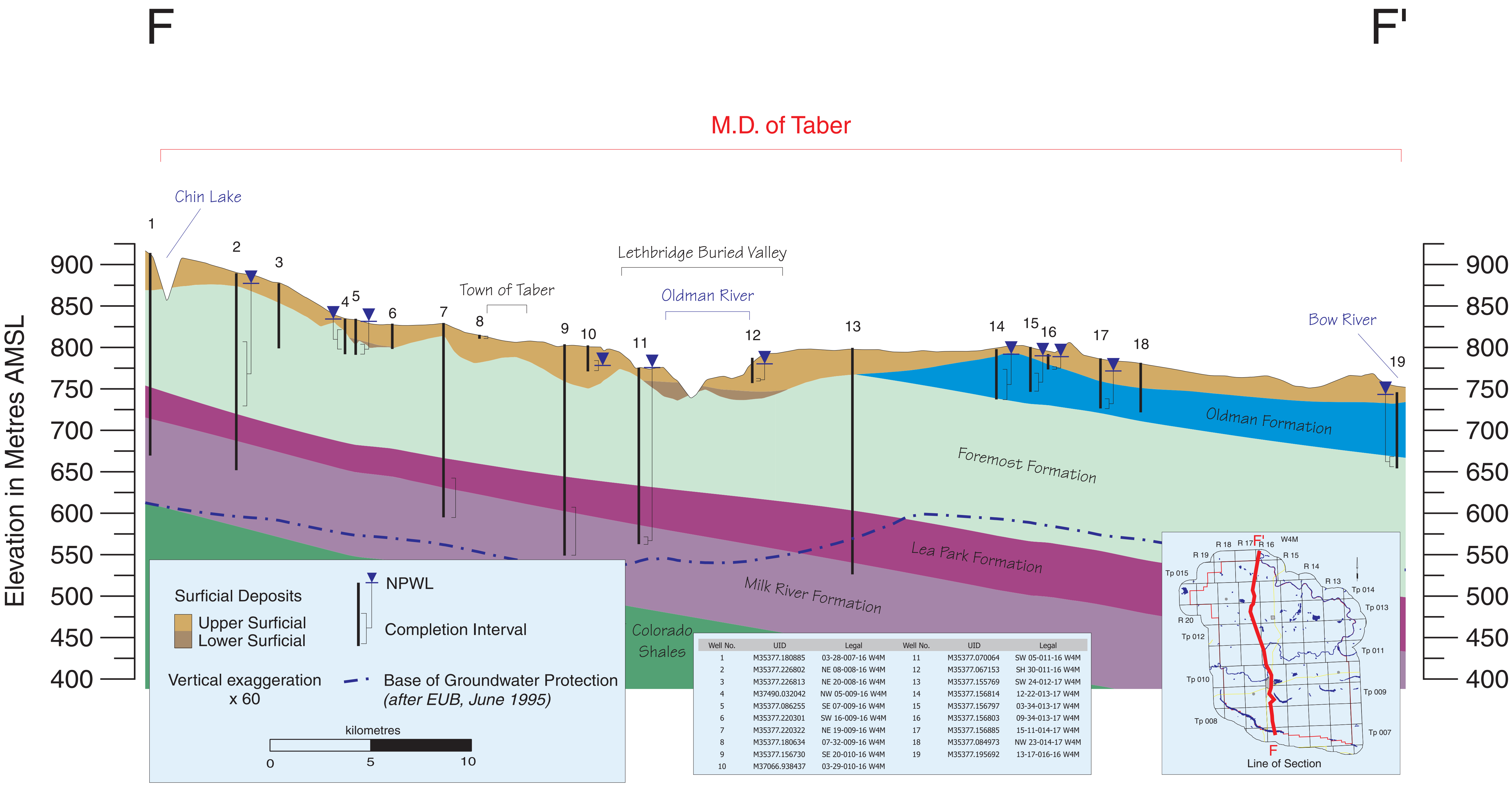
Cross-Section F - F'



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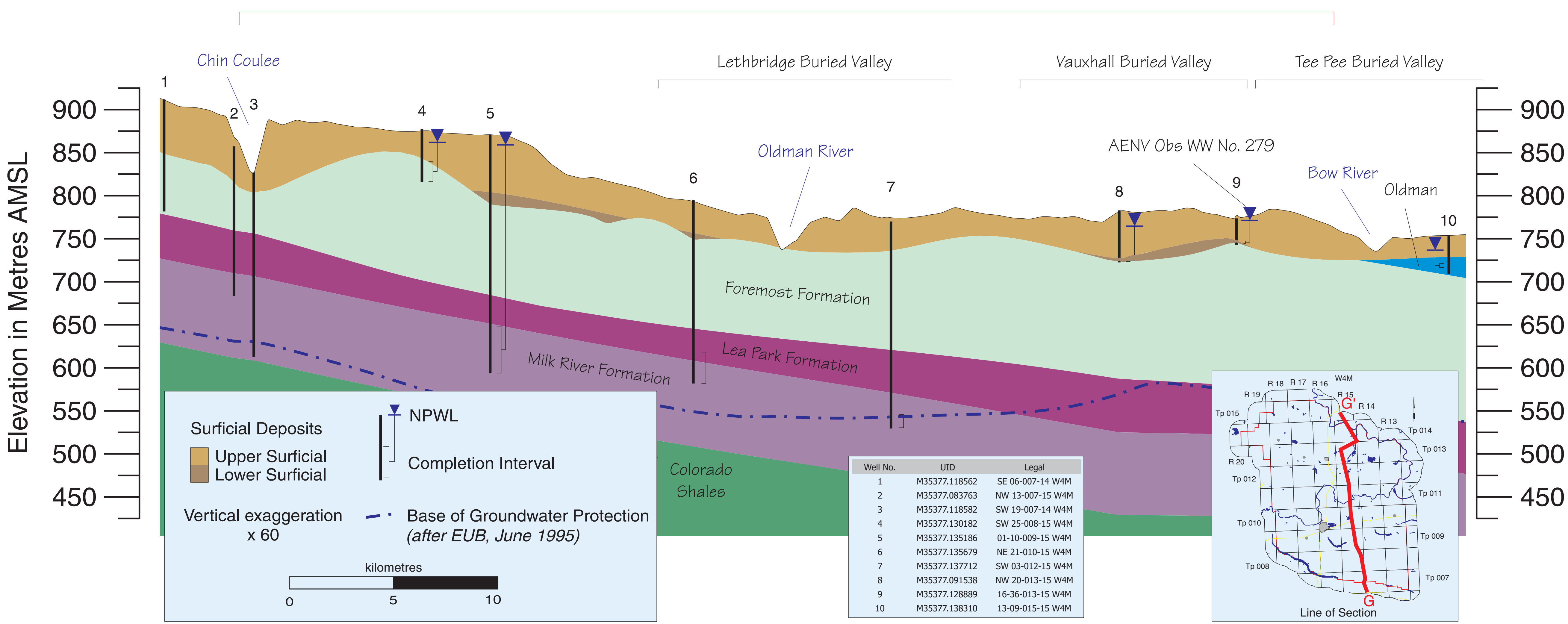
3	M35377.226813	NE 20-008-16 W4M	13	M35377.155769	SW 24-012-17 W4M
4	M37490.032042	NW 05-009-16 W4M	14	M35377.156814	12-22-013-17 W4M
5	M35377.086255	SE 07-009-16 W4M	15	M35377.156797	03-34-013-17 W4M
6	M35377.220301	SW 16-009-16 W4M	16	M35377.156803	09-34-013-17 W4M
7	M35377.220322	NE 19-009-16 W4M	17	M35377.156885	15-11-014-17 W4M
8	M35377.180634	07-32-009-16 W4M	18	M35377.084973	NW 23-014-17 W4M
9	M35377.156730	SE 20-010-16 W4M	19	M35377.195692	13-17-016-16 W4M
10	M37066.938437	03-29-010-16 W4M			

Cross-Section G - G'



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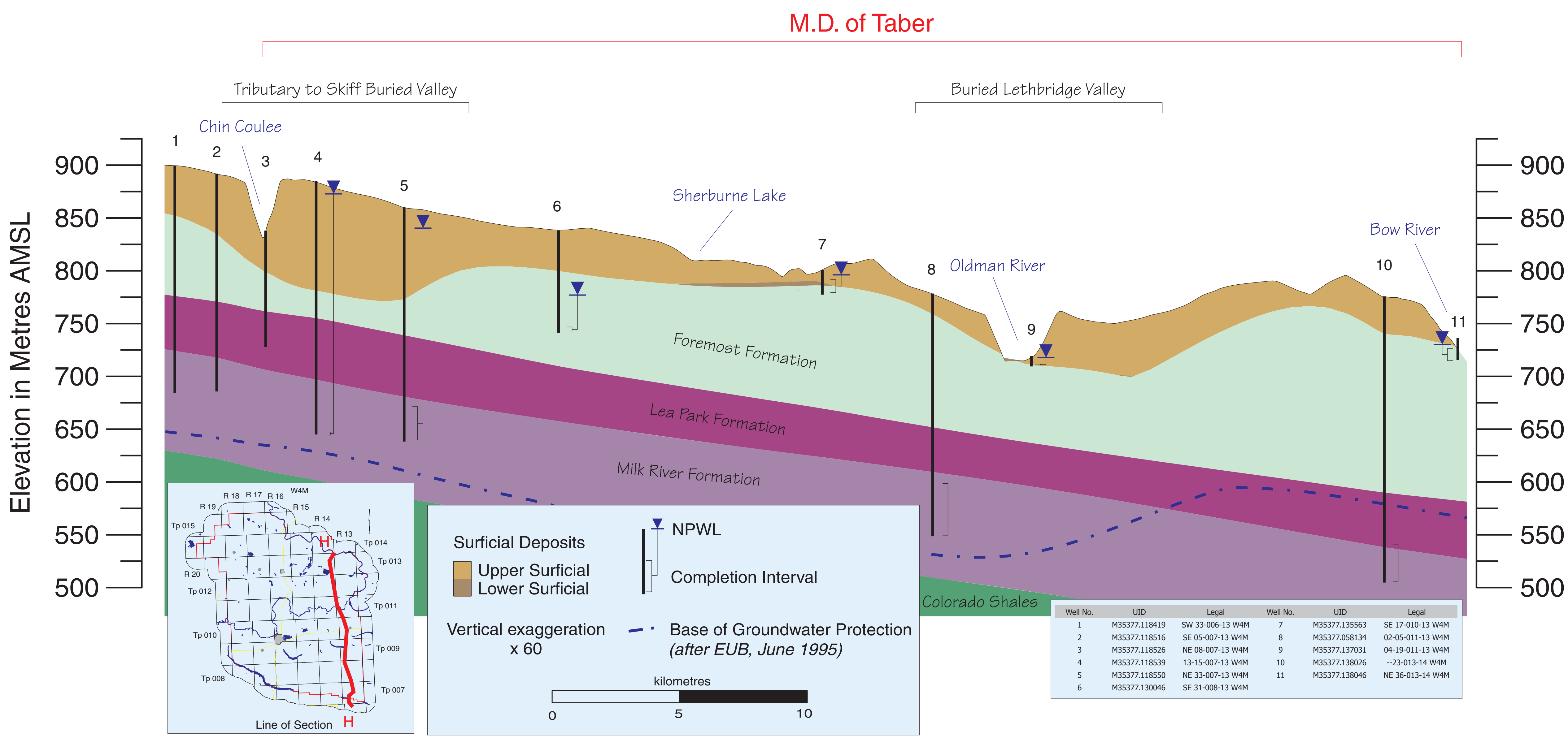
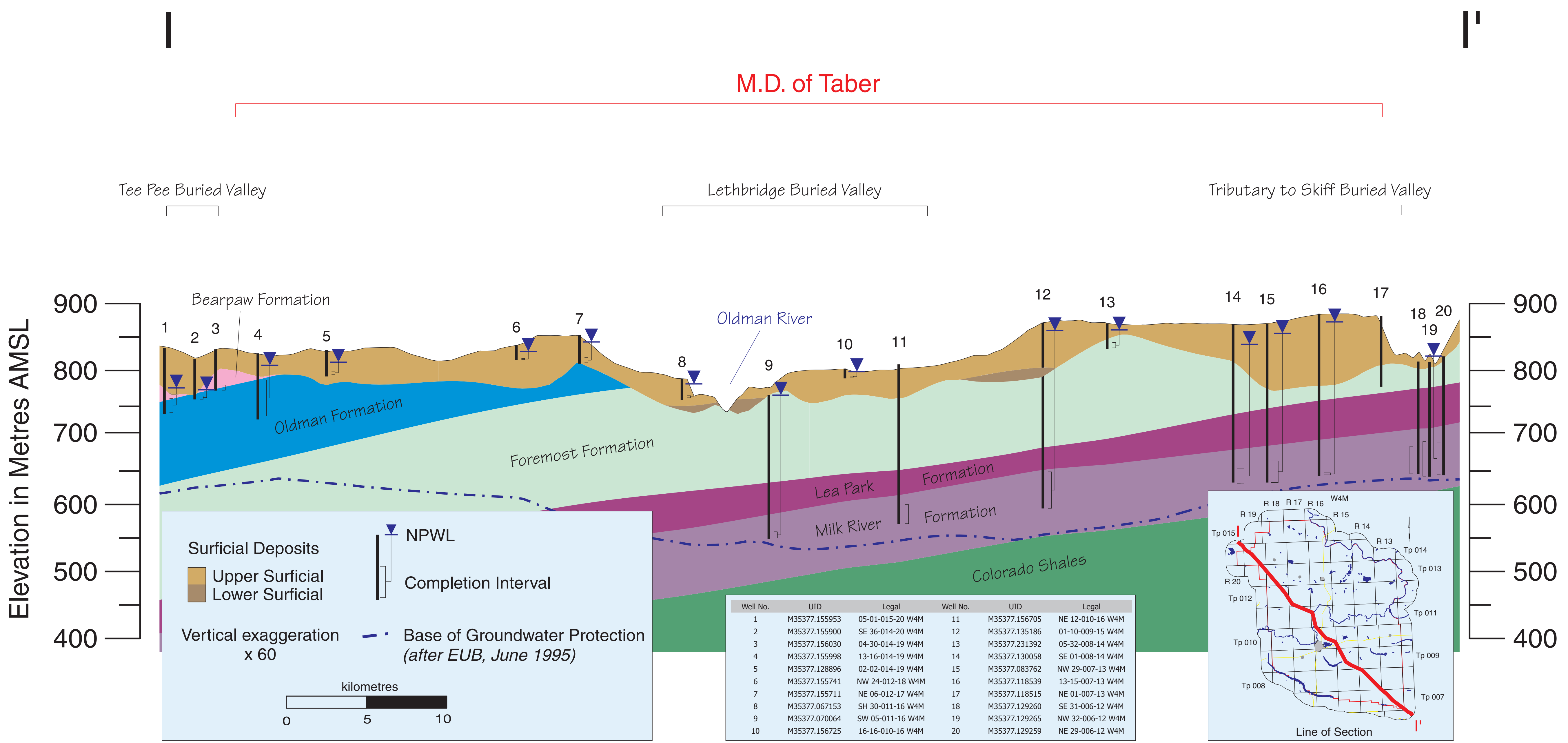
4	M35377.130182	SW 25-008-15 W4M
5	M35377.135186	01-10-009-15 W4M
6	M35377.135679	NE 21-010-15 W4M
7	M35377.137712	SW 03-012-15 W4M
8	M35377.091538	NW 20-013-15 W4M
9	M35377.128889	16-36-013-15 W4M
10	M35377.138310	13-09-015-15 W4M

Cross-Section H - H'



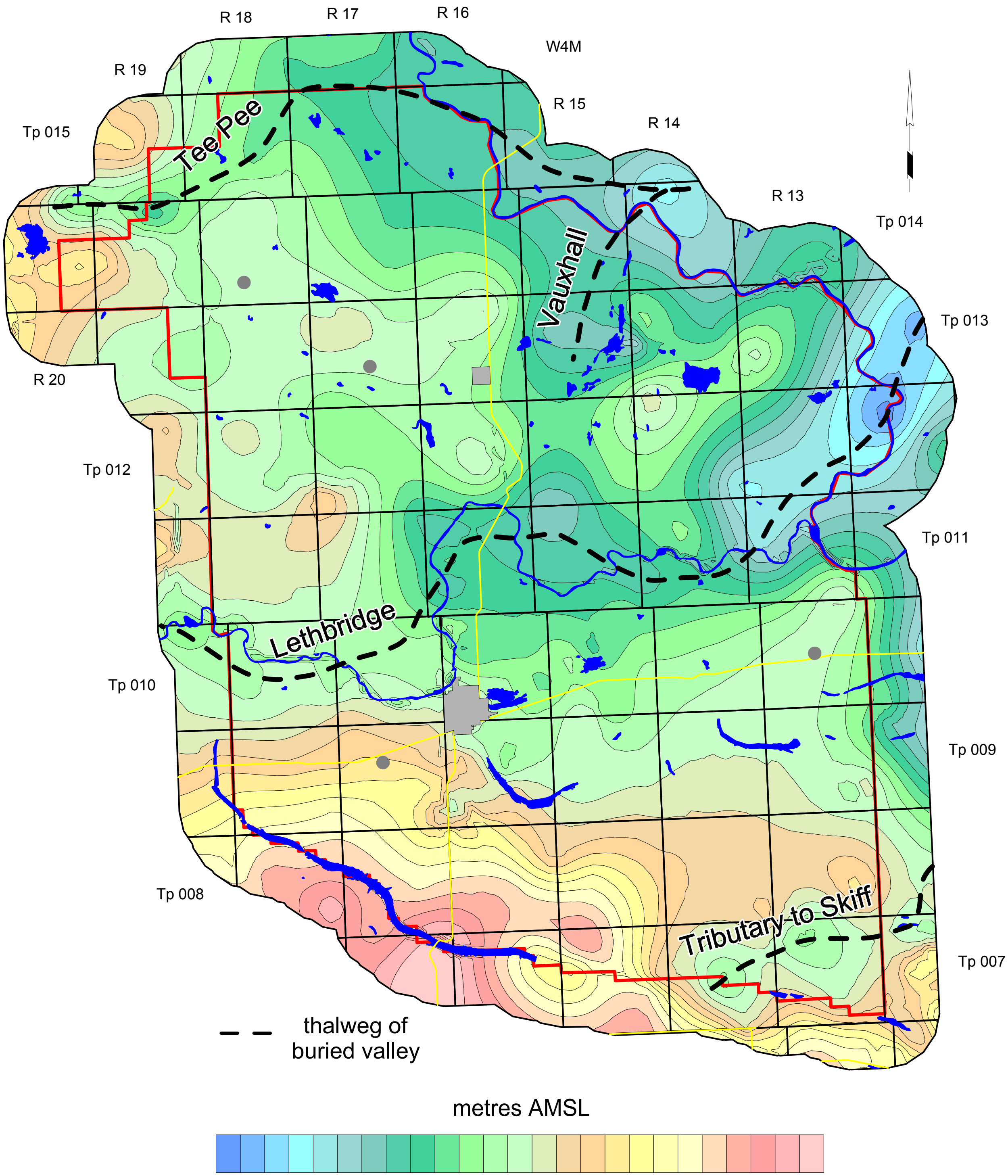
Well No.	UID	Legal	Well No.	UID	Legal
1	M35377.118419	SW 33-006-13 W4M	7	M35377.135563	SE 17-010-13 W4M
2	M35377.118516	SE 05-007-13 W4M	8	M35377.058134	02-05-011-13 W4M
3	M35377.118526	NE 08-007-13 W4M	9	M35377.137031	04-19-011-13 W4M
4	M35377.118539	13-15-007-13 W4M	10	M35377.138026	--23-013-14 W4M
5	M35377.118550	NE 33-007-13 W4M	11	M35377.138046	NE 36-013-14 W4M
6	M35377.130046	SE 31-008-13 W4M			

Cross-Section I - I'

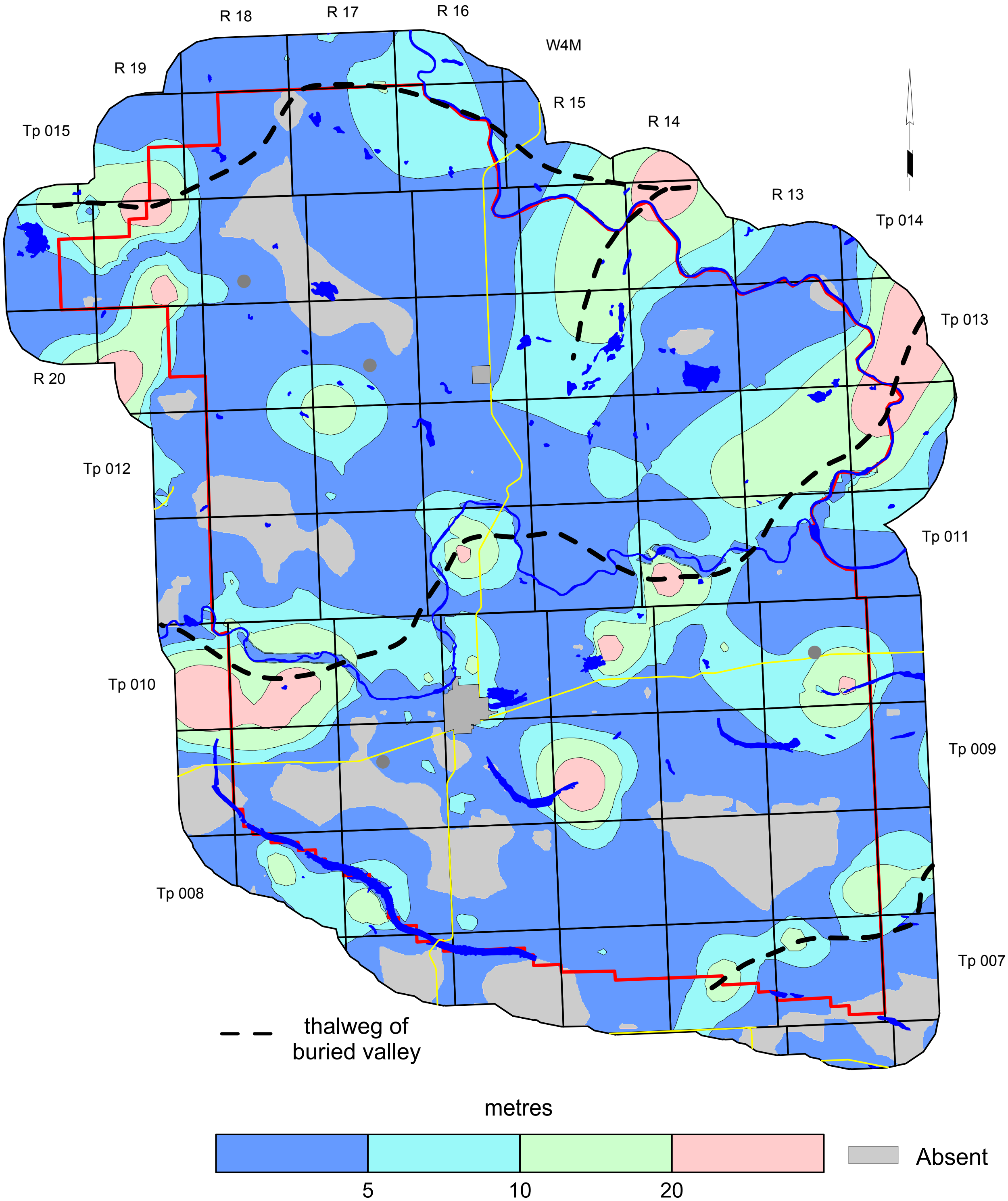


Well No.	UID	Legal	Well No.	UID	Legal
1	M35377.155953	05-01-015-20 W4M	11	M35377.156705	NE 12-010-16 W4M
2	M35377.155900	SE 36-014-20 W4M	12	M35377.135186	01-10-009-15 W4M
3	M35377.156030	04-30-014-19 W4M	13	M35377.231392	05-32-008-14 W4M
4	M35377.155998	13-16-014-19 W4M	14	M35377.130058	SE 01-008-14 W4M
5	M35377.128896	02-02-014-19 W4M	15	M35377.083762	NW 29-007-13 W4M
6	M35377.155741	NW 24-012-18 W4M	16	M35377.118539	13-15-007-13 W4M
7	M35377.155711	NE 06-012-17 W4M	17	M35377.118515	NE 01-007-13 W4M
8	M35377.067153	SH 30-011-16 W4M	18	M35377.129260	SE 31-006-12 W4M
9	M35377.070064	SW 05-011-16 W4M	19	M35377.129265	NW 32-006-12 W4M
10	M35377.156725	16-16-010-16 W4M	20	M35377.129259	NE 29-006-12 W4M

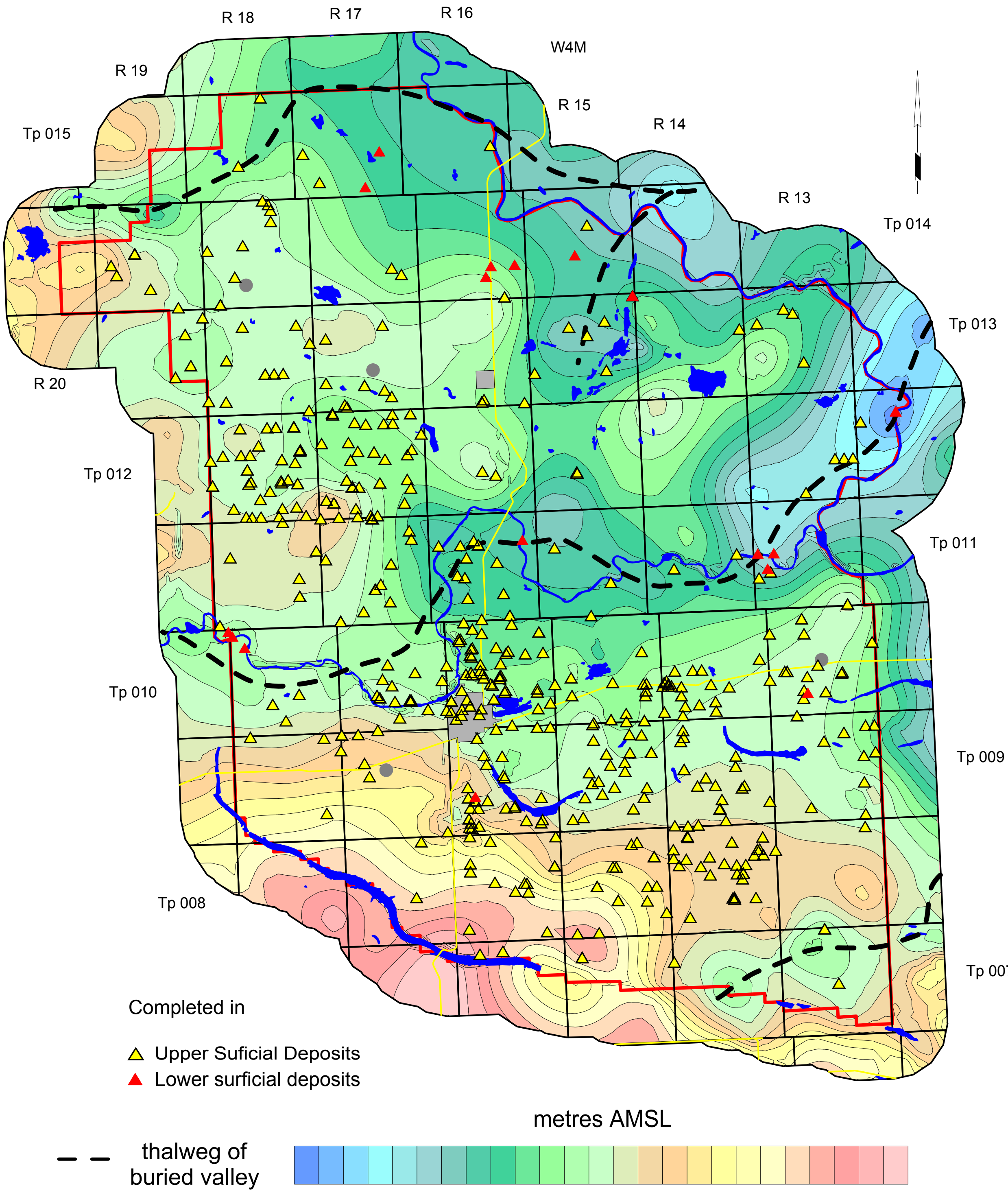
Bedrock Topography



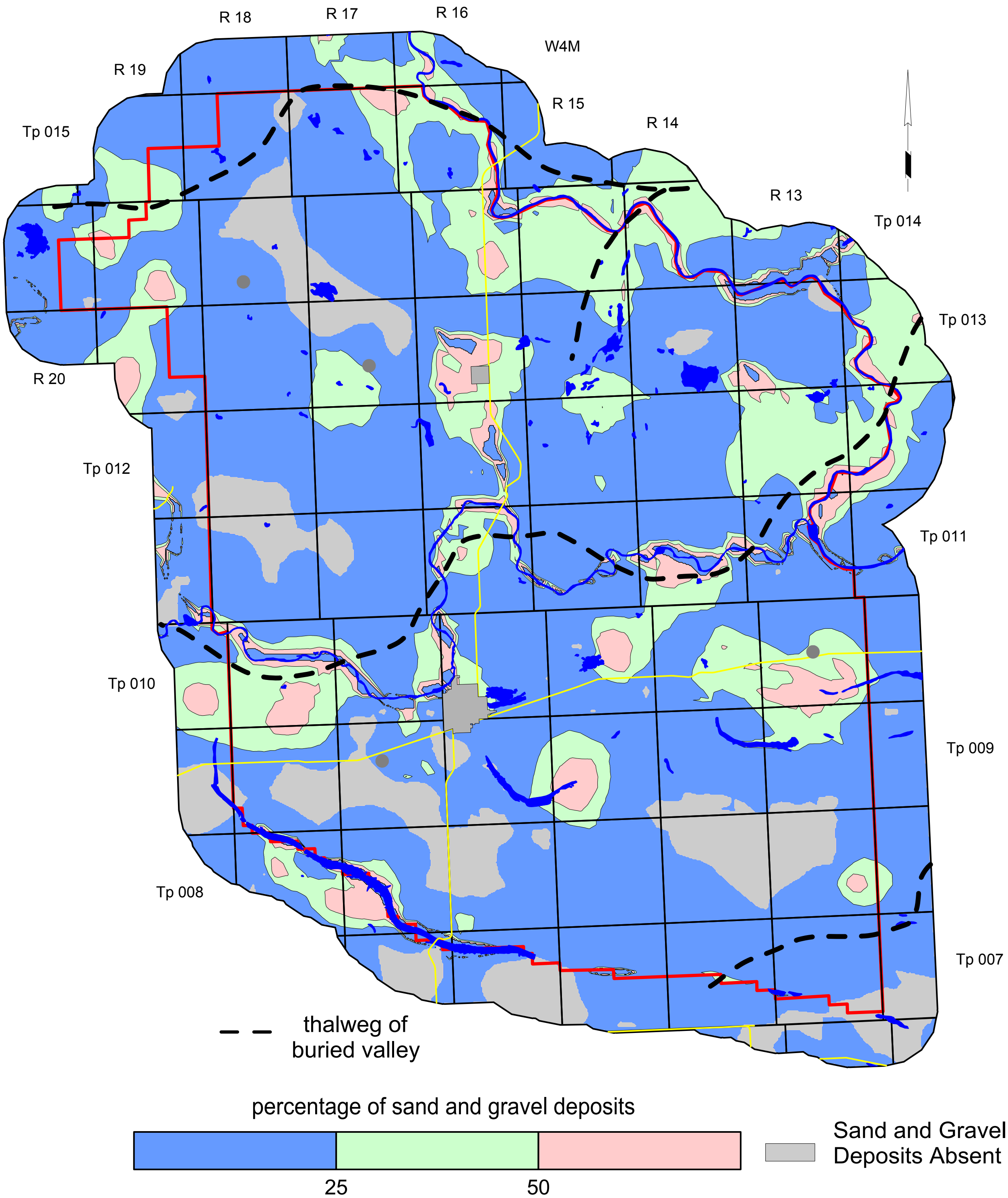
Thickness of Sand and Gravel Deposits



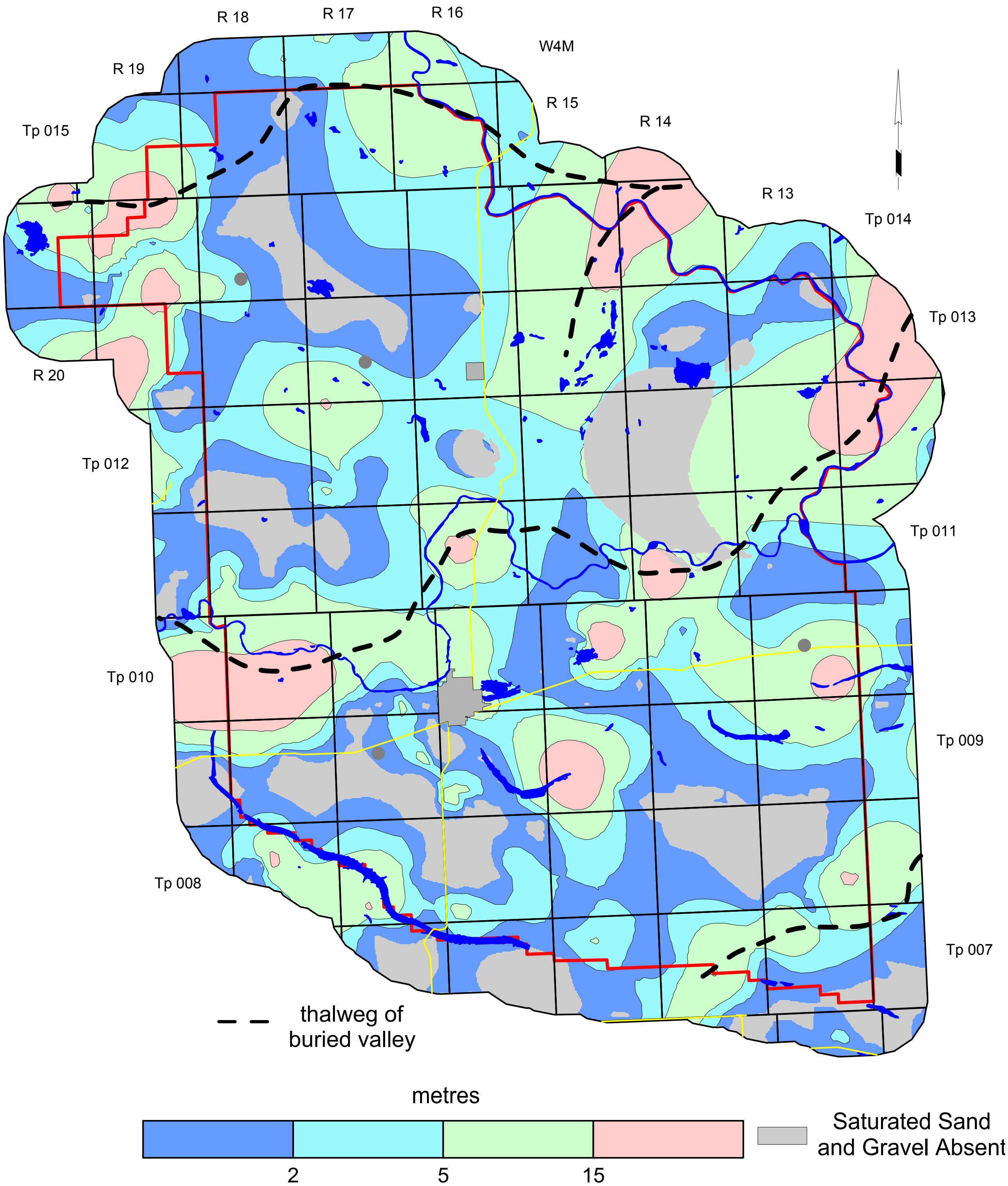
Location of Surficial Water Wells Relative to Bedrock Topography



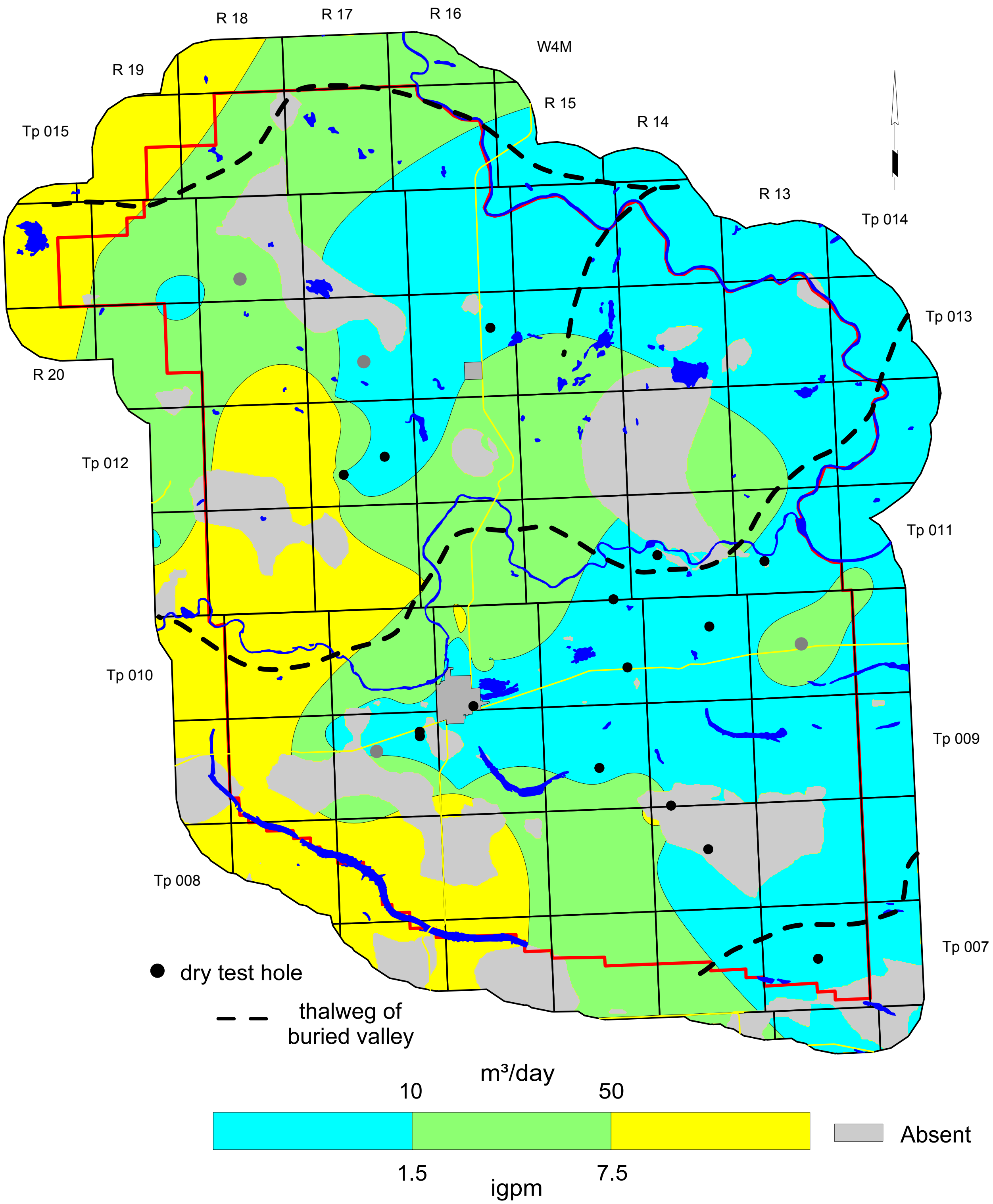
Percentage of Sand and Gravel in Surficial Deposits



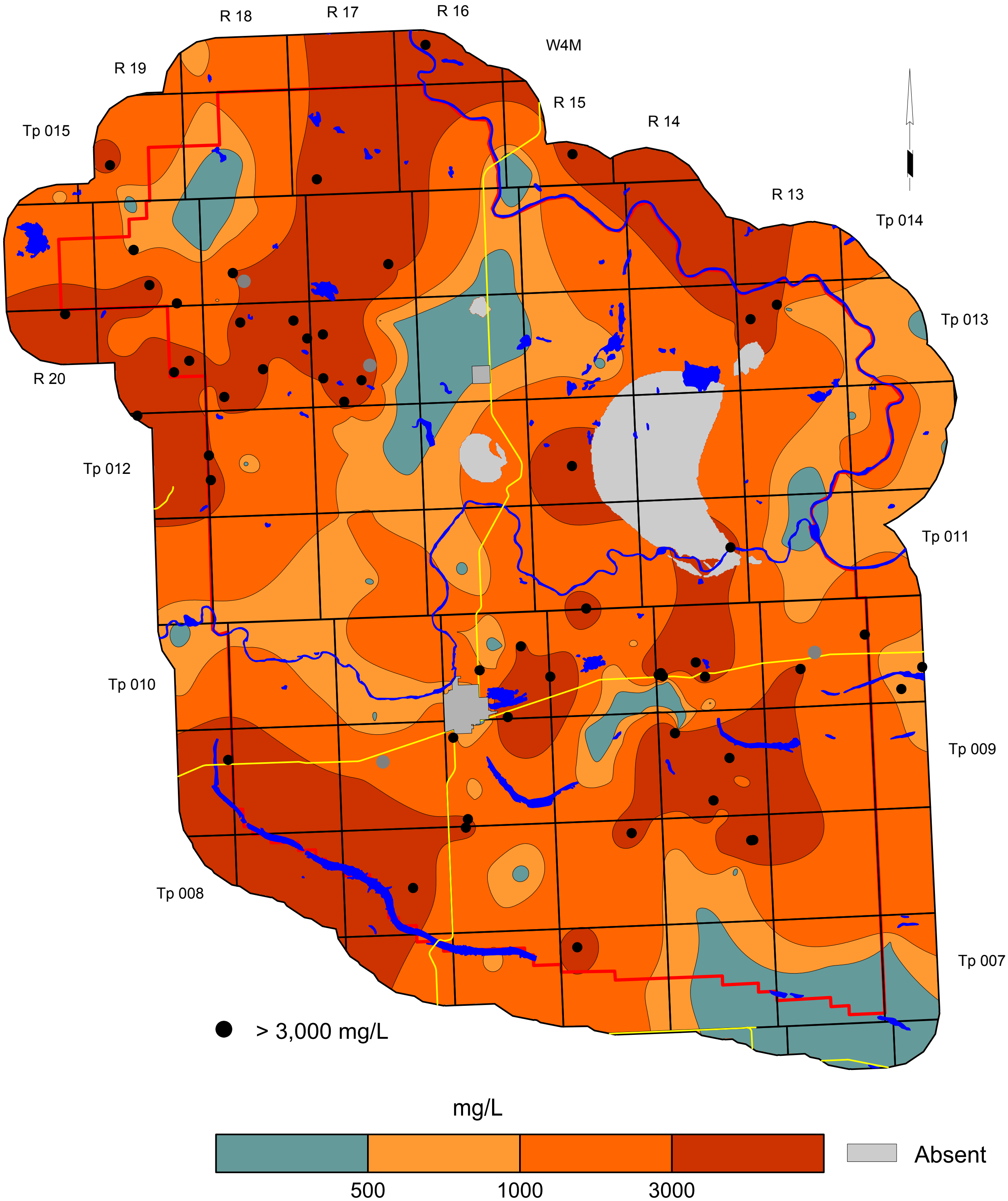
Thickness of Sand and Gravel Aquifer(s)



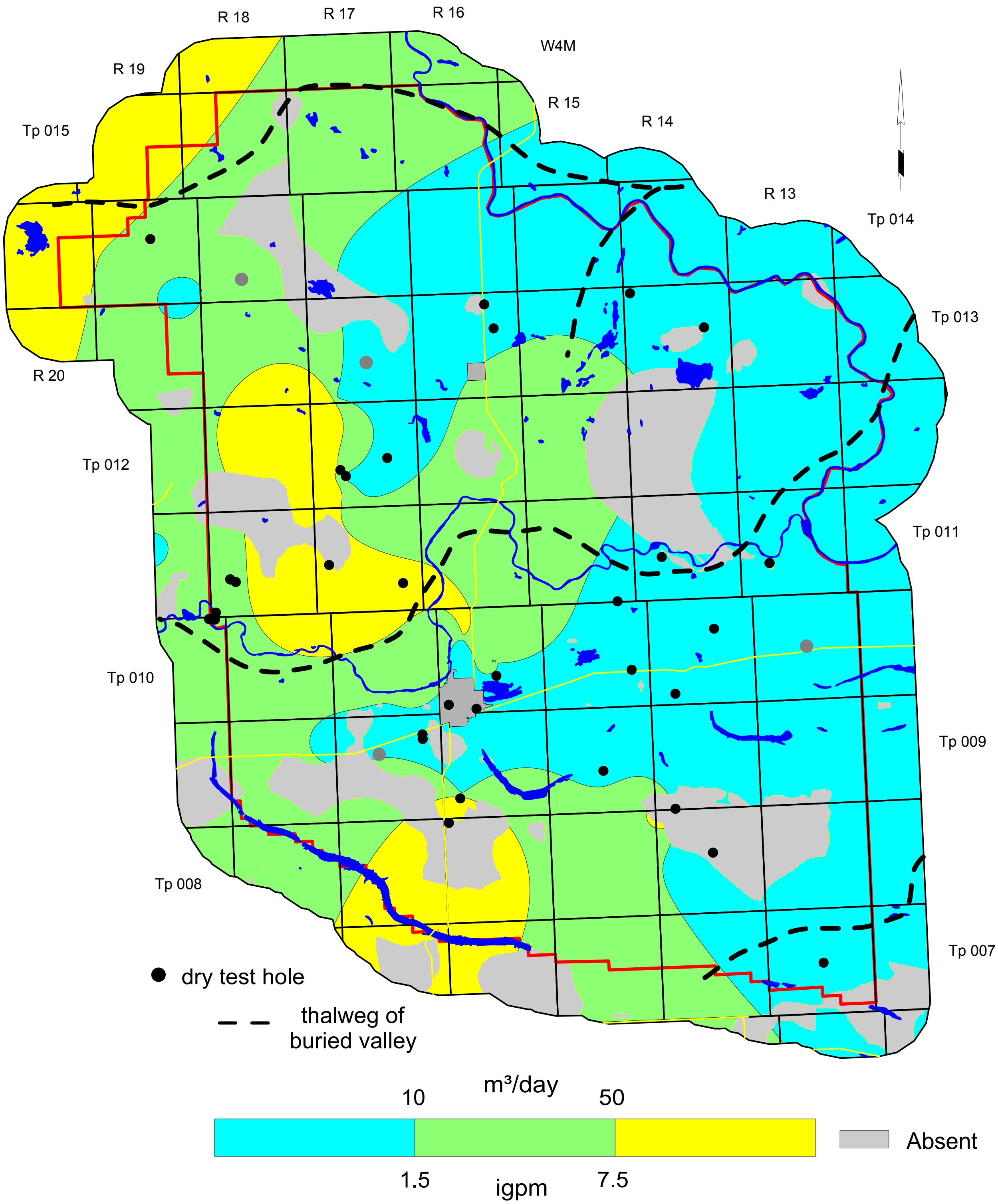
Apparent Yield of Water Wells Completed in Sand and Gravel Aquifer(s)



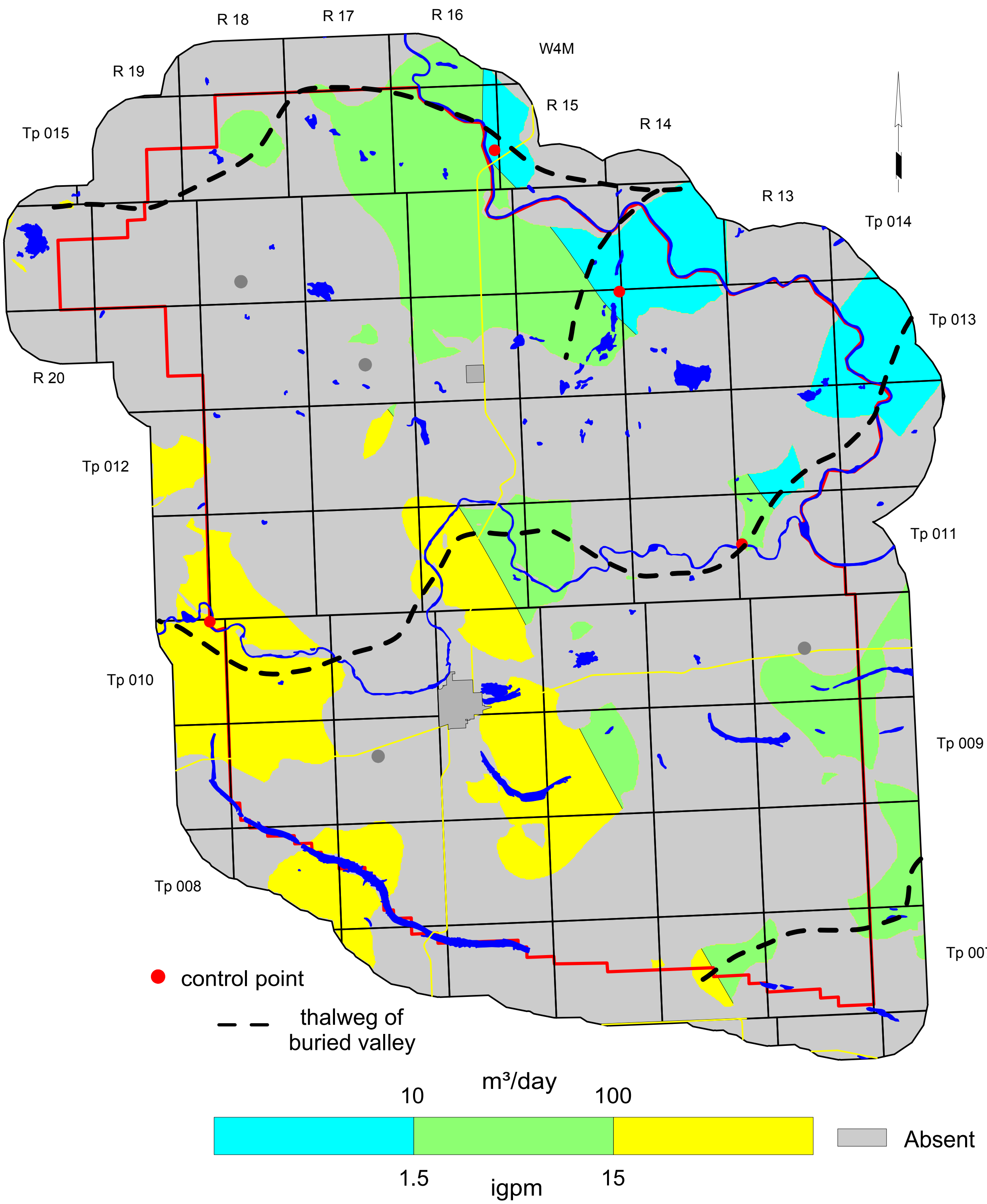
Total Dissolved Solids in Groundwater from Surficial Deposits



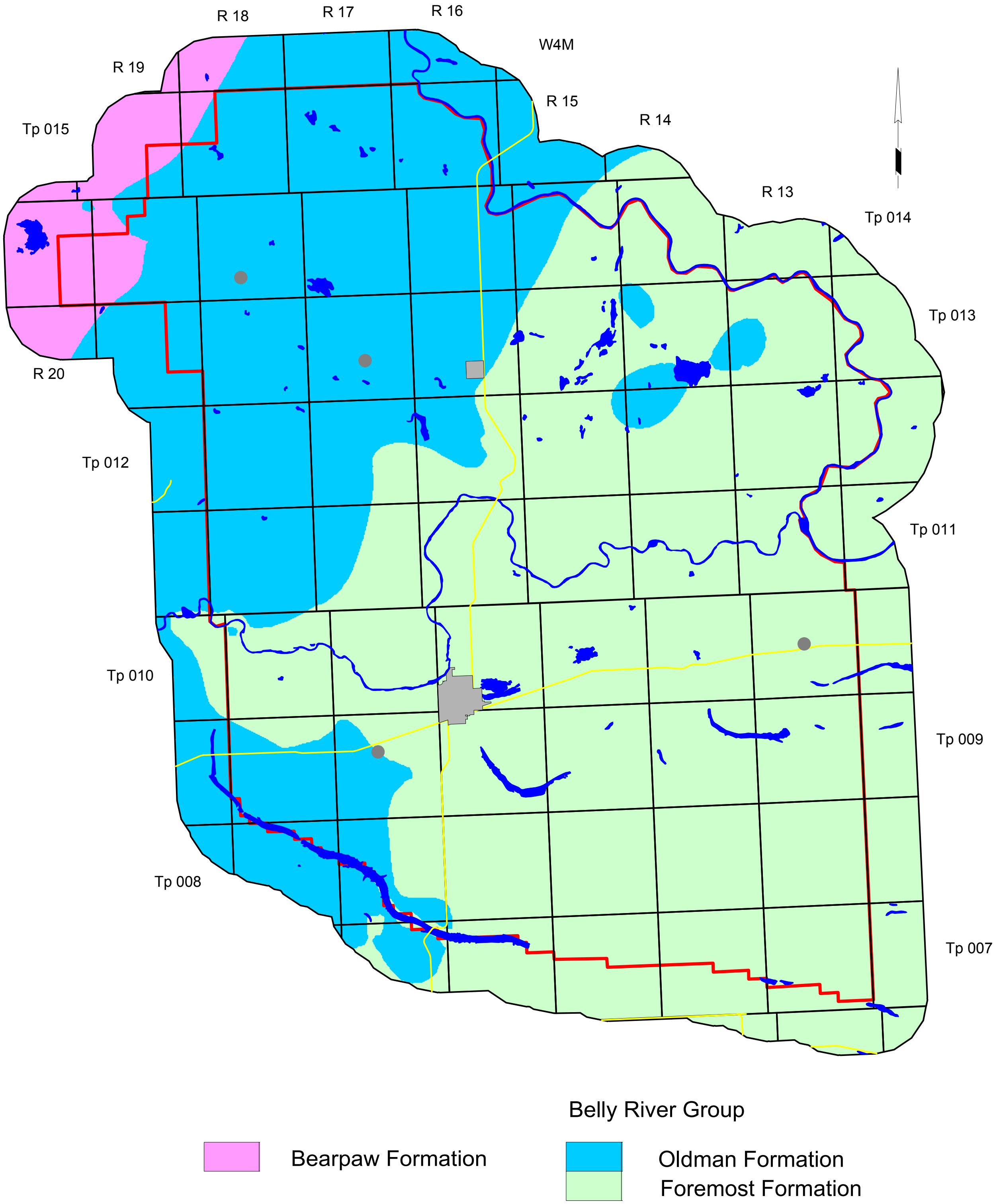
Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer



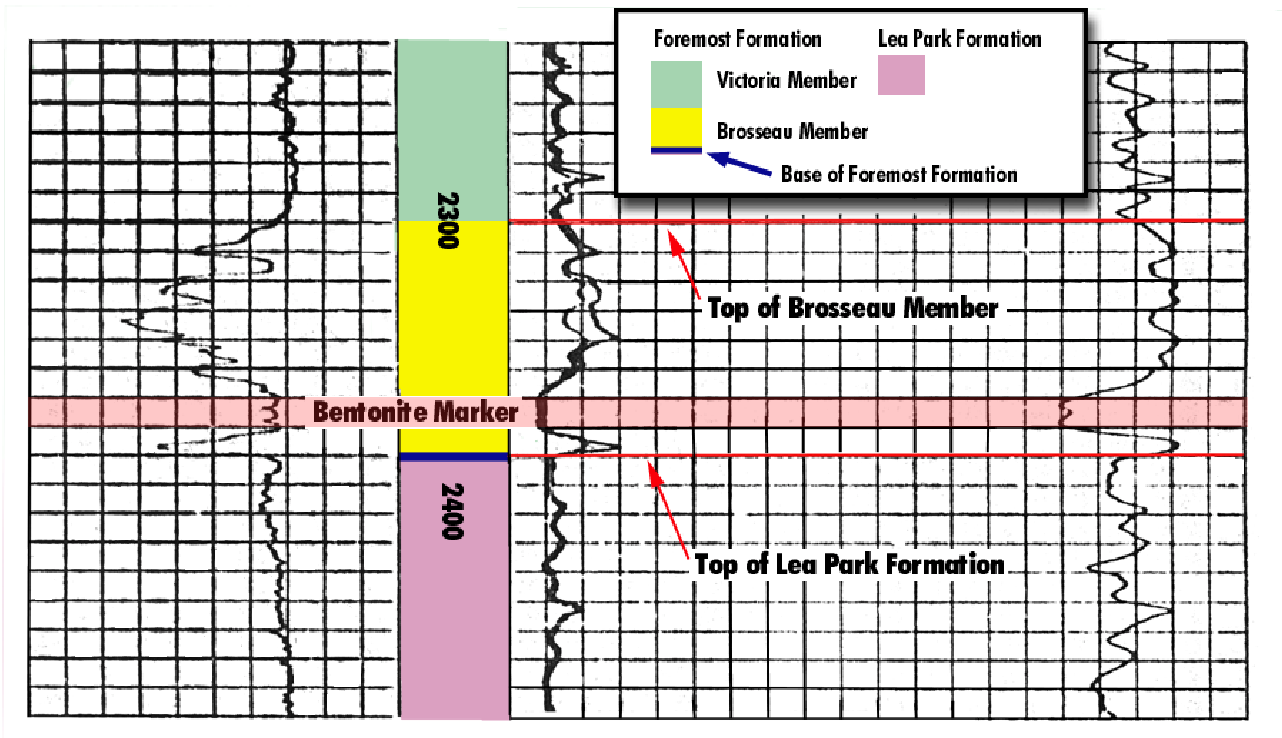
Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer



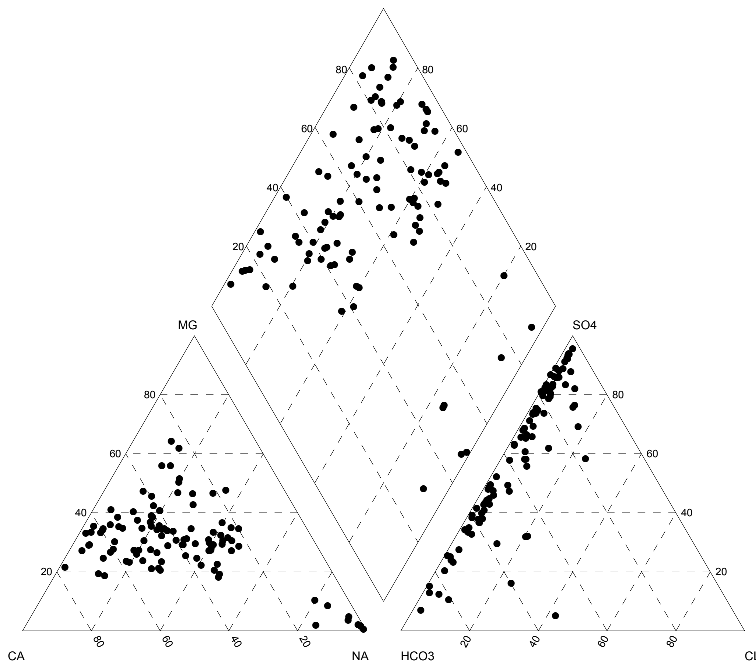
Bedrock Geology



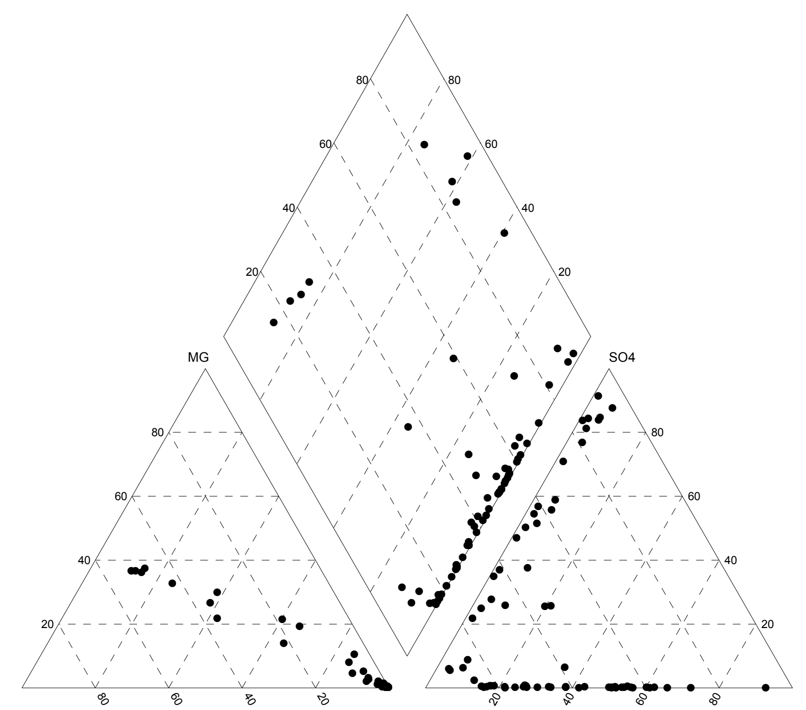
E-Log Showing Base of Foremost Formation



Piper Diagrams

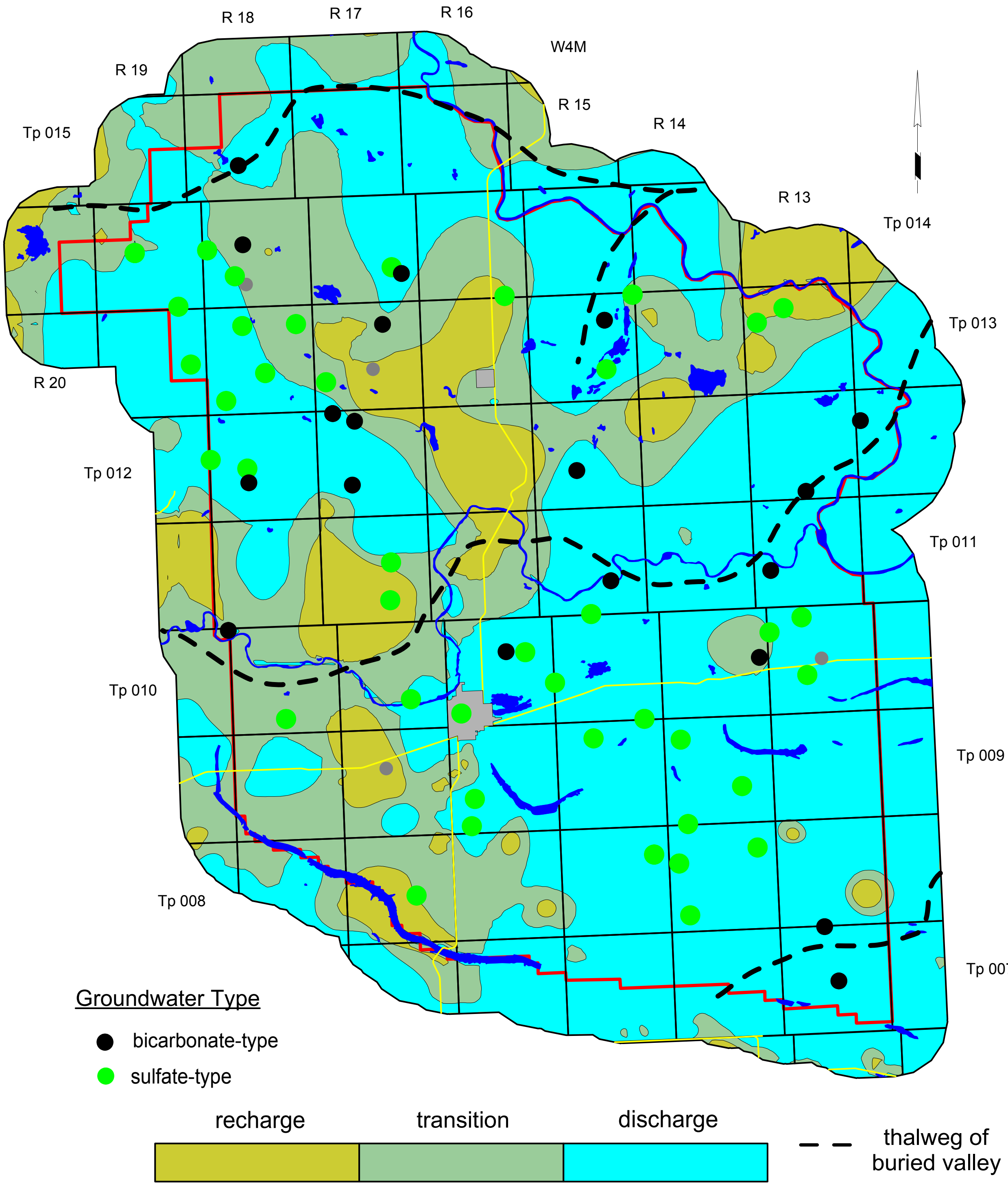


Surficial Deposits

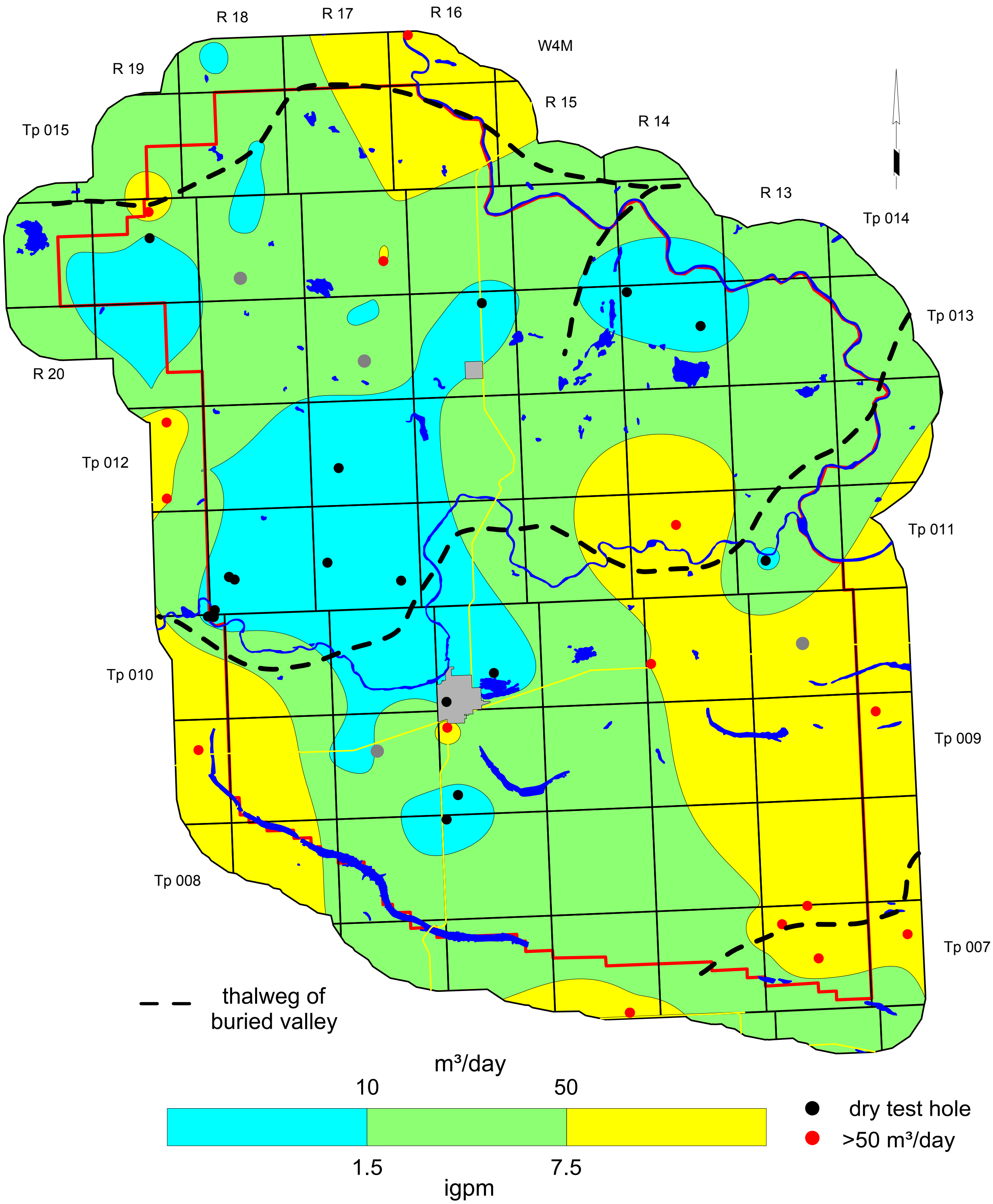


Bedrock Aquifers

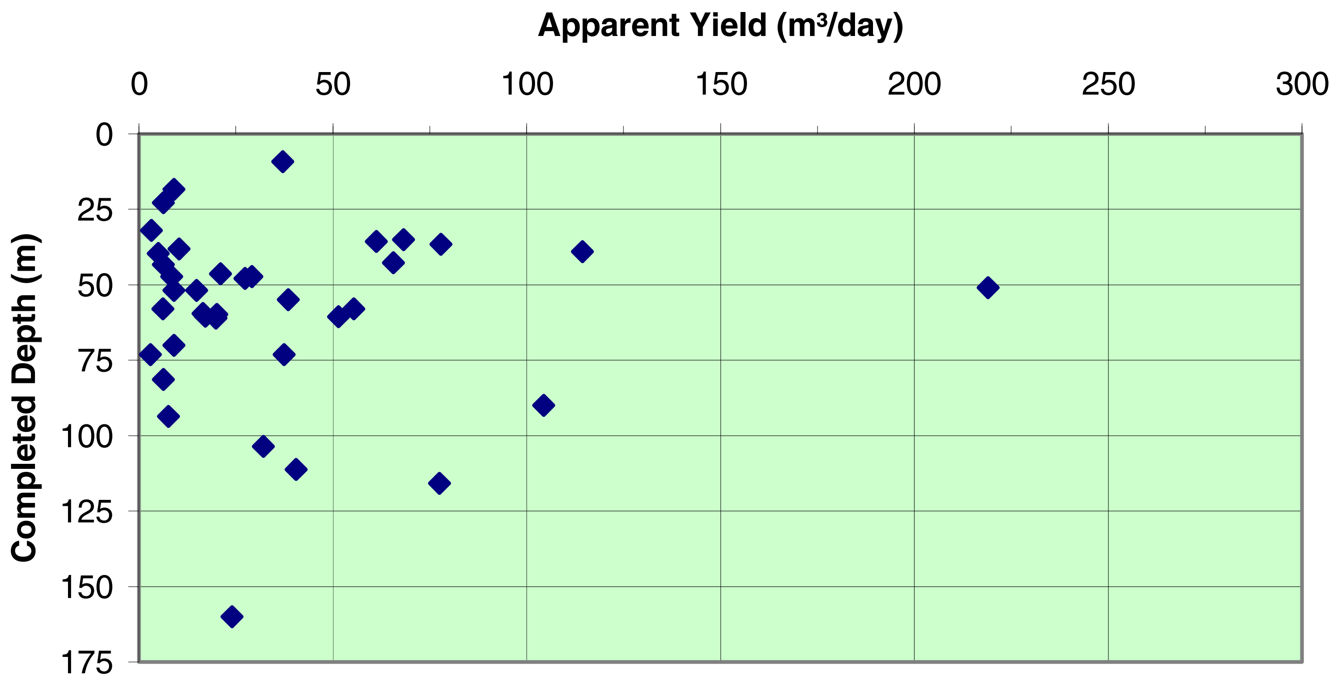
Types of Groundwaters in Surficial Deposits in Relation to Recharge/Discharge Areas



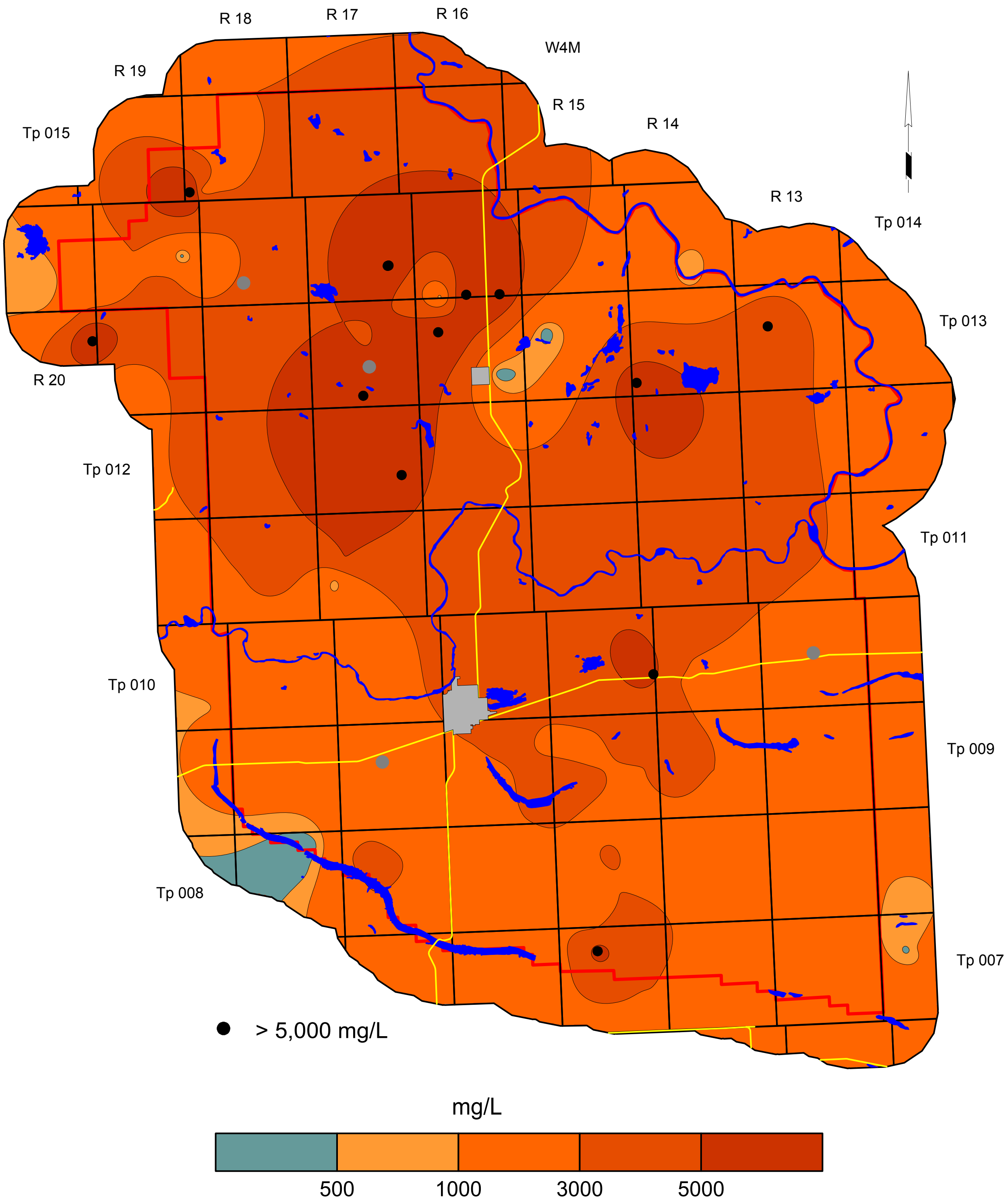
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



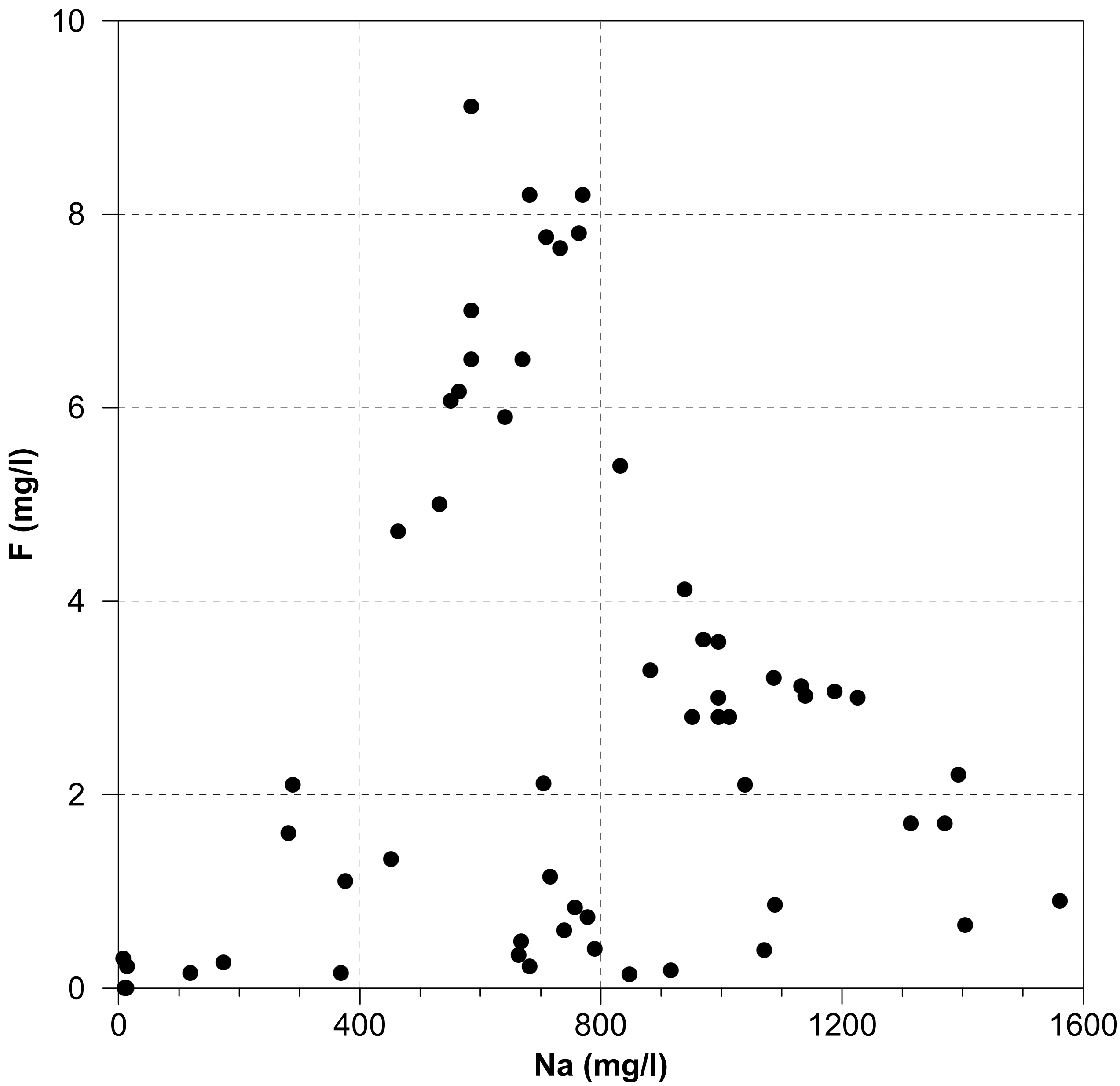
Bedrock Water Well Yields vs Completed Depth



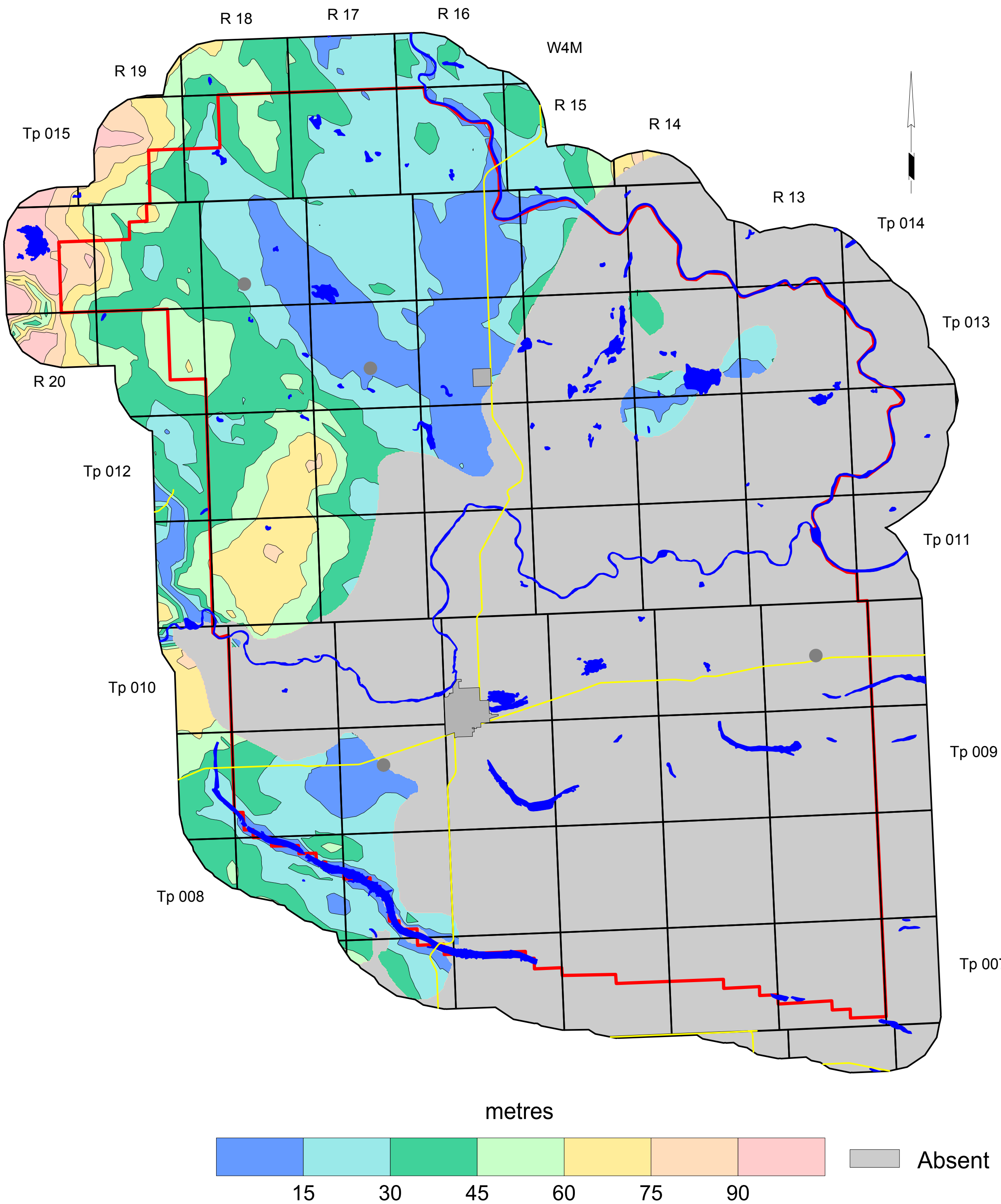
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



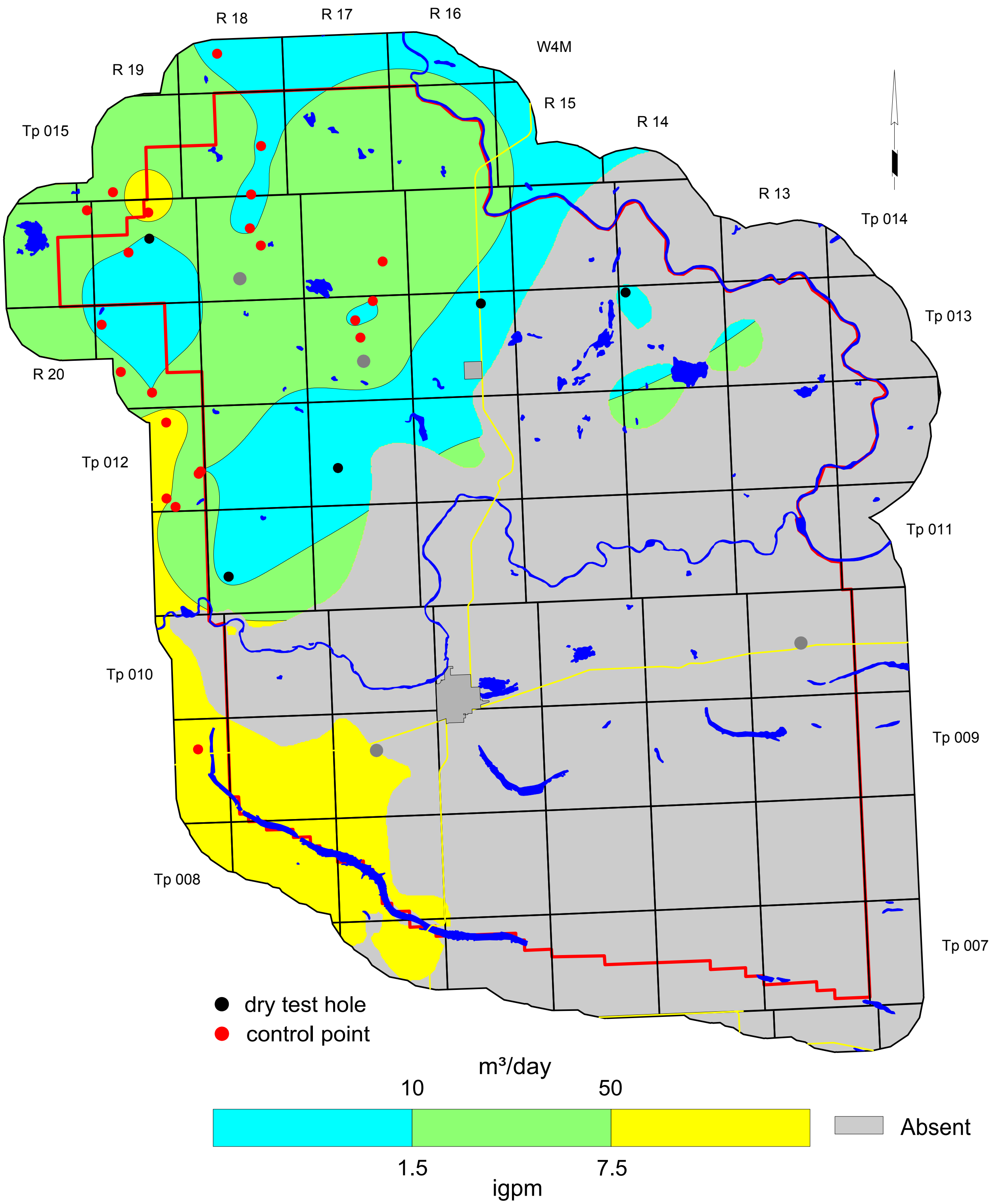
Fluoride vs Sodium Concentrations in Groundwater from Upper Bedrock Aquifer(s)



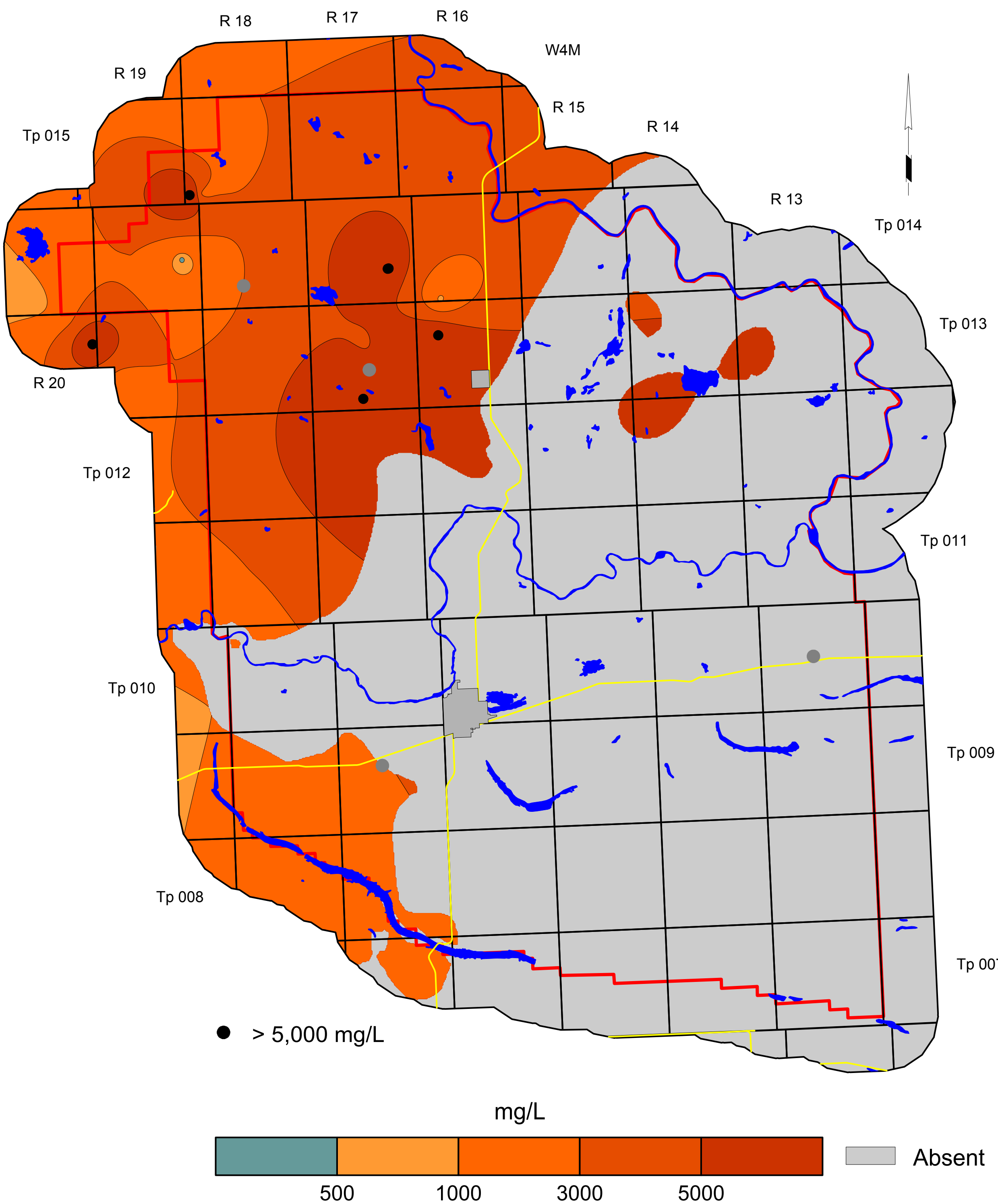
Depth to Top of Oldman Formation



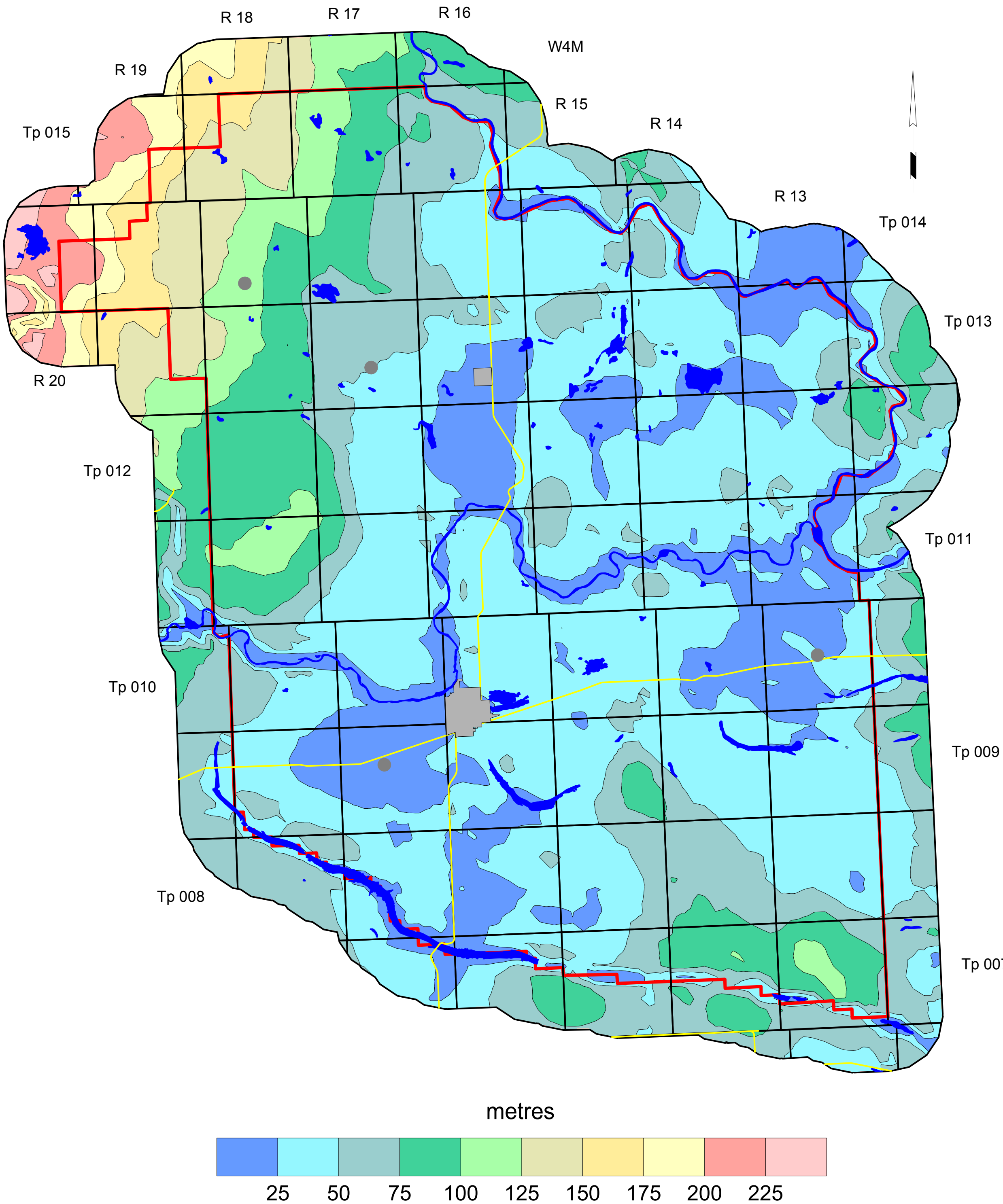
Apparent Yield for Water Wells Completed through Oldman Aquifer



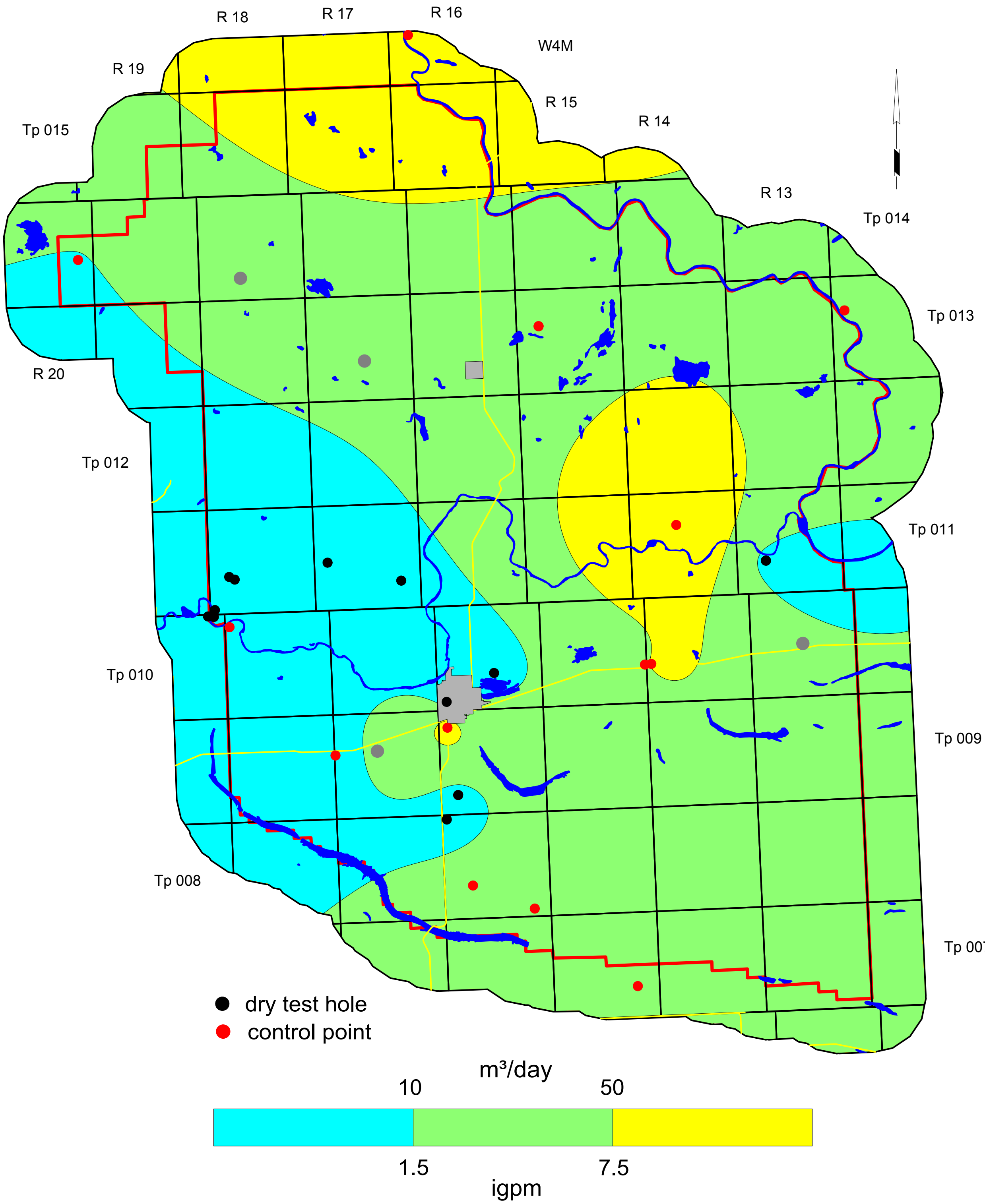
Total Dissolved Solids in Groundwater from Oldman Aquifer



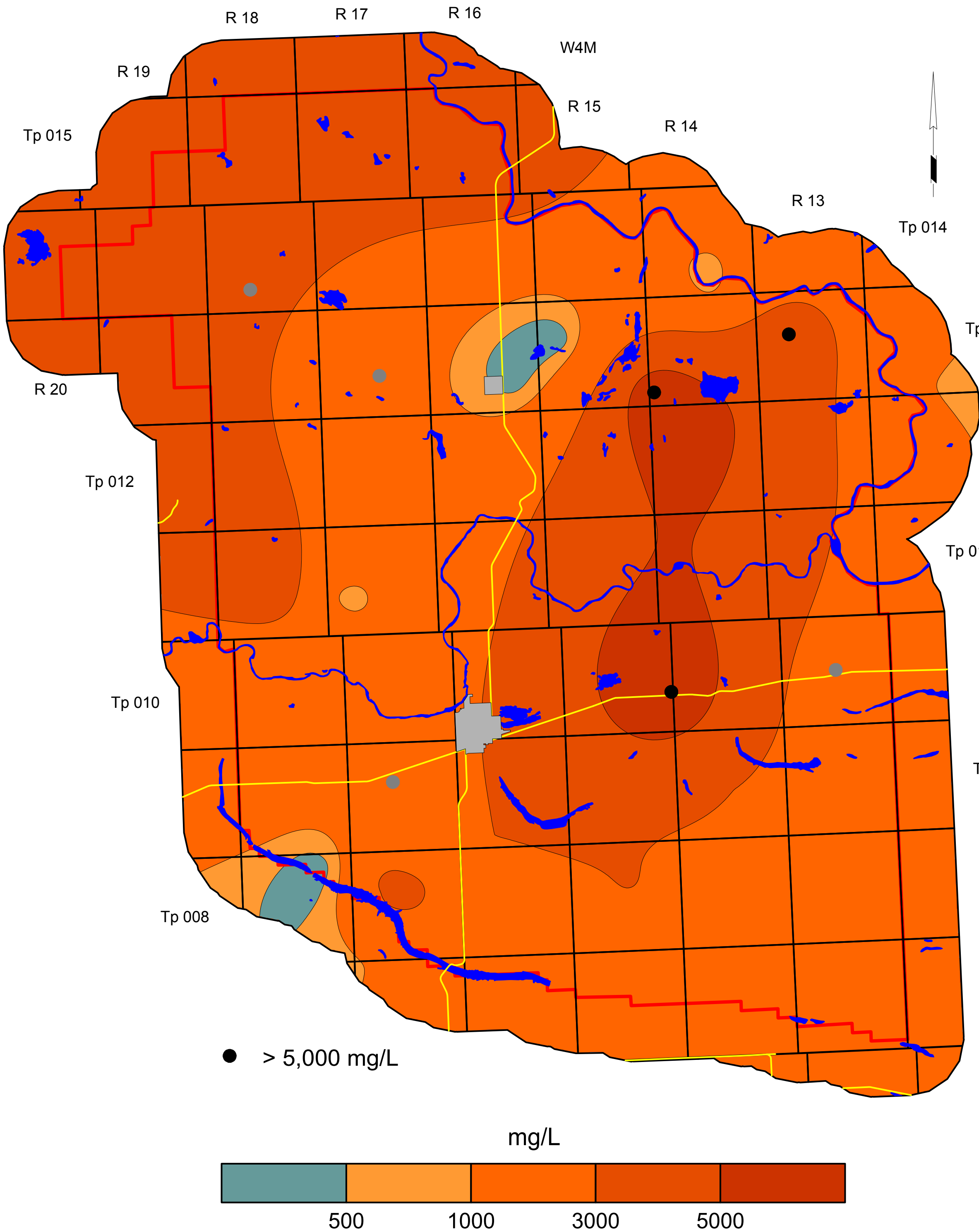
Depth to Top of Foremost Formation



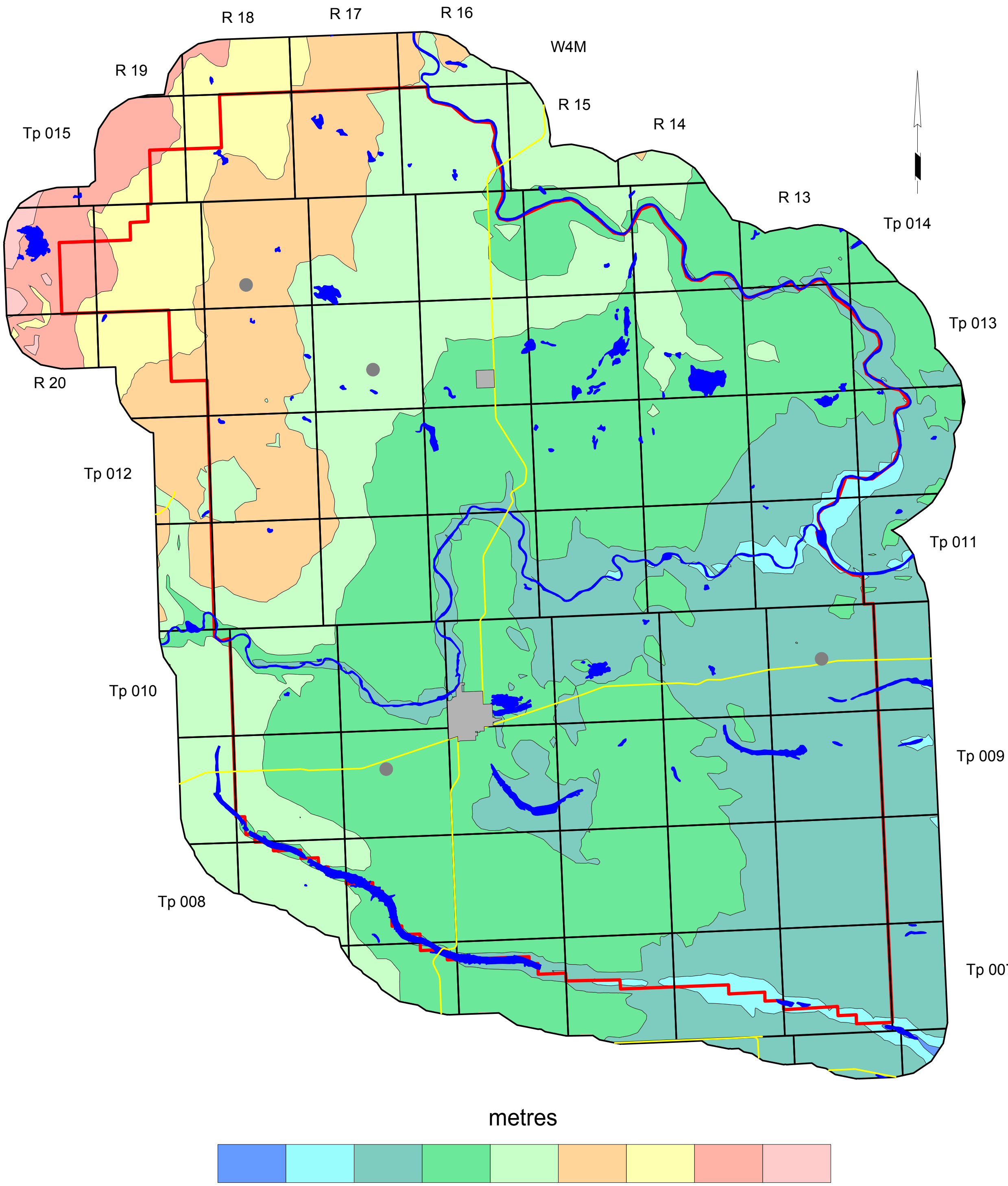
Apparent Yield for Water Wells Completed through Foremost Aquifer



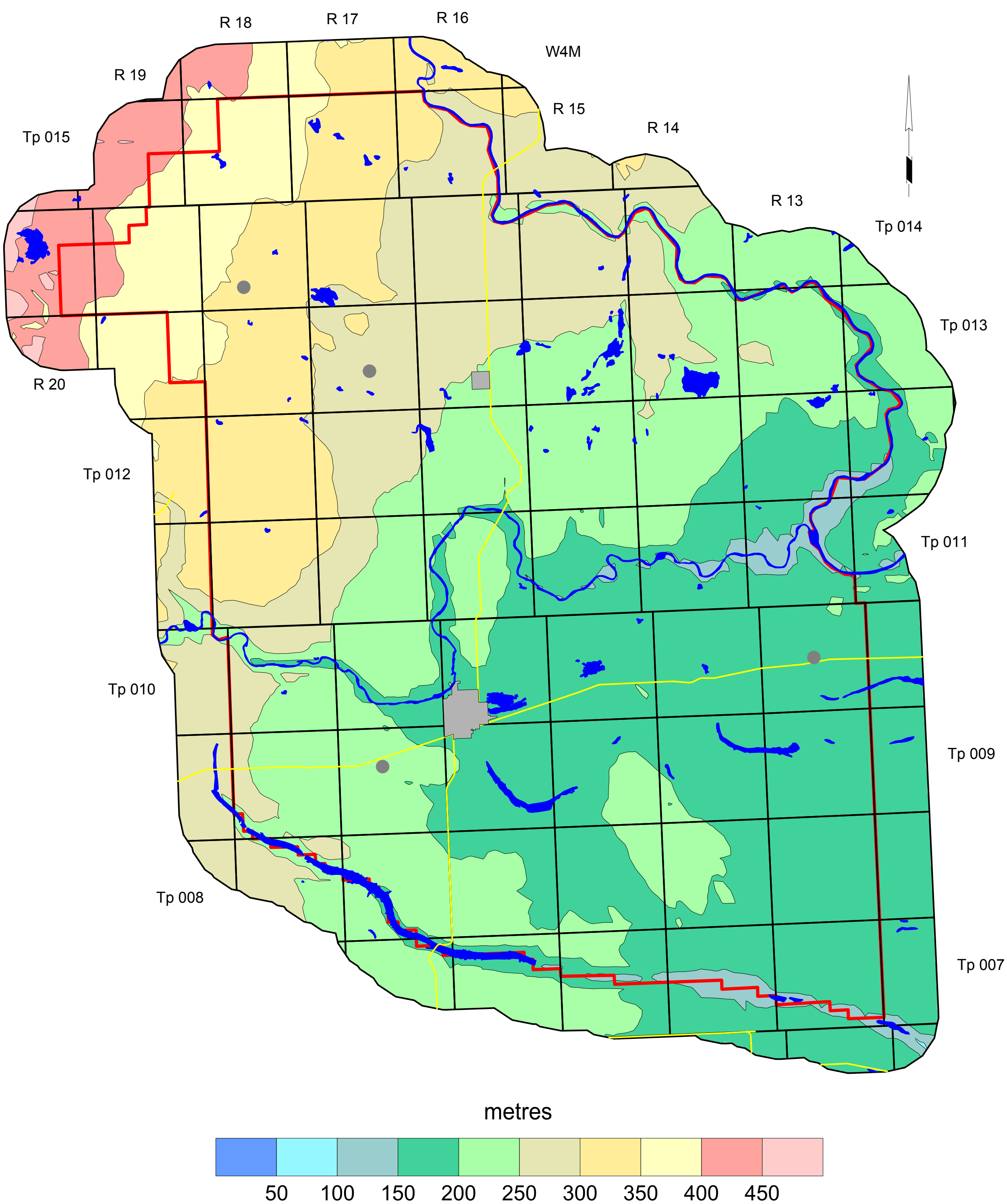
Total Dissolved Solids in Groundwater from Foremost Aquifer



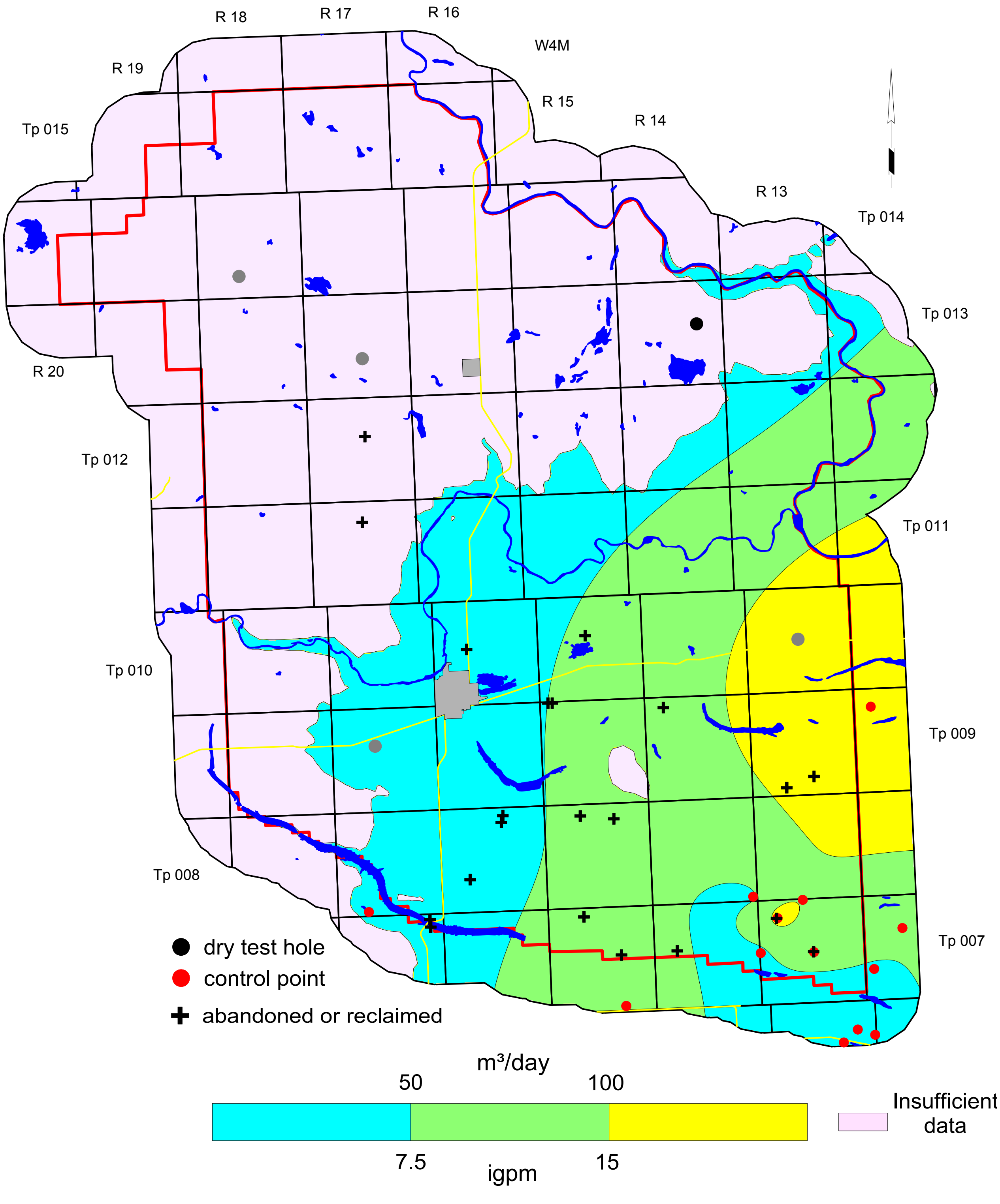
Depth to Top of Lea Park Formation



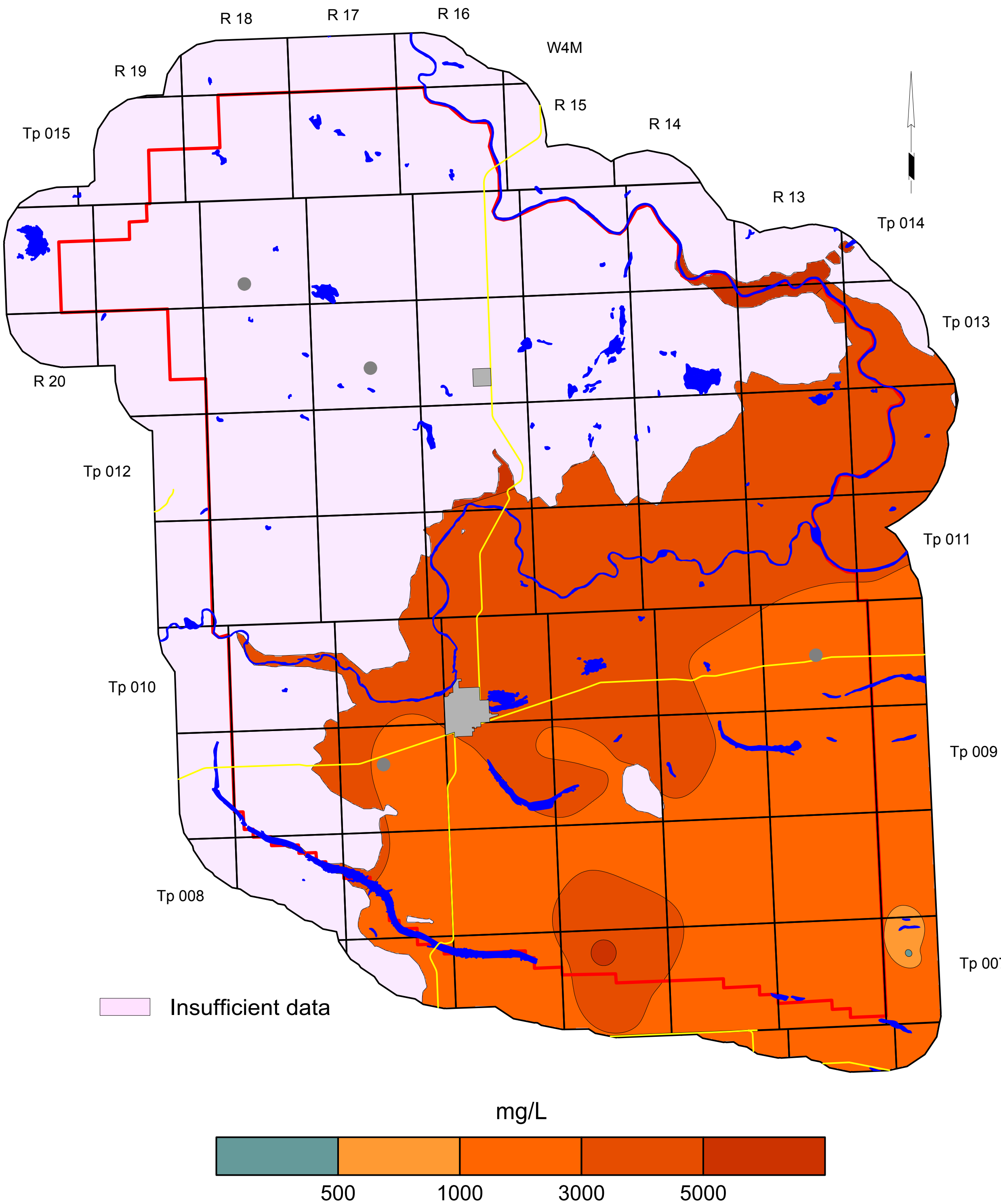
Depth to Top of Milk River Formation



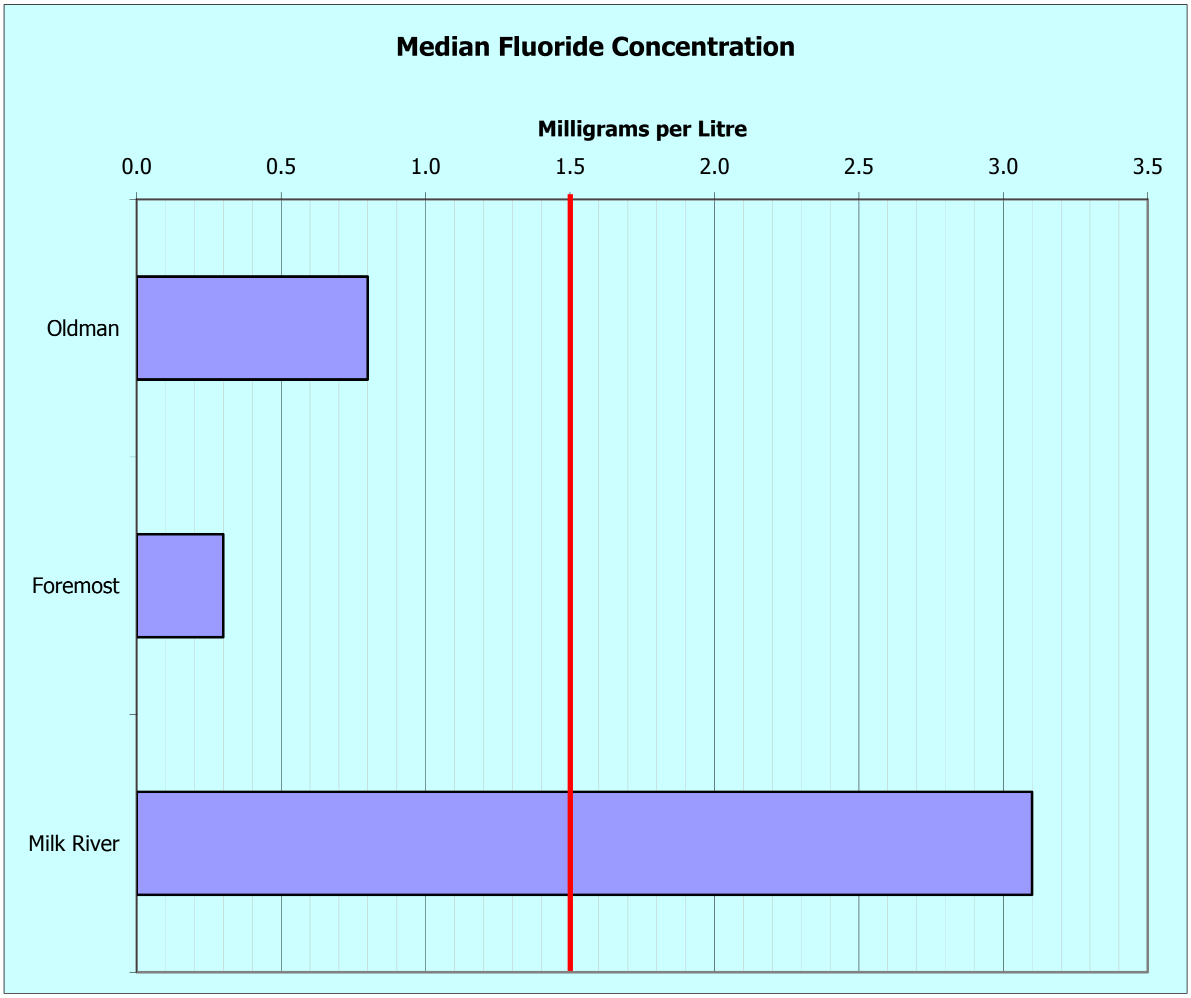
Apparent Yield for Water Wells Completed through Milk River Aquifer



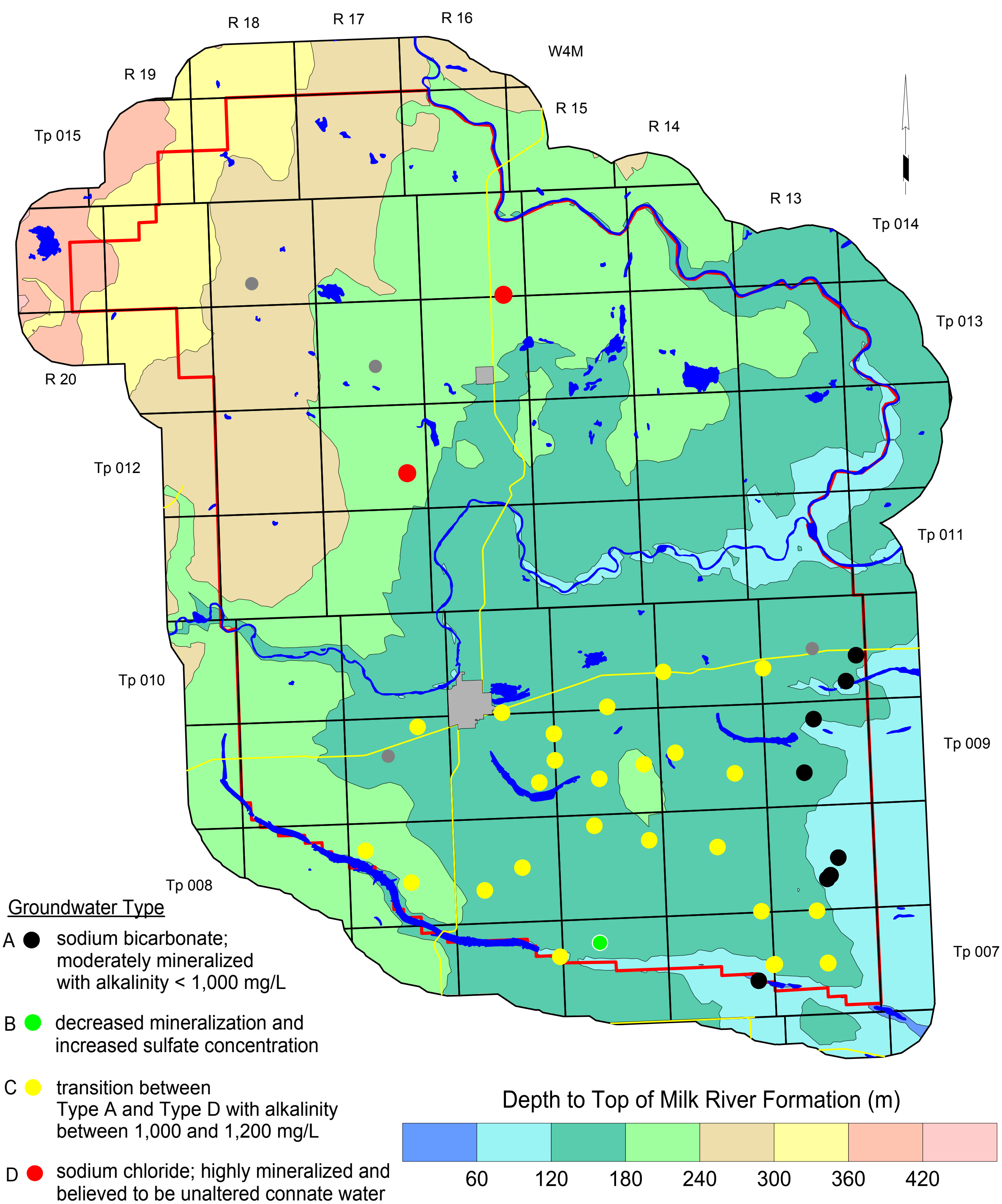
Total Dissolved Solids in Groundwater from Milk River Aquifer



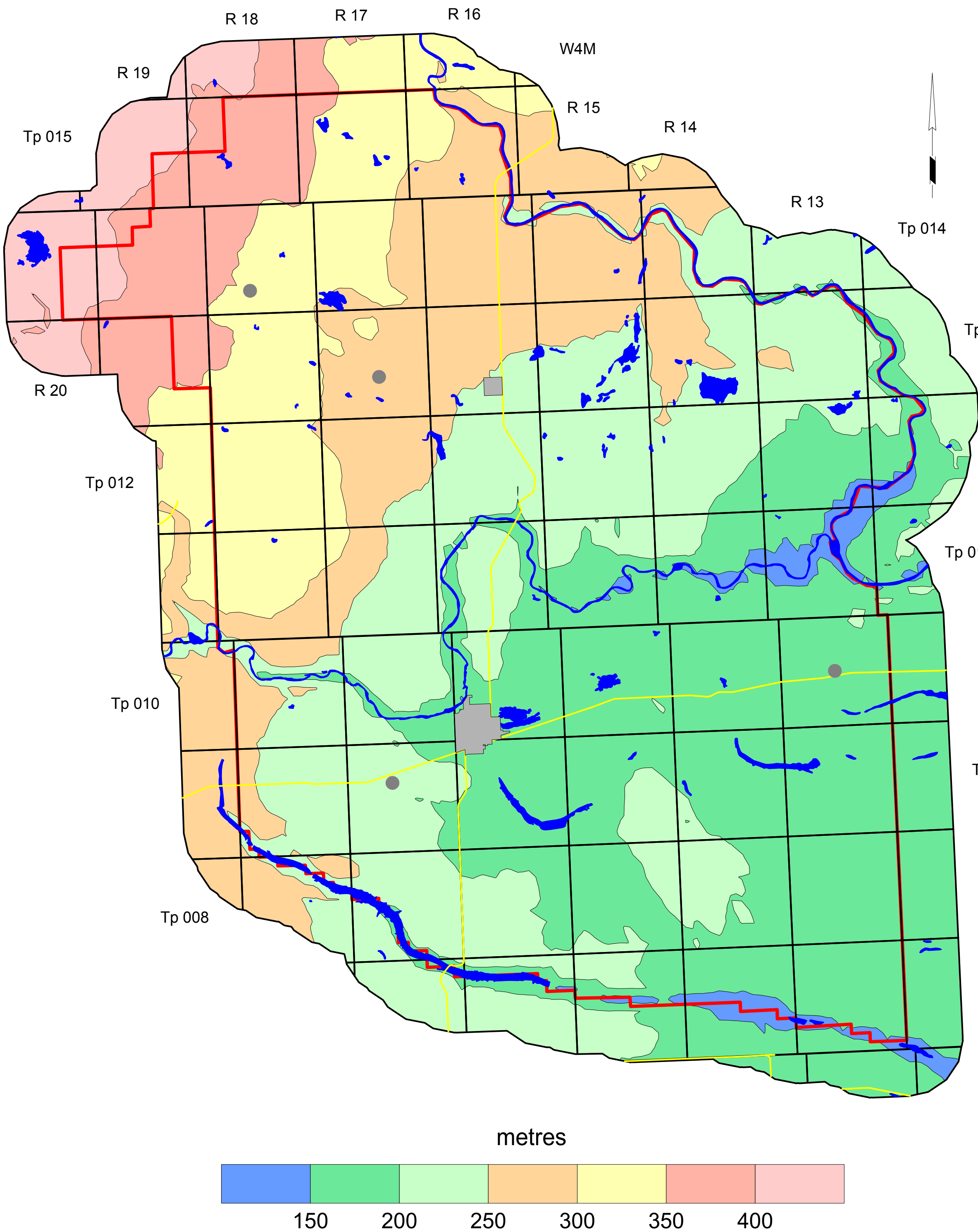
Median Fluoride Concentration



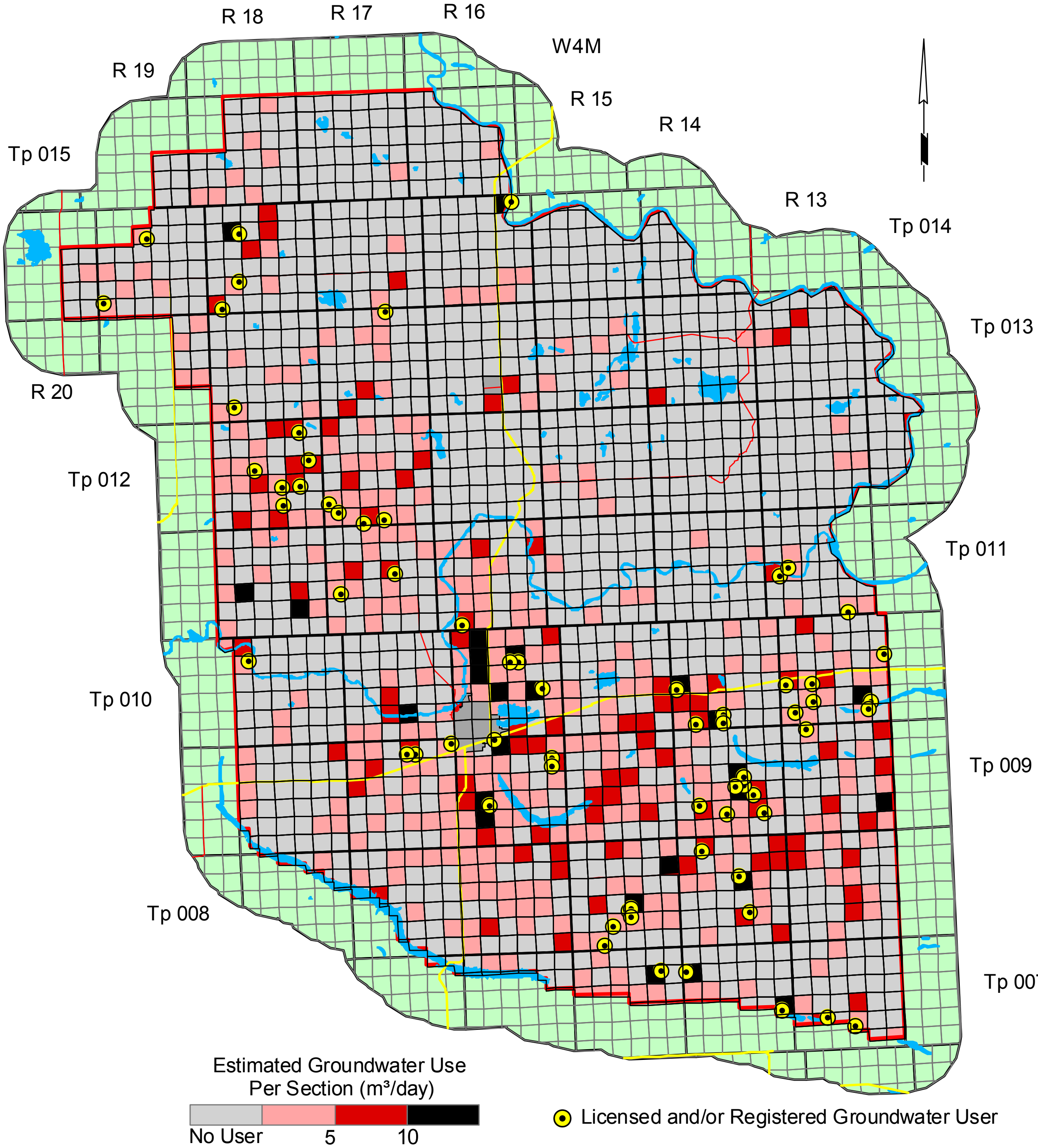
Types of Groundwater from Milk River Aquifer (modified after Meyboom, 1960)



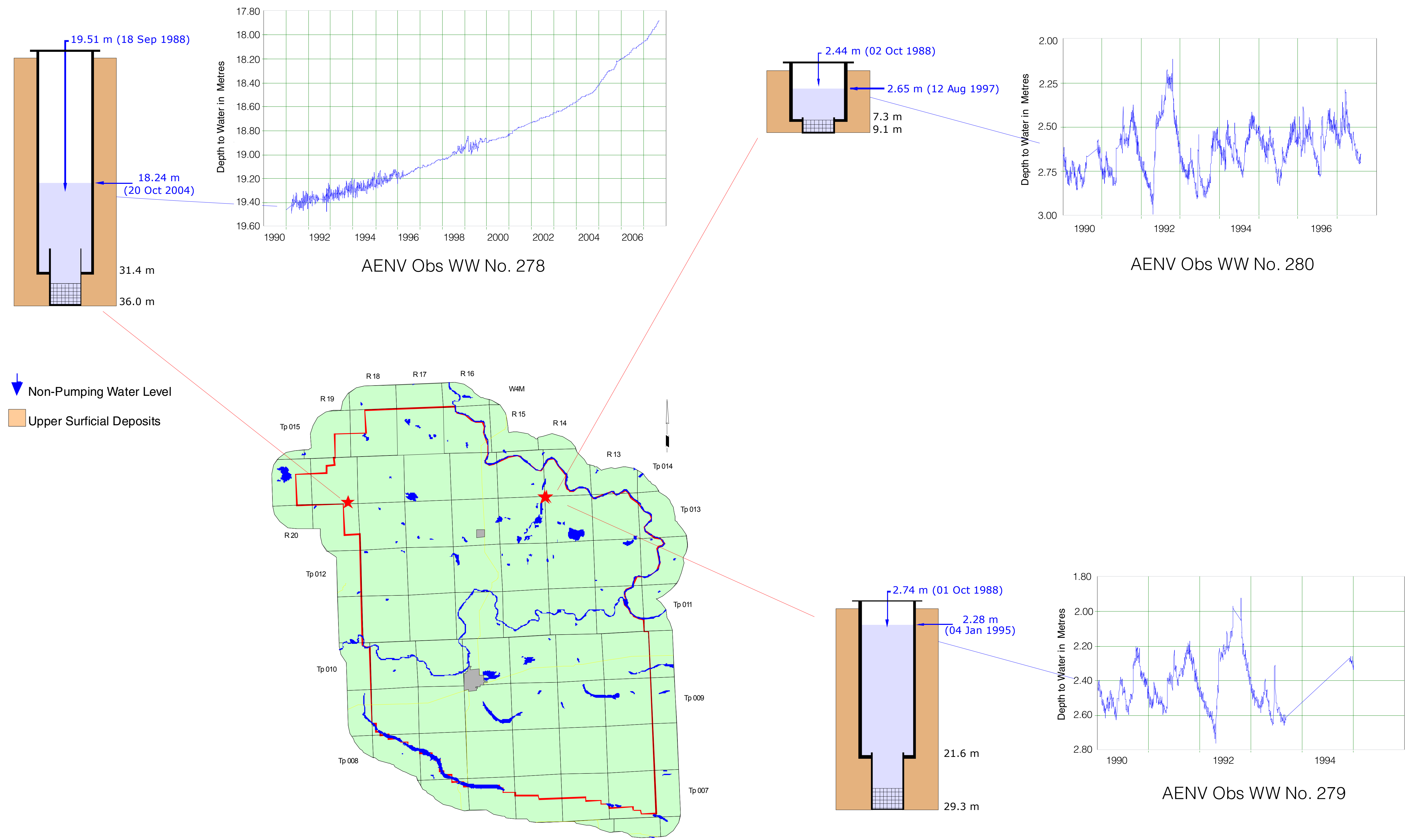
Depth to Top of Colorado Shales



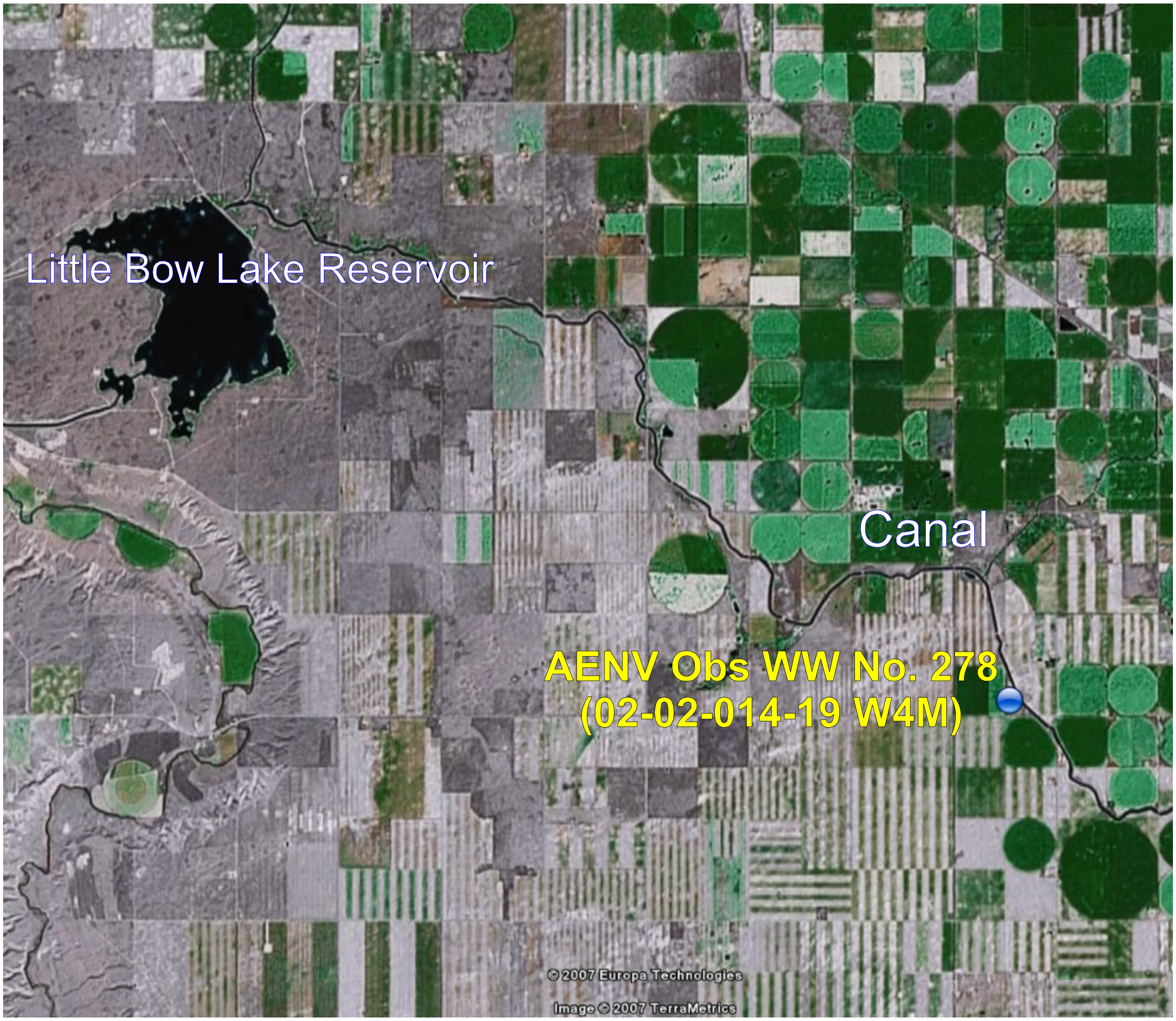
Estimated Water Well Use Per Section

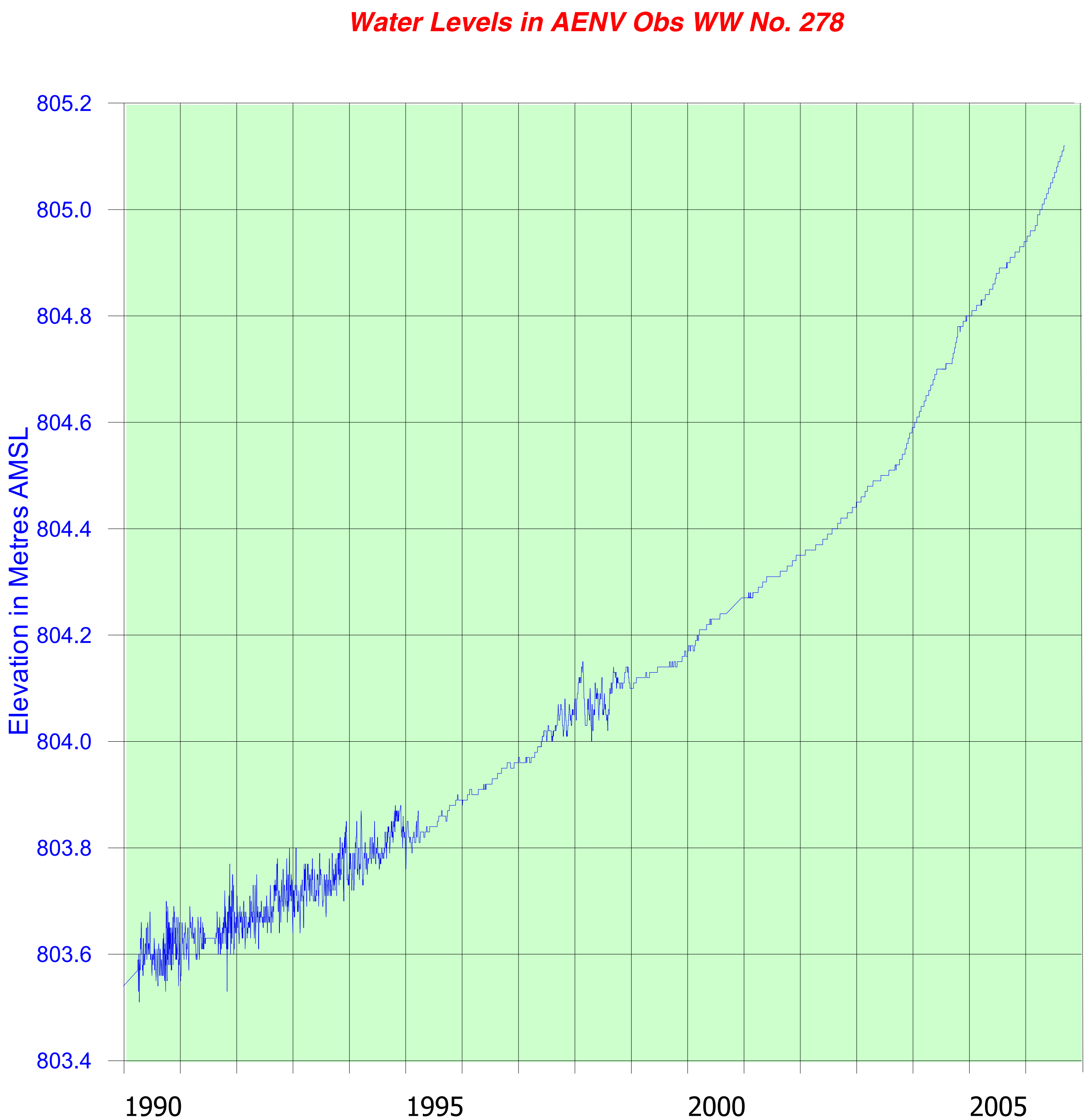


Hydrographs

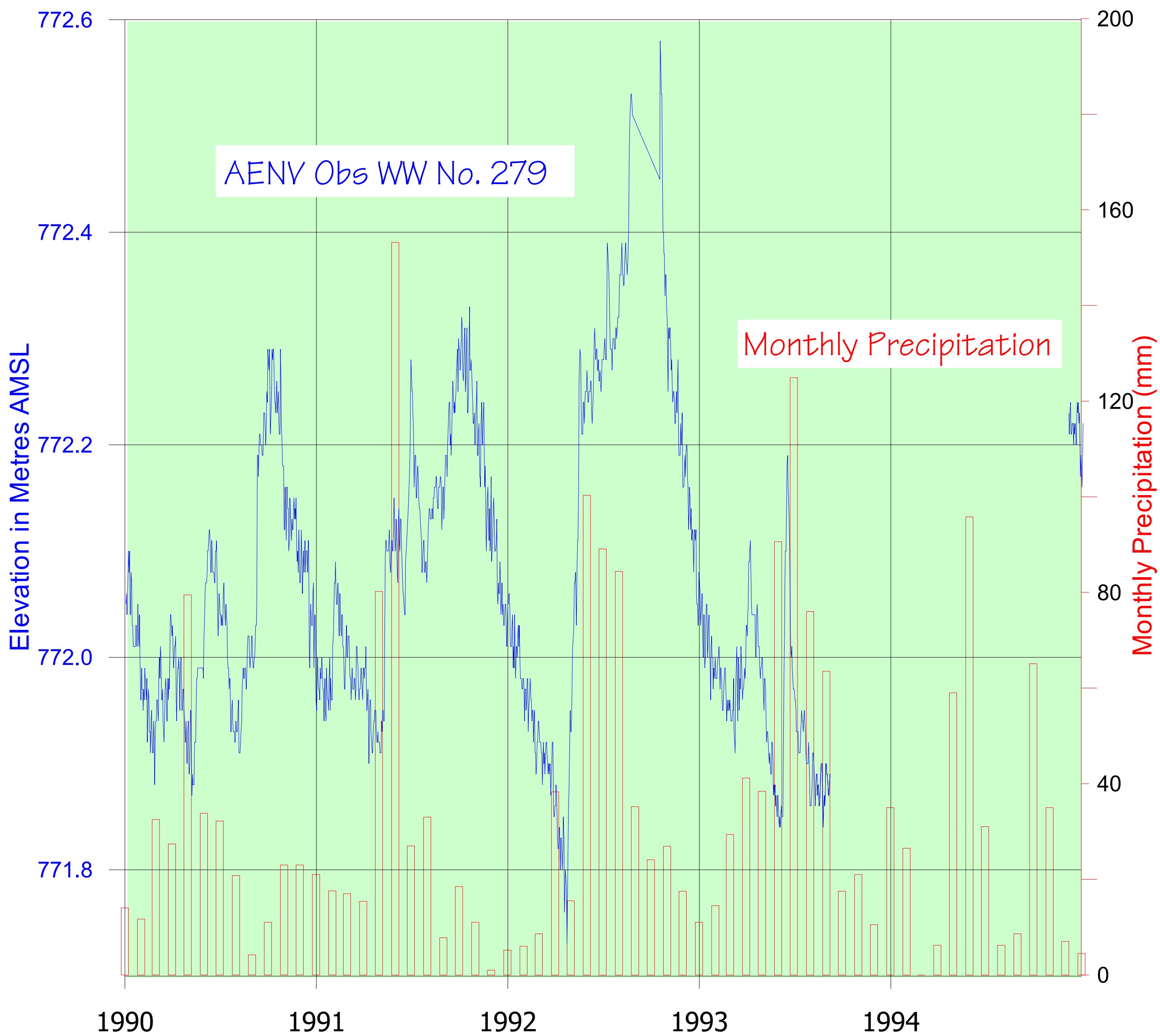


Location of AENV Obs WW No. 278 in Relation to an Irrigation Canal

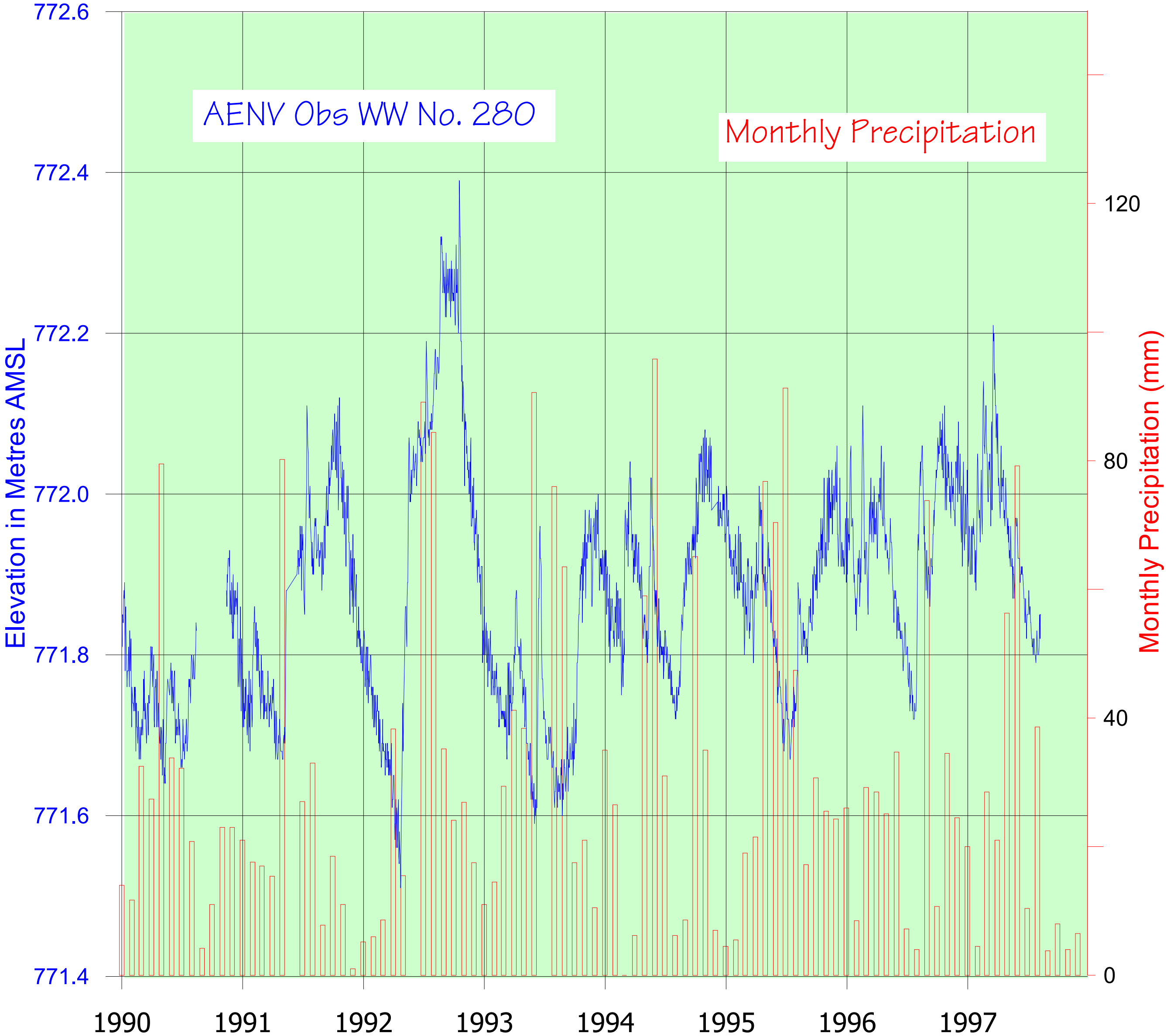



Water Levels in AENV Obs WW No. 278
Elevation in Metres AMSL
805.2
805.0
804.8
804.6
804.4
804.2
804.0
803.8
803.6
803.4
1990
1995
2000
2005

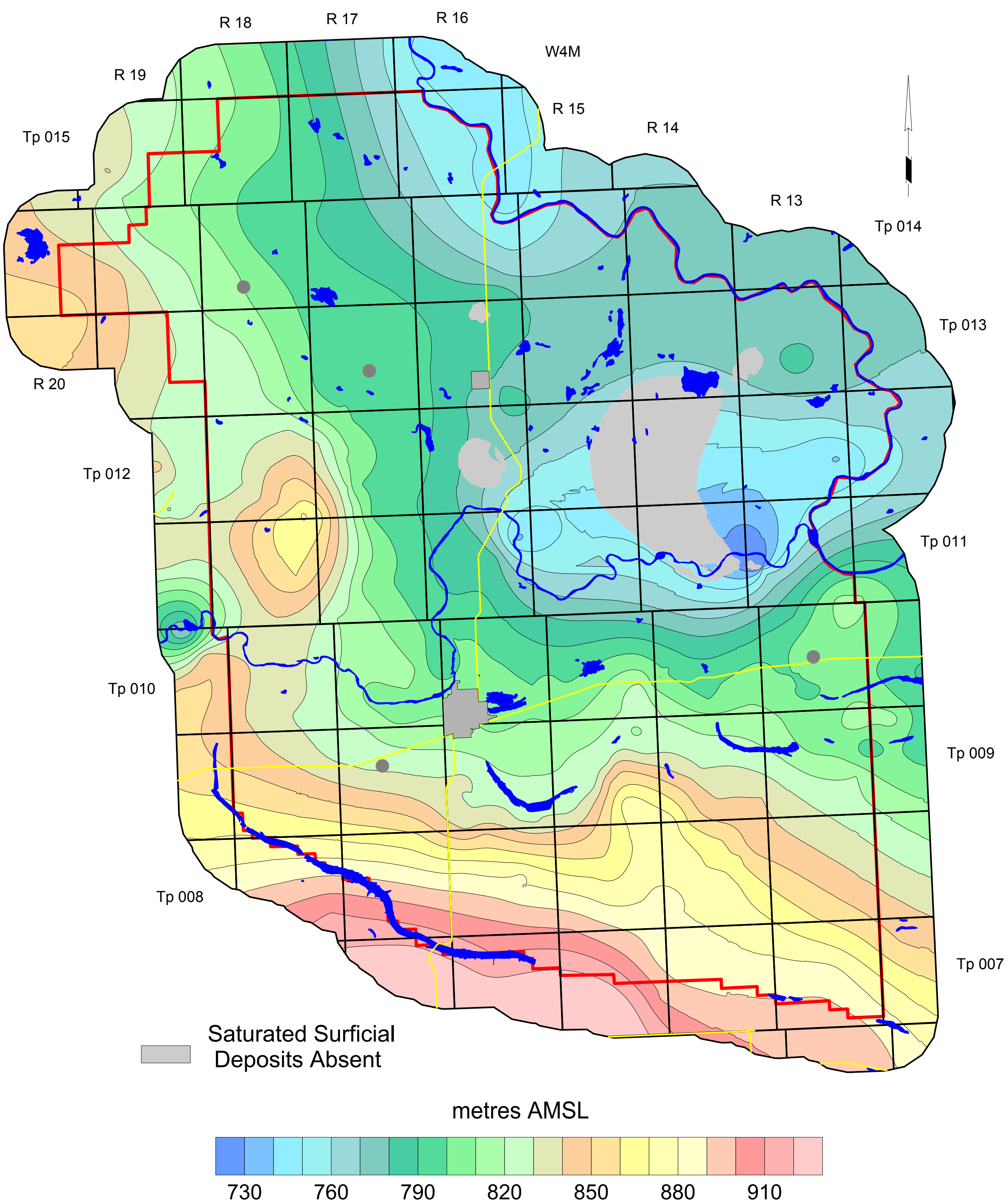
Comparison of Water Levels in AENV Obs WW No. 279 to Monthly Precipitation



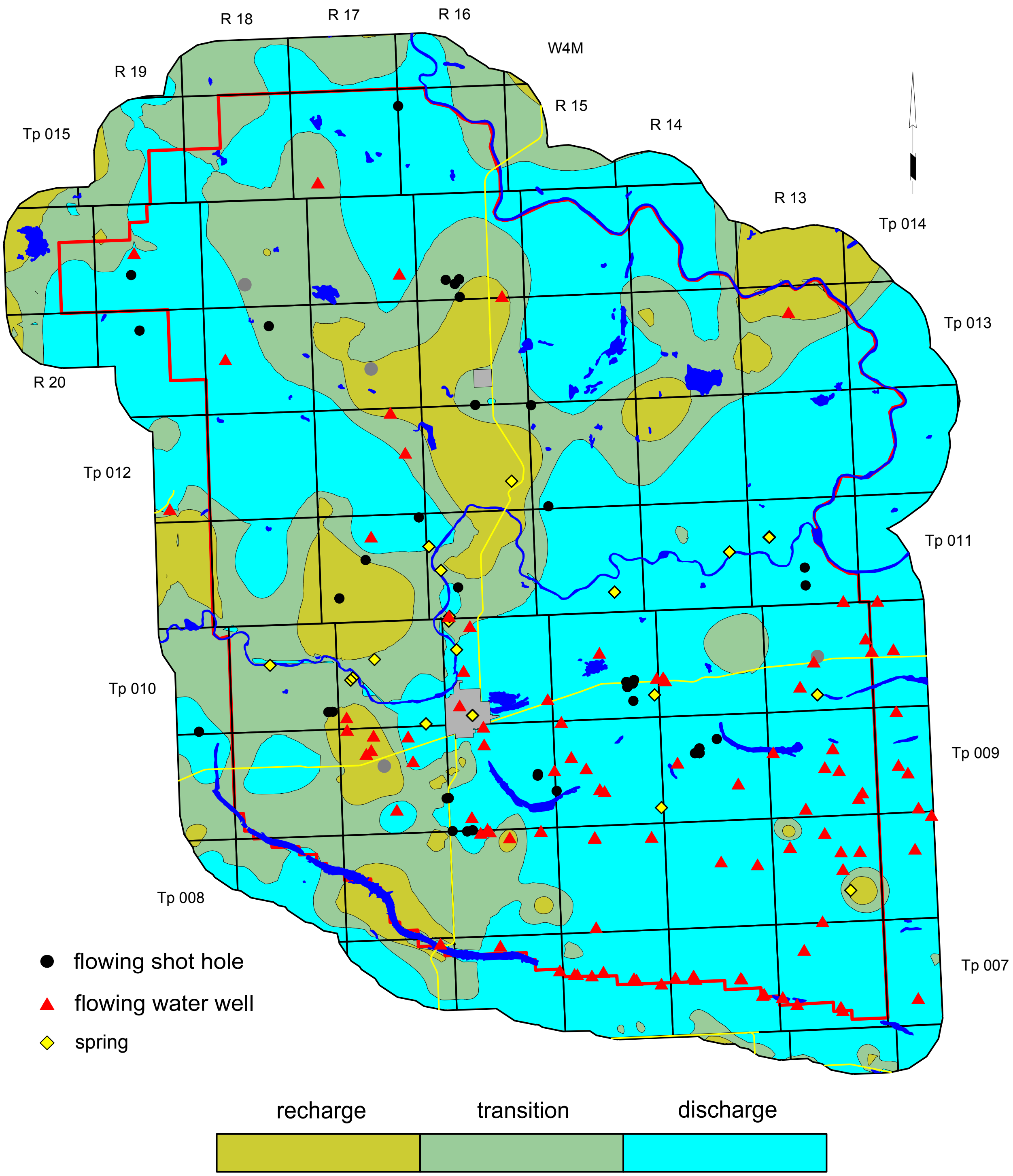
Comparison of Water Levels in AENV Obs WW No. 280 to Monthly Precipitation



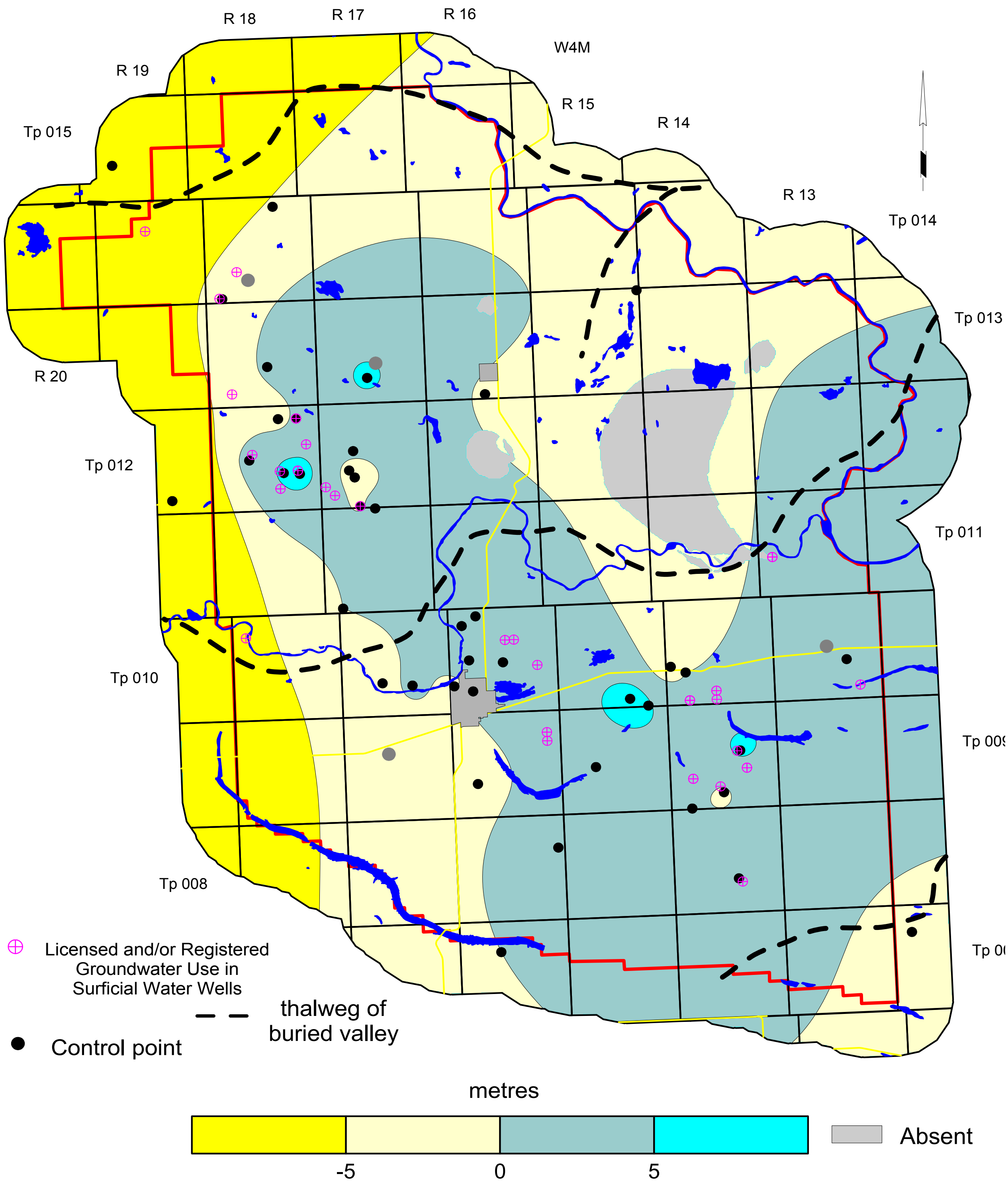
Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep



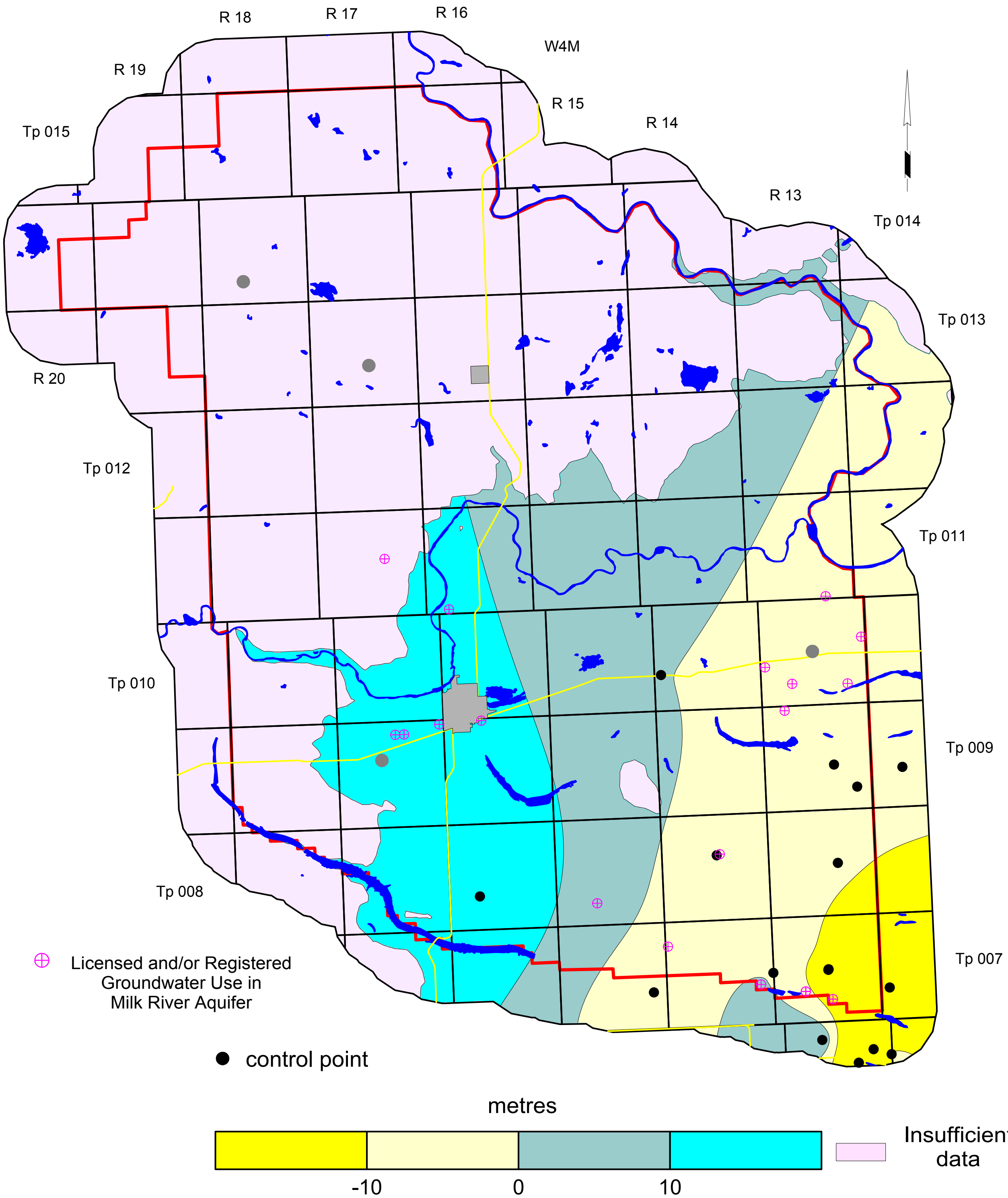
Bedrock Recharge/Discharge Areas

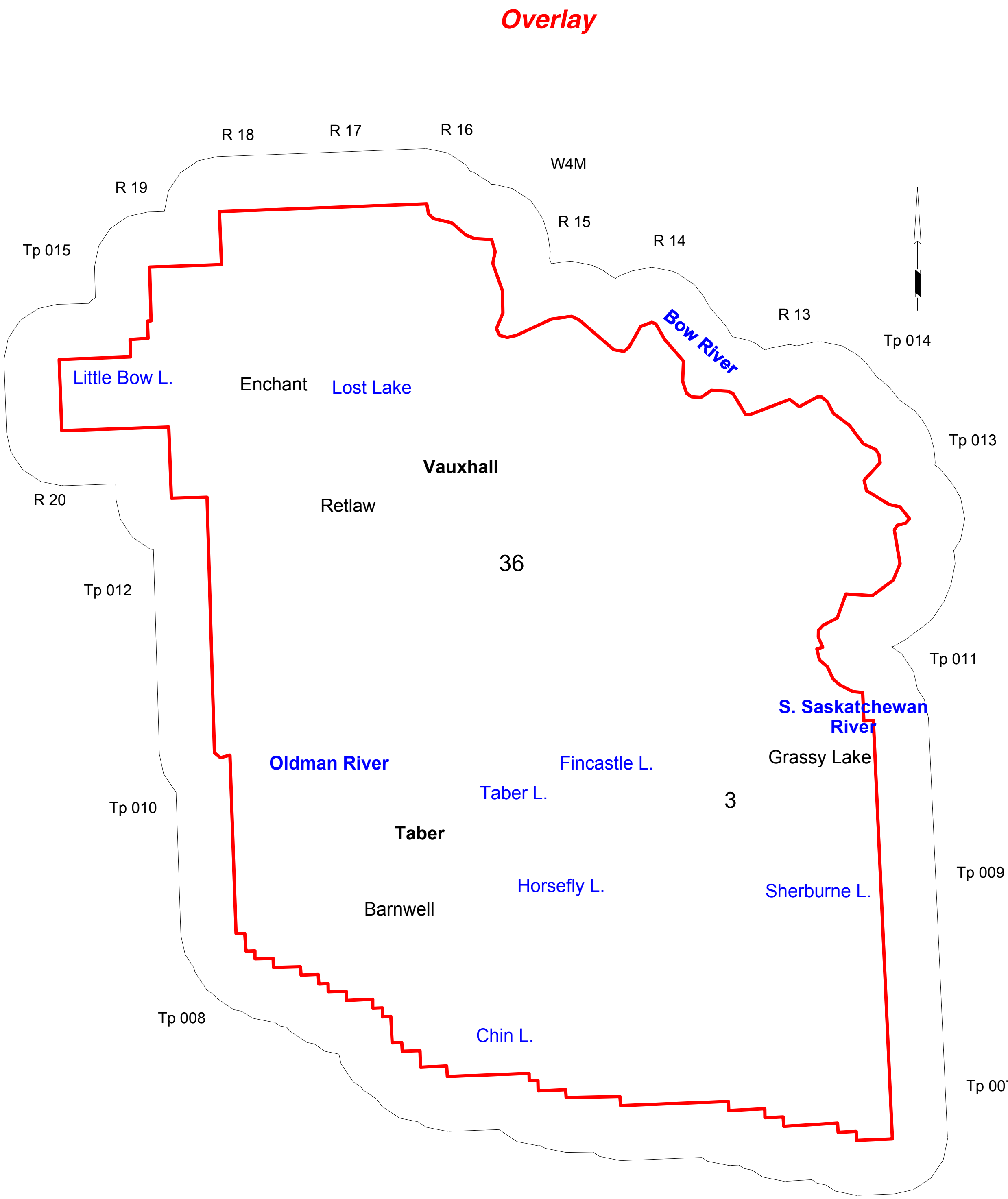


Changes in Water Levels in Surficial Deposits



Areas of Potential Groundwater Decline in Milk River Aquifer




Overlay
R 18
R 17
R 16
W4M
R 19
R 15
R 14
Tp 015
R 13
Tp 014
Bow River
Little Bow L.
Enchant
Lost Lake
Tp 013
Vauxhall
R 20
Retlaw
36
Tp 012
Tp 011
S. Saskatchewan River
Grassy Lake
Oldman River
Fincastle L.
Taber L.
3
Tp 010
Taber
Tp 009
Horsefly L.
Sherburne L.
Barnwell
Tp 008
Chin L.
Tp 007

M.D. OF TABER

Appendix B

Maps and Figures on CD-ROM

MAPS AND FIGURES ON CD-ROM

M.D. OF TABER
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

1

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/

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

WATER WELL INSPECTORS
Jennifer MacPherson (Edmonton: 780-427-9517)

WATER WELL LICENSING
Glenn Winner (Edmonton: 780-427-6429)

GEOPHYSICAL INSPECTION SERVICE
Edmonton: 780-427-3932 or 310-000 - e-mail LFS.Seismic@gov.ab.ca

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Jerry Riddell (Edmonton: 780-422-4851)

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
Jim Kiss (Edmonton: 780-427-2433)

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Terry Dash (Calgary: 403-292-5719) - dasht@agr.gc.ca

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

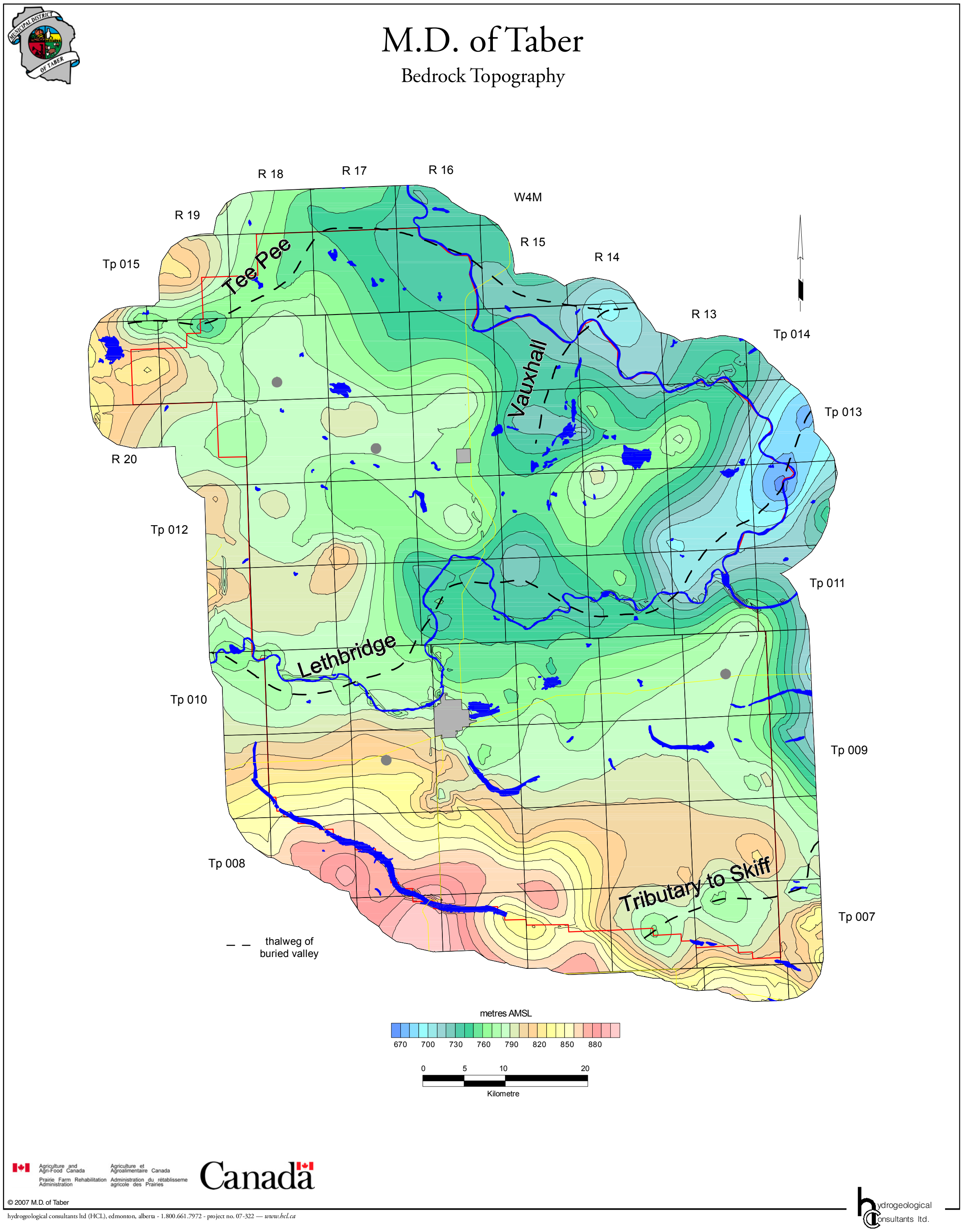
COUNTY OF GRANDE PRAIRIE
Jill Henry - *Rural Extension Officer - Alberta Environmentally Sustainable Agriculture Program*
(780) 513-3955 ext. 103

LOCAL HEALTH DEPARTMENTS

M.D. OF TABER
Appendix D

Maps and Figures Included as Large Plots

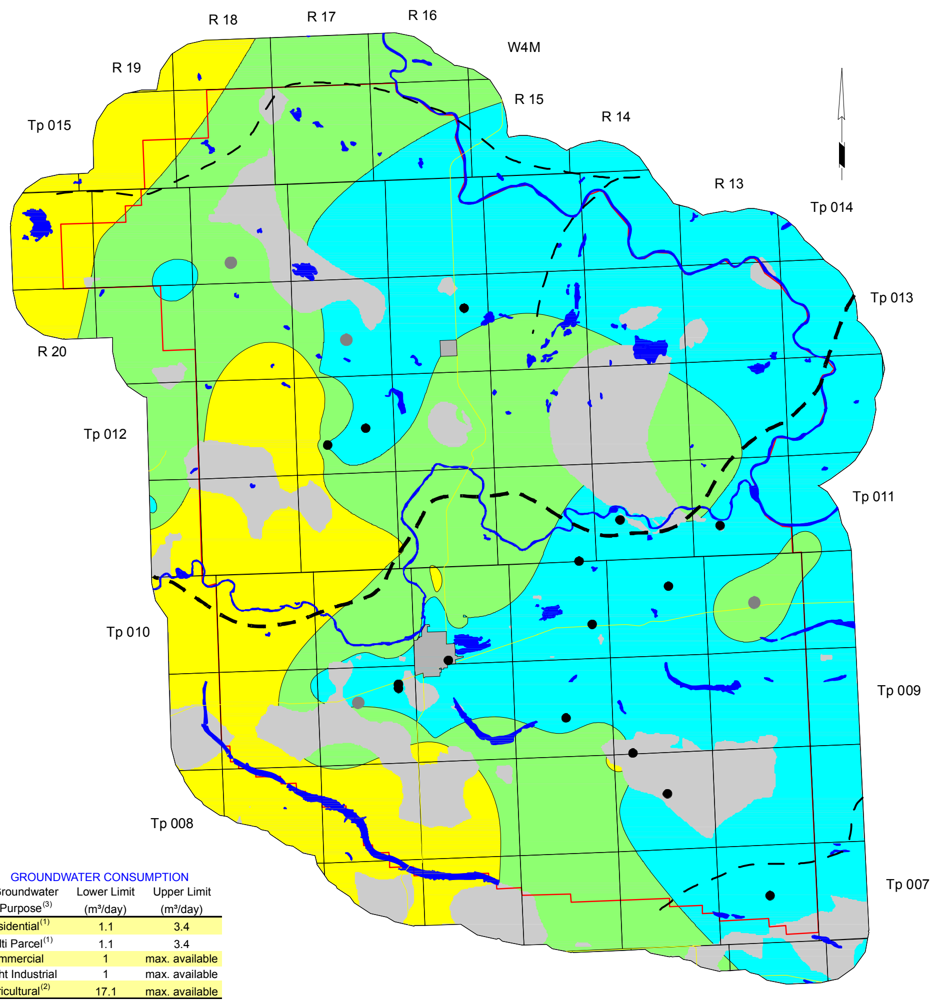
Bedrock Topography



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

M.D. of Taber

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



GROUNDWATER CONSUMPTION

Groundwater Purpose[3]	Lower Limit (m^3/day)	Upper Limit (m^3/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

thalweg of buried valley
dry test hole
Absent

0 5 10 20
Kilometre

m^3/day: 10 50
1.5 7.5 igpm

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Prairie Farm Rehabilitation Administration — Administration du rétablissement agricole des Prairies
Canada

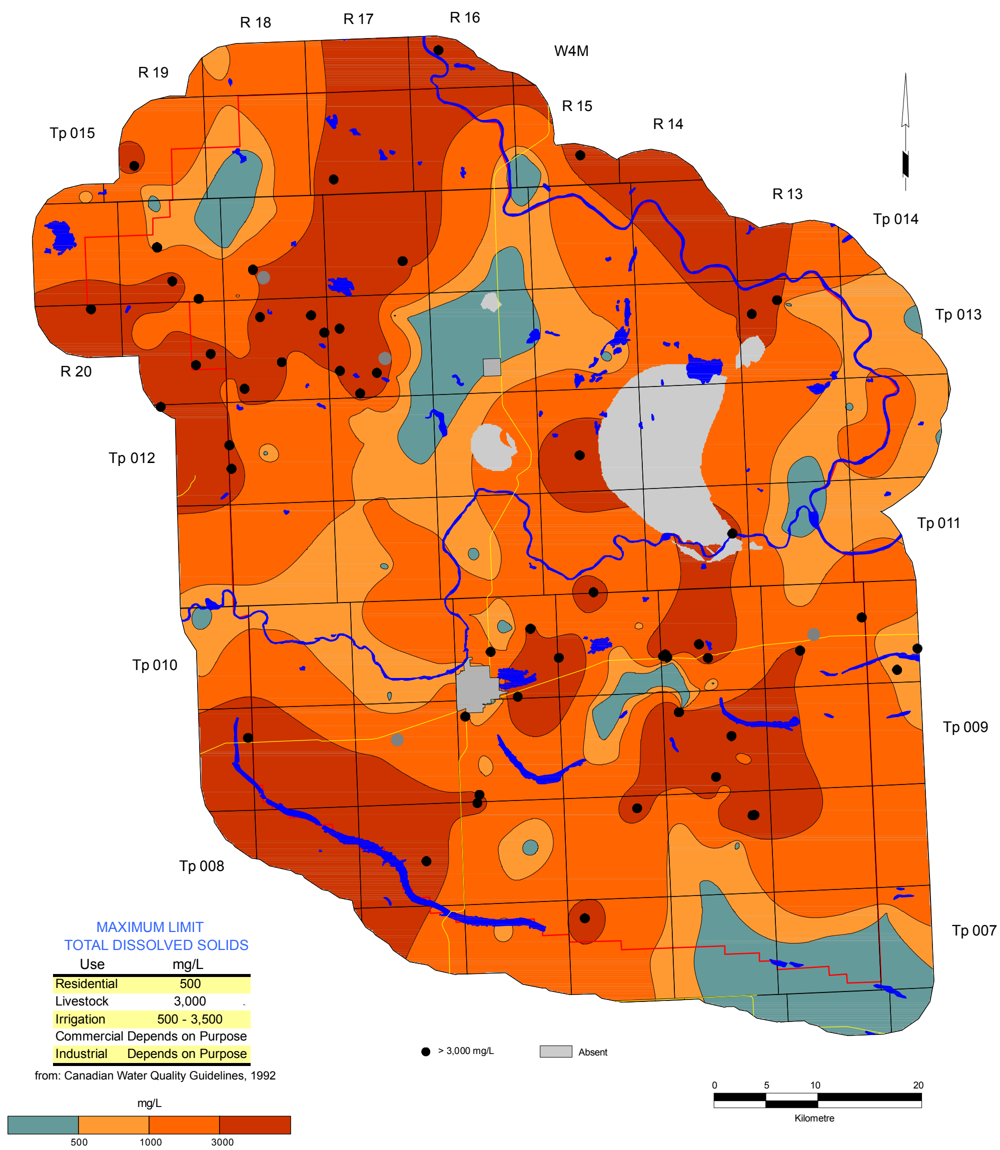
hydrogeological consultants ltd (HCL), edmonton, alberta - 1.800.661.7972 - project no. 07-322 — *www.hcl.ca*

hydrogeological consultants ltd.

Total Dissolved Solids in Groundwater from Surficial Deposits

M.D. of Taber

Total Dissolved Solids in Groundwater from Surficial Deposits



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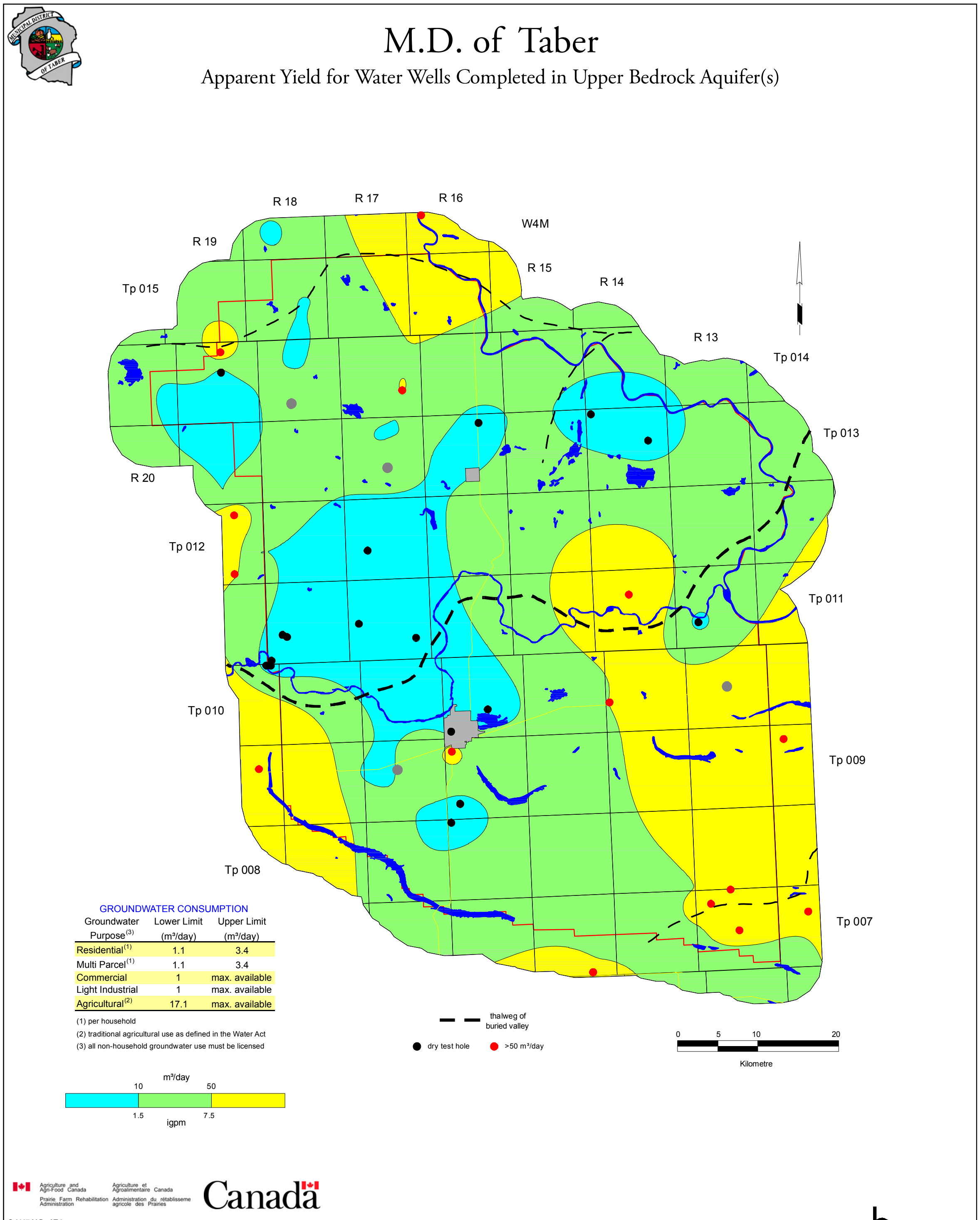
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



GROUNDWATER CONSUMPTION

Groundwater Purpose(3)	Lower Limit (m^3/day)	Upper Limit (m^3/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

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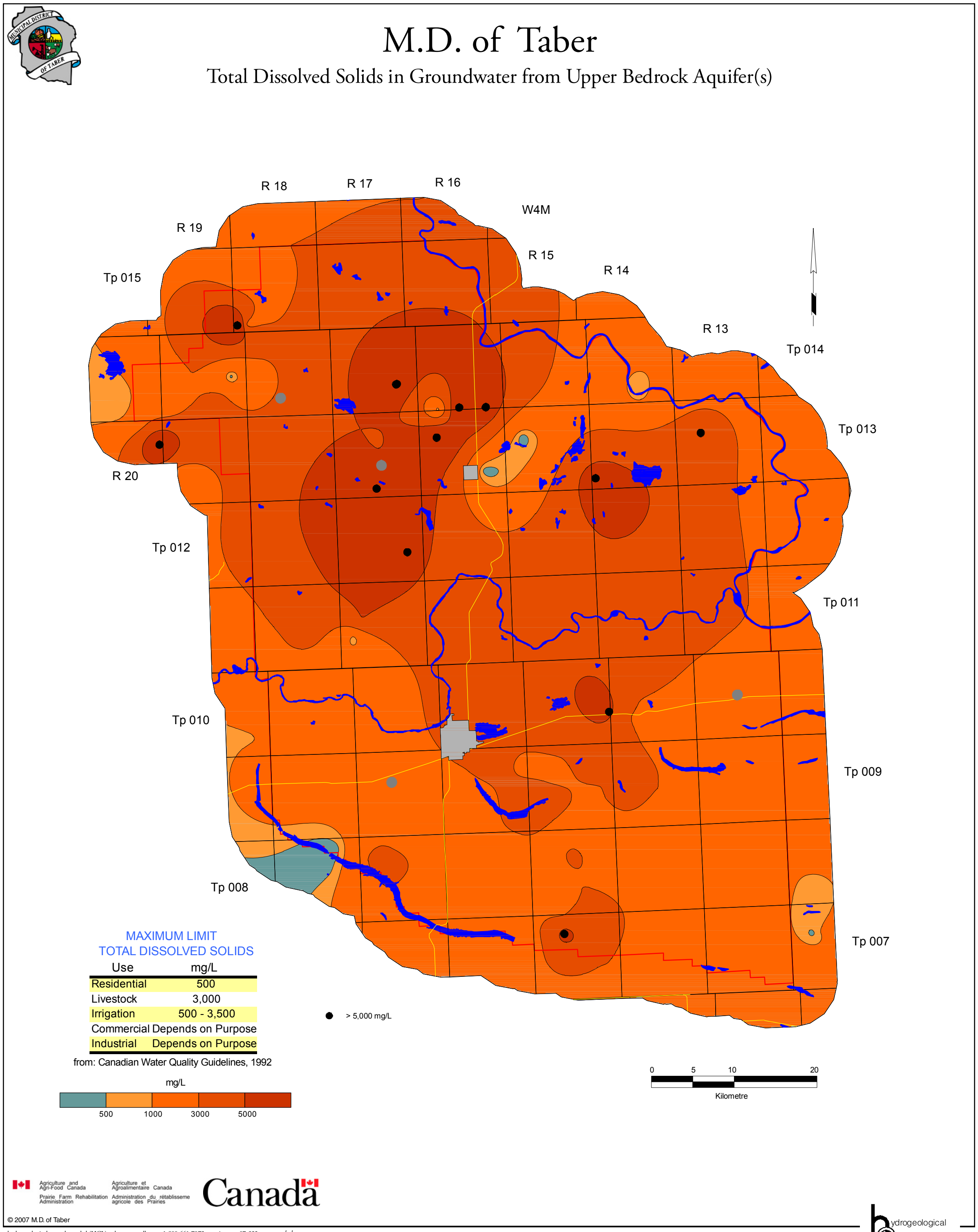
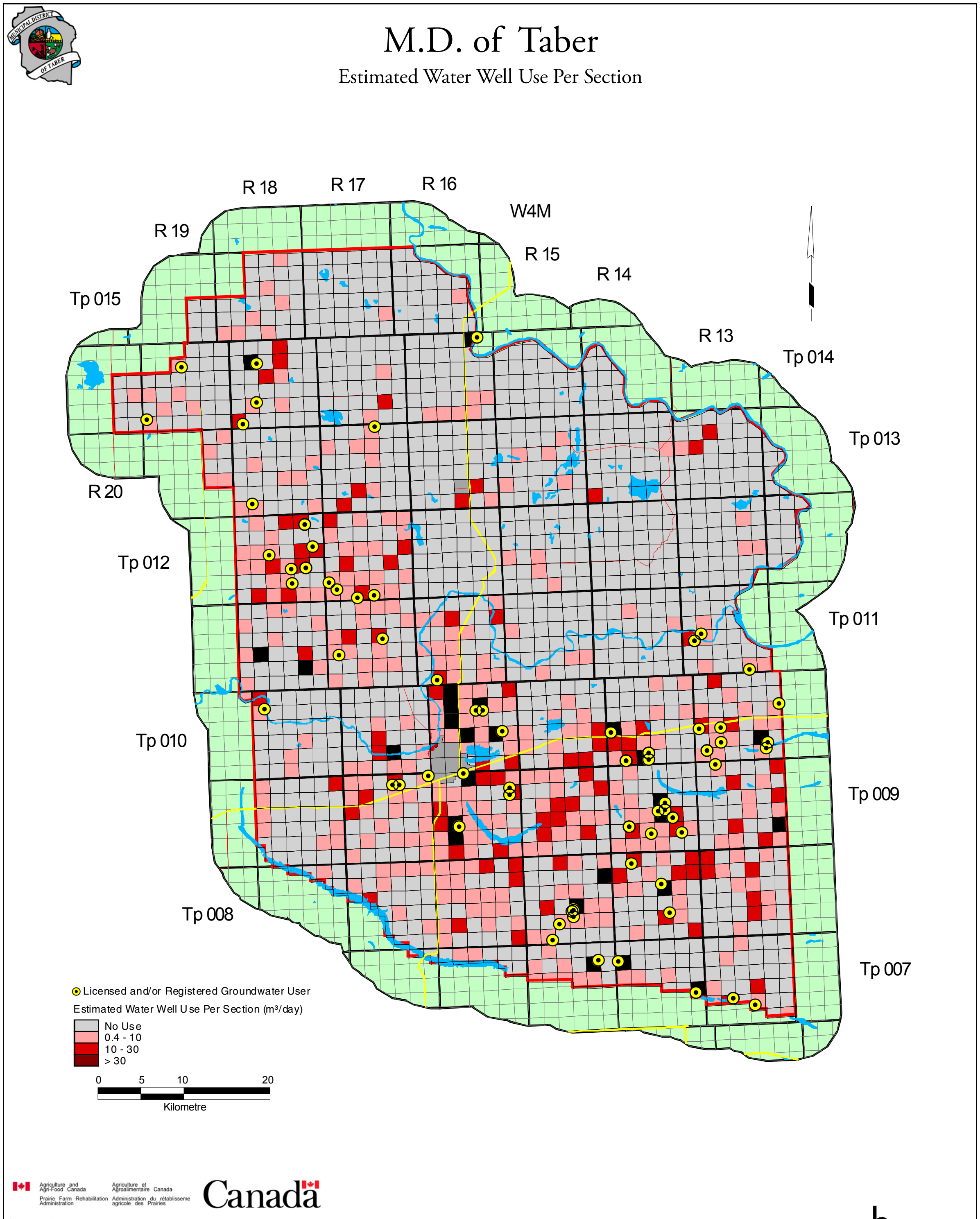
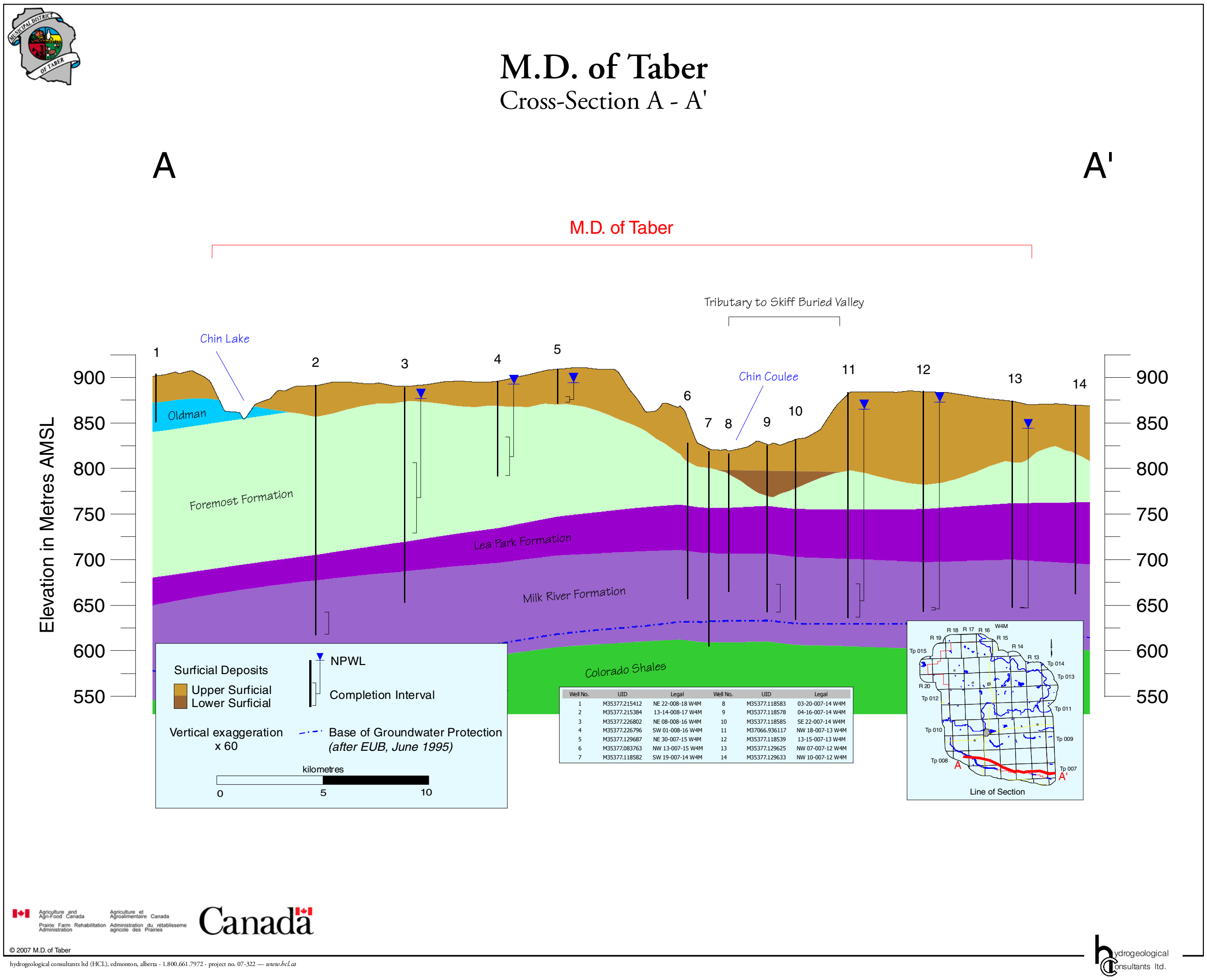
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



Estimated Water Well Use Per Section



Cross-Section A - A'



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3	M35377.226802	NE 08-008-16 W4M	10	M35377.118585	SE 22-007-14 W4M
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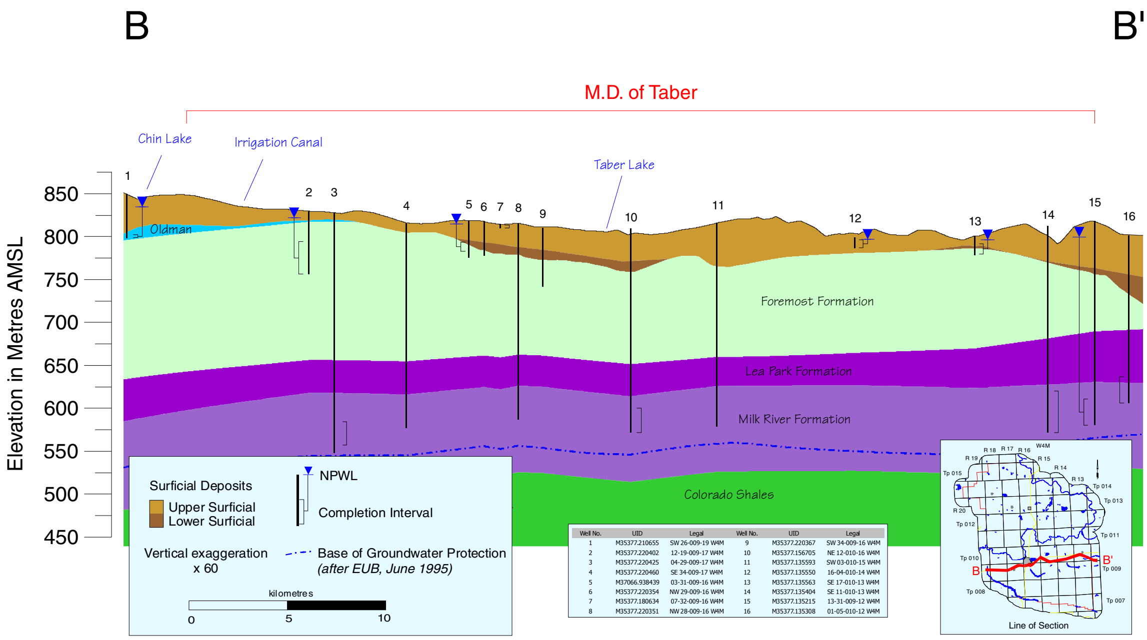
5	M35377.129687	NE 30-007-15 W4M	12	M35377.118539	13-15-007-13 W4M
6	M35377.083763	NW 13-007-15 W4M	13	M35377.129625	NW 07-007-12 W4M
7	M35377.118582	SW 19-007-14 W4M	14	M35377.129633	NW 10-007-12 W4M

Cross-Section B - B'

M.D. of Taber

Cross-Section B - B'



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4	M35377.220460	SE 34-009-17 W4M	12	M35377.135550	16-04-010-14 W4M
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8	M35377.220351	NW 28-009-16 W4M	16	M35377.135308	01-05-010-12 W4M

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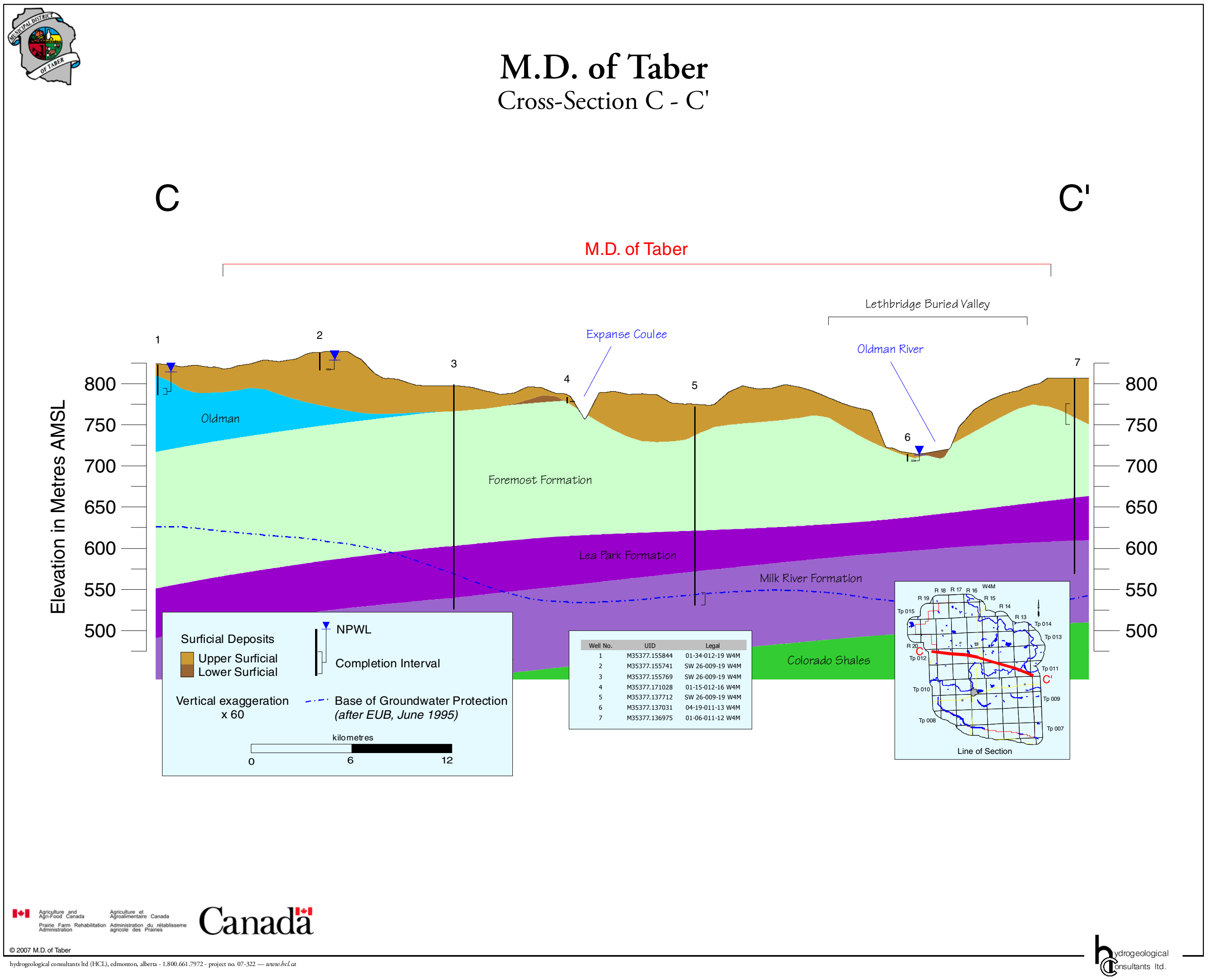
Cross-Section C - C'



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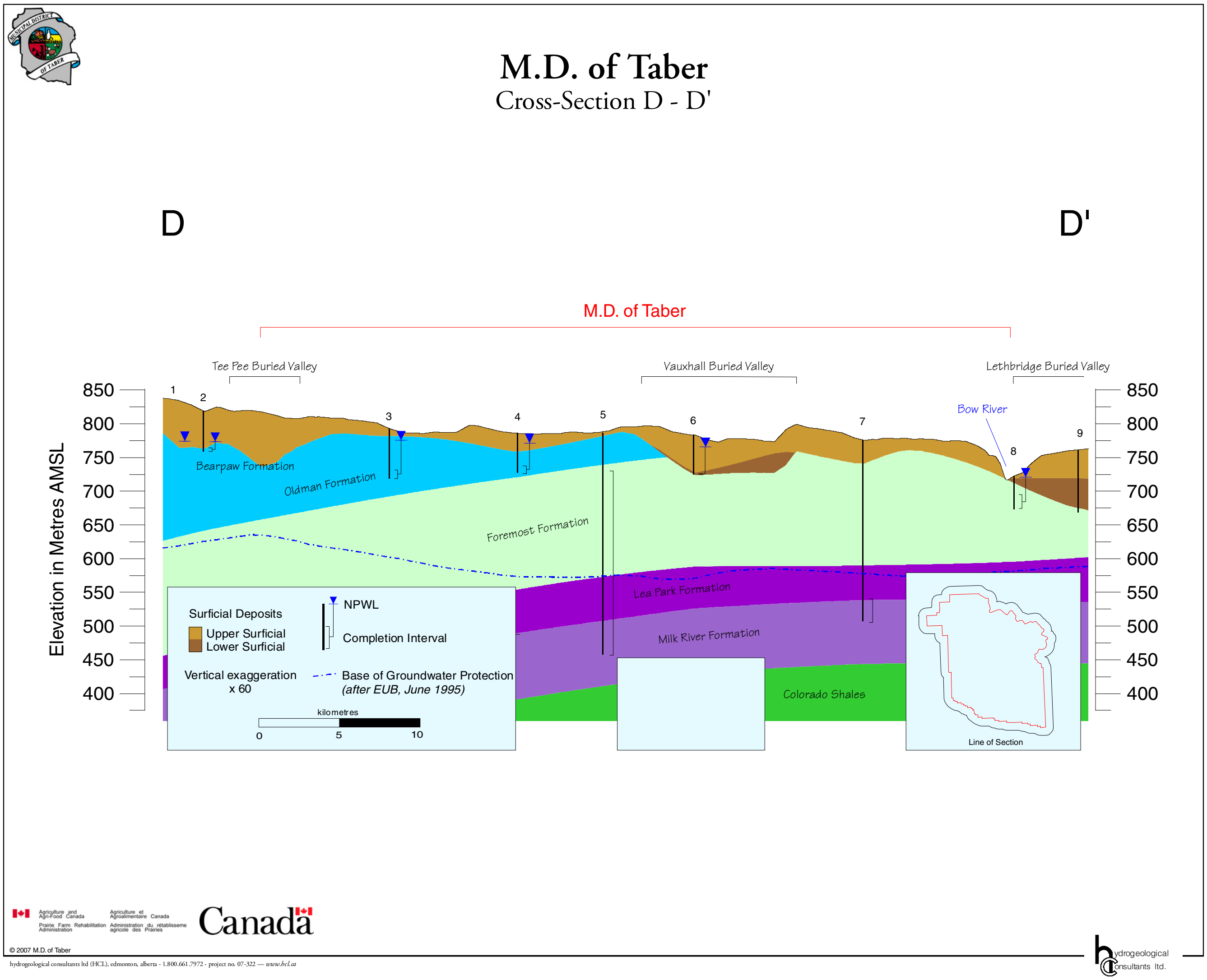
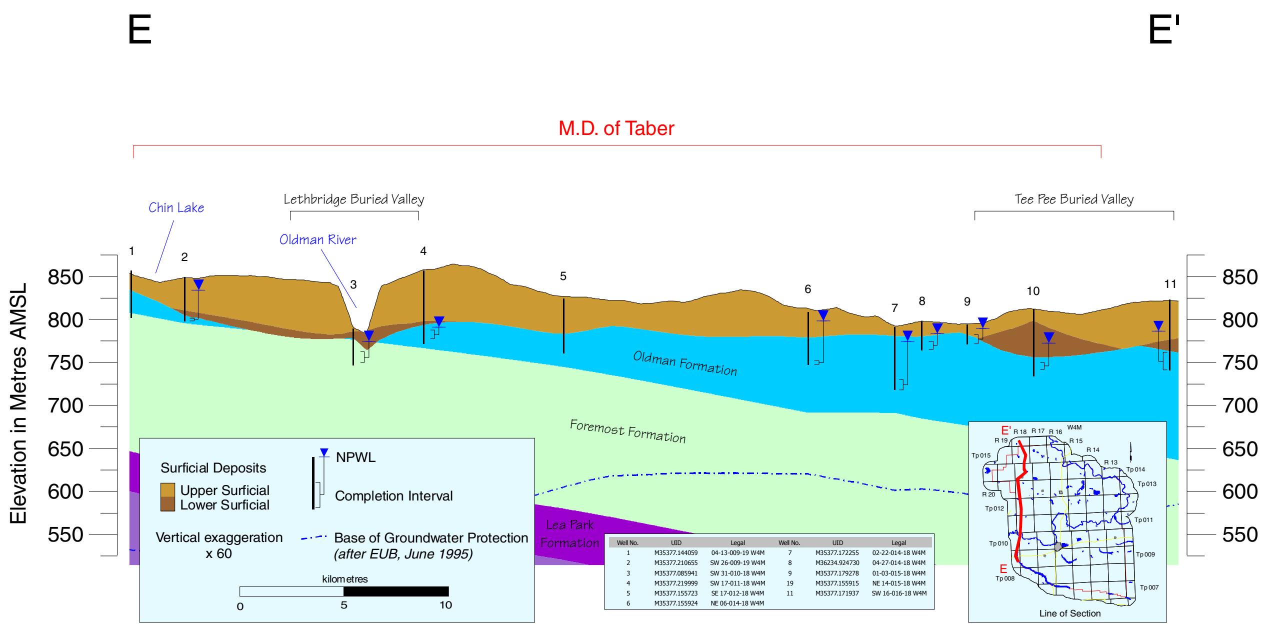
Cross-Section D - D'



Cross-Section E - E'

M.D. of Taber

Cross-Section E - E'



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5	M35377.155723	SE 17-012-18 W4M	11	M35377.171937	SW 16-016-18 W4M
6	M35377.155924	NE 06-014-18 W4M			

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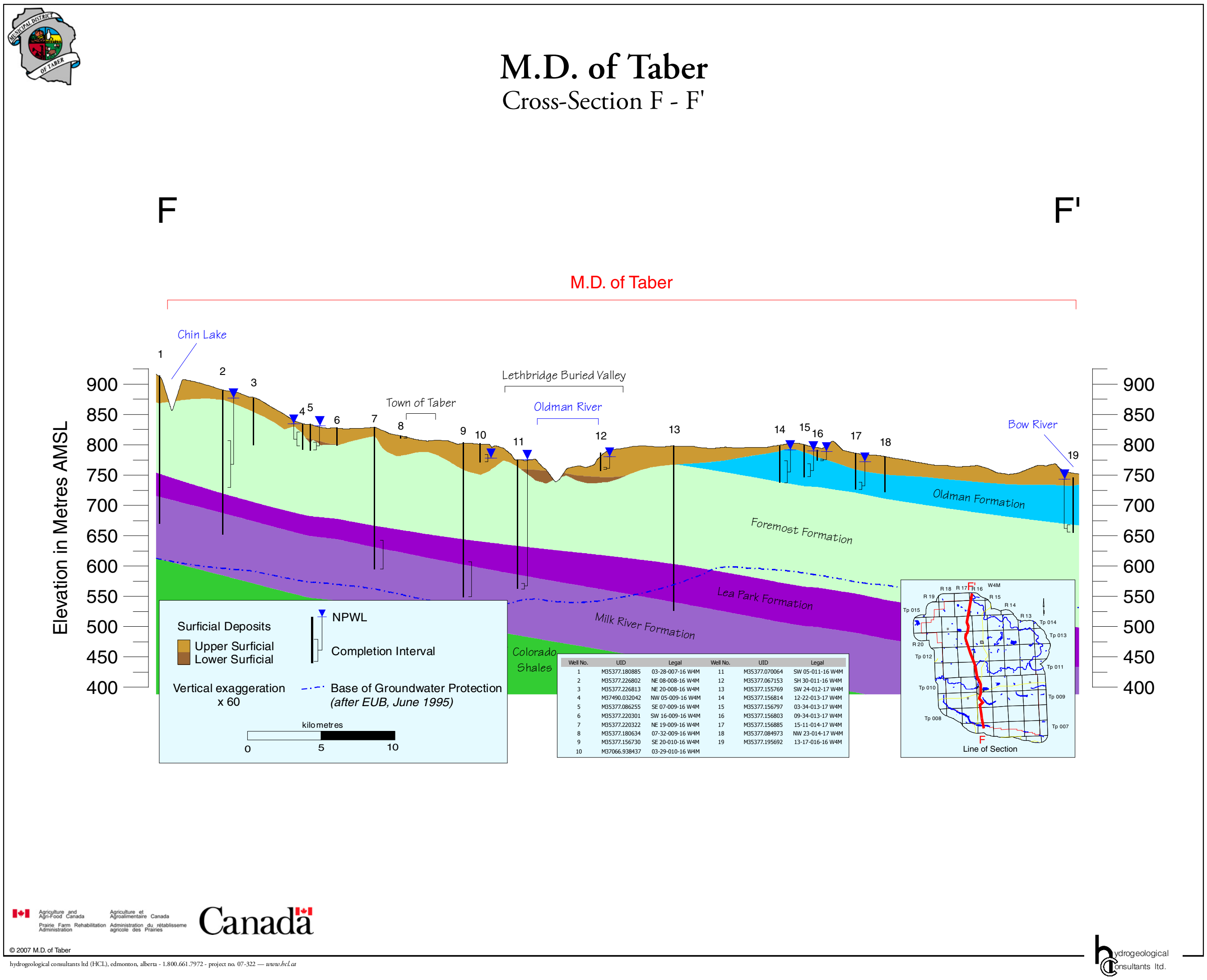
Cross-Section F - F'



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3	M35377.226813	NE 20-008-16 W4M	13	M35377.155769	SW 24-012-17 W4M
4	M37490.032042	NW 05-009-16 W4M	14	M35377.156814	12-22-013-17 W4M
5	M35377.086255	SE 07-009-16 W4M	15	M35377.156797	03-34-013-17 W4M
6	M35377.220301	SW 16-009-16 W4M	16	M35377.156803	09-34-013-17 W4M
7	M35377.220322	NE 19-009-16 W4M	17	M35377.156885	15-11-014-17 W4M
8	M35377.180634	07-32-009-16 W4M	18	M35377.084973	NW 23-014-17 W4M
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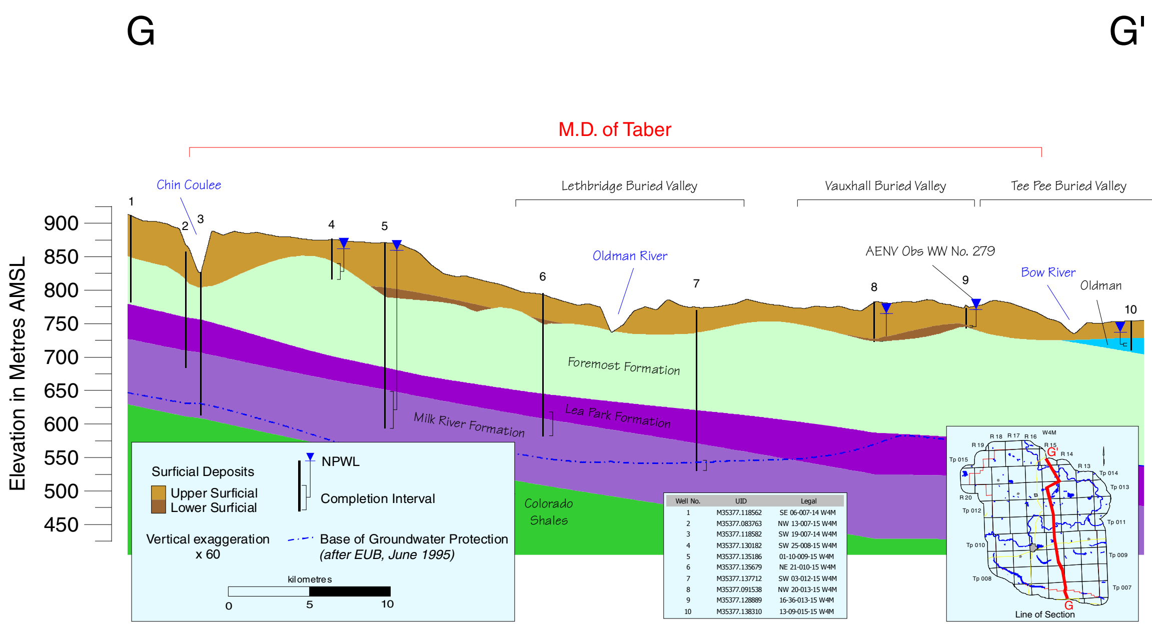
Cross-Section G - G'

M.D. of Taber

Cross-Section G - G'



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5	M35377.135186	01-10-009-15 W4M
6	M35377.135679	NE 21-010-15 W4M
7	M35377.137712	SW 03-012-15 W4M
8	M35377.091538	NW 20-013-15 W4M
9	M35377.128889	16-36-013-15 W4M
10	M35377.138310	13-09-015-15 W4M

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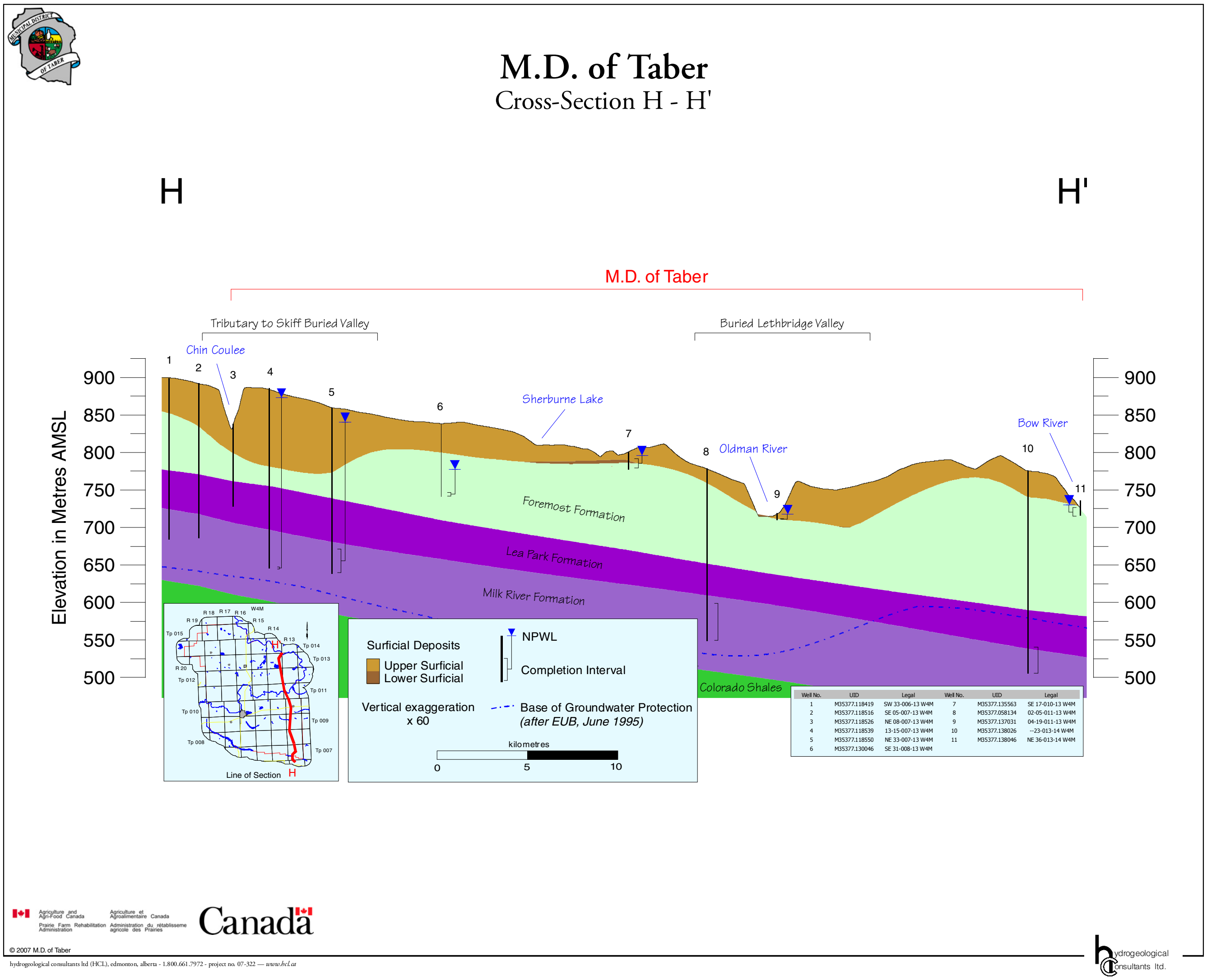
Cross-Section H - H'



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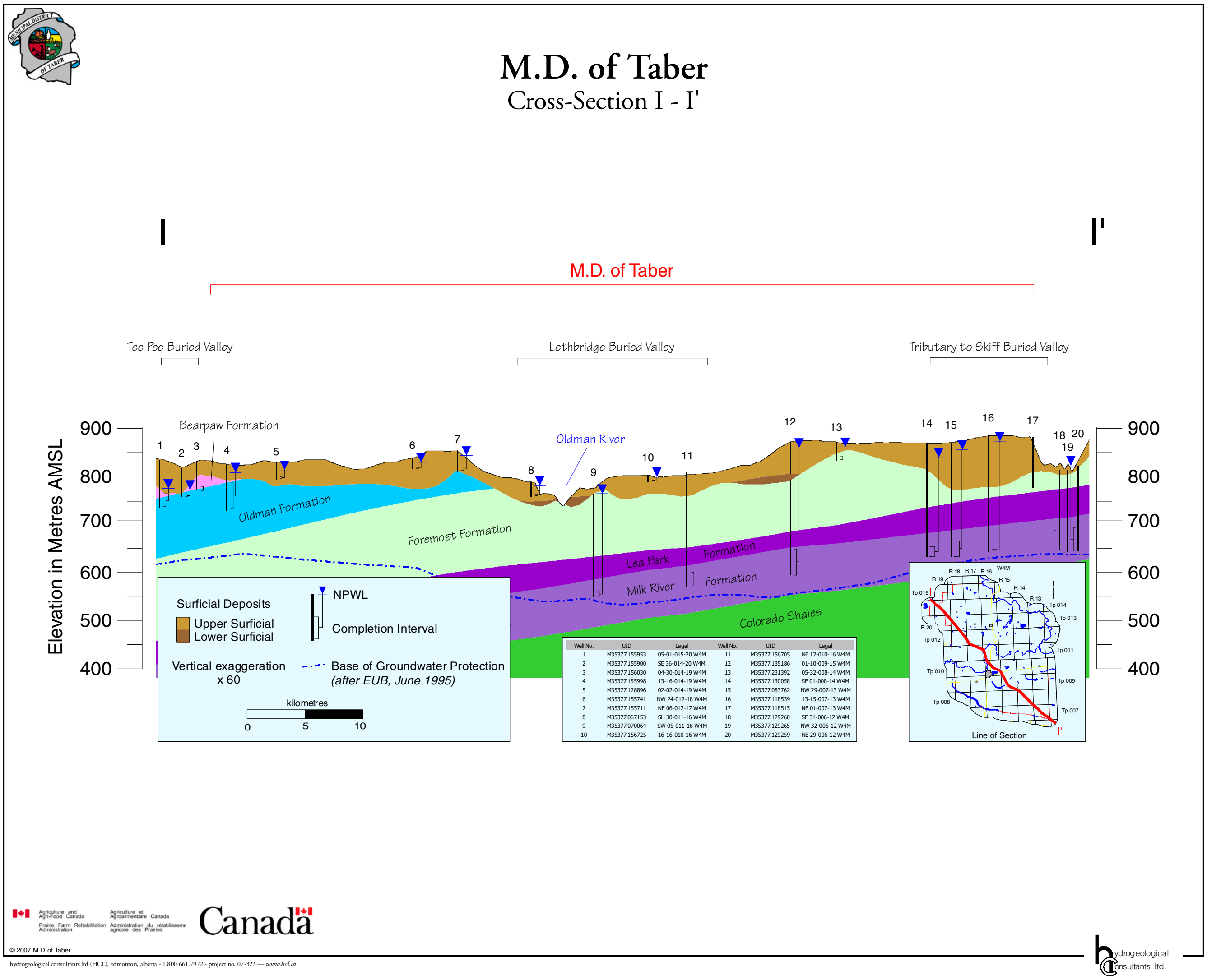
Cross-Section I - I'



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9	M35377.070064	SW 05-011-16 W4M	19	M35377.129265	NW 32-006-12 W4M
10	M35377.156725	16-16-010-16 W4M	20	M35377.129259	NE 29-006-12 W4M

M.D. OF TABER

Appendix E

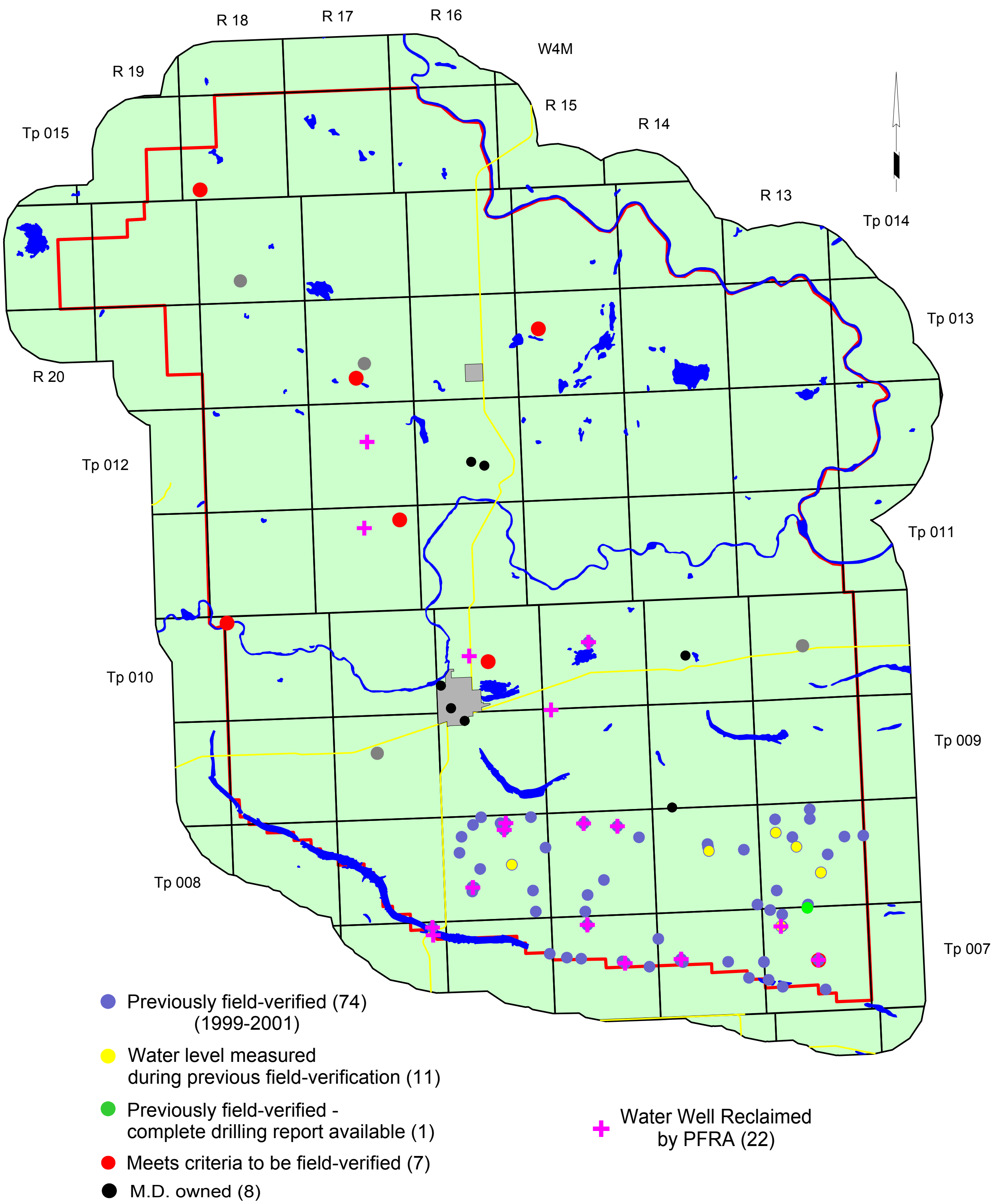
Water Wells That Have been Field-Verified
and Water Wells That Are Recommended for Field-Verification

including

M.D.-Operated Water Wells

Water Wells That Are Recommended For Field-Verification

(details on following pages)



WATER WELLS THAT HAVE BEEN FIELD-VERIFIED

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	Date Field Verified	UID
	SW 23-007-15 W4M	Milk River						17/06/99	M38022.504431
	SE 22-007-15 W4M	Lea Park						17/06/99	M38022.504433
	NE 20-007-15 W4M	Milk River						17/06/99	M38022.504434
	NW 07-007-13 W4M	[unknown]						22/06/99	M38022.504441
	NE 07-007-13 W4M	[unknown]						22/06/99	M38022.504442
	SE 07-008-13 W4M							14/06/00	M38022.504501
	NW 10-008-13 W4M	Milk River				15.24	50.0	5/7/2000	M38022.504509
	NW 33-008-16 W4M							19/06/00	M38022.504503
	NE 19-008-16 W4M	Milk River						22/06/00	M38022.504505
	NW 12-008-16 W4M							26/06/00	M38022.504506
	SW 20-007-14 W4M	[unknown]						17/06/99	M38022.504430
	NW 34-008-16 W4M							28/06/00	M38022.504508
	NE 13-007-14 W4M	Milk River		253	830.1	27.37	89.8	16/06/00	M38022.504502
AB, Agric.	NW 36-007-17 W4M	Milk River						29/05/00	M38022.504496
Atkins, Dave	NW 10-008-13 W4M	Milk River		213.4	700.2	15.24	50.0	4/7/2000	M35377.130006
Barany, Nicholas	SW 15-008-15 W4M	Bedrock	09-Jun-51	274.3	900.0	3.66	12.0	13/06/00	M35377.130164
Collet, Reuben	NE 08-008-16 W4M	Bedrock	27-May-50	284.1	932.0			22/06/00	M35377.226803
Collet, Ruban	10-08-008-16 W4M	Milk River		278.0	912.0			22/06/00	M35377.226804
Collett, Brian	08-08-008-16 W4M	Milk River	14-Feb-01			27.43	90.0	22/06/00	M37490.030432
Collett, D. Ruel	NE 08-008-16 W4M	Foremost	01-Nov-58	160.0	525.0	12.19	40.0	22/06/00	M35377.226802
Conrad, Brian	SW 33-007-15 W4M							29/03/01	M38022.504567
Conrad, Brian	SW 33-007-15 W4M	Bedrock	21-May-52	192.0	630.0			13/07/00	M37490.031334
Dick, P.	SE 30-008-13 W4M	Milk River	01-Jan-18	204.2	670.0	45.72	150.0	27/06/00	M35377.130037
Dyck, Henry	SE 29-008-13 W4M	Bedrock	10-Apr-50	243.8	800.0			1/10/2001	M35377.130035
Dyck, Rudy	NW 31-007-13 W4M	Milk River		249.9	820.0	4.57	15.0	26/09/01	M35377.118546
Fetting, John A.	04-13-007-14 W4M	Milk River		152.4	500.0	-1.22	-4.0	22/06/99	M35377.118572
Fletcher, Frank	13-22-008-14 W4M	Milk River	01-Jan-55	274.3	900.0	3.05	10.0	22/06/00	M35377.130092
Fletcher, Grant	05-33-008-15 W4M	Milk River		274.3	900.0	-0.91	-3.0	28/06/00	M35377.130193
Fletcher, J.R.	NW 22-008-14 W4M	Milk River	01-Jan-28	265.2	870.0	-2.74	-9.0	22/06/00	M35377.130089
Flickinger, Howard	12-32-007-13 W4M	Milk River		234.4	769.0			13/06/00	M35377.118547
Gilbert, Wm	NE 15-008-13 W4M	Milk River	01-Jan-18	202.7	665.0	-1.52	-5.0	4/7/2000	M35377.130019
Gilbertson, Melvin	EH 32-008-16 W4M	Milk River	31-Oct-49	260.0	853.0			19/06/00	M35377.180892
Goodfellow, James	13-16-008-16 W4M	Bedrock	24-Jun-50	278.0	912.0			22/06/00	M35377.226811
Gross, F.W.	SE 31-008-13 W4M	Bedrock	17-Jun-48	228.6	750.0			1/10/2001	M35377.130049
Hagerman, E.	NW 36-008-16 W4M	Milk River	01-Jan-26	213.4	700.0	-0.91	-3.0	19/06/00	M35377.226835
Hazel, Dennis	NE 33-007-13 W4M	Milk River	03-Jun-89	220.7	724.0	19.96	65.5	14/06/00	M35377.118550
Hazel, J.S.	SE 04-008-13 W4M	Milk River	01-Jan-18	198.1	650.0	-0.91	-3.0	23/06/00	M35377.130001
Hazell, Douglas	02-04-008-13 W4M	Bedrock	01-Jan-43	182.9	600.0	12.19	40.0	14/06/00	M35377.130003
Hendricks, Jocke	SW 21-008-13 W4M	Bedrock	14-Mar-56	256.0	840.0	9.14	30.0	26/09/01	M35377.130023
Hildebrand, George	NW 29-007-13 W4M	Milk River	17-Feb-90	236.5	776.0	13.81	45.3	14/06/00	M35377.083762
Hildebrand, Gerhard	NW 29-007-13 W4M	Milk River						14/06/00	M38022.504500
Hildebrand, Victor	NE 13-007-14 W4M	Milk River		253.0	830.0	5.81	19.1	16/06/00	M35377.118576
Hogan, Paulene	SW 10-007-13 W4M	Milk River	11-Jun-89	191.4	628.0	-2.44	-8.0	13/07/99	M35377.118528
Holtman, I.	03-20-007-14 W4M	Milk River	21-Jun-66	150.9	495.0	0.3	1.0	17/06/99	M35377.118583
Holtman, M	SE 22-007-14 W4M	Milk River	01-Jan-23	198.1	650.0	-0.91	-3.0	17/06/99	M35377.118585
Jesperson, Clarence	01-22-008-16 W4M	Milk River	01-Feb-73	262.1	860.0	30.48	100.0	16/06/00	M35377.226816
Jesperson, Clarence	01-22-008-16 W4M	Milk River		298.7	980.0	30.48	100.0	16/06/00	M35377.226817
Lawrence, Owen	SW 23-007-15 W4M	Milk River						17/06/99	M38022.504432
Lazerick, L.	NW 30-007-14 W4M	Milk River						26/06/00	M38022.504507
Leahy, J.	SE 34-008-15 W4M	Milk River						5/7/2000	M38022.504510
Leahy, J.	SE 33-008-13 W4M	Milk River	01-Jan-18	201.2	660.0	-1.22	-4.0	1/10/2001	M35377.130051
Leth Farms Ltd. / Leth, Arnold	NW 34-008-16 W4M	Bedrock	21-Mar-56	268.2	880.0			28/06/00	M35377.226832
Leth, Arnold / Leth Farms Ltd	NE 34-008-16 W4M	Milk River	26-Oct-49	268.2	880.0			28/06/00	M35377.180893
Leth, Nick	SW 34-008-16 W4M	Milk River	09-Feb-01	199.0	653.0			28/06/00	M37490.029694
Mcdonald, Lea	05-01-008-16 W4M	Bedrock		239.9	787.0	9.14	30.0	13/06/00	M35377.226797
Mckenzie, E.	NE 24-007-16 W4M	Milk River	01-Jan-26	214.0	702.0	1.22	4.0	6/6/2000	M35377.218964
Mckibben, Harry	NW 29-008-16 W4M	Bedrock	05-Nov-49	268.2	880.0			16/06/00	M35377.226824
Midland Hutterite Colony	SW 25-008-15 W4M	Milk River		243.8	800.0			26/06/00	M35377.130146
Nagurny Farms Ltd.	13-15-007-13 W4M	Milk River	01-Aug-73	240.8	790.0	36.57	120.0	14/06/00	M35377.118539
Nagurny, Joe	13-15-007-13 W4M	Milk River		243.8	800.0	14.63	48.0	14/06/00	M35377.118533
Neufelt, P.	NE 23-008-13 W4M	Milk River	01-Jan-31	198.1	650.0	-1.52	-5.0	27/06/00	M35377.130028
Newfelt, John	NE 24-008-13 W4M	Milk River		228.6	750.0			27/06/00	M35377.130030
Nikkel, John	SE 01-008-14 W4M	Milk River	01-Sep-73	237.7	780.0	30.48	100.0	23/06/00	M35377.130058
Noble, Art	SW 24-008-14 W4M	Milk River	01-Jan-24	224.0	735.0	-0.91	-3.0	4/7/2000	M35377.130111
Noble, Russ	SW 22-008-14 W4M	Milk River		274.3	900.0	10.70	35.1	22/06/00	M38022.504504
Owen, Richard	SW 20-007-14 W4M	[unknown]						17/06/99	M38022.504429
Owen, Richard	NE 19-007-15 W4M	Milk River	16-Sep-85	170.4	559.0	-1.52	-5.0	17/06/99	M35377.129682
Owen, Richard	NW 13-007-15 W4M	Milk River	26-Mar-90	172.2	565.0			6/8/1999	M35377.083763
Penner, Willard	NE 33-008-13 W4M	Bedrock	13-Jun-53	232.3	762.0			1/10/2001	M35377.130053
Sandy Hill Stockfarms	NE 21-010-15 W4M	Milk River	28-Oct-78	256.0	840.0			22/02/01	M35377.135676
Saunders, J.	SW 09-008-15 W4M	Milk River			0.0			12/6/2000	M38022.504499
Saunders, J.G.	SE 05-008-15 W4M	Bedrock	26-Oct-53	269.7	885.0			12/6/2000	M35377.130144
Sebok, George	01-25-008-16 W4M	Milk River	09-Apr-76	243.8	800.0			15/06/00	M35377.226821
Stimson, Derek	SW 33-008-15 W4M	Bedrock	19-Jun-50	253.6	832.0			28/06/00	M35377.130194

WATER WELLS RECOMMENDED FOR FIELD-VERIFICATION THAT MEET CRITERIA

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
Nagurny Farms Ltd.	13-15-007-13 W4M	Milk River	01-Aug-73	240.8	790.0	36.57	120.0	M35377.118539
Friesen, Vern	NW 20-013-15 W4M	Foremost	08-Sep-80	60.4	198.0	18.44	60.5	M35377.137971
Donick, Nick	16-16-010-16 W4M	Upper Surficial	13-May-78	12.8	42.0	4.57	15.0	M35377.156725
Struth, Robert	SE 09-013-17 W4M	Upper Surficial	27-Nov-79	14.6	48.0	7.62	25.0	M35377.156810
Severtson, A.S.	NW 05-015-18 W4M	Oldman	05-Nov-58	57.9	190.0	25.91	85.0	M35377.163581
Max Bullock Farms Ltd	01-35-011-17 W4M	Upper Surficial	03-Aug-82	8.5	28.0	2.44	8.0	M35377.219920
Cameron Farms Ltd.	12-31-010-18 W4M	Lower Surficial	03-Jul-84	13.1	43.0	7.01	23.0	M35377.220152

FIELD-VERIFIED WATER WELLS RECOMMENDED FOR FURTHER TESTING

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
Atkins, Dave	NW 10-008-13 W4M	Milk River		213.4	700.2	15.24	50.0	M35377.130006
Dick, P.	SE 30-008-13 W4M	Milk River	01-Jan-18	204.2	670.0	45.72	150.0	M35377.130037
Hazel, Dennis	NE 33-007-13 W4M	Milk River	03-Jun-89	220.7	724.0	19.96	65.5	M35377.118550
Hendricks, Jocke	SW 21-008-13 W4M	Bedrock	14-Mar-56	256.0	840.0	9.14	30.0	M35377.130023
Hildebrand, George	NW 29-007-13 W4M	Milk River	17-Feb-90	236.5	776.0	13.81	45.3	M35377.083762
Jesperson, Clarence	01-22-008-16 W4M	Milk River	01-Feb-73	262.1	860.0	30.48	100.0	M35377.226816
Jesperson, Clarence	01-22-008-16 W4M	Milk River		298.7	980.0	30.48	100.0	M35377.226817
Noble, Russ	SW 22-008-14 W4M	Milk River		274.3	900.0	10.70	35.1	M38022.504504
	NE 13-007-14 W4M	Milk River		253	830.1	27.37	89.8	M38022.504502

M.D. OF TABER-OPERATED WATER WELLS

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
Taber School Div	04-05-009-14 W4M	Upper Surficial	01-Jan-55	4.88	16.0	3.66	12.0	M35377.135132
Taber Hotel	NW 16-010-14 W4M	Milk River		193.54	635.0			M35377.135612
Town of Taber	SE 06-010-16 W4M	Milk River		204.21	670.0			M35377.156661
Town of Taber	SE 06-010-16 W4M	Milk River		204.21	670.0			M35377.156663
Taber Provincial Park	NW 07-010-16 W4M	Upper Surficial	20-Nov-70	9.14	30.0	3.66	12.0	M35377.156674
Taber, Md Of	01-15-012-16 W4M	Upper Surficial	28-Jan-83	5.79	19.0			M35377.171028
Taber, Md Of	05-15-012-16 W4M	Upper Surficial	28-Jan-83	5.79	19.0			M35377.171036
Town of Taber	-- 32-009-16 W4M	Milk River		204.21	670.0			M35377.220359